

PL-1

MOLECULAR RECOGNITION TECHNOLOGY: GREEN CHEMISTRY SEPARATION AND RECOVERY OF INDIVIDUAL RARE EARTH ELEMENTS FROM PRIMARY AND SECONDARY SOURCES

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SuperLig® Molecular Recognition Technology (MRT) has been used to selectively separate (99%) and recover (99%) at 99+% purity the entire suite of rare earth elements (REE, singular or plural), minus Pm, from Bokan-Dotson Ridge, Alaska feedstock [1]. Feed material was a pregnant leach solution (PLS) prepared from this feedstock. The entire set of 16 REE was initially separated from the non-REE gangue metals present in the PLS. Separation of the 16 individual REE at lab scale was done as follows: (1) Sc and Ce were removed; (2) light REE (Y, La, Pr, Nd) were separated from heavy REE (Sm through Lu); (3) individual members in the light and heavy groups were separated from each other. A pilot plant capable of making group and individual REE separations was constructed. Steps (1) and (2) were repeated in the pilot plant and Dy was recovered from the heavy group at the 99.99% level [1]. In operation, columns loaded with SuperLig® resins, consisting of a highly metal-selective ligand attached via a tether to silica gel or another substrate, accepted a feed solution containing REE originally separated from the PLS. The target REE was selectively bound to the SuperLig® resin, with remaining feed solution going to raffinate. Following column washing, bound REE was eluted using a small quantity of eluate and recovered in concentrated, pure form. The column was regenerated for repeated use. MRT processes feature rapid kinetics of metal-ligand binding and release, simple elution chemistry, non-use of solvents or harsh chemicals, ability to recover metals present in feed solutions at mg L⁻¹ or lower levels, and minimal generation of waste. High selectivity allows separations to often be achieved in a single pass eliminating need for extensive downstream processing, which also eliminates generation of large amounts of waste. Simplified MRT separation and recovery processes are very attractive compared to conventional solvent extraction, ion exchange, and precipitation processes from the standpoint of reduced capital and operating expenses. Potential sources for separation and recovery of REE using MRT include primary ore; tailings; coal ash, and spent industrial feedstock (permanent magnets, rechargeable batteries, lighting.).

[1] Izatt, R.M., Izatt, S.R., Izatt, N.E., Bruening, R.L., Krakowiak, K. E., Green Chemistry Molecular Recognition Processes Applied to Metal Separations in Ore Beneficiation, Element Recycling, Metal Remediation, and Elemental Analysis. In Beach, E.S. and Kundu, S. (Eds.), Handbook of Green Chemistry Volume 10: Tools for Green Chemistry, Wiley-VCH, Weinheim, Germany, 2017, pp 189-240.

PL-2

CRITICAL RAW MATERIALS SUPPLY: WHAT'S UP IN EXTRACTION AND RECYCLING OF RARE EARTHS

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Strategic, critical or high-tech metals have become political buzzwords since they have been recognized as essential to helping the world build an efficient, high-tech, and competitive economy, which can spur the growth of our industries. These metals are indispensable ingredients for the development of technologically sophisticated products. Modern cars, flat-screen televisions, mobile phones, and countless other products rely on a range of materials, such as cobalt, lithium, PGM's, tantalum, tungsten, gallium and more particularly REE. This group of high-tech metals is also fundamental to new environmentally friendly products, with electric cars requiring lithium and neodymium, turbine wind with neodymium and dysprosium, high performance aluminium alloys, lighting or hard ceramics requiring scandium, and computer/mobile phones with tantalum, gold and rare earths. As the world moves towards a cleaner, greener future, the uses for these metals are likely to increase rapidly and the rare earths supply crunch in 2010/2011 served as a wake-up call to businesses and governments, highlighting the fact that future strategic metals supply (not only rare earths) should not be taken for granted.¹ Thus, securing reliable and undistorted access to non-energy raw materials has become a critical challenge to many resource-dependent countries all over the world. In this context, many countries have thus asserted through several reports their desire to reduce their dependency on so-called strategic metals and to create or rather recreate on their territory an industrial activity in this sense. To meet the challenges of dwindling resources and the growth of needs, as well as in a perspective of a secure supply approach, three options are considered today based on the extraction of metals from waste of end of life materials (urban mine), from primary resources (old mines or new deposits), or from secondary resources (mining and industrial wastes). Understanding this challenges facing strategic metals supply today requires consideration not only of the sources (whether from mines or waste streams), but of the development of low cost, eco-friendly and always more efficient processes.

[1] European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (2017) Study on the review of the list of Critical Raw Materials: Critical Raw Materials Factsheets.

PL-3

**PROCESS FOR POTENTIAL UTILIZATION OF BAUXITE RESIDUE
FOR EXTRACTION OF RARE EARTHS**

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Bauxite residue is a process reject of Bayer process during alumina production. Rare earth elements are enriched in the bauxite residue which can be used as a potential resource for extraction of REEs. Scandium is the most valuable element among the REEs that are present in the bauxite residue. In this study, chemical characterization, techniques of physical beneficiation such as sieving, hydrocyclone, multi-gravity separator and subsequently leaching with different mineral acids for the selective extraction of REEs have been discussed. Various experimental parameters (such as acid concentration, solid/liquid ratio, leaching time and temperature) were studied in details. It was observed that leaching of Sc, La and Ce with 2-3M H₂SO₄ mixture at 95-100 °C for 5 hrs under optimized condition gave leaching efficiencies in a range of 81-90%. Advantage of leaching with H₂SO₄ is that the iron hardly gets dissolved leading to noninterference determination of the rare earths in the leachate by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES).

PL-4

**THE ROLE OF RARE EARTHS IN THE DESIGN OF NEXT
GENERATION ADVANCED FUNCTIONAL MATERIALS FOR
EMERGING APPLICATIONS**

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New functional materials discovery research is frequently driven by a desire to use ‘materials by design’ concepts in the quest for finding better, greener and more efficient materials. In recent decades, rare earth elements have become vital to design advanced inorganic functional materials for electronics, magnetism, energy conversion, lasers, lighting, and phosphors, to name a few. Due to their size similarities and significant electronic configuration differences, rare earths are particularly attractive elements for understanding how the subtle differences in composition and structure of materials may account for their functional properties leading to better materials design. This talk will summarize some of our research activities on complex transition metal oxides with rare earths as one of the key ingredients to achieve desired functional properties. However such research endeavor can occasionally lead to unexpected breakthrough discoveries in other interdisciplinary areas. I will describe our spectacular discovery of new class of highly durable intense color pigments based on rare earth transition metal oxides where transition metal cations occupy an unusual trigonal bipyramidal coordination that we were exploring for multiferroics. We have now leveraged this discovery to rationally design advanced inorganic oxide based pigments with desired color as well as other functionalities which are now commercialized by pigment industries.

**RARE EARTH BASED CERAMICS AND COMPOSITES FOR
MICROWAVE CIRCUIT APPLICATIONS**

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Rare earth based advanced ceramics and composites are finding applications in advanced areas such as aerospace, wireless communication, microelectronics etc. Long reliability is the key parameter for their ultimate use in strategic applications. Among these, microwave dielectric materials gained immense importance in wireless applications and many of the high dielectric ceramics are composed of rare earth elements as one of the constituents which in turn help in fine tuning the end properties by judiciously substituting rare earth ions having varying ionic radii. The personal communication devices and other wireless technology industries, such as direct broadcasting, global positioning systems, mobile communication systems etc. have witnessed an explosive and unprecedented growth in applications. The application areas are fast ranging from simple dielectric resonator to complex 3D modules realized through Low Temperature Co-fired Technology. More recently, rare earths based Ultra Low Temperature Co-fired Ceramics (ULTCC) are also finding applications in realizing miniaturised and cost effective devices including Substrate Integrated Waveguide (SIW) circuits. In order to meet these stringent requirements, novel materials with high dielectric constant and low loss tangent are required. High dielectric constant reduces the circuit size since the wavelength travelling through the medium is inversely proportional to the square root of the dielectric constant. On the other hand, extremely low loss tangent improves the signal integrity and avoids cross talks. Cu-cladded rare earth ceramic filled PTFE planar laminates are the ideal choice for high end microwave circuit fabrication which are currently available only from imported sources. Understanding the need for indigenous technology, C-MET has developed a proprietary and patented process methodology comprising of Sigma Mixing, Extrusion, Calendering followed by Hot pressing (SMECH Process) to fabricate dimensionally stable planar and isotropic PTFE/ceramic composite laminates. Pore free and dimensionally stable planar laminates have been prepared by incorporating variety of rare earth titanate ceramics in the PTFE matrix through SMECH process. C-MET has successfully developed wide variety of filled PTFE substrates with dielectric constant ranging from 2.2 to 14.8 together with ultra-low loss tangent (0.0018 at 10 GHz) and the technology for the same is already transferred to Industry for commercial production. High power solid state amplifiers have been fabricated by Raja Ramanna Centre for Advanced Technology (RRCAT), Department of Atomic Energy, Indore operating at a centre frequency of 505.8 MHz, which can withstand output power up to 750 kW. Excellent RF performance was obtained in terms of output power, gain and efficiency during system level evaluation and accordingly the high power solid state amplifiers have been successfully deployed in INDUS-2 particle accelerator.

PL-6

RARE EARTH PERMANENT MAGNETS AND OTHER RARE EARTH MAGNETIC MATERIALS FOR ENERGY SAVING APPLICATIONS

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Permanent magnets are the class of magnetic materials that retain their magnetism after magnetization. It was only in the early 20th century that high carbon steels replaced lodestone as the best available permanent magnet material. In the development of permanent magnets the improvement over steels came with the discovery of Alnicos (basically alloys of Fe, Al, Ni, Co), hard ferrites and rare earth based permanent magnets (REPMs). Traditionally, ferrites and alnicos were used for a majority of magnetic component applications. Ferrites have lower remanence and moderate coercivity and Curie temperature; but the greatest advantage is its lowest cost. So it is no wonder that ferrites are widely used in a majority of applications and observations indicate that ~ 98% of the world tonnage production is ferrites. Alnicos have high residual induction, high Curie temperature; but low coercivity. Therefore, they are preferred in high temperature applications, where moderate demagnetizing fields are encountered. With the introduction of rare earth magnets, the use of alnico is gradually declining. In a way, permanent magnets are responsible for the rapid growth in modern industrial society through their use in many electro-technical devices. The REPMs are characterized by large values of remanence, coercive force and energy density. The combination of high-energy product and a good thermal stability allows the magnet to be used at higher operating temperatures at the device level. Three families of rare earth - transition metal permanent magnets viz. SmCo_5 , $\text{Sm}_2\text{Co}_{17}$ and $\text{Nd}_2\text{Fe}_{14}\text{B}$ inter-metallic phases with high-energy product are well known and are in commercial production. Permanent magnets with high operational temperature combined with high energy products are required for improved performance of motors, generators, actuators, traveling wave tubes, etc. The distinct characteristics of these groups of magnets are brought out from their intrinsic and extrinsic magnetic properties. The intrinsic magnetic properties are the saturation magnetization ($4\pi M_s$), the anisotropy field (HA) and the Curie temperature (T_c). In this presentation the science and technology of the permanent magnets will be discussed in combination with other high performance magnetic materials. The applications towards automotive and aerospace applications will be highlighted.

IT-1

RECYCLING OF RARE EARTHS FROM MAGNETIC WASTE MATERIALS

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Rare earths are linchpin ingredient for clean and green energy sector due to their use in many products, including mobile electronics, electric vehicle traction motors, and direct-drive permanent magnet generators (DDPMGs) for wind turbines. Due to their growing demand in renewable energy and efficient lighting devices some of the rare earths in particular Nd, Dy, Tb and Y are considered critical, that is, at risk for short and mid-term shortages. There are two types of rare earths based permanent magnet namely Sm-Co and Nd-Fe-B magnets. Sm-Co based magnet performs at high temperature but is brittle which limits its size and therefore can pose a problem with integration in certain applications such as motors. However, Nd-Fe-B magnets are even stronger than Sm-Co magnet and because of their size is not restricted, they are rather suitable for large applications such as wind turbines and other electricity generators. Nd-Fe-B based DDPMGs contain 160-650 kg of the material per MW which translates to about 51-250 kg of rare earths /MW. Small amount of Dy and Tb is also added to Nd-Fe-B as they endow resistance to demagnetization at high operating temperatures. Often some Nd is also substituted by its neighbouring element Pr to reduce the price. Apart from its use in wind turbine, Nd-Fe-B magnets find applications in other types of renewable energy technologies such as underwater ocean, wave power and geothermal drilling. As the demand of the critical rare earth elements are projected to grow in coming years, to avoid any kind of hampering of green energy technologies recovery of valuable critical rare earths from secondary and other sources are essential. To address the issue of supply risk to these critical rare earths, industry are considering different mitigation strategies including reuse, recycling, substitution, increased mine production and by-product extraction. The concept of urban mining i.e recycling of the end of life product has recently been coined which addresses the issue of recovery of these critical elements from waste materials. Countries which don't have primary reserves have directed their efforts into this direction and also started banning of the end of life products which contain critical elements. The present talk will highlight the global scenario in the field of rare earths recycling from magnetic waste materials. Various techniques including pyrometallurgy, hydrometallurgy, plasma separation technique, solid-liquid and membrane will be discussed and compared for their suitability for recycling purposes. Additionally the use of novel tripodal type of nitrogen based extractant for its selectivity arising from the differences in stereochemistry of the rare earths-ligand complexes as a result of slight variation in ionic size will be illustrated for effective separation of rare earth elements from the recycled waste.

IT-2

**RARE EARTHS RECOVERY FROM PERMANENT MAGNETS SCRAPS
BY HYDROMETALLURGICAL METHODS**

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Rare earths (REs) application has gained visibility through many media outlets due to their significant utilization in modern technologies. The electronic revolution in new millennium modern lives is increasing day-by-day all over the world. Economics of the nation was mainly depended on imports and exports of the require goods. The South Korean peninsula having many manufacturing industries and the electrical/electronic (EE) goods supply to all over world demands. When manufacturing the EE items will lead the pre-consumer scraps as well as after utilization of the product will the possible to generate the post-consumer scraps. The scraps will cause to two major issues one is damaging environment the other one is landfilling problems. Both the problems will dissolved by one process is scraps treat as secondary resources for critical rare earths (REs). Permanent magnet scraps (PMS) are possible to having the REs such as dysprosium (Dy), neodymium (Nd), praseodymium (Pr) and terbium (Tb). All the the four REs are in critical supply for demand all over globe. Hydrometallurgical methods such as roasting, acid leaching, double salt precipitation, liquid-liquid extraction and recovery studies were studied and optimum condition established for REs processing.

IT-3

OVERVIEW ON TRENDS IN MONAZITE PROCESSING FOR THE RECOVERY OF RARE EARTHS

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There is worldwide interest in exploration of REE resources due to their applications in manufacture of environmentally benign products and supply-side constraints encountered due to monopoly held by a single nation. The efforts for new resources include focus on exploration and exploitation of both the primary and secondary resources besides recycling the end-of life REE bearing products. This paper elaborates on the aspects involved in processing of monazite mineral – both on its beneficiation and chemical processing for producing high purity individual REEs which are in high demand. Monazite occurs in placer deposits, beach sands, and important components of carbonatite related REE deposits. It displays a variety of chemical compositions, with enrichments in most incompatible elements such as thorium and uranium. Monazite is a phosphate mineral with a rare earth content (as REO) of about 70% but its processing is challenging due to presence of 4–12 wt.% thorium and variable amount of uranium. Monazite is widely distributed across all continents except Antarctica; however bulk of the mineral is concentrated in South Africa, Mozambique, Madagascar, India, Sri Lanka, Malaysia, Australia, Brazil etc. Though China, Malaysia and India are the only countries involved in its production and processing of monazite at present, Brazil and Russia are also contemplating entry into monazite processing. The physical beneficiation of monazite from beach sands and/or placers using gravity, magnetic and electrostatic separation techniques is well established. However, the complexity of a pre-concentration flowsheet hinges on the mineralogical composition of the feed. The pre-concentration assumes increasing complexity when the mineralization is in very-fine sizes like that of carbonatites or other hard rock deposits. Such mineralization demands adoption of centrifugal gravity separators or mineral specific flotation collectors or even multi-stage operations aimed at obtaining reasonable grade pre-concentrates. Some of the newer deposits in Australia, Turkey and even India are of this nature. The REEs are separated from other elements of monazite mineral by chemical leaching followed by either ion exchange or solvent extraction or a combination of both. Though the leaching chemistry has not shown any game-changing developments, it is the solvent extraction process which resulted in production of very-high purity end individual rare earths. India has well established technical success in recovering REEs from vast monazite resources available in sands of southern and eastern coast of the country. It is taking multiple steps for deriving technical advantages attributed to REEs by 360° approach right from resource augmentation, new solvents development and producing end-products ascribed with special properties.

IT-4

ABUNDANT RARE EARTH RESOURCE, YET IMPORTED – AN INDIAN PARADOX

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A set of seventeen elements which exhibit similar properties and belong to the lanthanide and actinide series are called Rare earth Elements (REEs). Cerium, Lanthanum, Neodymium and Praseodymium are the common elements among others and together account for over 75% of global rare earth element consumption. Rare earth metals find applications in numerous high technology products such as tablet computers, TVs, advanced military technology, nuclear batteries, laser repeaters, miniature, superconductors, numerous medical devices, rechargeable batteries and permanent magnets for hybrid cars and wind turbines. In addition, they are also used as catalysts in automotive and petroleum refining and as pigments in glass and ceramics. Elements such as Neodymium are extensively used in the manufacturing of permanent magnets. China remains the monopoly supplier controlling over 95% of global demand which makes India heavily dependent on imports of rare earths/ rare earth products. A potential opportunity for India to become self sufficient in rare earths remains a dream as significant rare earth resources in monazite remain untapped. Monazite occurring in the Indian beach sands along with other heavy minerals contains about 65% rare earth elements making it one of the richest RE resource compared to resources of much lower grades being mined in China and elsewhere in the world. A balanced and pragmatic approach to produce rare earths from monazite while at the same time addressing the strategic and security concerns around thorium which is projected as India's future nuclear fuel will pave the way for economic development. Given the successful "MAKE IN INDIA" initiatives in several strategic sectors including defense, telecom etc., a change in mind set and relook at the rare earth lying untapped in India is the need of the hour, whereby the country can leverage this resource potential to become a global super power.

IT-5

OCCURRENCE, EXPLORATION, CHEMICAL ANALYSIS AND ENVIRONMENTAL IMPACT OF RARE EARTHS

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Fast emerging green technologies, ranging from electric car batteries to solar panels to wind turbines where REE being widely used, are expected to drive tremendous growth and demand for these metals in near future. This presentation summarizes the occurrence of these metals in the Earth's crust, their mineralogy, different types of deposits both on land and oceans from the standpoint of the new data with more examples from the Indian subcontinent [1, 2]. Several studies are underway to develop new strategies for the future supply of REE including recent developments in the extraction of REE from coal fired ash. There is a greater need to intensify our search for REE resources not only on land but also in ocean bottom sediments. Deep sea mining would definitely be a feasible option in near future in addition to the development of cost-effective recovery of REE. In addition to their utility of REE to understand the formation of the major earth reservoirs, multi-faceted updates on the applications of REE in agriculture and medicine including new emerging areas will be presented. Environmental hazards including human health issues are on rise due to REE mining and large-scale dumping of e-waste containing significant concentrations of these elements [1, 3]. Extensive utilization of REE in day-to-day life may warrant an urgent toxicological assessment of these elements from a human health perspective [4]. Recycling of REE from e-waste has not yet taken off and more emphasis should also be put on the R & D efforts on finding out substitutes for REE to draw away from reliance on REE. Currently an array of high sensitive and selective analytical techniques is available for the accurate and precise determination of REE in different materials [5, 6]. Performance characteristics such as multi-element-nature, high sensitivity and resolving power of most interferences, HR-ICP-MS would become an important analytical tool in REE activities in future [7].

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IT-6

RARE EARTH MAGNETIC MATERIAL IN E.V.S

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Rare Earths materials find usage in varied industries like magnets, batteries, catalysts, paints and pigments, super alloys, lighting, etc. Of these, magnet industry is the major consumer of rare earths in value terms. While magnets are used in wind energy, automobiles, consumer electronics, military/aerospace applications, and automobile industry are going to be the major driver for magnets in view of clean and green energy drive and commitment to Paris Accord by major nations including India resulting in thrust for producing electric vehicles. Rare earth material is used in various parts of conventional as well as hybrid vehicles. In case of conventional vehicles approx.. 450 gms of RE elements are used of which 350 gms are NdFeB magnets. In case of hybrid cars, approx. 5200 gms of RE elements are used of which 4900 gms are in the form of NdFeB magnets. With rapidly increasing sales of xEVs and the likely manifold increase in production of these vehicles, the market share of xEVs is likely to increase exponentially. All major vehicle producers have announced their intend to either enter into this field or expand the existing business in this area. Assuming that 25% of vehicles are electrified by 2025, there will be 30 million xEVs in the global market by 2025 which is about 10 times the current sales. This would mean very high demand for RE magnetic material. To meet the increased demand from EV sector, there is need to augment RE supply as well as search for alternatives to rare earth magnets. This objective can be achieved by exploring new sources of rare earths like new rare earth resources as well as from sources such as coal, recycling, etc. Also, there are developmental work being undertaken by companies in this field to reduce or replace the RE elements in magnets. The current and future technologies to this effect would involve grain boundary diffusion, fine powder technology, cheaper RE replacement, RE reduction and RE free technology. Companies like Toyota have already initiated the process of reduction of rare earths by replacing some quantity of Nd by Ce and La. Further, many NdFeB magnet producers have started production of magnets by eliminating Dysprosium and research is on for replacing Nd and Pr by Cerium.

IT-7

RARE EARTH METAL DOPED CERIA SOLID SOLUTIONS FOR CATALYTIC APPLICATIONS

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Design and application of novel nanomaterials for environmental protection have been receiving more and more attention these days [1–4]. Selection of a suitable material and an appropriate synthetic methodology ultimately determines the success or failure of the nanostructured materials application, since physicochemical properties of the nanostructured materials are heavily dependent upon how they are synthesized. Ceria (CeO_2), an abundant rare-earth oxide, has attracted considerable interest in recent years because of its utilization in environmental and energy related applications. The importance of ceria originates from its remarkable $\text{Ce}^{4+}/\text{Ce}^{3+}$ redox couple and superior oxygen storage/release capacity (OSC). Ceria serves both as a promoter and as an active catalyst in three-way catalytic converters for abatement of hazardous exhaust emissions [3-6]. As well, the catalytic activity of ceria for soot combustion has also been investigated recently and proven to be a potential material. Therefore, numerous studies were undertaken on the application of ceria-based materials for various reactions. Nevertheless, a significant limitation encountered with pure ceria is its poor thermal stability, resulting in the loss of surface area and OSC, hence poor catalytic performance. An ongoing challenge in this respect is to develop efficient and thermally stable ceria-based catalysts in order to meet more demanding requirements. There are two promising options available for improving the properties of CeO_2 , namely, doping of suitable rare-earth or transition metal ion into the ceria lattice and reducing the ceria particle size into nanoscale. Our recent studies revealed that incorporation of appropriate dopants into the ceria matrix greatly enhances its redox properties and chemical reactivity [4–8]. In particular, small ionic size and low valence state dopants show strong influence on the physicochemical properties of the resulting materials. More details of these studies will be elaborated in this presentation.

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IT-8

COLORED INORGANIC COMPOUNDS - THE ROLE OF RARE-EARTH AND TRANSITION METALS

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Crystalline inorganic oxides displaying bright colours attracted much attention from early days for application as gemstones and pigments. Ruby (Cr^{3+} doped Al_2O_3) and Emerald (Cr^{3+} doped $\text{Be}_3\text{Al}_2(\text{SiO}_3)_6$) and Azurite ($\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$), Han blue ($\text{BaCuSi}_2\text{O}_6$) and Turquoise ($\text{CuAl}_6(\text{PO}_4)_4(\text{OH})_8 \cdot 4\text{H}_2\text{O}$) for example found application as gemstones and pigments since ancient times.^[1] In addition to the naturally occurring gemstones and pigments, several man-made (synthetic) coloured solids were also developed to meet the demand Y_2BaCuO_5 , copper substituted apatites, Mn(III) substituted YInO_3 and $\text{CaTaO}_2\text{N} - \text{LaTaON}_2$ perovskites are some of the more recent pigment materials for green, blue, red-yellow colours[1,2]. A scientific inquiry into the origin of colours of inorganic solids is essential for a rational design and synthesis of coloured materials. While there are several causes for the colour of solids, the main factor that causes colour in an inorganic oxide containing transition metal ion is the electronic transitions within the partially filled d-states arising from the ligand field effects around the transition metal ion. Octahedral and tetrahedral are the most common geometries where the colour and optical absorption spectra of all the transition metal ions have been well-documented. Transition metal ions in less symmetric geometries such as distorted octahedral and five-fold coordinated (square pyramidal and trigonal bipyramidal) geometries produce colours different from those in regular octahedral and tetrahedral geometries in materials. The present talk would address some of these issues and our efforts towards identifying new chromophores employing transition metal chemistry[3-5].

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IT-9

RARE-EARTH COORDINATED SOLIDS AS NOVEL PHOTONIC MATERIALS

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Rare-earth ion based coordination solids with distinctive optical characteristics such as long luminescence life times and sharp emission bands are prospective materials for application in OLEDs, lasers and sensors. Recently, design of new metal organic frameworks (MOFs) are sought with suitable ligands as it appears to increase the quantum efficiency of lanthanide ions through synergetic effects and prevents the coordination of solvent molecules that can quench its emission. In this talk, we present our recent results on the design, crystal structures and photophysical properties of novel photoluminescent materials built of the molecular cluster, $\{\text{CrMo}_6\text{O}_{24}\}^{n-}$ that exhibits ruby-like red emission coordinated with optically active rare-earth ions. For comparison, we have also examined the optical properties of the rare-earth solids combined with optically inactive aluminium analogue, $\{\text{AlMo}_6\text{O}_{24}\}^{n-}$. Structural landscape of the system $\{\text{Ln}(\text{H}_2\text{O})_m\}^{3+} - \{\text{XMo}_6\text{O}_{24}\}^{n-} - 2,6\text{-dipicolinic acid}$ shows the formation of three series of novel crystals: two structurally related $[\text{Ln}(\text{OH}_2)_7\{\text{X}(\text{OH})_6\text{Mo}_6\text{O}_{28}\}].x\text{H}_2\text{O}$, X=Al or Cr and $[\{\text{Al}(\text{H}_2\text{O})_6\}\{\text{Ln}(\text{pda})_3\}].10\text{H}_2\text{O}$. Photoluminescence of the single crystals of all chromium molybdates was dominated by a ruby-like emission including those which contain optically active lanthanide ions. In contrast, aluminum analogues showed photoluminescence with its well-known characteristic emissions. Our results strongly suggest a possible energy transfer between lanthanide ions to chromium levels for the quenching of lanthanide emission in lanthanide coordinated chromium molybdates.¹ Intensity measurements showed that the emission from chromium molybdates are almost two orders of magnitude lower than naturally occurring ruby with broader line widths at room temperature.

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IT-10

RADIOLANTHANIDES IN NUCLEAR MEDICINE: CURRENT TRENDS AND THE PATH AHEAD

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The role of nuclear medicine for the non-invasive *in vivo* assessment of physiological functions or metabolic processes to diagnose and treat diseases using radiopharmaceuticals has been well recognized. Radiopharmaceuticals often consist of a radionuclide and a carrier molecule to which the radionuclide is chemically attached and are designed to favor the accumulation at the targeted cell, tissue, or organ. The carrier molecules often consist of small organic molecules such as a drug, carbohydrate, lipid, nucleic acid, peptide, fragment of antibody, or even very large whole antibodies and radionuclides are generally attached by complexation to suitable chelating groups. For diagnostic purposes, the radiation emitted from the radionuclide on the disease site is detected by gamma camera to reconstruct images, whereas for therapeutic intent, the radionuclide deliver cytotoxic levels of radiation to the target site through its decay. Radiolanthanides, owing to the inimitable chemical and nuclear characteristics, occupied an important place at the forefront of nuclear medicine. Lanthanides usually exist in the +3 oxidation state, which precludes any solution chemistry reduction-oxidation complications and commonly forms nine coordination complexes. This property provides the potential for radiolabeling a variety of molecular carriers, which include small molecules, and peptides, proteins and antibodies through metabolically resistant chemical conjugation strategies. Owing to their ability to form high thermodynamically stable complexes with specific desired characteristics, radiolanthanide-based radiopharmaceuticals exhibit high *in vivo* stability while diffusing into extracellular spaces. While myriad factors contribute to the success of radiolanthanide-based radiopharmaceuticals, selection of the radionuclide is a key determinant underpinning their success. Although radiolanthanides share very similar chemistry, they have diverse nuclear properties and their selection for a specific application is primarily based on half-life as well as radioactive decay characteristics. Reactor production of radiolanthanides following (n, γ) nuclear reaction is attractive owing to the relatively high neutron capture cross-sections of the lanthanide target materials. Conscientious harnessing of the nuclear and chemical characteristics of radiolanthanides in conjunction with the advancement in molecular and cellular biology has not only stimulated the progress of nuclear medicine, but has also driven the field significantly forward. The *in vivo* applications of key radiolanthanide-based radiopharmaceuticals for a variety of therapeutic procedures include: (a) Bone pain palliation (^{153}Sm , ^{177}Lu), (b) Radiation synovectomy (^{165}Dy , ^{166}Ho , ^{153}Sm , ^{177}Lu and ^{90}Y), (c) Peptide receptor radionuclide therapy (^{90}Y and ^{177}Lu), and (d) Radioimmunotherapy using radiolabeled antibodies (^{90}Y and ^{177}Lu). There is a steadily expanding list of radiolanthanide-based radiopharmaceuticals that are currently being evaluated at the pre-clinical research or at various stages of development; these may potentially be used *in vivo* in humans for radionuclide therapy. The advances made so far on

the use of radiolanthanide-based radiopharmaceuticals for therapy are exciting, and further excitement is awaiting in the foreseeable future.

IT-11

RARE EARTH BASED FUNCTIONAL MATERIALS: RICH EXAMPLES OF STRUCTURE-PROPERTY CORRELATION

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Functional materials have assumed very prominent position in several high tech areas as well as in understanding the fundamental origins of functional properties. The functional materials usually are not classified on the basis of their origin, nature of bonding or processing techniques, etc. but are classified on the basis of functions which they can perform. This is a significant departure from the conventional classification of materials. By considering compositions, crystal structure, microstructure and morphology etc. such materials can be designed for a particular property or multiple properties. Thus the synthesis of such materials has been a challenge and also an opportunity to chemists. We have been designing a number of new functional materials guided by crystallographic approach coupled with novel synthesis protocols. The main focus of this talk will be on rare earth (RE) based functional materials, which are distinct in many ways. The lanthanide contraction ensures a graded variation in coordination number and structure which leads to a systematic variation in functional properties. RE based materials have remarkably different luminescent and magnetic properties as compared to transition metal based compounds. Also the systematic of lanthanides contraction are helpful to govern their structural and functional properties as well as for tuning any desired properties. A few typical examples which will be elaborated in this talk are $\text{La}_{1-x}\text{Ce}_x\text{CrO}_3$ (materials with tunable band gap), CeScO_3 (a multi-functional materials with unusual reversible conversion to fluorite lattice), $\text{Gd}_{1-x}\text{Y}_x\text{InO}_3$, $\text{GdSc}_{1-x}\text{In}_x\text{O}_3$ (tunable dielectrics), etc. Several perovskite and fluorite-type materials with trivalent Ce^{3+} were successfully prepared from suitable precursor powders by a controlled heating under low $p\text{O}_2$. Several interesting pyrochlore based oxygen storage materials, viz. $\text{Ce}_2\text{Zr}_2\text{O}_{7+x}$ ($x = 0.0$ to 1.0), $\text{Gd}_{2-x}\text{Ce}_x\text{Zr}_2\text{O}_7$ and $\text{Gd}_{2-x}\text{Ce}_x\text{Zr}_{2-x}\text{Al}_x\text{O}_7$ ($x = 0.0$ to 2.0) have been prepared, which have shown interesting redox catalysis. The simple concepts like rA/rB ratio of $\text{A}_2\text{B}_2\text{O}_7$ pyrochlores could be used to tailor the functional properties like ionic conductivity, dielectric etc. The major focus of this talk will be on the role of synthesis, novel properties exhibited by these RE based functional materials, and their crystallographic correlations.

IT-12

PROCESSING OF ZIRCONIA AND VALUE ADDED PRODUCTS OF INDUSTRIAL IMPORTANCE FROM INDIAN ZIRCON

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Zircon is the most used raw material for traditional applications to advanced ceramics and to nuclear/aerospace industries. Zirconia, an oxide of zirconium, is one of the most significant materials for use in high performance engineering ceramics when the crystal structure is in 'stabilized state'. It exhibits in three well-defined polymorphs. Monoclinic phase from room temperature to 1170°C and then transforms to tetragonal phase which is stable up to 2370°C and on further increase in temperature, it transforms to cubic phase and exists in this form till melting point of 2680°C is reached. The discovery of transformation toughening property in partially stabilized zirconia opened up a new generation of materials having excellent thermal shock resistance, toughness, greater strength and erosion/corrosion resistance at high temperature of applications. The R&D facilities of Indian Rare Earths Ltd (IREL) at Orissa Sands Complex (OSCOM) initiated research work on developing technologies, in the year 1986, for zircon processing and value added products aiming for scaling up the technology to commercial production. The developmental work were initiated by improving the quality and recovery of zircon, optimization of process parameters for zircon frit production and environmental friendly continuous process for the production of high pure zirconium oxy-chloride as starting compound for further processing of high pure zirconium oxide through zirconium basic sulphate and hydroxide. Stabilized zirconia with varying crystal structures were developed adopting co-precipitation technique doping with various oxides for making structural ceramic components for iron & steel industry, cubic zirconia single crystals, substrate for solid oxide fuel cells, and other high-tech applications. Based on the above technology an integrated zirconia processing pilot plant of 3.5 tpa capacity with effluent treatment and solid waste management were conceptualized, designed, built and commissioned in 1999, with in-house expertise, at OSCOM. Since then the multi product processing plant is producing high pure zirconium oxy-chloride, zirconium basic sulphate/hydroxide, ultrapure zirconia and stabilized zirconia doped with oxides, such as, ceria, yttria, dysprosia, calcia, magnesia, etc. The fracture toughness of components made of co-precipitated ceria stabilized zirconia (12 mol% ceria), sintered at 1450°C, were found to be more than 16 MPa m^{1/2}. The special ceramic atomizer nozzles fabricated from yttria and magnesia doped partially stabilized zirconia, iso-statically pressed at 270MPa, heat treated at 1600°C was tested for field trials by pouring molten super-alloy at 1610°C. The internal bore of nozzles withstood the highly corrosive environment of molten super-alloy without chemical and physical aberration. Zirconia single crystals were produced from ultra pure zirconia mixed with yttrium oxide using radiofrequency skull melting furnace. The crystals produced were very close to natural diamond with refractive index and hardness more than 2.2 and 9 mohs respectively. The presentation is the outcome of more than two decades of dedicated R&D work with my colleagues of TSD (OSCOM IREL) and other research agencies, such as, CGCRI

Calcutta, DMRL Hyderabad, BARC Mumbai and also DST New Delhi for part financial assistance.

IT-13

RARE EARTH DOPED GLASSES AND OPTICAL FIBERS: BREAKING THE BARRIERS OF TECHNOLOGY

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The incorporation of Rare Earth (RE) elements in Specialty Glasses and Optical Fibers brought dramatic improvement in the properties and functionalities of the developed products and enabled to achieve technological breakthroughs in several core areas encompassing communication, environmental monitoring, clean energy, industrial processing, healthcare and strategic sectors. The Erbium doped optical amplifier (EDFA) with a piece of Er- doped optical fiber as its prime component is the key technology behind the incredible increase in the bandwidth of the present day communication system enabling high speed internet services. Fiber laser technology based on specialty fibers doped with REs like Yb, Er, Tm and Ho has now been established as the most reliable and efficient laser technology for a wide range of civil, industrial and medical applications replacing conventional laser systems. High power fiber lasers with output extending over tens of kW are now reality due to the development of Yb doped fiber with more than 80% efficiency. Mid IR fiber lasers cover important atmospheric windows and have great potential for applications in environmental monitoring, pollution control, agriculture, non-invasive disease diagnosis and surgery. RE doped specialty glasses and crystals are now serving several niche areas with great precision. The attractive emissions ranging from visible to mid-infrared region depending on the presence of rare-earths have opened up the scope for realizing visible/IR lasers, up-conversion lasers and Mid-IR sensors. High energy high power lasers made of Nd doped glasses of special compositions have set the goal of demonstrating inertial confinement fusion, the best way to produce clean energy as the sun does. Suitable rare-earth doped glasses may also be used as luminescent layers on Si-PV to increase the efficiency of solar cell by down-conversion or up-conversion mechanism reducing thermalization or sub-band gap losses and thus to exploit the unused part of the solar spectrum. Fluorescence Cooling also referred as Optical Refrigeration, a methodology still in the conceptual stage, is expected to make a breakthrough in the cooling technique of electronics, computer and space bound components/ devices and is based on the mechanism of anti-stokes fluorescence from specific rare-earth ions. Such distinctive use of RE doped glasses and fibers of different host materials are unending. Thus modern era with its foundation on high end technologies owes a lot to the science of REs.

IT-14

DESIGN AND DEVELOPMENT OF HIGH ENERGY, HIGH POWER Nd:GLASS LASER IN INDIA FOR HIGH ENERGY DENSITY IMPLOSION PHYSICS EXPERIMENTS

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The indigenization of optical technology for building flash lamp pumped Nd: phosphate glass lasers are an absolute requirement as these lasers are used for strategic application of implosion dynamics. In India, a two arm HEHP (The High Energy, High Power) laser is operational in Raja Ramanna Centre for Advanced Technology. This laser delivers ~ 200 J of energy in one and half ns pulse duration from each arm. Because of requirement of indigenization, a laser glass melting program was initiated between Central Glass and Ceramic Research Institute (CGCRI), Kolkata and Raja Ramanna Centre for Advanced Technology. A glass melting facility having a 5 litre platinum crucible was set up to overcome problems of embargoes. Under this project, presently, Nd doped phosphate laser glass rods up to 50 mm diameter are now produced indigenously. Further, a glass melting facility having 15 litre platinum crucible is being set up in CGCRI to deliver large sized Nd doped phosphate laser glass rods and discs equivalent to LHG-8 of M/s Hoya, Japan. The futuristic requirements of large sized laser glass rods/and discs for HEHP laser installations in India can be met using the facility. In this talk we describe our efforts for the development of indigenous phosphate laser glass rods/discs for HEHP lasers. The laser glass quality for its use in HEHP lasers needs special control on optical parameters taking into consideration constraints of high energy operations and focusability of the laser. The stimulated emission cross section (σ) of the laser glass should be between $2-6 \times 10^{-20} \text{ cm}^2$ so that the losses due to amplified spontaneous emission (ASE) are minimal. The quality of laser glass strongly depends on transition metals TM and TE impurities along with OH bond impurity in case of phosphate glasses. The fluorescence life time (τ) of the upper laser level of Nd ions τ should be $\sim 300 \mu\text{s}$ and depends on the glass host impurities that cause loss of inversion like OH bond, (TM) and rare earth (RE) impurities in addition to concentration quenching. In addition to the non-radiative inversion losses, the laser glasses may have absorption and scattering losses light at the lasing wavelength. Typical absorption losses at the lasing wavelength depend on the impurities of TM and RE impurities and the absorption coefficient at the lasing wavelength is $\sim 0.0019 \text{ cm}^{-1}$, for the TM impurities of ~ 1 ppmw. Annealing for achieving high homogeneity of the refractive index and optical finishing plays an important role in the fabrication of laser rods/discs. The HEHP lasers are normally operated at very high powers of 100 GW to few TW, which is much higher than the power threshold of the self focusing causing the phase distortions. Hence, phosphate glass that has n_2 smaller than the silicate glass is preferred as the active gain medium of HEHP lasers. In this talk we will discuss about quality of the phosphate laser glass

presently achievable under our own indigenous program of laser glass development.

IT-15

RARE EARTH DOPED THIN FILM OXIDE SCINTILLATORS

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In scintillators, the high energy particles (electrons, neutrons, alpha particles) or photons (X-ray or gamma ray) excite electrons in atoms, which thereafter return to the ground state accompanied by emission of visible or UV photons. These photons are easily detected by existing photodetectors. At present, great efforts are being made to improve properties of new scintillation materials, mainly due to rapid development of their applications in medical techniques or for high rate detection and imaging. For these applications high light yield and fast response with short scintillation decay time are necessary. The films with thickness of several micrometres are used in high resolution electron or X-ray screens and in various applications for imaging of microscopic objects with submicron spatial resolution. Here we review particular achievements in film scintillators grown by the liquid phase epitaxy. This method is very effective for material screening and, due to the technological breakthrough, provides scintillators with properties comparable to the bulk single crystal counterparts [1]. We focus especially on oxide scintillator films, primarily garnets and perovskites doped with Ce^{3+} and Pr^{3+} ions. Particular attention is paid to multicomponent garnets $(\text{LuGd})_3(\text{GaAl})_5\text{O}_{12}:\text{Ce}$ due to their high light yield (up to 58000 photon/MeV) and good energy resolution [2]. Intentional co-doping by divalent Mg^{2+} ions brings about dramatic decrease of the thermoluminescence signal, significant reduction of afterglow, and substantial acceleration of scintillation decay kinetics [3]. These results demonstrate large suppression of shallow electron traps which otherwise give rise to delayed emission or non-radiative recombination channels with negative influence on scintillation properties. Such excellent timing properties make these materials competitive candidate e.g. for high rate imaging techniques or for e-beam inspection systems, where nanosecond timing resolution is required. The luminescent and scintillation properties of prospective garnet and perovskite scintillators will be reviewed and discussed in more detail.

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IT-16

PHOTO AND RADIO-LUMINESCENCE STUDIES OF Ln^{3+} DOPED GLASSES FOR SOLID STATE LIGHTING AND RADIATION DETECTION MATERIAL APPLICATION

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Glasses are source of material have properties like low cost, easy to prepare, high transparency at room temperature, hardness along with sufficient strength, excellent electrical resistance, absence of the grain boundaries and continuously variable composition for the optical applications. Glasses doped with lanthanide ions (Ln^{3+}) can be well developed as luminescence materials because of high emission efficiencies, corresponding to 4f–4f and 4f–5d electronic transitions of the Ln^{3+} . The 4f–4f transition gives an especially sharp fluorescence patterns from the ultraviolet to the infrared region, because of shielding effects of the outer 5s and 5p orbitals on the 4f electrons. In this review, up and down conversion luminescence properties of the glasses doped with several lanthanide ions, i.e., Ce^{3+} , Nd^{3+} , Sm^{3+} , Eu^{3+} , Dy^{3+} , Er^{3+} and Tb^{3+} have been explain. Moreover, the current status of their potential applications of Ln^{3+} doped glassesfor solid state lighting and radiation detection material are also given.

IT-17

TEMPERATURE SENSING USING UP-CONVERSION IN RARE EARTH DOPED THERMOGRAPHIC PHOSPHORS

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Er^{3+} and $\text{Er}^{3+}/\text{Yb}^{3+}$ melilite-based $\text{SrLaAl}_3\text{O}_7$ (SLA) phosphors were synthesized by a facile Pechine method. The differences in emission intensities of ${}^4\text{I}_{13/2} \rightarrow {}^4\text{I}_{15/2}$ transition in NIR region when excited with Ar^+ and 980 nm lasers were explained in terms of energy transfer mechanisms. Temperature and power dependence of upconversion bands in the visible region centered at 528, 548 and 660 nm pertaining to ${}^2\text{H}_{11/2}$, ${}^4\text{S}_{3/2}$ and ${}^4\text{F}_{9/2} \rightarrow {}^4\text{I}_{15/2}$ transitions were investigated. Fluorescence intensity ratio (FIR) technique was used to explore temperature sensing behaviour of the thermally coupled levels of ${}^2\text{H}_{11/2}/{}^4\text{S}_{3/2}$ of Er^{3+} ions in the phosphors within the temperature range 14–300 K and the results were extrapolated up to 600 K. Anomalous intensity trend observed in Er^{3+} -doped SLA phosphor was discussed using energy level structure. Cytotoxicity of phosphors has been evaluated using 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay in Bluegill sunfish cells (BF-2). The non-cytotoxic nature and high sensitivity of the present phosphors pay a way for their use *in vitro* studies and provide potential interest as a thermo graphic phosphor at the contact of biological products. On the other hand our group also working very actively on electrochromic properties of transparent MoO_x thin films on flexible substrates which are being modified with rare earth ions that also will be covered in our talk.

IT-18

HIGH PRESSURE EFFECT ON LUMINESCENCE PROPERTIES OF Pr³⁺ AND Eu³⁺ DOPED OXIDES WITH PEROVSKITE AND LAYERED PEROVSKITE STRUCTURES

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The layered perovskite oxide (LPO) compounds have received considerable attention as functional materials that serve two-dimensional microspaces. In this work, we demonstrated a high-sensitivity optical thermometric material based on the diverse thermal quenching behaviors in the Ruddlesden-Popper type perovskite Na₂La_{1.995}Pr_{0.005}Ti₃O₁₀ micro-crystals, which provide a perspective approach to design self-referencing optical temperature sensing materials with superior temperature sensitivity. The fluorescence intensities ratio (FIR) of Pr³⁺³P₀ and ¹D₂ multiplets, host excited and IVCT state interfered, reveals outstanding temperature sensing performance with the maximum relative sensitivity as high as 2.43% K⁻¹ at 425 K. In the meantime, it is found that ³P₁ and ³P₀ levels of Pr³⁺ can be adopted as thermally coupled energy levels (TCEL) for thermal sensing with relatively high sensitivity in the low-temperature range from 150 to 275 K. Furthermore, it is found that Pr³⁺ ions work as hole trap and recombination sites for efficient excitation energy transfer from host to Pr³⁺ ions. The decay kinetics and high-pressure of luminescence were also performed to confirm our interpretation of experimental results and the model proposed for the system. This work can be expected to lead to the development of novel photofunctional materials. Also classical RAlO₃ perovskites (R=Y, Lu, Gd, Tb) doped with trivalent europium were investigated. These materials in the form of the single crystalline film (SCF) are perspective as scintillating screens for microimaging applications. SCF samples were prepared by liquid phase epitaxy method from the melt solution based on the PbO-B₂O₃ flux onto YAP substrates. It was shown, that in these perovskite compounds Eu³⁺ tends to occupy various sites with various local symmetry. In order to better understand this phenomenon, high-pressure luminescence measurements were performed. So called asymmetry ratio for ⁵D₀→⁷F₂ and ⁵D₀→⁷F₁ transitions was calculated as $K = I(^5D_0 \rightarrow ^7F_2) / I(^5D_0 \rightarrow ^7F_1)$ for pressures up to 16 GPa. It was revealed, that for GdAP:Eu and TbAP:Eu perovskites, the K value

have the tendency to change with increase of pressure but for YAP:Eu the changes of K values with pressure were not observed. Nature of this phenomenon is discussed with relation to ionic radii of RE and details of crystallographic structure these materials.

IT-19

PHOTOLUMINESCENCE QUANTUM YIELD AS A TEST OF QUANTUM CUTTING PROCESSES IN IONIC DOWN-CONVERTING PHOSPHORS

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Ionic-like down-converting phosphors nowadays are actively discussed for solar spectrum modification and in such a way for possible enhancement of the efficiency of silicon solar cells. Phosphors co-doped with $Ce^{3+}-Yb^{3+}$, $Eu^{2+}-Yb^{3+}$ or $Bi^{3+}-Yb^{3+}$ ions are of particular interest because of the efficient and broad absorption in UV-blue range and the near-IR emission around $1\ \mu m$ from Yb^{3+} . However the real value of the energy transfer efficiency in such materials remains generally unknown. In other words, the question remains whether the energy transfer is cooperative (one-to-two) or non-cooperative (one-to-one energy transfer).

Efficiency of the energy transfer in such down-converting materials is usually estimated from shortening of the luminescence decay of donor (Ce^{3+} , Eu^{2+} or Bi^{3+}) ion, when the conversion ratio of 2.0 (*i.e.* an ideal quantum cutting mechanism) is postulated. Instead of this we propose a direct measurement of quantum yield (QY), which allows to estimate a real value of the conversion ratio. This procedure was already tested by us for such phosphors as $Y_4Al_2O_9$ (YAM):Bi,Yb; Gd_2O_3 :Bi,Yb; YVO_4 :Bi,Yb; $YNbO_4$:Bi,Yb; $Y_3Al_5O_{12}$ (YAG):Bi,Yb; $Gd_3Ga_5O_{12}$ (GGG):Bi,Yb and YAG:Ce,Yb. Results for these materials will be presented and discussed. Our results testify that not all the phosphors that demonstrate the energy transfer from Ce^{3+} or Bi^{3+} to Yb^{3+} have the cooperative energy transfer. The procedure used in this study can be also applied to other systems proposed for quantum cutting in order to evaluate their performance for solar spectrum modification.

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IT-20

SPECTROSCOPIC PROPERTIES AND LOCATION OF THE Ln^{3+} AND Ln^{2+} ENERGY LEVELS IN CRYSTALS UNDER HIGH HYDROSTATIC PRESSURE

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Control of the electron transfer from the dopant cations to the conduction band and from the valence band to the dopant cations in inorganic compounds are crucial for luminescence materials performance, since such transitions can be responsible for the luminescence quenching. Specifically, it is well known that ionization processes that take place in the excited 5d states of Ce^{3+} ions can quench the Ce^{3+} luminescence in many materials. Much less known is effect related to Eu^{3+} luminescence quenching caused by charge transfer processes. Awareness is growing that the energy of the localized states related to luminescence centers, specifically the trivalent and divalent lanthanides (Ln^{3+} and Ln^{2+}) with respect to delocalized states of conduction band and valence band can strongly affect the efficiency luminescence of excited lanthanide ions. Several experimental techniques have been used to determine these energies like absorption, luminescence excitation or UV photoelectron emission, excited state absorption or photoluminescence. The systematic study of the 4f-to-5d and charge transfer transitions (CTT) of rare earth ions allow to determine the location of the impurity levels in the host. In this contribution we show how the spectroscopy under high hydrostatic pressure can be used to determine the energies of the ground states of Ln^{3+} and Ln^{2+} with respect to the conduction and valence bands edges. The high hydrostatic pressure applied in diamond anvil cell (DAC) diminishes the distance between central ion and ligands and contracts the bond length of the host. Therefore pressure changes the energies of localized states and the bandgap. Especially, quite large increase of the energies of the localized states of the 4fⁿ electronic configuration of Ln^{3+} and Ln^{2+} with respect to the band states is observed. This effect is responsible for pressure induced luminescence quenching of Pr^{3+} and Tb^{3+} in oxides. The different effect is observed for Eu^{3+} doped materials where pressure recover the luminescence from higher excited states of Eu^{3+} . We have chosen $\text{Y}_2\text{O}_2\text{S}$ doped with Eu^{3+} and $\text{Y}_2\text{O}_2\text{S}$ doped with Tb^{3+} and Pr^{3+} doped LiNbO_3 , and LiTaO_3 to demonstrate this effect. As final results we are able to obtain the absolute energies of the Ln^{3+} and Ln^{2+} dopands and energies band edges of the hosts (with respect to vacuum level) and their pressure rates.

THE STRUCTURE AND TEMPERATURE FEATURES OF THE IR LUMINESCENCE PROPERTIES IN THE CHALCOGENIDE AND OXIDE GLASSES

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The search for new optical glasses with an aim of improvement of their properties is one of the main directions in development of modern materials science. One of the efficient ways to improve the properties of these glasses is to introduce the rare earth ions to allow for many applications in optical industry. In this talk we present the systematic studies of the glasses doped selected rare earth ion with a focus on the optical, non-linear optical and thermal properties of the studied materials in the IR spectral range. The talk will be supported by numerous examples, comparison with the experimental results and agreement between the experimental and theoretical data [1-6].

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IT-22

RARE EARTH LUMINESCENCE UNDER PRESSURE

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This talk will focus the attention on the luminescence properties of different rare earth (RE^{3+}) in crystals, nanocrystals, glass-ceramics, and glasses at high pressures. The pressure determination inside the hydrostatic chamber is a key question that requires calibrated standards. Thanks to the transparency of the diamonds to visible light, an in situ, indirect calibration can be done taking advantage of the high sensitivity to changes of pressure of some emission lines of rare earth in solids [1,2]. For pressure sensors applications, the shielding of the 4f-electrons of the RE in crystals produces very sharp emission lines in the optical range. In this sense, the luminescence in systems such as Nd^{3+} -doped garnets have been tested in the near-infrared range studying the pressure shifts of the $\text{R}_{1,2} \rightarrow \text{Z}_5$ lines of the ${}^4\text{F}_{3/2} \rightarrow {}^4\text{I}_{9/2}$ transition [2]. In addition, Nd^{3+} ion can be used as local probe when a structural phase transition is induced by pressure. As an interesting example is the changes observed in the optical properties of $\text{LaVO}_4:\text{Nd}^{3+}$ crystal when the mozazite-to- BaWO_4 -II phase transition occurs at around 12 GPa, which can be related to changes in the coordination number of Vanadium and in the local sites of Neodymium. The effect of the pressure is studied in the infrared-to-visible energy upconverted luminescence of the Er^{3+} ions in a nanocrystalline oxyfluoride glass-ceramic from ambient pressure up to 17 GPa. After exciting the sample at 800 nm with a Ti:sapphire laser, upconverted ${}^2\text{H}_{11/2}$, ${}^4\text{S}_{3/2} \rightarrow {}^4\text{I}_{15/2}$ green and ${}^4\text{F}_{9/2}$ ${}^4\text{I}_{15/2}$ red emission are observed by the naked eyes, even inside the DAC. The time-resolved luminescence measurements as a function of pressure indicate that the dominant mechanism of the upconversion processes is energy transfer (ETU). The roles of the pressure-induced energy transfer between optically active ions, their host local structures and the energy trap centers in the quenching of the rare earth luminescence are discussed. The concentration and pressure dependent luminescence properties of the Tb^{3+} and Sm^{3+} ions in lithium fluoroborate glasses have been studied by analyzing the de-excitation processes of the ${}^4\text{G}_{5/2}(\text{Sm}^{3+})$ and the ${}^5\text{D}_4(\text{Tb}^{3+})$ levels at ambient conditions as well as a function of pressure up to 21 and 35 GPa, respectively, at room temperature [3,4]. The lifetime and the energy transfer parameter have been obtained and analyzed independently as a function of pressure.

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IT-23

TERNARY METAL OXIDE COMPOUNDS PREPARED BY FACILE PROCESS AND FEASIBILITY FOR RARE-EARTH DOPED HOST MATERIALS

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In this topic, ternary metal oxide compounds in form of perovskite and spinel structures prepared by suitably facile processes are presented. First, Zinc Titanate (ZnTiO_3) perovskite structure was synthesized by sonochemical process employing intense ultrasonic energy for the growth of fine particles. Titanium isopropoxide and zinc chloride were designated as starting precursors for Ti and Zn with molar ratio of 1:1. The sonochemical process was carried out under high frequency ultrasound (20 kHz, 750 W) supplied directly to the mixed precursor at room temperature and ambient to obtain as-synthesized product followed by calcinations at specific temperature ranging from 400–900°C for crystallinity enhancement. Second, Zinc Stannate (Zn_2SnO_4) spinel-type structure with exceptional morphology was successfully prepared by facile co-precipitation method combined with post-calcination process. Zinc chloride and tin chloride were chosen as the precursors for Zn and Sn sources, respectively. Third, Zinc aluminate (ZnAl_2O_4) spinel structure was prepared by the vibrational milling method. Oxide precursor materials including Al_2O_3 and ZnO powder were used in the process. Several milling round and sintering treatment were the important parameters for studying phase transformation between $\text{Al}_2\text{O}_3/\text{ZnO}$ to ZnAl_2O_4 phase. The feasibility for applying these ternary metal oxide materials as host materials of rare-earth dopants was investigated by doping Sm into ZnAl_2O_4 compound and corresponding photoluminescence properties and lifetime measurements were measured and investigated. Further details of results and discussion will be presented.

DEVELOPMENT OF Nd³⁺ ION DOPED GLASSES FOR NIR LASER APPLICATION

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Laser is widely used in many applications such as industry, medical, military, and scientific. It is needed a system including pumping source, gain medium, and resonator to generate laser. Nowadays rare earth doped glass as a gain medium has been more attractive to be observed due to their low-cost production, synthesis flexibility, and properties. Nd³⁺ ion doped glasses such as borate, phosphate, tellurite, and silicate are an interesting topic to be investigated by scientist and researcher. As we know, Nd³⁺ ion can produce strong emission in the near infrared region due to ⁴F_{3/2} → ⁴I_{11/2} transition under $\lambda_{ex}=808$ nm. The radiative properties such as JO parameter ($\Omega = 2,4,6$), emission cross-section (σ_e), radiative transition probability (A_R), and branching ratios (β) show their potential for laser gain medium. The popular method for producing glasses called melt and quenching technique is used in this research. The addition of metal alkali as modifier or intermediate in the glass system can improve their transparency, chemical durability, thermal expansion, and glass structure. In this paper, the luminescence and radiative properties of Nd³⁺ ion doped glass will be discussed to understand the characteristic of glasses as laser gain medium. Keywords: Gain medium, a glass laser, luminescence, NIR, Nd³⁺.

IT-25

Nd³⁺-YAP NANOCRYSTALS: A HIGH PRESSURE LUMINESCENCE STUDY

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Perovskite crystals have been the object of several studies in the past, due to their outstanding structural, chemical and physical properties that allow their use in several fields. In particular, and concerning with optical properties, YAlO₃ doped with different RE³⁺ has found use as laser crystals, scintillators, phosphors and as sensor materials. Particularly, YAlO₃ crystals doped with Nd³⁺ ions have been studied for its application as high pressure (HP) optical sensor in the near-infrared (NIR) as well [1]. From the point of view of the luminescence properties YAlO₃ nanocrystals behave as their bulk counterparts. In this work, Stokes ⁴F_{3/2} ⁴I_{9/2} and ⁴F_{3/2} ⁴I_{11/2} transitions and anti-Stokes ⁴F_{9/2} ⁴I_{9/2} and ⁴F_{7/2}+⁴S_{3/2} ⁴I_{9/2} transitions exciting at 785 nm have been measured in different pressure ranges. Pressure induced linear shifts have been obtained, with linear coefficients similar to that found in the most widely used optical sensor, the ruby (Cr³⁺-Al₂O₃) and with emissions both in the visible (VIS) and in the NIR. Luminescence properties, focusing in the description of the effects of pressure on the energy levels of optically active Nd³⁺ ions, have been successfully simulated by crystal field analysis by using the simple overlap model combined with ab initio structural calculations [2].

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IT-26

FARADAY ROTATION IN RARE EARTH DOPED AND QUANTUM DOT BASED GLASSES.

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Currently, Magneto optical Faraday Rotator (MOFR) materials are of great interest for modern applications such as optical isolation, modulation and switching in telecommunication. However, single crystals having Verdet constant near to 173 degree/T-cm at 632 nm are the benchmark material is still used in these devices which are rather expensive and very difficult to fabricate. For this contest, many researchers have been reported the rare earth (RE) element (such as Tb, Er, Eu, Ce, Eu, Dy) doped glass and semiconductor quantum dot embedded glasses. The Verdet constant for RE doped glasses has achieved upto 135 degree/T-cm at 632 nm which near to single crystal TGG. Till RE doped glasses are not economical viable due to the rare nature of RE. Hence, the alternative should be find out. In view of this, we are reporting herewith the stable and novel Bismuth Chalcogenide (Bi_2X_3 , X=S and Te) quantum dot - glass nanosystem using controlled thermo-chemical method. The Q-dots of orthorhombic Bi_2S_3 and Hexagonal Bi_2Te_3 of size 4 to 20 nm were grown along the $\langle 1\ 2\ 1 \rangle$ and $\langle 1\ 1\ 3 \rangle$ direction, respectively. The strong quantum confinement in the nanosystem is clearly shown by the optical study. The band gap of host glass was drastically reduced (from 4.00 to 1.88 eV) due to the growth of Bi_2X_3 quantum dots. Faraday Rotation (FR) investigations of the Bi_2Te_3 quantum dot - glass nanosystem show a nonlinear response in Verdet constant with a decrease in the Bi_2Te_3 dot sizes. The Bi_2S_3 (6 nm) and Bi_2Te_3 (4 nm) Q-dot glass-nanosystem shows significant enhancement (300 and 70 times) in Verdet constant compared to the host glass and more radically better than conventional single crystal (TGG). This is the first time such type of unique nanosystem has been architected and conferred extremely good magneto-optical performance. It is noteworthy that expensive single crystals can be replaced with this cost effective novel glass nanosystem. Interestingly, present quantum dot glass nanosystem can be transformed into optical fibers very easily, which will have an exceptionally high impact on the fabrication of high performance magneto optics devices.

SYNTHESIS AND LUMINESCENCE CHARACTERIZATION OF RARE EARTH IONS ACTIVATED INORGANIC PHOSPHORS FOR ECO-FRIENDLY LED LIGHTING

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The scientific world is immensely interested in the white light generation because the consumption of electrical energy and operating expenses can be reduced to a great extent if they are replaced by some more efficient sources. Light-emitting diodes (LED) have been in the higher demands for the solid-state lighting technology in recent years [1, 2]. The technological advancements in the LED industry are rapidly growing with improvement in the quality and reliability of phosphors. Most of the times, the key to efficient solid state lighting lies in the proper selection of high efficiency phosphors capable of giving good visible light emission. Extensive investigation of LED phosphor has been conducted in recent years, in which the phenomenon of energy transfer among luminescence centers is widely utilized to tune luminescence in materials. In this context, much attention has been paid to the energy transfer among rare earth ions and transition metal ions, like $Ce^{3+} \rightarrow Eu^{2+}$, $Ce^{3+} \rightarrow Tb^{3+}$, $Eu^{2+} \rightarrow Tb^{3+}$, $Tb^{3+} \rightarrow Eu^{3+}$, $Ce^{3+} \rightarrow Mn^{2+}$, and $Eu^{2+} \rightarrow Mn^{2+}$. These energy transfer processes can tune luminescence in many phosphors for the generation of white light. The route of synthesis plays an important role for the development of good phosphors with proper morphology and desired characteristics. The lanthanide ions have a distinct ability to produce visible light emission by absorbing in the UV or near-UV region. Most of the lanthanides are capable of producing emission by virtue of f-f transition that are considered to be forbidden by selection rules. However, their introduction in some suitable host lattice can remarkably relax these forbidden transitions. If the lanthanide ion occupies a site with non-inversion symmetry, the probability of achieving intense electric dipole transitions increases. The Eu^{2+} and Ce^{3+} ions show their emissions by virtue of 5d \rightarrow 4f transitions and are spectroscopically allowed transitions. These ions vary their emission bands depending on the host in which they are incorporated. The objective of the present abstract is to summarize the trends in the synthesis, characterization and potential areas of application of lanthanide activated phosphor in the field of luminescence. This is supposed to be a step forward towards the next generation lamp phosphor. Non-absorbing hosts, doped with impurities to act as absorption and emission centers, provide useful phosphors. Our approach is to describe the possible classes of rare earth activated phosphors, which are characteristically associated with its luminescence study. Different low cost synthesis routes were considered for preparation of phosphors for lamp industry.

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SP-1

SUSTAINABLE PROCESSING OF METALLURGICAL WASTES FOR EXTRACTON OF RARE EARTH ELEMENTS

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The increasing need for rare earth elements (REEs) and limited primary sources in India vis-à-vis considerable global market demand, calls for exploitation of secondary resources. The exploitation of metallurgical wastes such as red mud, blast furnace slag as secondary source for rare earth elements has been claimed. It is difficult to directly recover REE's from such resources due to its low levels and presence of major minerals of Ca, Fe, Al, Ti and other gangue which not only hinders extraction but gets co-extracted. Considering the growing levels of REEs present in the metallurgical wastes, innovative and cost-effective technologies which drastically reduce the environmental impact of the overall recycling flow sheet with respect to the primary mining route, should be further developed. Recycling of rare earth containing products needs a careful analysis of availability of adequate waste material and appropriate technologies for economic recovery vis-a-vis scale of operation. CSIR-NML, Jamshedpur in collaboration with NALCO and TATA STEEL has developed first of its kind flow-sheets at 2.5kg scale to extract inherent REEs of interest respectively from red mud and blast furnace slag. A process was developed to produce 96% mixed REOs of La-Ce-Sc at 2.5kg scale by combined steps of leaching and ion exchange-precipitation from red mud. With blast furnace slag, a process was developed to produce 93% mixed REOs of La-Ce-Nd at 2.5kg scale. The processes are further investigated to recover individual pure REEs and other important elements for sustainable processing.

SP-2

PHENOMENA ASSOCIATED TO THE TRANSFER OF RARE EARTH INVOLVED IN SEPARATION CHEMISTRY: FROM THE MOLECULAR MODELLING TO THE CHEMICAL ENGINEERING

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Recycling of metals, such as rare earths, into valuable material relies on ion specific separation, basis of the hydrometallurgy [1]. Most of efficient methods known for separating ions are based on equilibria between complex fluids, typically between aqueous and organised organic phases. Indeed, ions migrate from the aqueous to the organic phase thanks to surfactant or extractant molecules in the organic phase, and then are captured in reverse micelles. Understanding the driving forces of the ion transfer is therefore a crucial issue to understand the properties of liquid-liquid interfaces between organic and aqueous phases, but also to assess the chemical potentials of the compounds involved. Here, we propose multi-scale approaches for calculating thermodynamics properties of ions in aqueous and organic phases directly comparable to the experiments ones only by taking into account the molecular properties of the solutes with no adjustable parameters. Based on the osmotic equilibrium method, activities and activity coefficients for aqueous electrolyte solutions composed of nitrate lanthanide salts have been successfully calculated [2]. In the meantime, thermodynamics properties of solutes in organic phase have been deduced from umbrella-sampling molecular dynamics simulations. We demonstrated that molecular complexes formed during solvent extraction self-assemble as reverse micelles, and therefore induce a supramolecular organization. In most of the cases, water molecules play an essential role in the organization of this non polar medium [3]. Coupling these solute molecular properties with a mesoscopic water/oil interface model allows for accessing all the thermodynamic properties needed for chemical engineering, e.g. activity coefficients, association constants, ternary phase diagrams [4].

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SP-3

**STRUCTURE AND DYNAMICS OF RARE EARTH - PHOSPHORIC ACID
LIGAND COMPLEXES: A MOLECULAR DYNAMICS STUDY**

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Phosphoric acid based extractants have been employed widely in solvent extraction of Rare Earth Elements. These extractants have shown selectivity towards heavier elements in lanthanide separations. While the extraction equilibrium for these ligands is well established, the microscopic details (i.e. atomistic level understanding) of the extraction mechanism is not yet resolved unequivocally. Furthermore, such detailed understanding of the working mechanism of a ligand is necessary in order to design newer extractants with enhanced selectivity. In this study, we employed Molecular Dynamics simulations to firstly elucidate the structure of the complex formed by phosphoric acid extractants with REE ions. Subsequently, we computed the free energies of the REE-ligand complexes in aqueous and organic phase, and show that the selectivity of phosphoric acid ligands for heavier REEs originates from the favourable differential stabilization of these complexes between the aqueous and organic phases.

SP-4

SPENT NICKEL HYDRIDE BATTERIES – A RICH SECONDARY RESOURCE OF WEEE FOR RARE EARTH EXTRACTION

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With the significant use of critical metals in rechargeable batteries, the recycling of the spent batteries is important to address the stringent environmental regulations as well as exploitation of such resources for secured supplies of rare earth elements. Approximately 7% of a typical NiMH battery is made up of REs. This equates to around 1 g of REs per AAA battery, 60 g for a household power tool and 2 kg for a HEV battery. The major phases of rare earth elements in spent NiMH batteries are Nd_2Ni_7 and Ni_5La apart from dominant nickel. In this context, a process is put forth for recovery of rare earth elements from spent nickel metal hydride (NiMH) batteries and synthesis of high pure rare earth salt. Under the optimised conditions of 2 M H_2SO_4 , 100 g/L pulp density, 348 K, and 120 min, 98.1% Nd, 98.4% Sm, 95.5% Pr and 89.4% Ce could be extracted. Regarding the mechanism of leaching, it is governed by the chemical reaction of the lixiviant on the particle surface of the electrode powder. The activation energy values for the leaching of rare earths viz., Nd, Sm, Pr and Ce are found to be 7.6, 6.3, 11.3 and 13.5 kJ/mol, respectively. The leach liquor composed (g/L) of 6.0 Sm, 4.3 Nd, 2.15 Pr, 2.2 Ce and 1.75 La along with 53.0 Ni, 4.45 Co, 2.5 Mn, 1.85 Zn and 1.65 Fe was subjected to precipitation with NaOH. REs were precipitated in the form of insoluble double sulfate salts with $\text{NaSm}(\text{SO}_4)_2 \cdot \text{H}_2\text{O}$ and $\text{NaNd}(\text{SO}_4)_2 \cdot \text{H}_2\text{O}$ as the major phases along with $\text{CeNa}(\text{SO}_4) \cdot \text{H}_2\text{O}$, $\text{NaNd}(\text{SO}_4)_2$ and $\text{NaPr}(\text{SO}_4)_2$ as the minor phases. The composition of the precipitate was 53.4 % Sm, 16.3% Nd, 10.8% Pr, 9.6% Ce and 3.8% La. SEM of the mixed rare earth salts exhibiting fully grown hexagonal top shaped (flowery) 4-5 μm particles comprising of mostly samarium sulfate.

SP-5

**PROCESS FOR EXTRACTION AND SEPARATION OF RARE EARTHS
FROM SPENT NdFeB MAGNET OF WIND TURBINE**

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NdFeB magnet is widely used in various technological application due to its superior magnetic properties. Due to increasing demand of rare earths in different application, spent NdFeB magnet emanates as potential secondary resource of rare earths. Spent NdFeB contains around 30% of rare earths which can be utilized for the recovery of valuable rare earths. In the present investigation, studies were carried out for selective recovery of rare earths (Nd, Pr and Dy) from spent NdFeB magnet of wind turbine. Pre-treatment condition and leaching parameters were varied in order to obtain optimum leaching condition. At optimized condition, 98% of rare earths were recovered in the leach liquor leaving behind iron in the leach residue. The leach residue was characterized by XRD and SEM, which indicated the major presence of hematite phase. The composition of leach liquor was obtained as 16.8 g/L Nd, 3.8 g/L Pr and 0.28 g/L Dy. Solvent extraction studies were carried out for individual separation of rare earth ions using new extractants Mextral A336t and Mextral 507P. Different extraction parameters such as equilibrium pH, extractant concentration, mixing time etc. were varied to optimize the extraction and separation of rare earth elements. The extraction efficiency of Mextral 507P was found to be better than Mextral A336t, but the separation factor of Mextral A336t was better than that of Mextral 507P. Thus, the present work developed a complete process for the extraction and separation of rare earths from spent NdFeB magnet.

SP-6

**GLOBAL RARE EARTH MARKET: RECENT DYNAMICS,
APPLICATION WISE ANALYSIS AND LONG TERM FORECAST**

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Rare earth elements (REE) are indispensable raw material for permanent magnet manufacturing, medical imaging, renewable energy, catalytic applications, specialty alloys, light emitting diode (LED) phosphors and energy storage applications. Along with the rapidly growing market of clean energy, energy efficient products and electric vehicles, global demand for REEs is set to increase multifold in forthcoming decades. In this presentation, we will analyze and understand global market of rare earths, pivotal points for growth of individual application market, REE supply chain dynamics and market forecast till 2030. As on today, the global REE production is mainly concentrated in China, Australia, Russia and Canada; they respectively contributed 83%, 10%, 3% and 1% of global production in 2017 [1]. As on June 2018, there are 178 REE deposits have been identified across the world, and assessed REE resources as of 2018 totaled 495 megaton (MT) rare earth oxides (REO); 59 deposits have been technically assessed and more than 8 deposits are moving ahead with on-site exploration [2]. These resources, if realized at full assessed capacity, can easily meet the global REE demand till 2070. Although there is lot of uncertainty in completion of these projects due to scarcity of sustained funding, environmental clearances and unpredictable Chinese rare earth policy, the development of new REE sites is expected to bring down the RE oxide and RE metal prices. Out of 17 REEs, the pricing of La_2O_3 and CeO_2 is going to be highly constrained due to excess availability till 2030. Whereas consumption of REEs such as Nd, Pr and Dy is expected to increase to 250000 TPA in 2030 compared to 48000 TPA in 2017. RE based permanent magnets are the demand driver and expected to be produced around 700000 TPA compared to 140000 TPA estimate for 2017. The RE-magnet market is expected to grow to \$50 billion compared to existing \$8 billion. The total RE application market is estimated to be around \$80 billion by 2030 out of which the permanent magnet market share will be 62%. Other demand drivers will be RE based catalysts and specialty alloys.

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SP-7

**SYNTHESIS AND CHARACTERISATION OF ECO-FRIENDLY YELLOW
PIGMENTS BASED ON $(\text{LiLa})_{1/2}\text{WO}_4$ - BiVO_4 FOR ENERGY SAVING
APPLICATIONS**

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Considering the performance of buildings, lesser surface temperatures reduce the heat penetrating into the building and thereby decrease the cooling loads while making a more comfortable interior thermal environment. Roofing materials with higher solar reflectance (the ability to reflect sunlight) and higher thermal emittance (the ability to radiate heat) stay cool in the sun. Thus, they reduce the cooling energy load in air-conditioned buildings and increase the resident comfort in unconditioned buildings[1]. Conventional near infrared (NIR) reflecting pigment coatings reduce the heat buildup and minimize the use of cooling power systems in buildings, automobiles, etc., which contributes to energy savings, cost effectiveness, and environmental security. New eco-friendly yellow inorganic pigments based on BiVO_4 having high NIR solar reflectance have been successfully designed. Doping of L^+ , La^{3+} and W^{6+} into the trivalent and pentavalent site of the BiVO_4 system causes changes in the absorption properties and also improved its optical and reflective properties. The influence of morphology on the optical and reflective properties of pigment powders is studied on pigments created by the conventional solid-state reaction method. Typically the pigment $[(\text{LiLa})_{0.125}\text{Bi}_{0.75}][\text{W}_{0.25}\text{V}_{0.75}]\text{O}_4$ displayed intense yellow color ($b^* = 83.53$) with near-infrared reflectance of 90% much better values than the commercial sicopal yellow. These colorants demonstrated good coloring performance with high solar reflectance in cement blocks and on metal sheets. These compositions containing less toxic elements can be used as sustainable pigments in surface coating applications as energy saving products.

SP-8

DESIGN STRATEGY FOR BRIGHT WHITE LIGHT EMISSION FROM Eu(III) -COMPLEX:EXPERIMENTAL AND THEORETICAL APPROACH

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In recent years, the synthesis of lanthanide (Ln) based electroluminescent materials are rising due to their line like emission characteristics (4f-4f electronic transition) [1]. However, the quantum efficiency (QE) and lifetimes are not satisfactory; due to inefficient energy transfer (ET) from the ligand to Ln's (influenced by transporting materials). This inefficient ET strategy is taken as an advantage in approaching the white light emission from the Eu(III) complex. In general, Eu(III) complex showed red emission and producing a white emission is a challenging research task. However, the design strategy followed to balance the primary colors (Blue, Green and Red) and it results in white light emission from the complex [2]. We have designed a bipolar ligand consist of aromatic amines into the antenna expected to improve the hole injection/ transport properties of the Eu^{III}-phosphor. Multi-functional Eu-complex (Eu(TTA)₃Phen-Ph-TPA), based on novel bipolar ligand (Phen-Ph-TPA) have been designed and synthesized. The photophysical studies of the synthesized Ligand and Eu-complex have been carried out in the solution, solid state and thin film study by UV-Vis spectroscopy and spectrofluorimetry. The UV-Vis studies of ligand compounds are showed absorption from 250 to 450 nm with λ_{\max} 362(±5), 277(±5) nm, these bands are due to the * transitions of the ligands (TTA, ligands). The PL emission spectra of Eu(III)-complexes are exhibits ⁵D₀-⁷F_J(J=0-4) transitions of Eu(III) ion [3]. The TGA analyses were shown thermal decomposition above 250°C. LEDs of the complexes are fabricated and characterized. Theoretical and experimental analyses are compared as well confirmed the ET process from ligand to Eu(III) metal ion. The detail results will be presented and discussed.

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SP-9

SYNTHESIS AND CHARACTERIZATION IN $ZrO_2-Nd_2O_3$ SYSTEM

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Inert matrix materials are proposed to act as transmutation targets to incinerate the minor actinides (MAs) in order to reduce the radio-toxicity of radioactive waste significantly [1]. The rare earth oxide Nd_2O_3 has been extensively used as non radioactive surrogate of radioactive MAs (Am_2O_3 and Cm_2O_3) [2]. Zirconia-based materials, on the other hand, are the potential inert matrix candidates to act as transmutation targets [3]. Consequently, $ZrO_2-NdO_{1.5}$ system has been investigated for phase relations to determine MA loading capacity in ZrO_2 matrix. This study aims at synthesis, and characterization of the nominal compositions in $Zr_{1-x}Nd_xO_{2-x/2}$ (0.0 x 0.5) series. All the nominal compositions in the series have been prepared by gel combustion route and the prepared materials were sintered at 1723 K for 48 h in static air. The sintered samples were characterized by X-ray diffraction (XRD). The effect of Nd^{3+} substitution in ZrO_2 has been investigated in the present study. Room temperature XRD patterns exhibit that pure ZrO_2 ($x = 0$) crystallizes in monoclinic structure while incorporation of 10 mol% Nd^{3+} in ZrO_2 ($x = 0.1$) forms a biphasic mixture consisting of monoclinic zirconia (m- ZrO_2) and fluorite-type Nd-stabilized cubic zirconia. Further incorporation of Nd^{3+} ($x = 0.2$) results into disappearance of m- ZrO_2 phase and XRD pattern shows peaks corresponding to fluorite-type Nd-stabilized zirconia only. The pyrochlore phase appears for the compositions $x = 0.4$ and 0.5 . However, the appearance of very weak reflections corresponding to pyrochlore type ordering for the composition $x = 0.3$ indicates the existence of micro domains of pyrochlore type phase in macro domains of fluorite type phase. The present study indicates ~ 20 mol% Nd^{3+} substitution is required for stabilizing m- ZrO_2 in cubic phase. A maximum of 50 mol% Nd^{3+} can be loaded in ZrO_2 maintaining single phase pyrochlore structure.

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SP-10

LUMINESCENCE PROPERTIES OF Er³⁺ IONS DOPED ALKALINE - EARTH BORO TELLURITE GLASSES

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The Alkaline-Earth Boro Tellurite (AEBT) glasses doped with different concentrations of Er³⁺ ions were fabricated by conventional melt quenching technique. The optical absorption, visible luminescence, Near-Infra Red (NIR) luminescence, Up-Conversion (UC) luminescence and luminescence decay spectra were recorded to analyze the spectroscopic properties of the titled glasses. Judd-Ofelt (J-O) intensity parameters ($\Omega_2, \Omega_4, \Omega_6$) were deduced by applying J-O theory to the recorded absorption spectral features and subsequently used to evaluate various radiative properties such as radiative transition probability (A_R), total radiative transition probability (A_T), radiative lifetime (τ_R) and radiative branching ratios (β_R). The titled glasses excited under 379 nm exhibited green luminescence at 547 nm ($^4S_{3/2} \rightarrow ^4I_{15/2}$). Upon pumping with a laser diode $\lambda_{exc} = 980\text{nm}$ (NIR), a broad emission spectra at around 1572 nm ($^4I_{13/2} \rightarrow ^4I_{15/2}$) has been observed for which stimulated emission cross-section (σ_{se}), effective band width ($\Delta\lambda_p$), gain band width ($\sigma_{se} \times \Delta\lambda_p$) and optical gain ($\sigma_{se} \times \tau_R$) parameters were evaluated. The up-conversion luminescence shown by these glasses has been analysed to understand the utility of these glasses as up-conversion lasers. Among all the prepared glasses the sample AEBTER1.0 exhibits better radiative properties compared to other reported glasses. The gain cross-section of the sample AEBTER1.0 was derived using absorption cross-section (σ_a) and emission cross-section (σ_e) for different values of population inversion (γ). The Decay spectral curves for the $^4I_{13/2}$ level of Er³⁺ ions in AEBT glasses were recorded under 980 nm excitation, to measure the experimental lifetimes (τ_{exp}) and quantum efficiencies. From the obtained results, it is conspicuous that the prepared glasses are quite suitable to fabricate optoelectronic devices in visible green and NIR region.

SP-11

DISCREPANCY ON THE ENHANCEMENT OF UPCONVERSION RED EMISSION IN CASE OF Yb³⁺, Er³⁺ CODOPED SYSTEMS UPON ~980 nm EXCITATION: A REVISIT ON THE ENERGY TRANSFER MECHANISM

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For the past couple of decades, photon energy Upconversion (UC) materials are being rigorously investigated in view of their potential applications in different domains like solar energy conversion, biological labelling, energy efficient lighting, upconverting lasers, display, optical sensors etc. Among all rare earth ions, (Yb³⁺, Er³⁺) pair is well known to exhibit high UC efficiency upon NIR 980 nm excitation due to their resonant energy level structure. Although, there are numerous papers published on the UC emission properties of Yb³⁺/Er³⁺ co-doped low phonon crystalline/amorphous materials, the discrepancy on the enhancement of UC red emission is still a question of research. Herein, we report a complete analysis on the enhancement of UC red emission and its influence for variable RE³⁺ ion concentrations and excitation (~980 nm) pump power densities. Acceptor Er³⁺ ion, radiative parameters derived from JO analysis have been taken as a tool to quantify the influence of UC emission transitions as a whole which were blindly omitted in the vastly reported literature. We believe our analysis will give a proper energy transfer mechanism which will have a great impact on designing UC materials for variety of photonic applications.

SP-12

MICROWAVE DIELECTRIC CHARACTERIZATION OF ULTRA-LOW TEMPERATURE FIRING $\text{Na}_5\text{Nd}(\text{MoO}_4)_4$ CERAMIC

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Ceramics with low dielectric constant (ϵ_r), high unloaded quality factor(Qu), and near zero temperature coefficient of resonant frequency(τ_f) are widely used for microwave circuit applications. Multilayer cofiring technology helps in large scale miniaturization by cofiring of stacked ceramic layers with microwave circuits screen printed on them using conducting inks. ULTCC ceramics are phase pure materials with ultra-low sintering temperature ($<660^\circ\text{C}$), which enable them to co-fire with aluminium electrodes. Non-reactivity with the electrode material during co-firing is another very important requirement for ULTCC applications. ULTCC substrates can be used for the fabrication of implantable antennas, substrate integrated wave guides, RF front end modules etc. In the present study, $\text{Na}_5\text{Nd}(\text{MoO}_4)_4$ ceramic with scheelite like structure in the Na_2MoO_4 - $\text{Nd}_2(\text{MoO}_4)_3$ phase diagram is being investigated. $\text{Na}_5\text{Nd}(\text{MoO}_4)_4$ ceramic is prepared by the conventional solid state ceramic route. Stoichiometric quantities of Na_2CO_3 (99.9%, Merck), Nd_2O_3 (99%, Aldrich) and MoO_3 (99%, Himedia) are wet mixed in distilled water medium. The slurry is dried in hot air oven and calcined at $450^\circ\text{C}/1\text{h}$. The calcined powder is ground well, mixed with 5wt% solution of PVA binder and dried. The powder is pelletised using hydraulic hand press and sintered to get maximum density in the range 540°C to 580°C for 1h. The crystal structure of the $\text{Na}_5\text{Nd}(\text{MoO}_4)_4$ ceramic is studied using powder X-ray diffraction and Laser Raman spectroscopic studies. Scanning electron microscopy (SEM) is employed to study the microstructure and phase homogeneity of the sintered samples. The microwave dielectric properties of the ceramic compacts have been studied using Hakki and Coleman post resonator and cavity perturbation techniques. $\text{Na}_5\text{Nd}(\text{MoO}_4)_4$ ceramic has a dielectric constant (ϵ_r) of 7.2, quality factor (Q x F) of 18,900 GHz. The ceramic is co-fired with 20wt % Al and the compatibility is studied using powder X-ray diffraction and Energy Dispersive X-ray Spectroscopy (EDS) analyses.

PS-1

**RECOVERY OF RARE EARTHS FROM SPENT NDFEB MAGNET BY
CHLORIDIZING ROASTING FOLLOWED BY LEACHING**

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Rare earths (RE) find wide application in a number of electronic goods and has an important role in the technological development. More than 90% of the rare earth are extracted and processed in China. The mining of the rare earth possesses a number of challenges including the unwanted radioactive wastes generation and stockpiling of large overburden of less desirable deposits. Rare earths are used extensively in permanent magnet (NdFeB and SmCo), lamp phosphors, rechargeable batteries because of their special magnetic and chemical properties. As NdFeB magnets contain about 30% of the RE elements, end-of-life magnets can be an important secondary source for RE elements if proper recycling method is adopted. In the present work, the chloridizing roasting of the NdFeB magnet was carried out with ammonium chloride followed by water leaching. A detailed study of the different process parameters like the roasting temperature, amount of ammonium chloride and the roasting time was carried out to optimize selective conversion of rare earth elements into their chloride form. Water leaching of the roasted product at 95°C for 1 hour selectively leached REs leaving iron in its oxide form in the residue. The chemical analysis and XRD analysis of the liquor and residue was carried out respectively. Rare earth elements from the leach solution could be separated by solvent extraction to produce high pure individual RE salts/oxides.

PS-2

¹⁷⁷Lu-RITUXIMAB THERAPY OF B-CELL LYMPHOMA: A PRECLINICAL STUDY TO ENHANCE THERAPEUTIC EFFICACY

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Non-Hodgkin lymphoma(NHL) is a heterogeneous group of hematological malignancies arises due to abnormal B or T-lymphocytes, account for more than 90% of NHL. These malignant cells express large number of CD20 proteins which can be considered as a possible target for the treatment of NHL. Rituximab is a chimeric monoclonal antibody raised against CD20, which has been approved by the US Food and Drug Administration for immunotherapy of NHL. Many patients do not show any response to Rituximab during the course of therapy. Hence to enhance the therapeutic efficacy, Rituximab was labelled with ¹⁷⁷Lu using DOTA as a bifunctional chelating agent. The application of radioisotopes in healthcare increased in leaps and bounds over the past few decades, both for diagnostic and therapeutic purposes. Lutetium-177 is one of the radionuclide that is being used extensively for its properties as a potential theranostic agent. The radionuclidic characteristics of ¹⁷⁷Lu such as the simultaneous emission of imageable gamma photons (208 keV, 11% and 113 keV, 7%) along with particulate α emission [$E_{\alpha}(\text{max}) = 497 \text{ keV}$] and its moderate half-life makes it a desirable radionuclide for targeting small primary tumours and micro metastasis. Hence, bioevaluation of ¹⁷⁷Lu-Rituximab was carried out in Raji, a B- cell lymphoma cell line. Cell binding of ¹⁷⁷Lu-Rituximab was carried out in Raji cells to determine specificity and 28% cell binding was observed. Which confirmed the specificity of labelled Rituximab to the CD20 protein and labelling do not hinder the specificity of Rituximab towards the CD20. Furthermore, to study the therapeutic efficacy 3.7MBq of ¹⁷⁷Lu-Rituximab was added in Raji cell for 24-48h, and different parameter such as cell binding, toxicity apoptosis and cell cycle was analysed. The study revealed that ¹⁷⁷Lu-Rituximab showed higher cell toxicity and apoptosis compared to the unlabelled Rituximab and it also arrests cell cycle at G1 phase. Hence, it has concluded that beta radiation emitted from the ¹⁷⁷Lu-Rituximab is more potent in inducing cell toxicity and apoptosis and thereby therapeutic efficacy can be enhanced.

PS-3

STUDY OF STRUCTURAL AND ELECTRICAL PROPERTIES OF PYROCHLORE TYPE COMPOSITIONS WITH MULTIVALENT ENVIRONMENT

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Pyrochlore type compounds form an important class of materials in the field of material science which belongs to the space group $Fd\bar{3}m$ with general formula $A_2B_2X_6Y$, where A and B sites are occupied by the metal atoms having oxidation states 3^+ and 4^+ or 2^+ and 5^+ and the X and Y sites are anions[1]. These oxides possess intrinsic oxide ion vacancies through these ordered vacancies conduction of oxide ion become feasible reducing the activation energy. Pyrochlore compositions with multivalent environment are a less explored area in this regard. So here in this work such compositions are studied in detail. Pyrochlore compositions, $Sm_2Zr_{(1-x)}(YNb)_xO_7$ ($x=0,0.25,0.5,0.75,1$) are prepared via conventional solid state reaction route. The prepared compositions are characterized by powder-XRD, impedance spectroscopy. The XRD confirms the formation of the pure pyrochlore structure in these compositions. As the substitution, increase the lattice parameter increase which is line with the Vegard's law. The conductivity of the samples measured using the impedance spectroscopy is of the order 10^{-4} S/cm which is high compared to the other compositions similar to this. That is such a study in which the oxygen stoichiometric ratio is maintained to be the same increases conductivity as the substitution increases.

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PS-4

Exploitation of Eu^{3+} Red Luminescence through Structural Transition in Lanthanide Stannate Pyrochlore for Warm White LED Applications

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Eu^{3+} ion epitomize as an excellent structural probe for the detection of disorder induced by the structural variation in stannate pyrochlores due to its relatively simple energy level structure. In this context, we have synthesized a series of Eu^{3+} doped $\text{Ln}_{2.85}\text{YSnNbO}_{10.5}:0.15\text{Eu}^{3+}$ ($\text{Ln} = \text{La}, \text{Gd}, \text{Y}$ and Lu) red phosphors via high temperature solid state reaction method to explore the influence of phase evolution on the luminescence properties. The substitution of Ln^{3+} ions in the A site of the pyrochlore induces a structural transition from an ordered pyrochlore to a disordered fluorite structure with decreasing ionic radius. The diminishing trend of characteristic superstructure peaks in the XRD pattern and the broadening of Raman modes with lanthanide substitution clearly substantiate the disorder induced in the cationic sublattice [1, 2]. These phosphors exhibit strong absorption in the near UV region and emit red luminescence under 392nm excitation which is also correlated with their crystal structures. Their luminescence properties got enhanced with increased ordering of cations from Lu to La. The more ordered structure of La system favors the more uniform distribution of Eu^{3+} ions preventing the cluster formation thus improve the luminescence properties. The splitting of $^5\text{D}_0 - ^7\text{F}_1$ transition of Eu^{3+} ions further provides a clue on the structural transition in support of the XRD and Raman analysis. The long range ordering, ligand polarizability and covalent nature of Eu^{3+} bonding influence the emission probability and improves the quantum efficiency of the La host. Eu^{3+} emission due to $^5\text{D}_0 - ^7\text{F}_1$ transition is significantly improved with increase in the concentration of Eu^{3+} ions in the La host. The distortion of the A site symmetry and the red shift of the charge transfer band with Eu^{3+} doping in $\text{La}_3\text{YSnNbO}_{10.5}$ system leads to an enhanced electric dipole transition. The extent of distortion in the EuO_8 polyhedra is reflected in the quantum efficiency values and J-O intensity parameters τ_2 and τ_4 , which are a measure of degree of polarizability of Eu-O bonds in the lattice. Our results suggest that we can manipulate the Eu^{3+} red luminescence in lanthanide stannate pyrochlores through order-disorder structural transition.

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PS-5

PHOTOLUMINESCENCE PROPERTIES OF $\text{Na}_{(1+x)}\text{Ca}_{(1-2x)}\text{TiNbO}_6:\text{xEu}^{3+}$ ($X = 0.05-0.3$) : NOVEL PEROVSKITE RED PHOSPHOR PREPARED BY BALL MILLING METHOD

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White light emitting diodes are excellent candidate for general lighting applications because of their advantages over conventional light sources. Effective lighting devices can be obtained by combining one or more phosphor materials with UV or blue LED chips. The most common and easiest way is the combination of a 460 nm blue InGaN LED chip and a yellow phosphor of a cerium(III)-doped yttrium aluminum garnet which is still in widespread use today, however this lacks red component resulting poor CRI and less efficacy. Blue LED with green, red phosphors or blue, red and green emitting phosphors with near UV LED are alternative to obtain white light with better CRI. Currently available red phosphors are environmentally unfriendly and have low efficiency compared to blue and green phosphors[1-3]. The properties such as good chemical stability, broad charge transfer (CT) band in the near UV region and the ability to capture radiation from a GaN based LED over a range of wavelengths etc., make perovskites as good host lattices for phosphor materials. Thus we attempted to develop a novel Eu^{3+} doped perovskite type red phosphor for pc - wLED applications. $\text{Na}_{(1+x)}\text{Ca}_{(1-2x)}\text{TiNbO}_6:\text{xEu}^{3+}$ phosphors were prepared via high energy ball milling method. The stoichiometric amount of the powder mixture of the reagents was ball milled in a pulveriser with a rotation speed of 250 rpm for 8hrs with acetone as the mixing medium. The high energy ball milling process can enhance the reactivity of the system and reduce the reaction temperature [2]. The ball milled powders were calcined at 1000°C for 6 hrs. XRD results confirmed Orthorhombic Perovskite phase with space group pbam. UV Visible absorption spectra showed broad band absorption in the UV region. The Photoluminescent excitation spectra exhibit strong characteristic f-f transition peak of Eu^{3+} at 392 nm (${}^7\text{F}_0-{}^5\text{L}_6$) and 465 nm (${}^7\text{F}_0-{}^5\text{D}_2$), matches well with the emission of UV and blue LEDs. It is also observed that these phosphors emit strong red light (615 nm) under both near UV (392 nm) and blue (465nm) excitations, which can be attributed to the forced electric dipole transition (${}^5\text{D}_0-{}^7\text{F}_2$) of Eu^{3+} . Concentration quenching occurs at 20mol% of Eu^{3+} concentration. Morphological studies of the samples shows uniform distribution of spherical particles (0.1-1 μm), which enhanced the photoluminescence properties. Thus ball milled samples with better morphology and intense red emission can be a suitable phosphor candidate for wLED applications.

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PS-6

PHOTOLUMINESCENCE AND COLOR TUNABILITY OF Bi³⁺ DOPED Y₃Sb₅O₁₂ PHOSPHOR

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Solid State lighting devices has already invaded the lighting industry, with its versatile application in many fields from residential lighting purpose to commercial and industrial applications. Its attractive features color tenability, long durability, small size, cool beam, directional distribution etc. make its irreplaceable presence in the industry. Though this technology has to face some challenges such as cost, heat management, power quality and lighting quality issues such as CRI, brightness, color consistency etc. Commercial WLEDs are based on blue LED combined with yellow phosphor YAG:Ce³⁺. But the lack of red component in these LEDs result in poor CRI values. Hence there is an urge for better phosphors for WLED applications. Eventhough different methods such as mixing the RGB colors are there it is found that use of single phase phosphor for wLED is a better option, so that we can overcome many persisting issues such as poor CRI values, low efficiency, higher color temperature etc. Ions like Bi³⁺ exhibit broad absorptions and emission bands. The emission band of these phosphors can be designed in the wavelength region from 400 to 700 nm depending on the crystal field strength and covalency of the host lattice. Hence it is expected to develop novel phosphors for wLED application by doping Bi³⁺ ions to appropriate host sites in order to improve the CRI and efficiency of the wLED. The luminescence of Bi³⁺ ions is based on the transitions between 6S₂ ground state and 6s₆p excited states. In this study we have incorporated Bi³⁺ ions into Y₃Sb₅O₁₂ garnet system. The luminescence enhancement of Y₃Sb₅O₁₂ host with different doping concentrations of Bi³⁺, which is prepared by solid state reaction route is studied. The structural properties were studied using X-ray diffractometer and structural purity is obtained. The photoluminescence properties of this phosphor material were studied using Fluorolog HORIBA fluorescence spectrophotometer with a Xenon lamp (450W) as the excitation source. The morphological characterization was also carried out. The PL studies shows a broad excitation and emission peaks in the range 400-600nm. The broad nature of excitation and emission spectra is very suitable for wLED applications, since it can be coupled with n-UV or blue LEDs to generate direct white light. Hence this phosphor can be a promising candidate for LED applications.

PS-7

ENHANCED PHOTOLUMINESCENCE PROPERTIES OF Eu^{3+} DOPED $\text{A}_2\text{Ce}_2\text{O}_7$ (A = La, Y AND Gd) RED PHOSPHOR

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The choice of the host lattice, crystallographic structure of the host lattice and nature of the activator ion plays a vital role in the luminescence properties of various phosphor materials for WLED applications [1]. Ternary type oxides having the general formula $\text{A}_2\text{B}_2\text{O}_7$ (A, B = Metals) have attracted great attention in recent years due to their excellent physical and chemical properties. $\text{A}_2\text{O}_3\text{-CeO}_2$ (A = Rare earths) oxides have fascinated due to their remarkable electrical, catalytic, optical and mechanical properties. Furthermore, CeO_2 is a well known functional material that absorbs light in the near UV-visible region and also abundant in nature, nontoxic and inexpensive. Eu^{3+} is a well-known narrow-band red emitter, and its central emission band is at around 612 nm while located in a non-centrosymmetric site [2]. However, the literatures shows that by doping Eu^{3+} in ceria systems may increases the trivalent state of Ce and defect concentration which adversely affect the luminescence properties. In this paper, we made an attempt to enhance the luminescence properties of cerium based system by reducing the reduction of Ce^{4+} and defect concentration. Eu^{3+} was substituted in the $\text{La}^{3+}/\text{Y}^{3+}/\text{Gd}^{3+}$ site of $\text{A}_2\text{Ce}_2\text{O}_7$ (A = La, Y and Gd) oxides and studied the distribution and photoluminescence properties of Eu^{3+} . Studies revealed that the gadolinium sample showed better luminescence properties in terms of f-f emission intensity, the asymmetric ratio and quantum efficiency. To understand the effect of the Eu^{3+} concentration, the PL properties of the as-prepared $\text{Gd}_{2-x}\text{Ce}_2\text{O}_7:x\text{Eu}^{3+}$ were also studied in detail. By increasing the Eu^{3+} concentration the intra-4f6 transition bands of Eu^{3+} at 466 nm (${}^7\text{F}_0\text{-}{}^5\text{D}_2$ transition in the blue region) is more dominant than the other transition bands, which matches well with the emission of commercial GaN LED (440–470 nm) chips.

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EMISSION ANALYSIS OF Ho³⁺ AND Ho³⁺/Zn²⁺ CO-DOPED PVA POLYMER FILMS

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Pure PVA, Ho³⁺ and Ho³⁺/Zn²⁺ doped and co-doped PVA polymer films were prepared by solution cast technique. For prepared polymer films optical absorption, photo luminescence and decay curve were analyzed. The optical absorption bands were observed for pure PVA, PVA: Ho³⁺ and PVA: Ho³⁺/Zn²⁺ at 275 nm, 336 nm, 361 nm (⁵I₈ - ⁵G₄), 416 nm (⁵I₈ - (⁵G, ³H)₅), 450 nm (⁵I₈ - ⁵G₅), 484 nm (⁵I₈ - ⁵F₃), 535 nm (⁵I₈ - ⁵F₄) and 639 nm (⁵I₈ - ⁵F₄₅) respectively. The photo luminescence properties were recorded at room temperature under the excitation of 370 nm (⁵I₈ - (⁵G, ³H)₅), with this excitation three emission bands were observed at 406 nm (⁵G₆ - ⁵I₈), 433 nm (⁵G₅ - ⁵I₈) and 461 nm (⁵G₆ - ⁵I₈). Among these three emission bands, 433 nm is the intense prominent emission band corresponding to the transition (⁵G₅ - ⁵I₈). The nature of decay curves for Ho³⁺ doped PVA and various concentrations of Ho³⁺/Zn²⁺ co-doped PVA polymer films have been analyzed and the lifetimes are noticed. From obtained results, PVA: Ho³⁺, PVA: Ho³⁺+Zn²⁺ polymer films could be recommended for the blue LED applications and optical devices.

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PS-9

EFFECT OF SAMARIUM DOPING IN MANGANESE BISMUTH MELT-SPUN RIBBONS

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Mn-Bi has received considerable interest due to its unusual magnetic properties and attractive magneto-optical properties, rare-earth free intermetallic alloy. It crystallizes in Ni-Astype hexagonal crystal structure with the c-axis being the easy direction of magnetization [1]. It is noteworthy that the coercivity of the LTP MnBi phase increases with temperature, unlike Nd-Fe-B magnets, where coercivity decreases with increase in temperature [2]. In this work, we have investigated the structural and magnetic properties of 'Sm' doped MnBi prepared by melt-spinning. The as-rapidly quenched Mn-Bi-Sm melt-spun ribbons exhibited a high coercivity of 8 kOe at room temperature. This could be due to the small crystallite size of 62.12 nm obtained due to meltspinning. We have heat treated the melt spun ribbons at 260 °C for 1h. It has been observed that the fraction of LTP MnBi phase increases in annealed ribbons. Due to its effect, is the increase of saturation magnetization from 1.23 emu/g to 31.53 emu/g. Structural characterization was done using Rigaku diffractometer, which reveals in XRD patterns that LTP MnBi phase increased with annealing. But it is observed that annealing leads to the decrease in the coercivity. It is observed that ball milling leads to increase in the coercivity. Detailed structural and magnetic and microstructural properties of Sm-doped MnBi with ball milling would be presented.

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PS-10

GENERATION OF RGB PRIMARY COLORS IN PHOSPHATE GLASSES DOPED WITH Er^{3+} , Tm^{3+} AND Yb^{3+} IONS UNDER NIR LASER EXCITATION

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Photon upconversion (UC) of materials doped with trivalent rare earth (RE^{3+}) ions is an important approach for white light generation. Typical efficient systems are based on tri-doped RE^{3+} ions host matrix, where white light emission is possible due to the capability of RE^{3+} ions to convert the near-infrared (NIR) light into visible UC emissions. The interest of these compounds reside on the employment of low cost and high power NIR diode lasers as pumping source, with the objective of its implementation in optical devices as, for example, lasers, solid-state 3D color displays or nanophosphors. In this work, phosphate glasses doped with rare earth Er^{3+} , Tm^{3+} and Yb^{3+} ions have been studied. Intense red, green, and blue (RGB) primary colors via UC emissions were observed under cw diode laser excitation at 980 nm. Some samples exhibit an adequate combination of UC emissions, giving rise to white light that can be easily observed by the naked eye. For technological applications, the control of the relative intensities of the RGB emissions is required and, in this sense, the UC emissions were studied in the framework of the 1931 Commission International l'Eclairage (CIE) diagram [1]. With this aim, dependence of the UC emissions were investigated as function of doping concentrations of RE^{3+} ions and excitation power densities. The tunability of the RGB UC emissions were intensively studied in terms of the chromaticity coordinates in the CIE diagram, observing pure blue, green and white light depending on the doping concentrations. With respect to the power dependence, the color of the total emitted luminescence, for white emitting samples, can be tuned shifting from mostly blue (slightly white) to mostly white (slightly green) when pumping power is decreased. As a conclusion of this work, RE^{3+} -doped phosphate glasses can be considered as promising material for white generation in optical devices.

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PS-11

OPTICAL CHARACTERISTICS OF Dy³⁺ IONS IN ALKALI FLUOROBORATE GLASSES FOR SOLID STATE LASERS AND WLEDs

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Rare earth doped glasses are potential candidate in a diverse area such as waveguide, optical fibers, solar concentrators, plasma display panel, optical amplifiers and many other. Borate glasses doped with rare earth oxides have significant applications for solid state lighting, LASER hosts, lamp phosphors, broad band amplifiers, sensors and so on. In the present work, spectroscopic properties of a new economic alkali fluoro borate glasses doped with dysprosium were studied to check the suitability of these glasses for white light solid-state lighting (w-LEDs)[1-2]. The glass samples used for the present investigation were prepared by the conventional melt quenching method with the molar composition 10K₂O + 10BaO+ 10ZnF₂ + (70-x) B₂O₃ + xDy₂O₃, where x=0.1, 0.5,1.0,1.5 and 2.0 mol%. Absorption spectra of the samples were recorded in UV-Vis-NIR ranges. The different absorption transitions were identified and assigned accordingly. The spectra were further used to determine band gap energies and to evaluate the Judd-Ofelt intensity parameters. The intensity parameters follows a trend $\lambda_{2>4>6}$ in the present system. Using the phenomenological intensity parameters different radiative properties such as emission cross section, branching ratio etc were determined and compared with previous reports. The luminescence spectra of the title glasses have been recorded under an excitation at 348nm. It is noted that the intensity of emission bands increases continuously with increase in concentration of Dy³⁺ ions from 0.1 to 2.0 mol %. The variation of the integrated intensity of blue and yellow band and the variation of Y/B ratio with concentration of Dy₂O₃ are studied. To manifest the true color of luminescence of the prepared Dy³⁺ doped alkali fluoroborate glasses under 348 nm the color coordinates were calculated in the framework of CIE 1931. The colour coordinates for all glass samples are fall in the white region and thus suggest their utility as potential materials for white light applications. The lifetime values were estimated and observed significant decrease with increasing dopant concentration. The mechanism involved in quenching of life time is also identified.

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HOST SENSITIZED ENERGY TRANSFER AND OPTICAL STUDIES OF Er^{3+} DOPED Ba_2CaWO_6 PHOSPHORS

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In the present study we have synthesized a series of Er^{3+} doped Ba_2CaWO_6 phosphors by the conventional solid state reaction method. The structural and photoluminescence properties of the phosphors were investigated at the room temperature. The prepared phosphors were characterized by X-ray diffraction analysis (XRD) for structural analysis and Scanning electron microscope (SEM) analysis for morphological studies. The average crystallite sizes were calculated from the XRD data using the Debye-Scherrer equation [1]. The optical behavior of the prepared phosphor was determined by photoluminescence spectra. The optical excitation spectrum consists a broad charge transfer band in the UV-region, which corresponds to the charge transfer absorption from 2p orbitals of oxygen to the 5d orbitals of tungsten [2, 3] and the characteristic peaks of erbium. The emission spectra consists of an intense green emission band at 566 nm ($^4\text{S}_{3/2} \rightarrow ^4\text{I}_{15/2}$) along with weak red emission at 680 nm ($^4\text{F}_{9/2} \rightarrow ^4\text{I}_{15/2}$) are observed under 314 nm, 378 nm corresponding to charge transfer band and rare earth excitations respectively [4]. Under charge transfer excitation $\text{Ba}_2\text{CaWO}_6:\text{xEr}^{3+}$ samples exhibits high intense emission peaks of Er^{3+} than the rare earth excitation. This is due to an efficient energy transfer from WO_6^{6-} to Er^{3+} . The maximum emission intensity was observed for 0.08 wt% concentration of Er^{3+} ions in Ba_2CaWO_6 phosphors. The critical energy transfer distance between Er^{3+} ions is calculated to be 15.18 Å and the quenching mechanism is due to dipole-dipole interaction[5, 6]. The CIE color coordinates were calculated. The $\text{Ba}_2\text{CaWO}_6:\text{Er}^{3+}$ phosphor exhibits a strong excitation band in the UV region, matching well with the emission band of a UV light emitting diode (LED) chip, which could be a potential candidate for UV- converting white light emitting diodes.

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**PLASMONIC AND FLUORESCENCE STUDIES OF SILVER
NANOSPECIES DOPED $\text{SiO}_2\text{-TiO}_2\text{-ZrO}_2\text{:Eu}^{3+}$ TERNARY MATRIX**

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Eu^{3+} and silver nanoparticle/nanowires (Ag NP/NW's) co-doped ternary matrices based on $\text{SiO}_2\text{-TiO}_2\text{-ZrO}_2$ were prepared via non-hydrolytic sol gel process. The amorphous nature of the matrix is evident even after doping it with crystalline nanoparticles. The structural characterization was evaluated using XRD, TEM and SAED pattern. FTIR spectrum clearly shows different characteristic peaks there by conclusively evidencing the formation of ternary matrices. The absorption spectra of the samples identifies the presence of bands corresponding to europium ions, Surface Plasmon Resonance (SPR) band of Ag NP and the transverse and longitudinal contributions to SPR by the silver nanowires. A six fold enhancement in the emission intensity is observed for Ag NP samples whereas; the enhancement is eight fold for Ag NW samples. This higher enhancement for Ag NW samples is due to the Surface Plasmon Coupled Emission (SPCE). SPCE is the combined effect of enhancement of electromagnetic field around Ag NP/NW's and spontaneous plasmophore emission. The prepared glasses could be used as potential red light emitting sources and for sensor applications.

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PS-14

NOVEL SINGLE PHASE WHITE LIGHT EMITTING Tb³⁺ AND Sm³⁺ CO-DOPED CePO₄ PHOSPHORS WITH UV EXCITATION

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A novel single phase white light emitting Tb³⁺ and Sm³⁺ co doped CePO₄ nanocrystals are synthesized through sol gel route for the first time. The X-ray powder diffractograms of all the samples are identified as that of monoclinic cerium phosphate having chemical formula CePO₄ with space group-P2_{1/n}. The spherical morphology of Ce_{1-x-y}PO₄:Tb_x³⁺,Sm_y³⁺ nanocrystals are identified by transmission electron microscopy. The triple energy transfer processes from Ce³⁺ to Tb³⁺, Ce³⁺ to Sm³⁺ and Tb³⁺ to Sm³⁺ in CePO₄ nanocrystals are investigated by photoluminescence excitation and emission spectra. The role of Tb³⁺ as a bridge to connect the Ce³⁺ and Sm³⁺ ions in CePO₄ is systematically studied by varying the concentrations of Tb³⁺ and Sm³⁺. The existence of energy transfer channels from Tb³⁺ to Sm³⁺ from ⁵D₃ and ⁵D₄ energy levels of Tb³⁺ is revealed with the help of decay analysis. The quality of white light is characterized by CIE chromaticity coordinates and color temperature and demonstrates that the newly developed cool white light emitting Tb³⁺ and Sm³⁺ co doped CePO₄ phosphor has potential applications in the field of optoelectronics.

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SYNTHESIS AND PHOTOLUMINESCENCE STUDIES OF HOST-SENSITIZED Dy³⁺ DOPED Na₃Y(VO₄)₂ NANO-CRYSTALS.

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A novel Na₃Y(VO₄)₂:Dy³⁺ phosphor was synthesized by citrate based solution combustion reaction method. The phase formation was characterized through X-ray diffraction which confirmed monoclinic phase with space group of P2₁/n. Transmission electron microscopy studies revealed an agglomerated morphology. The metal composition and concentration of elements was further analyzed by its corresponding energy dispersive X-ray spectrum. Photoluminescence (PL) characteristics such as UV-Vis absorption spectra, excitation, emission spectra were investigated. Na₃Y(VO₄)₂ exhibits a broad and intense UV absorption (200–350 nm) due to O²⁻-V⁵⁺ charge transfer band and a corresponding broadband emission at 438 nm. There is a strong and broad charge transfer band ranging from 200 nm to 445 nm with a maximum 320 nm and shoulder at 295 nm in the PL excitation spectrum. Under the excitation of ultraviolet (295 nm) and (320 nm) light, the characteristics emission peaks of Dy³⁺ due to the transitions of ⁴F_{9/2} - ⁶H_{15/2} at 482 nm (Blue) and ⁴F_{9/2} - ⁶H_{13/2} at 573 nm and 577 nm (Yellow) were observed in the emission spectra and the optimal doping concentration of Dy³⁺ ions is about 3.5 mol %. The CIE chromaticity coordinates of Na₃Y(VO₄)₂:Dy³⁺ sample revealed it as an efficient yellow emitting phosphor and the investigations suggest that Na₃Y(VO₄)₂:Dy³⁺ might serve as a promising yellow phosphor in white light emitting diodes and display application.

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PS-16

MULTICOLOUR EMISSION IN Eu^{3+} ACTIVATED TERBIUM OXALATE NANO CRYSTALS VIA Tb^{3+} - Eu^{3+} ENERGY TRANSFER

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Multicolour emitting $\text{Tb}_{2-x}\text{Eu}_x(\text{C}_2\text{O}_4)_3 \cdot 10\text{H}_2\text{O}$ nano phosphors were synthesized by a facile microwave assisted co-precipitation method. The powder X-ray diffraction, Transmission electron microscopy, photoluminescence analysis and lifetime measurements were used to characterize the as synthesized nano phosphors. The powder X-ray diffractogram revealed that the synthesized phosphors crystallize in monoclinic system with space group $\text{P}2_{1/c}$ and TEM analysis revealed the nano size of the samples [1]. The photoluminescence properties and energy transfer between Terbium and Europium ions were analyzed systematically based on the relative fraction of Tb^{3+} and Eu^{3+} ions in oxalate matrix. The photoluminescence analysis and decay measurements confirmed the efficient luminescence in Eu^{3+} activated Terbium oxalate nano phosphor via resonant dipole-dipole mechanism. The rise time observed in the decay curves of Eu^{3+} ion, monitoring the 616 nm emission for the excitation of Terbium ion at 487 nm and the absence of rise curve in the direct excitation of Europium ion at 464 nm strongly supports energy transfer from Terbium to Europium. Among the Eu^{3+} activated samples, the rise time duration is observed to be maximum for the 1% Eu^{3+} activated sample and it found to be decreases with an increase in Eu^{3+} content due to the decrease in donor-acceptor distance [2]. Moreover, the energy transfer efficiency were found to be depend on the relative fraction of the Tb^{3+} and Eu^{3+} ion, resulting in controlled energy transfer between Terbium and Europium ions in oxalate matrix and thereby giving tunable emission colour from green to red under a single excitation wavelength at 487 nm.

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PS-17

**TUNABLE PHOTOLUMINESCENT EMISSION OF Tb³⁺/Eu³⁺ CO-
DOPED LANTHANUM MOLYBDATE NANOPHOSPHORS**

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A series of highly crystalline Tb³⁺/Eu³⁺ co-doped lanthanum molybdate nanophosphors were synthesized by conventional co-precipitation method. The prepared samples were characterized by Powder X-ray diffractogram (XRD), Fourier transform infrared spectroscopy (FTIR), Transmission electron microscopy (TEM), UV-Vis absorption spectroscopy, Fluorescence spectroscopy and decay analysis. The Powder X-ray diffractogram revealed the formation of tetragonal nanocrystals with space group I41/a and the detailed analysis of the small variation of lattice parameters of the system with Tb/Eu co doping on the host lattice were carried out. The fundamental vibrational modes in La_{2-x-y}(MoO₄)₃:xTb,yEu nanocrystals were identified from FTIR spectra. The HR TEM analysis disclosed the fact that the basic growth mechanism behind the formation of nanocrystal was oriented attachment of small nanoparticles. The broad Mo⁶⁺-O²⁻ CTB and the sharp excitation peaks of Tb and Eu identified from the UV-Vis absorption spectra facilitates the suitability of exciting the phosphors effectively over NUV and visible region of the spectra. The possibility of energy transfer from host to Tb³⁺/Eu³⁺ ions and from Tb³⁺ to Eu³⁺ ions were confirmed from the PL excitation spectra monitoring ⁵D₀ - ⁷F₂ transition of Eu³⁺ ions around 615 nm. The correlated analysis of PL emission spectra, life time measurements and CIE diagram, upon different excitation channels elucidate the excellent luminescent properties of La_{2-x-y}(MoO₄)₃:xTb,yEu nanophosphors with tunable emission colours in a wide range varying from yellow green region to reddish orange region and the efficient energy transfer from Tb³⁺ to Eu³⁺ ions in lanthanum molybdate host lattice. The continuous decrease in life time values of ⁵D₄ - ⁷F₅ emission transition of Tb³⁺ ions under host and direct excitation again confirmed the Tb-Eu energy transfer process, as we have fixed the Tb³⁺ doping at 15% in all the synthesized nanophosphors. The Tb - Eu energy transfer efficiency and probability were calculated from the decay measurements and the values were found to be satisfactory for exploiting the prepared nanophosphors for the development of multifunctional luminescent nanophosphors.

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**RED, GREEN AND BLUE COLOUR EMITTING ZIRCONIUM
TITANATE NANO COMPOSITES**

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Nano phosphors which show efficient upconversion photoluminescence are in great demand. In this context, current challenge is to produce material which emits white light. More generally Red, Green and Blue colours of appropriate wavelength are mixed in proper proportion to obtain white light. Thus nano phosphors emitting RGB colours are of prime importance in producing white light. In this investigation, Erbium and thulium doped $ZrTi_{1.4}O_4$ samples are synthesized by solution combustion method. Structural studies are done by X-ray diffraction analysis and Field Emission Scanning electron Microscope studies. Upconversion photoluminescence can be realized in $ZrTi_{1.4}O_4$ by doping minimum amount of Erbium and Thulium. Erbium doped sample show green and red emission with 980nm excitation. Appreciable enhancement in the intensity of both green and red peaks is observed by introducing ytterbium as a sensitizer. Thulium doped samples show upconversion photoluminescence only in the presence of sensitizer and emits blue and green colours with 980 nm excitation. Raman report supports the use of $ZrTi_{1.4}O_4$ as a suitable host for upconversion photoluminescence with lowest phonon energy at 800cm^{-1} . The multi-photon relaxation and cross-relaxation mechanisms may be responsible for the energy transform process and in turn the UC emission. This work provides a simple and promising method to develop novel nano phosphors. Thus white light emitting phosphor can be obtained by combined doping of both erbium and thulium along with ytterbium is the scope of our future work.

BLUE EMITTING PHENANTHRO-IMIDAZOLE BASED HOST MATERIALS FOR ORGANIC LIGHT-EMITTING DIODES

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The design strategy of luminescent emitters was one of the major breakthroughs toward efficient OLEDs. Rendering to spin statistics, 75% triplet and 25% singlet excitons are reformed by recombination of an electron and a hole (100% IQE in PhOLEDs) [1]. However, the phosphorescent emitter is usually embedded in a suitable host to avoid self-quenching and triplet-triplet-annihilation. In addition, to efficient energy transfer; it is essential that the triplet energy of the host is higher compared to the emitter to prevent reverse energy transfer from the emitter back to the host. The combination of both very high brightness and deep blue emission from phosphorescent organic light-emitting diodes (PHOLED) is required for both display and lighting applications [2]. Effective host-guest systems have been commercialized for green and red emitters, whereas blue phosphors and suitable matrix materials are still a challenge [3]. To overcome the above shortcoming issues, we have designed and synthesized two phenanthroline based materials, Ph_{en}-OCH₃(p)-An-Np, Ph_{en}-OCH₃(o)-An-Np using 1,10-Phenanthroline, 1-Naphthaldehyde and substituted aniline. 1,10-phenanthroline is acted as an electron-withdrawing group and substituted aniline may as an electron-donating group. Their rigid molecular structures improve their thermal stability with high glass transition temperatures. The photophysical studies of the synthesized ligand have been carried out in the solution, solid state and thin film study by UV-Vis spectroscopy and Spectrofluorimetry. The photoluminescence emission spectra of ligand exhibited blue emission. LEDs of the complexes are fabricated and characterized. Energy transfer process and theoretical investigations are made. The detail results will be presented and discussed.

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SPECTROSCOPIC, STRUCTURAL AND THERMAL STUDIES OF RARE EARTH DOPED SODIUM BOROTELLURITE GLASSES

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We report on effect of varying rare earth ion content on the sodium borotellurite glass system. Samples having composition $(70-x)\text{TeO}_2-20\text{B}_2\text{O}_3-10\text{NaO}-x\text{Dy}_2\text{O}_3$, where $x = 0, 0.5, 1.0, 2.0$ and 2.5 mol% were fabricated using conventional melt quenching technique. The effect of rare earth was studied on the optical, thermal, physical and structural properties of base glass. Thermal properties were studied with Differential Thermal Analysis (DTA). An increase in the values of stability factor was observed with increasing dysprosium ion (Dy^{3+}) concentration. The UV-Vis-NIR spectroscopy results revealed that Dy^{3+} entered the glass matrix giving peaks around 453, 571, 800, 902, 1092, 1273 and 1691 nm corresponding to transitions $^4\text{I}_{15/2}$, $^6\text{F}_{3/2}$, $^6\text{F}_{5/2}$, $^6\text{F}_{7/2}$, $^6\text{F}_{9/2}$, $^6\text{F}_{11/2}$ and $^6\text{H}_{11/2}$. Urbach energy was calculated from the absorption spectra, decrease in their values indicated a decrease in the disorderedness of glass system with the increase in the concentration of Dy^{3+} . The structure of the prepared glasses was studied using Fourier Transmission Infrared Spectroscopy (FTIR), showed that the addition of Dy_2O_3 results in the formation of TeO_3 at the expense of Te-O-Te linkage.

LUMINESCENCE STUDIES ON Er³⁺ IONS DOPED BISMUTH BOROPHOSPHATE GLASSES FOR PHOTONIC APPLICATIONS

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Over the past few decades, trivalent rare earth ions (REIs) doped borate, silicate, tellurite and phosphate based glasses have been widely investigated due to their technological potential applications such as optical detectors, solid state lasers, fluorescent display devices, optical amplifiers and optical fibers for telecommunication etc., [1,2]. Among the various RE³⁺ ions, Er³⁺ ion is the most significant active ion due to its exclusive energy level structure which covers the wavelength region of visible-mid-infrared successively and delivers the concurrent green and red emissions [2,3]. In the present study, Er³⁺ ions doped boro-phosphate glasses with the chemical composition (50-x)B₂O₃+25P₂O₅+15BiF+10Li₂O+xEr₂O₃ (where x=0.1,0.5, 1 and 2 in wt%) have been prepared following the melt quenching technique and their luminescence properties were studied and reported. The Judd-Ofelt (JO) intensity parameters have been calculated using the absorption spectra and refractive index values. The visible luminescence spectra exhibit strong ²H_{11/2}→⁴I_{15/2}, ⁴S_{3/2}→⁴I_{15/2} emission bands and weak ⁴F_{9/2}→⁴I_{15/2} emission band corresponding to the band positions at 533, 550 and 660 nm respectively under 488 nm excitation. Using the JO intensity parameter values, various lasing parameters such as stimulated emission cross-section (σ_p^E), experimental and calculated branching ratios (β_R) and radiative lifetime (τ_{cal}) have been calculated for the dominant ⁴S_{3/2}→⁴I_{15/2} emission transition. Of all the prepared glasses, BiBP0.5E glass exhibit higher stimulated emission cross-section, branching ratio and radiative lifetime values and the same is suggested for suitable green laser applications.

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Eu³⁺ IONS DOPED ZINC BORO-PHOSPHATE GLASSES FOR PHOTONIC APPLICATIONS

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Trivalent rare earth ions (RE³⁺) doped heavy metal Zinc Boro-Phosphate glasses have been studied extensively for the development of optoelectronic devices such as lasers, fiber amplifiers, light emitting diodes and color display devices [1]. Among the RE³⁺ ions, Eu³⁺ ion emits narrow band, almost monochromatic with longer lifetime [2]. In the present work, Eu³⁺ ions doped Zinc Boro-Phosphate glasses with the chemical composition 40B₂O₃+(30-x)P₂O₅ +20ZnO +10Bi₂O₃ +xEu₂O₃ (where x=0.1, 0.5, 1.0, 2.0 and 3.0 in wt % labeled as ZBP0.1E, ZBP0.5E, ZBP1E, ZBP2E and ZBP3E glasses respectively) have been synthesized by conventional melt quenching method. The prepared glass samples were characterized through recording optical absorption, photoluminescence and decay spectral measurements in order to study their suitability for developing photonic devices. From the band positions of absorption spectra, the bonding parameters () were calculated to explore the chemical bonding nature of the Eu³⁺ ions with its surrounding ligands. The luminescence spectra of titled glasses recorded by monitoring an excitation at 394 nm and all the spectra exhibit emission bands at 572, 586, 607, 649 and 703nm corresponding to ⁵D₀ ⁷F₀, ⁵D₀ ⁷F₁, ⁵D₀ ⁷F₂, ⁵D₀ ⁷F₃ and ⁵D₀ ⁷F₄ transitions respectively. The Judd-Ofelt (JO) intensity parameters Ω_{λ} ($\lambda = 2, 4$ and 6) have been calculated from the emission bands to examine the symmetry and bonding of the ligand environment around Eu³⁺ ions site in the prepared glasses. The luminescence spectra were then characterized through CIE 1931 chromaticity diagram to explore the dominant emission color exhibited by the studied glasses for the suitable light emitting device (LED) applications. The radiative parameters such as transition probability (A), stimulated emission cross-section (σ_p^E), branching ratios (β_R) and radiative lifetime (τ_R) have been determined for the prominent emission transitions and among the prepared glasses, ZBP1E exhibits higher radiative parameters for the ⁵D₀ ⁷F₂ transition and hence the same can be suggested for the fabrication of photonic devices which include solid state lasers as well as optical amplifiers.

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STUDY OF STRUCTURAL AND OPTICAL PROPERTIES OF Er³⁺ IONS IN LITHIUM-ZINC-FLUORO-BORATE GLASSES

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A new family of novel optical glasses based on 15 ZnF₂- 10 BaO- 8 Al₂O₃ – 12 Li₂CO₃- (55-y) B₂O₃- yEr₂O₃ (where y = 0.5, 0.7, 1.1, 1.3 and 1.5 mol %) were prepared by conventional melt quench technique. Initially, the influence of three alkali metals Li₂CO₃ /Na₂CO₃/K₂CO₃ on the optical properties of zinc fluoro borate glasses doped with 1mol% Er³⁺ ions were studied through absorption spectra [1]. Among three alkali metals, Li₂CO₃ showed optimum performance and has been used for further study on Er³⁺ doped zinc-fluoro-borate glasses. Structural properties of these ZnLiBEr glasses included density, molar volume, led to a better understanding of the micro structural changes ensued in the glass matrix with successive addition of modifier Er³⁺ ions [2]. Optical properties were investigated for their luminescence behavior through spectroscopic technique UV-Vis–NIR absorption. Based on the properties studied the samples can be recommended as fiber optics material [3].

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**STUDY OF STRUCTURAL AND OPTICAL PROPERTIES OF
SAMARIUM DOPED ALKALI BORATE GLASS**

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The study of optical properties of the glass formed with different substances was acquired more interest, since the discovery of artificial glass. In this work, most exciting optical investigation was carried out with the glass matrix CdLNBSm01 ($19.9\text{CdCO}_3+15\text{Na}_2\text{CO}_3+15\text{Li}_2\text{CO}_3+50\text{H}_3\text{BO}_3+0.1\text{Sm}_2\text{O}_3$) prepared. It has the wide applications in lightning devices, display devices and amplifiers. In alkali elements, internal structure bonding enhances the optical efficiency of the glass material. Cadmium being a heavy metal, it acts as a modifier to the glass matrix prepared. A rare earth element plays an important role in the enhancement of optical properties in any material; especially samarium has a high preference due to its intense luminescence in the visible and infrared regions. CdLNBSm01 glass was prepared with conventional melt-quenching technique. X-ray diffraction technique employed to investigate the structure of the glass. XRD spectrum doesn't show any discrete peaks exhibiting amorphous characteristics. FTIR method helps to demonstrate the band positions of BO_3 and BO_4 groups of the host glass. For optical investigation, optical absorption technique was adopted. From the absorption spectrum, Judd-Ofelt parameters ($\Omega_2, \Omega_4, \Omega_6$), root mean square value for oscillator strength (u_{rms}), Nephelauxetic effect (\bar{S}) and bonding parameter (u) and optical band gaps were evaluated.

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OPTICAL CHARACTERIZATION OF Dy³⁺-DOPED LEAD FLUOROSILICATE GLASSES FOR YELLOW LIGHT EMISSION APPLICATIONS

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Dy³⁺-doped lead fluorosilicate (SKNPfLfDy:SiO₂+K₂O+Na₂O+PbF₂+LiF+Dy₂O₃) glasses by varying Dy³⁺ ion concentration have been prepared by conventional melt quenching technique. These glasses are characterized through optical absorption, photoluminescence and decay measurements to evaluate the spectroscopic parameters. Judd-Ofelt (JO) intensity parameters were estimated from optical absorption spectrum of 1 mol% of Dy³⁺:glass. JO intensity parameters in turn are used to predict the radiative properties of Dy³⁺:SKNPfLf glasses. The emission spectra have been recorded by using 348 nm excitation. Among all the transitions, ⁴F_{9/2} - ⁶H_{13/2} transition around 572 nm (yellow region) is found to be stronger emission intensity. The decay profiles of ⁴F_{9/2} level of Dy³⁺ ions exhibit single exponential nature for lower concentrations (0.1 mol %) and turn into non-exponential for higher concentrations (0.5 mol %). The lifetime values were found to be decreased with increase in Dy³⁺ ion concentration (1192 μs to 34 μs) due to cross-relaxation among Dy³⁺ ions. In order to estimate the ion-ion (Dy³⁺-Dy³⁺) interactions, Inokuti-Hirayama (IH) model has been applied for luminescent decay curves. The calculated color chromaticity coordinates (CIE) have been fallen in yellow region as shown in the figure. Therefore, the obtained results suggest that the Dy³⁺-doped lead fluorosilicate glasses could be useful for yellow light emission applications [1,2].

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**PHOTOLUMINESCENCE UPCONVERSION STUDIES OF Tm³⁺-DOPED
TELLURITE GLASSES**

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Thulium (Tm³⁺)-doped tellurite glasses with molar composition of (75-x) TeO₂ + 15 ZnO + 5 Nb₂O₅ + 5TiO₂ + xTm₂O₃ (where x = 0.01, 0.05, 0.1, 0.5 and 1.0 mol %) have been synthesized using melt quenching technique. The upconversion (UC) spectra were recorded by using 808 nm diode laser as an excitation source with pump power of upto 93 mW. Only the blue emission bands pertaining to the ¹G₄ → ³H₆ (480 nm) transition was observed. The glass doped with 0.5 mol% of Tm³⁺ ions exhibit highest luminescence intensity. The slope of the linear fit is found to be 1.55, indicating that the two photons are involved in the UC process. One of the most common mechanisms, i.e., excited state absorption is expected to involve in this UC process. The decay curves of ¹G₄ level were measured and found that all are exhibiting single exponential nature. Also, the lifetime values are found to be 182, 179, 176, 97 and 45 μs for the glasses doped with 0.01, 0.05, 0.1, 0.5 and 1.0 mol % of Tm³⁺ ions, respectively.

LUMINESCENCE DYNAMICS OF Pr³⁺-DOPED LEAD PHOSPHATE GLASSES: LASER AND OPTICAL AMPLIFIER APPLICATIONS

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Trivalent praseodymium doped glasses are considered as a promising activator for diverse applications due to various strong emissions, resulting from both inter-configurational (d→f) and intra-configurational (f→f) transitions extending UV-VIS-NIR regions. Based on these exceptional properties of Pr³⁺ ion, the present work concentrated on spectroscopic investigations of Pr³⁺-doped lead phosphate glasses for visible lasers and optical amplifier applications. Lead based phosphate glasses with composition of 44P₂O₅-(24-x)PbO-17K₂O-9Al₂O₃-6Na₂O-xPr₆O₁₁, where x = 0.1, 0.5, 1.0 and 2.0 mol % referred as PPbKANPr0.1, PPbKANPr0.5, PPbKANPr1.0 and PPbKANPr2.0, respectively, were prepared by a melt, sudden quenching and casting technique. The luminescence spectra exhibit emission bands in the visible region of 480-780 nm attributed to the ³P₀→³H₄, ³H₅, ³H₆, ³F₂, ³F₄ and ³P₁→³H₅, ³F₃, ³F₄ transitions. The emission spectra in the NIR region (800-1600 nm) with the excitation of 488 nm of argon ion laser has been measured and the spectra has three emission bands at 868 nm (¹D₂→³F₃), 1032 nm (¹D₂→³F₄) and 1469 nm (¹D₂→¹G₄). With the increasing of Pr³⁺ ion concentration, the emission intensities were decreased due to concentration quenching. The full-width at half maxima of the PPbKANPr0.5 glass was found to be 57 nm. The analysis of the results confirms that the present Pr³⁺-doped lead phosphate glasses are useful for visible lasers as well as optical amplifiers.

TUNABLE LUMINESCENCE PROPERTY OF $\text{Sr}_{0.95}\text{Ba}_{0.05}\text{La}_{2-x}\text{O}_4$ DOPED RE^{3+} IONS (RE=Eu,Er,Ce AND Ho) PHOSPHORS

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The $\text{Sr}_{0.95}\text{Ba}_{0.05}\text{La}_{2-x}\text{O}_4:x\text{RE}^{3+}$ (RE=Eu,Er,Ce and Ho) phosphors are synthesized through high temperature solid-state reaction method at steps of 1000, 1100, 1200°C. The impact of temperature on phase structures, luminescence properties and decay lifetime are investigated. The prepared $\text{Sr}_{0.95}\text{Ba}_{0.05}\text{La}_{2-x}\text{O}_4$ phosphors exhibit abundant luminescent properties with doping of different RE^{3+} ions under ultraviolet-visible and infrared excitation (980 nm) excitation. The $\text{Sr}_{0.95}\text{Ba}_{0.05}\text{La}_{2-x}\text{O}_4:x\text{Er}^{3+}$ particles characterize red emission (${}^4\text{F}_{9/2} \rightarrow {}^4\text{I}_{15/2}$) through up-conversion emissions at 980 nm NIR irradiation. The chromaticity (CIE 1931) color coordinates of the titled phosphors have also been evaluated. The merits of multicolor emissions in the visible region endow the synthesized material by UV irradiation reveals potential candidate in the field of light display systems, lasers and optoelectronic devices.

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**STRUCTURAL AND OPTICAL PROPERTIES OF
OXYFLUOROBOROSILICATE GLASSES DOPED WITH Er³⁺ IONS FOR
1.53 μm OPTICAL AMPLIFIER APPLICATIONS**

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The Er³⁺ doped oxyfluoroborosilicate (SBNC) glasses with composition of 35SiO₂+25B₂O₃+10Na₂CO₃+15NaF+15CaF₂+ x Er₂O₃ (where x = 0.01, 0.05, 0.1, 0.5, 1.0 and 2.0 mol%) were prepared by adopting melt quenching technique. The thermal, structural and optical properties of as prepared glasses have been studied by using differential thermal analysis (DTA), Fourier transform infrared (FT-IR), optical absorption, emission and decay analysis respectively. J-O intensity parameters (= 2, 4 and 6) have been calculated from the absorption spectrum of 0.5 mol% erbium ions doped glass and these values are used to predict the radiative properties for different luminescent levels of Er³⁺ ions. By using 980 nm laser diode as an excitation source, an intense NIR emission at 1.53 μm (⁴I_{13/2} → ⁴I_{15/2}) has been observed with the maximum full width at half maximum (FWHM) values for prepared oxyfluoroborosilicate glasses doped with Er³⁺ ions. From the emission spectra different laser characteristic parameters have been calculated. The higher Er³⁺ ion solubility, relatively high gain and broad emission at around 1.53 μm are the notable features of the prepared glasses doped with Er³⁺ ions to realize efficient optical amplifier applications.

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**INVESTIGATION OF STRUCTURAL, OPTICAL PROPERTIES AND Eu^{3+}
LOCAL SITE ANALYSIS OF $\text{CaZn}_2(\text{PO}_4)_2:\text{Eu}^{3+}$ PHOSPHOR**

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A new red-emitting trivalent europium doped calcium zinc phosphate, $\text{CaZn}_2(\text{PO}_4)_2:\text{Eu}^{3+}$ phosphor, was synthesized using one-step solid-state reaction route. The obtained structure of synthesized phosphors were good consistent with the crystal structure of $\text{CaZn}_2(\text{PO}_4)_2$ phosphor (triclinic structure), which was supported by X-ray diffraction analysis. The vibrational modes were identified by Fourier transform infrared spectroscopy. The core-level binding energies (O 1s, P 2p, Ca 2p, Zn 2p and Eu 3d) of $\text{CaZn}_2(\text{PO}_4)_2:\text{Eu}^{3+}$ phosphor was investigated using X-ray photoelectron spectroscopy. The phosphors have strong red emission around 620 nm ($^5\text{D}_0 \rightarrow ^7\text{F}_2$ transition) under an excitation wavelength of 393 nm ($^7\text{F}_0 \rightarrow ^5\text{L}_8$ transition). The emission spectra composed of the non-degenerated $^5\text{D}_0 \rightarrow ^7\text{F}_0$ transition and other Stark-crystal field splitting lines for $^5\text{D}_0 \rightarrow ^7\text{F}_{1,2,3,4}$ transitions. The Commission International de l'Eclairage chromaticity coordinates of phosphor was situated in the red region of visible spectrum.

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OPTICAL AND STRUCTURAL STUDIES OF Er³⁺ DOPED LEAD FLUOROBORATE GLASSES FOR PHOTONIC APPLICATIONS

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A new series of Er³⁺ doped lead fluoroborate glasses were prepared by traditional melt quenching technique with molar composition of 39PbO+25B₂O₃+15Na₂O+1Er₂O₃+XF₂ (where X = Ca, Sr and Ba denoted as PBNErCaF₂, PBNErSrF₂, PBNErBaF₂ respectively). The thermal, structural and optical properties of these glasses have been studied by DTA, FTIR, optical absorption, emission and decay analysis respectively. The absorption spectra have prominent absorption bands because of the Er³⁺ ions in the glass network. From the emission spectra were recorded by using 980 nm laser diode as an excited source as shown in fig. For this an intense emission peak at 1544 nm is observed and corresponding to ⁴I_{13/2}→⁴I_{15/2} transition. Judd-Ofelt intensity parameters have been calculated from the absorption spectra by using J-O theory. The emission intensity of present glasses varies with the different fluorides. Among all glasses PBNErCaF₂ has highest intensity peak at 1544 nm. So PBNErCaF₂ glasses may be used in optical amplifiers. Apart from these spectroscopic parameters some physical parameters like density, refractive index and reflection loss etc, were also calculated.

SPECTROSCOPIC STUDIES AND ENERGY TRANSFER BETWEEN Nd³⁺ AND Eu³⁺ IONS IN ZINC-LITHIUM FLUOROBORATE GLASSES

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Nd³⁺ single and Nd³⁺/Eu³⁺ co-doped ZnF₂-LiF-Na₂CO₃-Bi₂O₃-H₃BO₃, zinc lithium fluoroborate (ZLFNBiB) glasses with good optical properties have been prepared by high temperature melt-quenching method. The Judd-Ofelt intensity parameters were calculated from optical absorption spectrum and radiative parameters from the emission spectrum of 0.5 mol% of Nd³⁺ doped glass. The single and co-doped samples exhibit emission bands centered at 874, 1058 and 1330 nm under the excitation of 808 nm. The photoluminescence spectra for co-doped glasses were recorded under the 394 nm of xenon lamp as excitation source. The large stimulated emission cross-section and branching ratio values are evaluated and compared with the other Nd³⁺ doped systems, the energy transfer from Eu³⁺ to Nd³⁺ ions is observed and thoroughly discussed from NIR emission spectra ($\lambda_{exc} = 394$ nm) of co-doped glasses. The decay profiles are recorded for all the concentrations of co-doped samples and the experimental lifetimes (τ_{exp}) were obtained from the decay profiles. The efficient energy transfer obtained between the Nd³⁺ and Eu³⁺ ions in zinc-lithium fluoroborate glasses.

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**EMISSION ANALYSIS OF Sm³⁺ ION DOPED LaAlO₃ NANOPHOSPHORS
BY HYDROTHERMAL METHOD**

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Rare earth ion doped Lanthanum Aluminate (LAO) nanophosphors composition of La_{1-x}AlO₃:xSm³⁺ (x=0, 2, 4, 6 and 8 mol%) were well synthesized by hydrothermal technique at low temperature. The structural and luminescence properties of these prepared nanophosphor samples were investigated. The PXRD confirms the crystallinity and Phase purity of the samples. The photoluminescence emission observed in the 540-720 nm region and emission peaks observed at 566, 600, 647 and 712 nm for a given dopant concentration which are ascribed to the ⁴G_{5/2} to ⁶H_J (J = 5/2, 7/2, 9/2 and 11/2) transitions, respectively with excitation at 407 (⁶H_{5/2} → ⁴K_{11/2}) nm. All the four emission peaks originated from the f-f transitions in the 4f electron shell of Sm³⁺ ion. The intense emission peak observed at 600 nm due to partially magnetic and electric dipole transitions. The extreme PL intensity observed at 6 mol% Sm³⁺ doped LAO nanophosphors. The calculated CIE coordinate values were well paired with standard National Television Standard Committee (NTSC) value of orange-red emission as a result it might be potential material for preparing phosphor converted light emitting source in orange-red region.

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Nd³⁺-DOPED BISMUTH PHOSPHATE GLASSES FOR 1.06 μm SOLID STATE LASER APPLICATIONS

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In the present work, the spectroscopic properties of Nd³⁺-doped bismuth phosphate glasses with the chemical composition (65-x)P₂O₅ + 15Bi₂O₃ + 10Li₂O + 10Na₂O + xNd₂O₃ (where x = 0.1, 0.3, 0.5, 1.0, 1.5, 2.0 in mol %) prepared by conventional melt quenching technique have been studied. The structural and optical properties are reported. Judd–Ofelt (JO) theory has been applied to the absorption spectra of Nd³⁺-doped bismuth phosphate glasses to estimate the JO intensity parameters (, = 2, 4 and 6) which are in turn used to analyse the radiative properties of luminescent level of Nd³⁺ ions. The near infrared emission spectra recorded with 808 nm laser excitation for different concentrations of Nd³⁺ ions show that the emission of ⁴F_{3/2} → ⁴I_{11/2} transition at 1063 nm found to be high intense. The measured decay times of ⁴F_{3/2} level decreased with the increase of Nd³⁺ concentration due to concentration quenching. The calculated laser parameters have been found to be high for the present Nd³⁺-doped bismuth phosphate glasses when compared with the other Nd³⁺ doped glasses. The obtained results suggested that the present glasses could be useful for 1.06 μm solid state laser applications.

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**CONCENTRATION EFFECT ON NIR LUMINESCENCE BEHAVIOR OF
ND³⁺ DOPED CALCIUM BOROPHOSPHATE (CBP) PHOSPHORS**

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Different concentrations of neodymium(Nd³⁺) doped calcium borophosphate (CBP) phosphors were prepared by solid state reaction method. These phosphors were characterized by XRD, SEM, XPS, FT-IR, ³¹P solid state NMR, photoluminescence (PL) and decay profiles. Crystal phase, morphology, elemental analysis and structural studies were obtained. XRD profiles showed that the prepared phosphors exhibit a hexagonal phase in crystal structure. XPS spectra were recorded and discussed about various anionic groups. From ³¹P NMR spectra of these phosphors, mono-phosphate complexes Q⁰-(PO₄³⁻) were observed. From the diffuse reflectance spectra, the optical band gaps were obtained for different concentrations of Nd³⁺ doped CBP phosphors. NIR photoluminescence spectra were measured for Nd³⁺ doped calcium borophosphate phosphors and the spectra were studied for different concentrations. Decay curves were obtained for the transition, ⁴F_{3/2} → ⁴I_{11/2} of Nd³⁺ in these calcium borophosphate phosphors and lifetimes were measured. The above results showed that Nd³⁺ doped CBP phosphors might be used for NIR emission applications.

OPTICAL AND SPECTROSCOPIC PROPERTIES OF Er³⁺ DOPED DIFFERENT CHLOROFLUORO BORO PHOSPHATE GLASSES

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Er³⁺ ions doped chlorofluoro boro phosphate glasses with compositions (in mol %) (50-x) (B₂O₃) +10 P₂O₅+ 10 PbO+15 NaCl+15 MgF₂ + x Er₂O₃, x= 0.2, 0.4, 0.6, 0.8, 1.0 and 2.0 system have been prepared by melt quenching technique. The X-ray diffraction (XRD) pattern confirms the amorphous nature of the prepared glass and the FTIR spectra explore the fundamental groups and the local structural units in the prepared chloro fluoro boro phosphate glasses and optical absorption, emission and decay measurements were carried out. From the optical absorption spectra, derive the spectral intensities (f) and Judd-Ofelt intensity parameters, ($\Omega_2, \Omega_4, \Omega_6$) were determined through experimental and calculated oscillator strengths obtained from the absorption spectra and their results are studied and compared with reported literature. Using Judd-Ofelt intensity parameters, radiative transition probabilities (A_R), radiative lifetimes (τ_R), integrated absorption cross sections (σ) and branching ratios (β_R) are calculated for all the concentrations. From the photoluminescence spectra, experimental branching ratios (β_{exp}) and stimulated emission cross-sections (σ_p) for all the observed emission transitions are calculated. The excited state transitions ²H_{9/2} ⁴I_{15/2} and ⁴S_{3/2} ⁴I_{15/2} emission level of Er³⁺ doped different chlorofluoro boro phosphate glasses. Experimental radiative lifetimes (τ_{exp}) are obtained from decay curve analysis for all glass matrices. Finally, these observed results are discussed and compared with the literature data.

OPTICAL AND LUMINESCENCE FEATURES OF Nd³⁺ IONS IN LEAD BISMUTH PHOSPHATE GLASS SYSTEM MIXED WITH SOME SESQUIOXIDES

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PbO P₂O₅ Bi₂O₃ R₂O₃ (R = Al, Ga, In, Tl) glasses doped with Nd₂O₃ were prepared by melt quenching technique. The prepared glasses were characterized by the XRD patterns. Conventional spectroscopic studies *viz.*, FTIR, optical absorption and photoluminescence were carried out on these glasses. The optical absorption spectra exhibited eleven absorption bands around 351,431,473,514,526,581,628,683,747,804 and 874 nm wavelength corresponding to the transitions ⁴I_{9/2} ⁴D_{1/2}, ²P_{1/2}, ²G_{9/2}, ⁴G_{9/2}, ⁴G_{7/2}, ⁴G_{5/2}, ²H_{11/2} ⁴F_{9/2}, ⁴F_{7/2}, ⁴F_{5/2} and ⁴F_{3/2} respectively. Judd-Ofelt parameters have been evaluated for the prepared glasses using optical absorption spectra and these J-O intensity parameters have exhibited the trend $\lambda_{2} > \lambda_{6} > \lambda_{4}$. Emission spectra of the prepared glasses were recorded at the excited wavelength 804 nm and it exhibited three prominent peaks at about 885, 1054, 1323 nm wavelength corresponding to the ⁴F_{3/2} ⁴I_{9/2, 11/2, 13/2} transitions respectively in the near infrared region. By using J-O parameters various radiative parameters for the excited luminescent levels of Nd³⁺ ions are evaluated. Emission cross section and branching ratio values are observed to be high for ⁴I_{11/2} level of Nd³⁺ ions. The emission intensities, evaluated quantum efficiency, branching ratio, scattering emission cross section values of three transitions are found to be high for Ga₂O₃ mixed glasses. The above investigations indicate that the glass system mixed with Ga₂O₃ could be a suitable candidate for 1.06 μm laser source in the near infrared region.

**SPECTROSCOPIC STUDIES OF DY³⁺ IONS DOPED OXY-CHLORO
BORO TELLURITE GLASSES FOR VISIBLE PHOTONIC
APPLICATIONS**

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Oxy-chloro boro tellurite (OCBT) glasses doped with different concentrations of Dy³⁺ ions were prepared by using a conventional melt quenching technique and characterized through XRD, FT-IR, Raman, absorption, excitation, photoluminescence (PL) and fluorescence decay spectral measurements. The XRD, FT-IR and Raman spectral patterns were used to confirm the glassy nature and to identify several functional groups present in the prepared glasses respectively. From the absorption spectral profiles, oscillator strengths were measured to evaluate the Judd-Ofelt (J-O) intensity parameters. The PL spectra recorded under 386 nm excitation wavelength have two intense peaks in blue (485 nm) and yellow (576 nm) regions related to the transitions ⁴F_{9/2} – ⁶H_{15/2} and ⁴F_{9/2} – ⁶H_{13/2} respectively. By correlating the J-O parameters with PL spectral data, various radiative properties like radiative transition probability (A_R), radiative lifetime (τ_R), stimulated emission cross section (σ_{se}) and branching ratios (β_R) have been measured for ⁴F_{9/2} – ⁶H_{13/2} and ⁶H_{15/2} transitions. Using the PL decay curves the experimental lifetimes (τ_{exp}) were measured and in turn used to measure the quantum efficiency of the present series of glasses. The yellow to blue intensity ratio (Y/B) was evaluated to understand white light emission capability of the host glass by changing the concentration of the Dy³⁺ ions. In order to confirm the white light emission from the series of OCBT glasses, the CIE color co-ordinates have also been evaluated. From all the aforementioned studies, it is concluded that 1.0 mol% of Dy³⁺ ions doped OCBT glass is aptly suitable for visible photonic applications.

PHYSICAL AND OPTICAL PROPERTIES OF Nd³⁺ IONS DOPED BARIUM LEAD ALUMINO FLUORO BORATE GLASSES FOR LASING APPLICATIONS

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Rare earth ions doped glasses occupies the prominent place due their applications in the fields of fluorescent display devices, optical detectors, bulk lasers, optical fibres wave guide lasers. Optically transparent Nd³⁺ ions doped Alkaline earth lead fluoro alumino borate (BaPbAlFB) glasses have been synthesized by melt quenching technique. The amorphous nature of the un-doped glass has been confirmed through XRD measurements. The FT-IR spectral data recorded for an un-doped glass gives the information pertaining to various functional groups. The weight loss in the as-prepared un-doped glass has been studied by TGA studies. The glass transition (T_g), onset crystallization (T_x), crystallization (T_c) and melting (T_m) temperatures were determined from DSC measurements. The optical properties of the titled glasses have been explored from the absorption, photoluminescence excitation (PLE) and photoluminescence (PL) spectra. Judd-Ofelt (JO) analysis was carried out and the intensity parameters (Ω_{n=2,4,6}) also spontaneous radiative probability and stimulated-emission cross-sections were estimated. The magnitude of Ω₂ confirms the covalency nature. The near infrared emission spectra were measured by 808 nm excitation in which the emission intensity is found to be high at 1064 nm for the ⁴F_{3/2} → ⁴F_{11/2} transition. The relatively higher values of emission cross-sections, branching ratios values obtained for 1.0 mol% of Nd³⁺ ions in BaPbAlFB glass suggests it's aptness in generating lasing action at 1064 nm in NIR region. Therefore, the present study suggests that 1.0 mole % of BaPbAlFB glass can act as suitable host for laser emission at 1064 nm(transition) as well as optical fiber amplifier.

ENHANCED PHOTOLUMINESCENCE AND NON LINEAR OPTICAL PROPERTIES OF RARE EARTH (Ce³⁺ Tb³⁺ ,Eu³⁺) ADDED SULFAMIC ACID SINGLE CRYSTALS FOR OPTOELECTRONICS AND DEVICE APPLICATIONS

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Single crystals added with rare-earth (RE) ions are exhibiting a combination of active (laser) and nonlinear properties (active nonlinear crystals) have been investigated intensively. The trivalent lanthanide ions are eminent for their photo luminescent properties in the visible and near-infra regions are suitable for several applications such as telecommunications, displays, laser materials, data storage, radiation detection, and medical applications. The pursuit for new nonlinear optical crystals has the top priority in the present day scenario. Most of the amino acids show optical nonlinearity as they contain a proton donor carboxyl (COOH) group and a proton acceptor amino (NH₂) group in the structure and hence complexes of amino acids naturally exhibit nonlinearity. With this view, attempts have made to grow rare earth (Ce³⁺ Tb³⁺ ,Eu³⁺) added sulfamic acid(SA) single crystals grown by conventional slow evaporation solution technique(SEST), and unidirectional growth/Sankaranarayanan-Ramasamy (SR) technique and to test their photoluminescence properties for opto-electric device applications. The grown crystal was examined by XRD, HRXRD to know its morphology, crystal structure and lattice parameters, FTIR analysis was used to describe functional groups and effects of influence of dopant in the grown crystal. The optical transparency of the grown crystal was studied by UV-visible spectroscopy. Thermogravimetric and differential thermal analysis (TG/DTA) is carried out for its thermal stability. SEM with EDAX technique is used to identify the cerium incorporation in the bulk grown crystal. Dielectric constant, dielectric loss studies are carried at different temperatures and nonlinear efficiency was measured by Kurtz powder method. The photoluminescence character of grown crystal reveals the fact that it can be an excellent host material for optical emissions at low temperature.

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**IMPROVEMENT OF EMISSION OF ERBIUM ION IN ORANGE REGION
BY CODOPING WITH TIN IONS IN $\text{Li}_2\text{O-PbO-P}_2\text{O}_5$ GLASS SYSTEM**

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Lithium lead phosphate glasses doped with fixed concentration of Er_2O_3 and mixed with varying concentrations of SnO_2 (from 0 to 7.0 mol%) have been synthesized. Optical absorption and luminescence spectra of the prepared glasses were recorded at ambient temperature. The radiative lifetimes were measured from the luminescence decay profiles recorded at room temperature. Similar studies have also been carried out on SnO_2 singly doped glasses. Absorption and luminescence spectra of Er^{3+} ions doped glasses were characterized using Judd–Ofelt theory. Radiative parameters viz., transition probability A , branching ratio and the radiative lifetime of principal emission transitions of these glasses have been evaluated. The energy transfer mechanism between Sn^{4+} and Er^{3+} in co-doped glasses has been explored as a function of SnO_2 concentration with the help of rate equations. The results indicated a significant enhancement in the intensity of orange emission $^4\text{G}_{11/2} \rightarrow ^4\text{I}_{11/2}$ of Er^{3+} ions due to co-doping with SnO_2 . The results were further analysed with IR spectral data and ac conductivity studies. The reasons for this enhancement have been analysed in the light of varying environment of rare earth ions due to the variations in the content of SnO_2 . The analysis pointed out that about 3.0 mol% of SnO_2 is the most favourable concentration for getting the highest quantum efficiency of orange emission and for the maximum energy transfer with low non-radiative transition probabilities. The energy transfer mechanism from Sn^{4+} ($\text{S}_1 \rightarrow \text{S}_0$) to Er^{3+} ($^4\text{G}_{11/2} \rightarrow ^4\text{I}_{11/2}$) is quantitatively discussed with the rate equations.

STRUCTURAL AND NON-LINEAR OPTICAL PROPERTIES OF Eu³⁺ IONS DOPED BORO-TELLURITE GLASSES

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A new series of Eu³⁺ ions doped boro-tellurite glasses have been prepared following the melt quenching technique with the composition (69-x) B₂O₃-xTeO₂-15Na₂CO₃-15NaF-1Eu₂O₃ (where x=0, 10, 20, 30 and 40 in wt%). The density, molar volume, FTIR and UV-Visible studies have been used to determine structural and non-linear optical properties of the title glasses. The FTIR spectral measurements reveal the presence of various functional groups such as OH group, stretching vibrations of B-O bonds in BO₃ and BO₄ groups, Te-O bonds in TeO₃ and TeO₄ groups and the bending linkages of Te-O-Te/O-Te-O or B-O-B/O-B-O bonds in the prepared glasses. The boron-boron separation(<d_{B-B}>), oxygen packing density(OPD), bond density(n_b) and calculated Poisson's ratio (μ_{cal}) values are found to decrease with the addition of TeO₂ thus reveal the fact that the network connectivity decreases due to the formation of non-bridging oxygen sites and the glass network becomes less tightly packed. Further, covalent nature of the Eu³⁺-metal ligand bond have been identified from the measured optical basicity (β_{th}), covalent and ionic characteristic factor values. The observed variations in the optical electronegativity, basicity and metallization criterion values have been discussed in terms of the structural changes that takes place due to the addition of TeO₂ into the B₂O₃ network. The higher refractive index, increased optical basicity and metallization imply the enhanced non-linear optical behavior of the present glasses. Further the calculated two-photon absorption coefficient (χ⁽²⁾) values of titled glasses imply that they are ideal for the fabrication of optical signal processing devices.

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**ENHANCED LONGER EXCITED STATE LIFETIME OF
Er³⁺:Yb³⁺ CO-DOPED TELLUROBORATE GLASSES
FOR OPTICAL AMPLIFICATION AT 1.5 μm**

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A new series of Dy³⁺ ions doped (30-x-y)B₂O₃+30TeO₂+20CaCO₃+10ZnO+10ZnF₂+xYb₂O₃+yEr₂O₃ (x=1; y=0.01, 0.1, 0.25, 0.5, 1, and 2 in wt%) Zinc calcium tellurofluoroborate glasses were prepared and their optical absorption, luminescence and excited state dynamics have been studied to explore the amplification properties. The bonding parameters (σ and τ), optical band gap, Urbach's energy, oscillator strengths and Judd-Ofelt (JO) intensity parameters were calculated from the absorption spectra. Oscillator strength values of the hypersensitive transitions $^4I_{15/2} \rightarrow ^4G_{11/2}$ and $^4I_{15/2} \rightarrow ^2H_{11/2}$ possess higher values compared to the other transitions. The σ parameter possess higher values for all the prepared glasses and the JO parameters follows the trend as $\sigma_2 > \sigma_6 > \sigma_4$ uniformly for all the glasses. The higher σ_2 parameter values and smaller σ_6 parameter values indicate the lower symmetry. The luminescence properties have been analyzed through luminescence excited state dynamics and radiative properties such as transition probability (A), stimulated emission cross-section ($\frac{E}{P}$), branching ratio values (β) and radiative lifetimes (τ_R) values. The luminescent intensity corresponding to the $^4I_{13/2} \rightarrow ^4I_{15/2}$ transition changes with the change in Er₂O₃ content and is due to the energy transfer process taking place between Yb³⁺ and Er³⁺ ions. The absorption and emission cross-section values for the $^4I_{13/2} \rightarrow ^4I_{15/2}$ emission band have been calculated using McCumber theory and the Gain cross-section for the $^4I_{13/2} \rightarrow ^4I_{15/2}$ emission transition also obtained. The emission cross-section corresponds to the 1.53 μm emission band is found to be 4.11×10^{-20} cm² and the effective bandwidth is found to be 91 nm. The luminescence decay curves corresponding to the $^4I_{13/2} \rightarrow ^4I_{15/2}$ transition of the Er³⁺/Yb³⁺ co-doped telluroborate glasses under 980 nm excitation have also been studied. The lifetime pertaining to the $^4I_{13/2} \rightarrow ^4I_{15/2}$ transition is found to be higher than the reported Er³⁺/Yb³⁺ doped glasses and the values are found to be in the order of 17 ms. The τ values are found to change with the increase in Er³⁺ ions concentration and the same is due to the enhanced inter-ionic interaction between Yb³⁺ and Er³⁺ ions. The obtained results were compared with the reported Er³⁺/Yb³⁺ glasses and it is concluded that the present glasses can be used as a promising gain medium for laser and fiber amplifier applications.

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OXYFLUORIDE GLASSES FOR SOLID STATE LASERS

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Lead borate oxyfluoride glasses activated with different concentrations of Pr^{3+} ions of composition were prepared by melt quenching technique and characterized. The amorphous nature and compositional analysis was studied by powder X-ray diffraction, Fourier transform infrared and Raman studies. Using the room temperature optical absorption spectra, the spectroscopic properties were determined applying the modified Judd-Ofelt theory [1-3]. The three phenomenological Judd-Ofelt intensity parameters ($\Omega_{2,4,6}$) were obtained by least square fit method and they were found to be $\Omega_2 = 1.85 \times 10^{-20} \text{ cm}^2$, $\Omega_4 = 3.42 \times 10^{-20} \text{ cm}^2$ and $\Omega_6 = 2.36 \times 10^{-20} \text{ cm}^2$. The photoluminescence excitation spectrum recorded monitoring the emission at 604 nm corresponding to the $^1\text{D}_2 \rightarrow ^3\text{H}_4$ transition shows a prominent excitation band peaked at ~450 nm ($^3\text{H}_4 \rightarrow ^3\text{P}_2$). When excited through $^3\text{H}_4 \rightarrow ^3\text{P}_2$ transition, the studied glasses exhibit four emission transitions: $^3\text{P}_0 \rightarrow ^3\text{H}_4$ (~490 nm), $^3\text{P}_1 \rightarrow ^3\text{H}_5$ (~530 nm), $^1\text{D}_2 \rightarrow ^3\text{H}_4$ (~604 nm) and $^3\text{P}_0 \rightarrow ^3\text{F}_2$ (~645 nm). The emission spectra show a red shift with the increase of concentration of Pr^{3+} ions. The fluorescence decay time of $^1\text{D}_2$ emission level of Pr^{3+} ions was found decreased with increase of Pr^{3+} concentration. The quenching of decay time was assigned to the energy transfer among the excited Pr^{3+} ions at relatively higher concentrations. The experimental results show that the studied glasses were suitable candidate to design intense orange-red emitting laser glasses.

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**INVESTIGATION ON STRUCTURE AND CHEMISTRY OF MONAZITE
MINERAL USING RAMAN SPECTROSCOPY**

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The beach sands of India contain large reserves of monazite, a rare-earth phosphate mineral. It shows an appreciable range of rare-earth elements Ce, La, Nb and actinide elements Th, U. In general it contains about 55 – 60% total rare earth oxide and 9-10% ThO₂. Raman spectroscopy has been used to study the chemistry and structure of natural monazite mineral, in general shows good agreement with the results of other characterisation techniques. The strongest peak near 970 cm⁻¹ belongs to A_g mode assigned to the symmetric stretching of the PO₄ tetrahedrons and has a small contribution from B_g mode also. The medium peak near 412 cm⁻¹ and 460cm⁻¹ belongs to Ag/Bg. The small peak near 270 cm⁻¹ belongs to A_g mode. The monazite mineral crystallise in the monoclinic system (space group *P2₁/n*, Z=4) which consists of chains of alternating AO₉ polyhedrons (where A is Ce, and other light rare earth elements substituting for Ce) and distorted PO₄ tetrahedrons parallel to the c axis. Raman spectroscopy enabled characterisation of monazite minerals impacted on the efficiency for determining their grade and potential applications.

RARE EARTH Dy³⁺ DOPED -MoO₃ NANOPHOSPHORS FOR SOLID-STATE LIGHTING AND ADVANCED FORENSIC APPLICATIONS

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In the present work, we report white light emitting Dy³⁺ ions activated MoO₃nanophosphors (NPs) were synthesized by solution combustion method by using Barbituric acid as a fuel. The crystal structure, morphology, optical band gap, and luminescent properties of the prepared samples were extensively studied. A single orthorhombic phase of the samples was confirmed by powder X-ray diffraction (PXRD) results, which signifies effective substitution of Dy³⁺ ions in the MoO₃ host. Hierarchical microstructures of the fabricated samples were investigated. The characteristic intense photoluminescence (PL) emission peaks were observed in the range ~ 450 – 700 nm, which were ascribed to ⁴F_{9/2} – ⁶H_J (J = 15/2, 13/2 and 11/2) transitions of Dy³⁺ ions. Variation in the PL emission intensity with a maximum of ~ 5 mol % of Dy³⁺ concentration was due to concentration quenching phenomena. The photometric and theoretical spectral calculations of the samples were successfully investigated. The optimized NPs were explored as a novel material for visualization of latent fingerprints (LFPs) on various porous, semi-porous and non-porous surfaces under normal light. The obtained results indicated that well-defined ridge characteristics with all three level fingerprints (FPs) with highly sensitive, efficient and without background interference were observed owing to its nano regime and better adhesion efficiency. From aforementioned results, the MoO₃: Dy³⁺ (1-9 mol %) NPs are considered to be most promising luminescent materials for solid-state lighting and advanced forensic applications.

MONOVALENT IONS (Li, Na, K) CO-DOPED ZnAl₂O₄: Eu³⁺ NANOPHOSPHORS FOR LATENT FINGERPRINT VISUALIZATION

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In the present work, we tailoring alkali metal ions ($M^+ = \text{Na, Li, K}$) co-doped ZnAl₂O₄: Eu³⁺ (5 mol %) (ZAE) nanopowders (NPs) via solution combustion route using *mimosa pudica* (MP) leaves extract as a fuel. The effective substitution of co-dopants improves crystallinity and grain growth which confirms through PXRD results. Photoluminescence (PL) emission spectra of the prepared ZAE and ZAE: M⁺ ($M^+ = \text{Na, Li, K}$) NPs exhibits intense red emission peaks at ~ 550 – 750 nm due to ⁵D₀ → ⁷F_J ($J = 0, 1, 2, 3, 4$) transitions of Eu³⁺ ions. The Na⁺, Li⁺ and K⁺ ions co-doped samples exhibits enhanced PL emission intensity may be due to the creation of oxygen vacancies which induced by ionic radii mismatch. Latent fingerprints (LFPs) visualization is the most important approach to identify individuals, and there is a persisting need for the development of simple, rapid, accurate, and universal recognition methods. Hence, the optimized ZnAl₂O₄: Eu³⁺ (5 mol %), Li⁺ (1 wt %) (ZAEL) NPs creates novel sensing platform for visualization of highly sensitive LFPs under normal and UV light (254 nm) on various porous, semi-porous and non-porous surfaces through robust powder dusting technique. The visualized LFPs reveals well defined level 1-3 ridge characteristics even after abrasion and aquatic environmental tests. Hence, it evidences versatility of the development techniques for visualization of LFPs with superior sensitivity, little background hindrance, extraordinary efficiency, lesser toxicity and stress-free detection. The obtained results bridge gap between prepared NPs and its multifunctional applications namely, advanced forensic and solid state lightning.

OPTICAL STUDIES OF HOLMIUM DOPED OXYFLUOROPHOSPHATE GLASSES FOR GREEN LIGHT DEVICES

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Researchers have paid much attention on rare earth (RE³⁺) doped materials due to their potential applications in the field of laser radars, laser guided missiles, optical communication, atmospheric pollution monitoring, cataract eye surgery, etc.,. An intense green and red emission regions of holmium (Ho³⁺) ions has motivated for fabricating green or red luminescent devices. Present work focuses on the Ho³⁺-doped oxyfluoro-titania-phosphate (HOFTP) glasses with glass composition, P₂O₅-BaF₂-CaF₂-TiO₂-Ho₂O₃, were prepared by usual melt-quenching technique. There are fourteen well resolved absorption peaks were noticed from visible to NIR region. An intense emission band was revealed at 545 nm and two more low intense bands at 659 nm and 752 nm. The emission wavelength at 545 nm and 659 nm could be utilized for the development of green and red lighting devices.

RARE EARTH DOPED NOVEL MATERIALS FOR OPTICAL REFRIGERATION

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Optical refrigeration or laser cooling of solids based on anti-stokes fluorescence has been proposed for the first time by Pringsheim [1]. However, this was demonstrated experimentally by Epstein *et al.* [2] in Yb³⁺-doped ZBLANP fluoride glasses. Subsequently, selective number of novel materials doped with trivalent rare earth (RE³⁺) ions have been explored. These materials include glasses [3], glass-ceramics containing nanocrystals [4], optical fibers [5–7], single crystals [8] and nanocrystals [9]. For laser cooling, the materials must possess high photoluminescence quantum yield (PLQY), low background absorption and low phonon energy. Novel materials such as glasses and nanocrystalline glass-ceramics have lot of advantages compared to other interesting materials (fluoride glasses, nanocrystals and single crystals) such as simple and rapid synthesis process, high chemical resistance, high PLQY, shape into required dimension and less expensive. The scope and study of these RE³⁺-doped materials for laser cooling applications could be discussed during the conference.

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Tb³⁺-DOPED OXYFLUORO-TITANIA-PHOSPHATE GLASSES FOR SOLID STATE LIGHTING DEVICES

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Recent times, phosphate glasses have been extensively investigated for high-energy high-power lasers [1], bioactivity [2], nuclear waste immobilization [3], and magneto optical effect [4]. Addition of transition metal oxides such as titania (TiO₂) to the phosphate glasses could improve their optical, physical, chemical and mechanical properties [5]. Terbium doped glasses have found potential applications in lasers, solid state lighting and display devices. This work focuses on the fabrication of Tb³⁺-doped oxyfluoro-titania-phosphate glasses of chemical composition (in mol%), (60 - x) P₂O₅ - 15 BaF₂ - 20 CaF₂ - 5 TiO₂ - x Tb₄O₇, x = 0.05, 0.1 and 1.0 by usual melt-quenching technique. These samples were characterized through optical absorption, excitation, emission and decay profiles. Upon excitation at 377 nm, the PL spectra exhibit an intense band at 541 nm which corresponds to the ⁵D₄ - ⁷F₅ transition. Lifetime of the ⁵D₃ and ⁵D₄ levels of Tb³⁺ ion was obtained by analyzing the decay curves with exponential function. Green emission was predominant in Tb³⁺-doped oxyfluoro-titania-phosphate glasses which could be a potential candidate for green emitting devices.

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**NOVEL RED-EMITTING ZrO_2 : Eu^{3+} NANOPHOSPHOR FOR
LATENT FINGERPRINT TECHNOLOGY**

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Fingerprints have been used in forensic investigation for the identification of individuals. Herein, we report a novel red-emitting Eu^{3+} ions doped ZrO_2 nanophosphors for latent fingerprint technology. Eu^{3+} ions doped (1 – 7 mol %) ZrO_2 nanoparticles (NPs) were synthesized by a facile green synthesis method using *Aloe vera* as fuel. The obtained ZrO_2 : Eu^{3+} (1-7 mol %) NPs were characterized by using powder X-ray diffraction studies (PXRD), scanning electron microscopy (SEM) and photoluminescence (PL) techniques. The dependency of dopant concentration on the crystal structure, surface morphology and luminescence properties were discussed in detail. The PL emission of ZrO_2 : Eu^{3+} NPs shows characteristic transitions of Eu^{3+} ions. The CIE chromaticity and CCT confirms the phosphor material as red emitting hence it was quite useful in display applications.

**INVESTIGATIONS ON LOCAL FIELD SYMMETRY AROUND Eu^{3+} IONS
IN B_2O_3 - ZnO - Li_2O - SrO - P_2O_5 GLASSES: CORRELATION BETWEEN
STRUCTURAL AND LUMINESCENCE BEHAVIOR**

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The correlation between structural and luminescence behavior of Eu^{3+} ions is a well known spectroscopic probe to estimate the local field environment in different host matrices due to its simple energy level structure i.e. ${}^7\text{F}_0$ ground and the ${}^5\text{D}_0$ excited state of Eu^{3+} ions are single and non-degenerate under any symmetry. The intensity ratio between electrical-dipole (${}^5\text{D}_0 \rightarrow {}^7\text{F}_2$) and magnetic-dipole (${}^5\text{D}_0 \rightarrow {}^7\text{F}_1$) transitions can be used as a probe for site symmetry to investigate the local field environment. The phonon sideband appear in the excitation and emission spectra as a result of coupling of the 4f electrons to the lattice vibrations provides direct measurements of the phonon environment around the Eu^{3+} ions site. In the present work, Eu^{3+} ions doped borophosphate glasses, $51\text{H}_3\text{BO}_3 + 10\text{ZnO} + 20\text{Li}_2\text{CO}_3 + 9\text{SrCO}_3 + (10-x)\text{H}_6\text{NO}_4\text{P} + x\text{Eu}_2\text{O}_3$ (where $x=0.1, 0.25, 0.5, 1, 2$ and 3 in mol%) were prepared by melt-quenching technique and their structural, optical behavior were studied and reported. The local structure and vibronic spectral analysis were performed in order to correlate them with the local field environment of Eu^{3+} ions on the basis of FTIR, Raman, Phonon sideband spectroscopy. The PSB with three discrete phonon modes located at around 1320 and 1690 cm^{-1} have been compared with the FTIR band assignments and are in good agreement with the observed bands. The PSB located at 1320 cm^{-1} is mainly due to the presence of isolated BO_4 units, B–O stretching in BO_4 units and B–O stretching in BO_3 units, respectively. Another PSB located at 1690 cm^{-1} is associated with the P–O stretching vibration in PO_3 units. The Nephelauxtic intensity ratio (β) and bonding parameter (b) values obtained from the absorption bands reveals the covalent nature of the Eu–O bond in the prepared glasses. The five emission transitions were observed in the luminescence spectra while exciting at 464 nm as a result of radiative transitions from the excited ${}^5\text{D}_0$ level to the lower energy levels ${}^7\text{F}_{J(=0,1,2,3,4)}$ of Eu^{3+} ions. The JO intensity parameters (α) and the asymmetric intensity ratio (R) values were calculated from the emission spectra which are used to explore the nature of the bonding and asymmetry around the Eu-ligand field environment. The increasing β intensity parameter values and R values confirms the higher asymmetry around Eu^{3+} ions and the covalency of Eu–O. The excited state lifetime pertaining to the ${}^5\text{D}_0$ level of Eu^{3+} ions has been found to be single exponential for all concentration of Eu^{3+} ions and the values are found to increase with the increase in Eu^{3+} ions concentration due to the higher asymmetry around Eu^{3+} ions. The obtained (x,y) chromaticity coordinates (0.61, 0.32) in the CIE chromaticity diagram suggests that the prepared glasses are promising materials for red laser applications.

RARE EARTH BASED DOWN CONVERSION PHOSPHORS FOR ENHANCED LIGHT HARVESTING IN DYE SENSITIZED SOLAR CELLS

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The inability of dye sensitized solar cells (DSSCs) to utilize light in the ultraviolet (UV) spectral range, which constitutes almost half the energy of the sun's radiation, is a major limitation to their power conversion efficiency (PCE) [1]. Photon down conversion through rare-earth ions is one of the promising approaches to convert UV into visible, where DSSCs typically have high sensitivity [2]. In this regard, we demonstrated the application of the $\text{Ca}_2\text{SiO}_4:\text{Dy}^{3+}$ down converting phosphors (DCPs) to improve the PCE of DSSCs. We herein report the up gradation of efficiency in DSSCs by spin coating the proposed DCPs on TiO_2 working electrode. The best photovoltaic performance was achieved for the champion cells incorporating $\text{Ca}_2\text{SiO}_4:\text{Dy}^{3+}$ DCPs with current density $J_{\text{sc}} = 10.95 \text{ mA cm}^{-2}$, Voltage $V_{\text{oc}} = 0.79 \text{ V}$ and efficiency $\eta = 4.23\%$, relative to the test cells fabricated without DCPs. ($J_{\text{sc}} = 9.71 \text{ mA cm}^{-2}$, $V_{\text{oc}} = 0.78 \text{ V}$, $\eta = 3.13\%$) under one sun illumination, resulting in an enhancement in PCE.

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PHOTOLUMINESCENCE OF SAMARIUM DOPED ANTIMONY-MAGNESIUM-STRONTIUM-OXYFLUOROBORATE GLASSES

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Trivalent rare earth (RE^{3+}) ions have emerged as active ions in the many optical devices. For the past few years RE^{3+} -doped glasses got much attention due to their potential applications in emerging fields of science and technology include display monitors, lasing devices, optical fibers, detectors, sensors and solar concentrators. This work reports the photoluminescence properties of samarium (Sm^{3+})-doped antimony-magnesium-strontium oxyfluoroborate (B_2O_3 MgF_2 SrO Sb_2O_3 Dy_2O_3) glasses. These glasses were prepared by melt-quenching technique and investigated their properties through optical absorption, photoluminescence excitation, photoluminescence emission and decay curve analysis. Absorption band consists of ten bands in which a transition, $^6H_{5/2} \rightarrow ^6F_{7/2}$ is called as hypersensitive is observed. A peak related to $^4G_{5/2} \rightarrow ^6H_{7/2}$ transition in the luminescence spectra shows a strong reddish-orange emission under the wavelength excitation of 401 nm. Decay curves are mono-exponential at lower concentration and non-exponential at higher concentration. Lifetime (τ) of $^4G_{5/2}$ level was decreased with increase of Sm^{3+} ion concentration. The red to orange (R/O) ratio was examined to understand the symmetric character about the Sm^{3+} ion. The value of τ is found to be 2.21, 1.63, 1.12, 0.82, 0.59 and 0.49 ms for 0.1, 0.5, 1.0, 1.5, 2.0 and 2.5 mol% of Sm^{3+} ion concentration, respectively. It is observed that τ value decreases with increasing Sm^{3+} ions concentration. From the CIE colour coordinates and CCT values, it is concluded that the synthesized glasses are suitable for reddish orange luminescence. Therefore the present glass system can be used as an active media for the development of reddish orange lighting devices.

PHOTO-EMISSION AND THERMALLY STIMULATED LUMINESCENCE PROPERTIES OF DY³⁺-DOPED ZINC SODIUM BISMUTH BORATE GLASSES

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Present study reports the effects of varying concentrations of Dy³⁺ ions on the optical properties of 10ZnO-5Na₂CO₃-10Bi₂O₃-75-xB₂O₃-xDy₂O₃ (x=0.1 to 1 mol%) glasses prepared through melt-quench technique with an aim to achieve suitable optical gain medium for illumination applications. Minimal changes in the measured density, X-Ray diffractogram and Fourier Transform Infrared spectra of the prepared samples confirmed the stability of the glass structure even after 1 mol% doping of the Dy³⁺. The oscillator strength and Judd-Oflet (JO) intensity parameters of the glasses were determined using optical absorption spectra. The photoemission spectra exhibited two prominent emissions around 480 nm and 587 nm at 387 nm excitation. The calculated color chromaticity with x = 0.401, y = 0.441 coordinates for 0.3 mol% of the Dy³⁺ in the glasses suggests suitable optical gain medium for white colour LED applications. Metastable lifetimes of the Dy³⁺ ion were found-out by exponential fitting to the decay profiles. Lasing parameters of the glasses such as branching ratio, radiative transition probability and stimulated emission cross-section of ⁶F_{9/2} – ⁶H_{13/2} transition were calculated using JO parameters indicating 0.3 mol% Dy³⁺-doped glasses suitable for 587 nm solid-state laser applications. The mechanism of energy transfer is determined by applying the Inokuti-Hirayama model and was found to involve a dipole-dipole type of interactions. Thermoluminescence (TL) glow curves of the gamma-ray treated 0.3 mol% Dy³⁺-doped zinc sodium bismuth borate glasses were deconvoluted using Computerized Glow Curve Deconvolution method to evaluate the energy storage properties of the glasses. The intensity variation of the TL component peak (CP2) at 500 K showed linear behavior up to 3 kGy suggesting application in high dose measurements.

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PRODUCTION OF RADIO-LANTHANIDES BY DIRECT ACTIVATION REACTIONS UTILIZING DHRUVA RESEARCH REACTOR FOR RADIOPHARMACEUTICAL SCIENCES

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Radioactive lanthanides offer enticing properties and is extensively studied in Radiopharmaceutical Sciences during recent years. Radiolanthanides produced by direct activation reactions in a research reactor offers attractive nuclear properties for its use in endoradiotherapy using appropriate radiolabeled molecules. Among various neutron induced nuclear reactions, the option of utilizing direct activation reactions i.e., (n,) is not only attractive but also effective in achieving prospective radiolanthanide precursors in a facile manner suitable for radiopharmaceutical chemistry. Many lanthanide isotopes have very high neutron activation cross section, and therefore provide suitable targets for production of radiolanthanides. Lanthanide radioisotopes such as ^{177}Lu [$T_{1/2} = 6.65$ d, $E_{(\text{max})} = 497$ keV (78.6%); $E = 113$ keV (6.6%), 208 keV (11%)], ^{153}Sm [$T_{1/2} = 47\text{h}$, $E_{(\text{max})} = 807$ keV (21%); $E = 103$ keV (28%), 70 keV (5%)], ^{175}Yb [$T_{1/2} = 4.185$ d, $E_{(\text{max})} = 480$ keV (80%); $E = 113$ (1.9%), 282 (3.1%)], ^{169}Er [$T_{1/2} = 9.4\text{d}$, $E_{(\text{max})} = 351$ keV (55%); $E = 110.5$ keV (0.0014%)] and ^{166}Ho [$T_{1/2} = 27\text{h}$, $E_{(\text{max})} = 1.84$ MeV (100%); $E = 80.5$ keV (6.7%)] having favorable radionuclide decay properties were studied and their radiochemical process procedures optimized. Measured amounts of chemical targets in their respective oxide forms were weighed into standard aluminum cans, cold weld sealed and neutron irradiated at a thermal neutron flux of 1×10^{14} n/cm².s for optimized time of irradiation. Subsequently, irradiated samples were retrieved in each case and radiochemical procedures optimized in a lead shielded production plant facility with remote handling provisions. Quality control procedures were followed to ascertain the radioactivity yield, radiochemical and radionuclide purity of the respective radiochemical prepared. Under optimized conditions, large scale production of radiolanthanides ^{177}Lu , ^{153}Sm , ^{175}Yb , ^{169}Er and ^{166}Ho [1-5] with radionuclide purity >99.9% radiochemical purity >95% suitable for therapeutic radiopharmaceutical formulations suitable for patient treatment is the positive outcome.

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MAGNETIC AND OPTICAL PROPERTIES OF Gd³⁺ IONS IN SLBP GLASSES

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Glasses of sodium-lead borophosphate(SLBP) containing 1.0 mol% Gd³⁺ ions have prepared. EPR spectra have been studied at different temperatures (93-303 K). The EPR spectrum at room temperature exhibits three prominent features with effective g-values of 5.99, 2.85 and 1.98 and weaker features at g = 3.60 and 4.77. The spectra are similar to the U-spectra familiar in many oxide glasses, indicating very low and disordered site symmetries with a broad distribution of crystal fields. The number of spins (N) participating in resonance for g=5.99 resonance signal has been calculated as a function of Gd content and temperature. It is observed that N increases with Gd content. A linear relationship was established between log N and 1/T and the activation energy was calculated from the graph. The paramagnetic susceptibility (χ) was calculated from the EPR data at various temperatures and the Curie constant (C) and paramagnetic Curie temperature (θ_p) have been evaluated from the 1/ versus T graph and shows Curie–Weiss type of magnetic behavior[1]. The photoluminescence spectra of the prepared glasses have also been studied. The excitation spectra exhibits a broad peak at 278nm, which is due to the transition from the ground state $^8S_{7/2}$ to the excited state 6I_j . The emission spectrum exhibits a strong peak at 313 nm which is attributed to the transition from the excited state 6P_j to the ground state $^8S_{7/2}$ [2].The study of FTIR absorption spectrum reveals the presence of BO₃,BO₄, and PO₄ structural units. The detailed results are discussed.

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**OPTICAL AND PHOTOLUMINESCENCE DYNAMICS OF
Er³⁺: B₂O₃+Li₂F GLASSES**

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Trivalent lanthanide ions doped glasses achieved major importance due to their feasible utilization in the field of photonics as sensors, lasers, fiber optic communication and display devices. Among various host matrices the borate glasses are being investigated so extensively because of their novel properties such as high transparency, large refractive index and good rare earth ion solubility. It is well known that boric acid (B₂O₃) is one of the best glass former among the known good glass formers. The Er³⁺ emission at 1.53μm has drawn attention for use in communication applications. Trivalent erbium (Er³⁺) doped lithium fluoride glasses with molar composition of (50-x/2)B₂O₃+(50-x/2)LiF+xEr₂O₃, where x = 0.05, 0.1, 0.5, 1.0 and 2.0 mol % referred as B50LfEr0.05, B50LfEr0.1, B50LfEr0.5, B50LfEr1.0 and B50LfEr2.0 respectively, have been prepared by a melt, sudden quenching and casting technique. By applying Judd-Ofelt (JO) theory, JO parameters ($\Omega_2 = 7.38 \times 10^{-20} \text{cm}^2$, $\Omega_4 = 2.64 \times 10^{-20} \text{cm}^2$ and $\Omega_6 = 4.88 \times 10^{-20} \text{cm}^2$) were evaluated from the absorption spectra of Er³⁺-doped B50Lf glasses. The emission intensity increases from 0.01 mol% to 1.0 mol% and then decreases due to concentration quenching. With the help of JO parameters the radiative properties such as transition probability ($A_r = 1.0 \text{ s}^{-1}$), branching ratios ($\beta_r = 1.0$), radiative lifetimes ($\tau_r = 2.607 \text{ms}$), stimulated emission cross-section ($\sigma_{se} = 1.2461 \times 10^{-20} \text{cm}^2$), gain band width ($\beta_r \times \sigma_{se}$) and optical gain ($\beta_r \times \sigma_{se} = 3.2486 \times 10^{-20} \text{cm}^2$) parameters for the prominent luminescent level of Er³⁺: ⁴I₁₃ → ⁴I_{15/2} at 1.53μm have been evaluated. In general, both radiative and non-radiative emission processes, the lifetime of ⁴I_{13/2} level is strongly influenced. The analysis of the present studies indicates that Er³⁺ ions doped B50Lf glasses may also be suitable for green lasers and optical amplifiers.

EFFECT OF CONCENTRATION ON PHYSICAL, STRUCTURAL AND LUMINESCENCE PROPERTIES OF Sm^{3+} - DOPED LEAD BOROSILICATE GLASSES FOR PHOTONIC APPLICATIONS

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Different concentrations of Sm^{3+} ions (0.1, 0.5, 1.0 and 2.0 mol%) were doped into lead borosilicate (LBS) glasses by the melt-quench method. The prepared glasses were characterized using XRD, FTIR, absorption and luminescence techniques. The amorphous nature of the glass has been confirmed from XRD analysis and functional groups present in the glasses were identified by using FTIR spectrum. From the absorption spectra, the f_{exp} and f_{cal} were evaluated to find the JO intensity parameters ($\Omega = 2, 4$ and 6). The computed JO parameters are further used to calculate certain radiative properties for the excited level of $^4\text{G}_{5/2}$ of Sm^{3+} ion. From the emission spectra, the effective bandwidths ($\Delta\lambda_{\text{eff}}$), stimulated emission cross-sections (σ_{p}), optical gain (OG), gain bandwidth (GBW) and lifetimes (τ) were determined. From the decay analysis, the experimental lifetime (τ_{exp}) decreases with increase in Sm^{3+} ion concentration. From the emission analysis, it can be concluded that the Sm^{3+} doped LBS glasses are suitable for photonic applications.

UPCONVERSION LUMINESCENCE STUDIES OF Tm³⁺/Yb³⁺-DOPED OXYFLUOROSILICATE GLASSES

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Oxyfluorosilicate glasses with the composition (in mol%) of 41 SiO₂ + 10 Al₂O₃ + (25.9-x) LiF + 23 SrF₂ + 0.1 Tm₂O₃ + xYb₂O₃ (x=0.1, 0.5, 1.0 and 2.0, denoted as SALfSfTm0.1Ybx) have been synthesized and characterized their upconversion (UC) properties. The UC luminescence has been observed in Tm³⁺/Yb³⁺ co-doped glasses under 975 nm laser excitation in the wavelength range of 325-700 nm. Four emission bands are observed at around 362, 450, 474 and 650 nm, which correspond to the ¹D₂ → ³H₆, ¹D₂ → ³F₄, ¹G₄ → ³H₆ and ¹G₄ → ³H₄ transitions of Tm³⁺ ion, respectively. Among these four emission bands, it is observed that the red emission at 650 nm is relatively weaker than the blue one at 474 nm. The increase in UC luminescence intensity up to 1.0 mol% of Yb³⁺ ions can be explained as due to increase in the efficiency of energy transfer processes from Yb³⁺ to Tm³⁺ ions. The decrease in UC luminescence intensity at higher concentrations of Yb³⁺ ions is caused by concentration quenching through energy migration among the Yb³⁺ ions and then transfer to traps[1,2]. The results reveal that the co-doped glasses are promising for near-infrared to visible upconversion lasers.

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OPTICAL SPECTROSCOPY OF Sm³⁺ -DOPED FLUOROPHOSPHATE GLASSES FOR PHOTONIC DEVICE APPLICATIONS

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The present work reports the optical spectroscopy of multichannel emission transitions of Sm³⁺-doped alkali and alkaline mixed fluorophosphate glasses with molar composition of 45 P₂O₅ + 15K₂O + 10 Al₂O₃ + 19BaF₂ + 10NaF₂ + 1Sm₂O₃ (PKABfNfSm1.0). These glasses have been prepared by conventional melt quenching technique and characterized through absorption, emission and decay rate analysis. Absorption spectrum was analysed by Judd-Ofelt (JO) theory and the three phenomenological JO intensity parameters (Ω_2, Ω_4 and Ω_6) are calculated which are in turn utilized to evaluate various radiative parameters for different excited states of Sm³⁺ ion [1,2]. Stimulated emission cross-sections ($\sigma_{e(\lambda)}$) was determined for visible ⁴G_{5/2} - ⁶H_J (J = 5/2, 7/2, 9/2 and 11/2) and NIR ⁴G_{5/2} - ⁶F_J (J = 3/2, 5/2, 7/2 and 9/2) emission transitions. The obtained values for the ⁴G_{5/2} - ⁶H_{7/2} and ⁶H_{9/2} transitions are found to be higher when compared to the other transitions. The decay time has been measured under the excitation of 405 nm by monitoring both the visible (599 nm) and NIR (958 nm) emissions of Sm³⁺ ions and lifetimes were found to be 1.746 and 1.762 ms, respectively. Quantum efficiency (η) of the glass is found to be 83%, indicating that the prepared glasses have intense emission. The CIE co-ordinates (x=0.601 and y=0.372) of the overall emissions observed in the PKABfNfSm1.0 glass fallen to be reddish-orange region. The obtained results indicate that they are useful for photonic device applications.

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SPECTROSCOPIC PROPERTIES OF Nd³⁺ DOPED BISMUTH BORATE GLASSES FOR PHOTONIC APPLICATIONS

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Nd³⁺ doped bismuth borate glasses (BBZPA) were prepared with a chemical composition of (65-x) B₂O₃-10Pb₃O₄-5Bi₂O₃-10ZnO-10AlF₃-xNd₂O₃ (where x=0.0, 0.1, 0.5, 1.0, 2.0 and 3.0 mol %) by the conventional melt quenching method. The prepared glasses were studied to determine their structural, absorption, emission and decay properties. From the X-ray diffraction spectrum, amorphous nature of the prepared glass has been confirmed. The oscillator strengths (f) measured from the absorption spectra were used to calculate the Judd-Ofelt (J-O) intensity parameters (Ω_2, Ω_4 and Ω_6). The evaluated J-O parameters have been used to determine the various radiative parameters such as transition probabilities (A_R), total transition probability rate (A_T), radiative lifetimes (τ_R) branching ratios (β_R) and stimulated emission cross-sections (σ_{sp}) for the excited ⁴F_{3/2} level of Nd³⁺ ions. The emission spectra revealed three emission peaks, identified at 901, 1059 and 1331 nm and are assigned to ⁴F_{3/2} → ⁴I_{9/2}, ⁴F_{3/2} → ⁴I_{11/2} and ⁴F_{3/2} → ⁴I_{13/2} transitions, respectively. It is observed that, the transition ⁴F_{3/2} → ⁴I_{11/2} at 1059 nm is more intense than the other two transitions which is used for the laser emission. The intensity of the ⁴F_{3/2} → ⁴I_{11/2} transition increases with increase of Nd³⁺ ions concentration from 0.1 to 1.0 mol% and thereafter decreases at higher concentrations due to the quenching effect. The fluorescence decay curves for all the Nd³⁺ doped BBZPA glasses exhibits single exponential decay constant because of negligible effect of ligands on Nd³⁺ ions. The above results suggest that Nd³⁺ doped BBZPA glass system could be suitable for photonic applications.

**DETERMINATION OF RARE EARTH ELEMENTS IN
URANIUM RICH ROCK SAMPLES BY
INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS**

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INAA is considered as one of the best analytical techniques especially for the determination of Rare Earth elements and trace elements in the rock samples of varying matrix. In the INAA laboratory, samples from diverse geological environment with different concentrations of uranium are subjected to REE analysis. Determination of REEs such as La, Ce, Nd, Sm and Lu directly by INAA in the uranium rich rock samples gives erroneous data due to the spectral interference from fission products of uranium and gamma ray of activation product of uranium (^{239}Np). In order to obtain the accurate values of REEs in the rock samples containing high concentration of uranium (>200 ppm), REEs were separated adopting the procedure of solid phase micro extraction using Activated Charcoal before irradiation. Samples and certified reference standards after irradiation in DHRUVA reactor, at BARC, Mumbai were analysed using a p-type HPGe coaxial semiconductor detector coupled to DSP based Multi-Channel-Analyser. For validation of the data the same samples were analysed by ICP-OES. Concentrations of uranium range from 400 ppm to 4.5 % in rock samples were taken up for the study. La, Ce, Nd, Sm, Eu, Tb, Yb and Lu obtained by INAA before and after the separation of uranium in the rock samples. Before separation of uranium, La, Nd, Sm and Lu could not be determined and erroneous values of Ce were obtained in the samples containing uranium (>0.2%) due to the interference of the fission products and the gamma energy peak of ^{239}Np . Concentration of these elements can be determined by INAA after separation of uranium by solid phase micro extraction method. These samples were analysed by ICP-OES for the validation of the data and observed that the results are in good agreement except in the case of one sample with the concentration of uranium 4.5 %. This is due to incomplete separation of uranium since the concentration of uranium in this sample is 4.5 %. The uncertainties in the determination of all the elements are ± 1 to 5 % except for Nd which is ± 10 % due to its lower sensitivity in coaxial HPGe detector for INAA.

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**DEPENDENCE OF THE POWER ON THE UPCONVERSION OF BiNbO₄
CERAMIC DOPED WITH Er³⁺ AND Yb³⁺ IONS**

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The optical properties and energy upconversion in Er³⁺/Yb³⁺ co-doped BiNbO₄ matrix were investigated in this work. The solid-state reaction method have been used to prepare BiNbO₄ matrix. X-ray diffraction confirms the composition and its doping. The grain distribution and the behaviour of doping with Er³⁺ and Yb³⁺ on the sample surface were obtained by scanning electron microscope. Raman spectral characterization shows the behaviour of the vibrational modes of the samples. Upconversion emissions in the visible region at 484.5, 522, 541.5 and 670.5 nm in the matrices of BiNbO₄:Er,Yb and BiNbO₄:Er were observed and analyzed as a function of 980 nm laser excitation power and rare-earth doping concentration. The results show that the BiNbO₄ is a good host material for upconversion phosphors.

COMPARATIVE STUDY OF LUMINESCENCE AND OPTICAL PROPERTIES OF Sm^{3+} DOPED GLASSES WITH DIFFERENT HOSTS

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The spectroscopic properties of lithium-gadolinium-borate and zinc-barium-borate glasses doped with samarium ions had been published in previous studies where metaphorical results were investigated. At present, the samarium-doped lithium-gadolinium-borate glasses (LGBO:60Li₂O:10Gd₂O₃:(30-x)B₂O₃:xSm₂O₃, where x = 0.05, 0.10, 0.50, 1.00 and 1.50 mol%) and zinc-barium-borate glasses (ZBaB:(60-x)B₂O₃:30BaO:10ZnO:xSm₂O₃, where x= 0.0, 0.5, 1.0, 1.5, 2.0 and 2.5 mol%) have been prepared by the melt quenching method. In both the glasses, the absorption spectra are found to be similar in transitions from the ground state ⁶H_{5/2} to the excited states with minor changes due to modifier effect. The emission spectra was measured with the excitation of 404 nm and the spectra has intensity peaks at 562 (⁶H_{5/2}), 600 (⁶H_{7/2}), 646(⁶H_{9/2}), and 707 (⁶H_{11/2}) nm, respectively. The concentration quenching effect (CQE) was found at 1.0 mol % for LGBO: Sm³⁺ glass, but not for ZBaB: Sm³⁺.

PHYSICAL AND OPTICAL PROPERTIES OF Sm³⁺ IONS IN B₂O₃-Al₂O₃-CaO-Na₂O

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In the present work, the physical and optical properties of borate glasses doped with Sm₂O₃ concentration of 0.0 to 2.0 mol% have been investigated. The glass samples with chemical composition of (40-x)B₂O₃ : 20Al₂O₃ : 20CaO : 20Na₂O : xSm₂O₃ (where x = 0.00, 0.05, 0.10, 0.50, 1.00, and 2.00% by mol) were prepared by the normal melt-quench technique. The results show that the density and molar volume increased with increasing of Sm₂O₃ content. The absorption spectra in the range of 500-2200 nm have nine bands at 945, 1079, 1228, 1375, 1475, 1522, 1588, 1641 and 1959 nm. The luminescence spectra of the Sm³⁺ doped glasses exhibited three intensity peaks at 565 (⁴G_{5/2}→⁶H_{5/2}), 600 (⁴G_{5/2}→⁶H_{7/2}), 645 (⁴G_{5/2}→⁶H_{9/2}) along with a feeble peak at 706 (⁴G_{5/2}→⁶H_{11/2}) nm when excited by a 405 nm source. The quantified physical and optical properties indicate that these glasses are found to be potential applications for the development of visible lasers.

LUMINESCENCE PROPERTIES OF Nd³⁺-DOPED BARIUM PHOSPHATE GLASSES FOR NIR LASER APPLICATIONS

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Barium phosphate glasses doped with varying Nd³⁺ ions concentration were prepared by melt quenching method and characterized through absorption, emission and decay rate measurements. Judd-Ofelt (JO) intensity parameters were evaluated from the absorption spectrum of 1.0 mol % Nd₂O₃ -doped glass. Near infrared (NIR) luminescence of Nd³⁺ ions is obtained for all the glasses upon 808 nm diode laser excitation. The spectra exhibit a strong emission at 1.06 μm corresponding to the ⁴F_{3/2} → ⁴I_{11/2} transition. Obtained JO parameters and refractive index are used to calculate the radiative properties, such as effective bandwidth (Δ_{eff}), emission cross-section (σ_e), radiative transition probabilities (A_R) and branching ratio (β_R) for the ⁴F_{3/2} → ⁴I_{J/2} (where J = 9, 11 and 13) transitions of Nd³⁺ ions [1,2]. The decay rates for the ⁴F_{3/2} level of Nd³⁺ ions are showing single exponential nature for all concentrations and the lifetime is found to decrease from 296 μs to 74 μs when concentration of Nd³⁺ increased from 0.01 mol % to 4.0 mol %. Among three emission transitions, ⁴F_{3/2} → ⁴I_{11/2} shows higher value of stimulated emission cross-section and branching ratio indicates that the present glasses could be useful for the development of NIR laser at around 1.06 μm.

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**OPTICAL AND INFRARED LUMINESCENCE PROPERTIES OF
NEODYMIUM DOPED MAGNESIUM BASED PHOSPHATE GLASSES**

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Magnesium phosphate glasses doped with various concentrations of neodymium ions with the composition (PMgNd: P₂O₅-MgO-xNd₂O₃) were prepared by conventional melt quenching technique. Absorption, near infrared (NIR) luminescence and decay properties of these glasses have been investigated. Judd-Ofelt analysis was carried out and the intensity parameters ($\Omega_\lambda = 2, 4, 6$), spontaneous radiative probability and stimulated emission cross-section were estimated using absorption spectrum. The NIR luminescence spectra were measured by 808 nm excitation in which the emission intensity is found to be high at 1054 nm which corresponds to the ${}^4F_{3/2} \rightarrow {}^4F_{11/2}$ transition. The absorption and emission spectra are similar to the results reported [1,2]. The stimulated emission cross-section, effective band width and branching ratios were found to be $3.26 \times 10^{-20} \text{ cm}^2$, 25 nm, 0.51, respectively, for ${}^4F_{3/2} \rightarrow {}^4F_{11/2}$ transition. The measured decay curves for ${}^4F_{3/2}$ fluorescent level exhibit single exponential nature with shortening of lifetime from 337 to 56 μs with increase in Nd³⁺ concentration. Hence, the results suggest that PMgNd glasses could be used as an efficient infrared laser source around 1.05 μm region.

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OPTICAL ANALYSIS OF Er³⁺ AND Nd³⁺ IONS DOPED CADMIUM LEAD BORO ALUMINUM FLUORIDE GLASSES

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Er³⁺ and Nd³⁺ ions doped CdPbBAIF glasses in the chemical compositions of (50-x) H₃BO₃-10PbO - 30CdO -10AlF₃: xEr₂O₃ where x= 0.25, 0.5, 1.0, 1.5, 2.0 mol% and (50-y) H₃BO₃-10PbO - 30CdO -10AlF₃: y Nd₂O₃ where y= 0.5, 1.0, 1.5, 2.0 mol% were prepared using the conventional melt quenching technique. Optical properties of the prepared glasses were carried out by XRD, FTIR, optical absorption analysis, and photoluminescence (PL) analysis. An NIR emission at 1539 nm corresponding to the ⁴I_{13/2} - ⁴I_{15/2} transition was observed for 0.5 mol% of Er³⁺ doped CdPbBAIF glasses. The emission spectra of the Nd³⁺ ions doped CdPbBAIF glasses have shown strong emission at 1070 nm (⁴F_{3/2} - ⁴I_{11/2}) with an excitation wavelength λ_{exc} = 514.5 nm. The luminescence quenching behavior of the prepared glasses as a function of the doping molar concentration of Er³⁺ and Nd³⁺ ions was analyzed. Energy level diagram representing the emission lines and decay curves of the prominent emission transitions of the glasses have been presented.

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**INFLUENCE OF Al_2O_3 ON THERMOLUMINESCENCE EFFICIENCY OF Tb^{3+}
DOPED BOROPHOSPHATE GLASS SYSTEM-A POSSIBLE MATERIAL FOR
RADIATION DOSIMETRY**

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Aluminoborophosphate glasses doped with Tb^{3+} ions were prepared and studied their thermoluminescence (TL) characteristics after irradiating them with different doses of γ -rays (in the range 0–8.0 kGy) as a function of Al_2O_3 content. The TL glow curve of the samples exhibited a dosimetric peak at about 210°C and its intensity is found to increase with the increase of irradiation dose. TL output vs γ -ray dose is found to be near linear up to about 4.0 kGy. With increase in Al_2O_3 content up to 3.0 mol% an increase in the TL output is observed and beyond this concentration a decrement in the TL output is detected. The TL emission mechanisms and variation of TL output with the concentration of Al_2O_3 are discussed in terms of structural defects induced due to γ -rays. Quantitatively, the addition of Al_2O_3 beyond 3.0 mol% caused to oxidize Tb^{3+} ions into Tb^{4+} ions; such ions were predicted to act as TL killers and are found to be responsible for the observed decrement in TL output. Overall, these glasses are suggested to be potential candidates for dosimetry applications in the dose range up to 4.0 kGy.

**OPTICALLY ACTIVATED Ce³⁺-Tb³⁺ IONS CO-DOPED
Ga₂O₃-BaO-B₂O₃-SiO₂ GLASSES**

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The main goal of the present work is to study characteristics features of Ce³⁺-Tb³⁺ ions and the energy transfer from Ce³⁺ to Tb³⁺ in Ga₂O₃-BaO-B₂O₃-SiO₂ glasses. Within the host matrix the gradual increase of Ce³⁺ ion by reducing the B₂O₃ content, such variations leads to the structural modifications and the variation of local field environment in the glass network and influence the various luminescence transitions. The prepared glasses were investigated by XRD, EDS, FTIR, DTA, optical absorption and photoluminescence spectra. From the physical parameters, the density of the studied glasses increases with the addition of ce³⁺-Tb³⁺ ions concentration, which modify the borate glass network. The result of IR spectral studies indicates the structural changes in the glass network by the various concentrations of the rare earth ions. The DTA investigation reveals about the thermal stability of the glasses. From the optical absorption spectra of the glasses, the optical band gap was calculated for direct and indirect transitions. The optical basicity of the glasses increases with increasing the polarizability of the glass matrix. The analysis of the emission spectra indicates the transition of ⁵D₄ - ⁷F₅ (543 nm) has strong green emission and decay curves indicate the energy transfer from Ce³⁺ to Tb³⁺ ions in co-doped glasses. From the chromaticity diagram it is observed that the shift of CIE coordination towards the green region.

INFLUENCE OF ENERGY TRANSFER FROM BISMUTH IONS ON GREEN EMISSION OF Ho^{3+} IONS IN PbO-SiO_2 GLASSES

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In this study, we have synthesized lead silicate glasses doped with fixed concentrations of Ho_2O_3 and mixed with different concentrations of bismuth oxide and investigated the influence of bismuth ions on $^5\text{S}_2+^5\text{F}_4 \rightarrow ^5\text{I}_8$ (green) emission of Ho^{3+} ions. The PL spectra recorded at an excitation wavelength of 450 nm exhibited two prominent emissions of Ho^{3+} ions viz., green and red emissions due to the $^5\text{S}_2+^5\text{F}_4 \rightarrow ^5\text{I}_8$ and $^5\text{F}_5 \rightarrow ^5\text{I}_8$ transitions, respectively. Additionally, we have also observed NIR emission at 2.0 μm due to $^5\text{I}_7 \rightarrow ^5\text{I}_8$ transition. The analysis of the PL spectra indicated that the glass mixed with 5.0 mol% of Bi_2O_3 exhibited the highest intensity of green emission (nearly three times when compared with that of Bi_2O_3 free glass). The energy transfer from Bi^{3+} to Ho^{3+} ions is found to be the main reason for such enhancement. The decrement observed in the PL output of the glasses containing more than 5.0 mol% of Bi_2O_3 is ascribed to the reason that in these glasses the Bi^{3+} ions prevalingly occupied network forming positions and are predicted to enhance the phonon losses. The results were further explained quantitatively with the help of IR and Raman spectral studies.

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INFLUENCE OF OXYGEN DEFECT CENTERS OF HfO₂ ON GREEN EMISSION OF Er³⁺ IONS IN LEAD ANTIMONATE GLASS SYSTEM

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In this study we have prepared Lead antimonate glasses doped with 1.0 mol% of Er₂O₃ and co-doped with HfO₂ and studied their luminescence characteristics in the visible region. The optical absorption spectra of PbO Sb₂O₃ HfO₂: Er³⁺ glasses have exhibited the absorption bands due to the following transitions of Er³⁺ ions: ⁴I_{15/2} → ⁴G_{11/2}, ⁴G_{9/2}, ⁴F_{3/2}, ⁴F_{5/2}, ⁴F_{7/2}, ²H_{11/2}, ⁴S_{3/2}, ⁴F_{9/2}, ⁴I_{9/2}, ⁴I_{11/2} and ⁴I_{13/2}. The emission spectra of these glasses excited at 380 nm exhibited emission bands corresponding to ²H_{11/2} → ⁴I_{15/2}, ⁴S_{3/2} → ⁴I_{15/2}, ⁴F_{9/2} → ⁴I_{15/2} and ⁴I_{13/2} → ⁴I_{15/2} transitions. The emission spectrum of HfO₂ mixed glasses (without Er³⁺ ions) obtained by exciting at the same wavelength exhibited distinct emission bands in the region 400-550 nm. These bands are predicted to be the emissions from oxygen deficient centers in this glass. When HfO₂ and Er³⁺ ions are present together the intensity of green and orange emissions of Er³⁺ ions is observed to be much higher when compared with that of HfO₂ free glass. In the regions of green and orange emissions (²H_{11/2}, ⁴S_{3/2} → ⁴I_{15/2}) of Er³⁺ ions, an additional emission due to oxygen defect centers in HfO₂ mixed glasses when excited at the same wavelength is detected. The cooperative addition of these two emissions is found to intensify the green and orange emissions and hence the intensity of emission bands due to ²H_{11/2} → ⁴I_{15/2}, ⁴S_{3/2} → ⁴I_{15/2} transitions is observed to be enhanced to a large extent. Various radiative parameters *viz.*, transition probability A, branching ratio S and the radiative lifetime τ_{rad} were evaluated using J-O theory. The lifetime of ²H_{11/2} of Er³⁺ ions is evaluated from luminescence decay curves with and without HfO₂. The results were further analyzed using IR spectra and the specific reasons for enhanced PL output were identified and reported.

STRUCTURAL AND OPTICAL TRANSITIONS IN DY³⁺-DOPED BOROPHOSPHATE GLASSES FOR WHITE LED'S APPLICATION

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The Dy³⁺-doped (45-x)B₂O₃+20NH₄H₂PO₄+10Al₂O₃+10PbO+15MgCO₃+xDy₂O₃ (x=0.0, 0.1) borophosphate glasses were synthesized using melt quenching technique [1] and characterized through XRD, FTIR, absorption and emission measurements. The amorphous nature of the glasses have been confirmed through XRD pattern. The FTIR spectra reveal various functional groups and are identified [2]. From absorption spectra, the oscillator strength and bonding parameter were calculated and the ionic/covalent nature of the prepared glasses were identified from their negative or positive sign of the bonding parameter (). The luminescence spectra display two characteristic bands at ⁴F_{9/2} - ⁶H_{15/2} (Blue) and ⁴F_{9/2} - ⁶H_{13/2} (Yellow) transitions of Dy³⁺ ions [3]. The possibility of white light generation have been calculated by the yellow-to-blue emission intensity ratios and CIE chromaticity coordinates as a function of Dy³⁺ concentration for white LED'S applications.

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SYNTHESIS AND OPTICAL STUDIES ON CONCENTRATION DEPENDENT Dy³⁺ DOPED FLUORO-BOROPHOSPHATE GLASSES

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A new series of Dy³⁺ doped fluoro-borophosphate glasses with the chemical composition (50-x)B₂O₃+10P₂O₅+10ZnO+15Li₂CO₃+15NaF+xDy₂O₃ (where x = 0.1, 0.3 and 1.0) were prepared following conventional melt quenching technique and characterized using XRD, FTIR, optical absorption and luminescence measurements. From XRD pattern of the prepared glasses confirms the amorphous in nature. The fundamental stretching vibrations of various borates (BO₃, BO₄) were identified through the FTIR analysis. From the UV-Vis-NIR absorption spectra, the oscillator strength and bonding parameter were calculated and the ionic bond nature of the prepared glasses were identify from their negative sign of value. The Absorption and luminescence spectra data have been used to calculate the Judd-Ofelt parameters, oscillator strength, transition probability and branching ratio. The luminescence spectra exhibit two visible bands ⁴F_{9/2} ⁶H_{15/2} (Blue) and ⁴F_{9/2} ⁶H_{13/2} (Yellow) respectively. The radiative properties such as peak wavelength and effective band width for the ⁴F_{9/2} ⁶H_{15/2} and ⁴F_{9/2} ⁶H_{13/2} emission transition were calculated. The yellow to blue (Y/B) ratios and color coordinates have been calculated from the luminescence spectra and the utility of the present glasses for white LED applications.

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SPECTROSCOPIC BEHAVIOR OF DY^{3+} IONS IN A VARIETY OF LITHIUM AND SODIUM BOROPHOSPHATE GLASSES

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Synthesis the alkali varying Dy^{3+} doped borophosphate glasses with the compositions of $34H_3BO_3+20P_2O_5+10Al_2O_3+10PbO+25x_2CO_3+1Dy_2O_3$ (where $x=Li, Na$) by conventional melt quenching technique. The structural properties of the prepared glasses were studied through XRD, FTIR and the spectroscopic behaviors characterized through absorption and emission spectra. XRD spectral analysis conform the amorphous nature of the prepared glasses and fundamental units of the stretching vibration and bending vibration of the functional group were examined through FTIR. The ionic natures of the metal-ligand bond in the prepared glasses were evaluated by the bonding parameters (ν and ν_{max}) from absorption spectra. The J-O parameter, the theoretical and experimental oscillator strength were determined and reported. The luminescence measurement used to determine the radiative properties like the effective bandwidth (λ_{eff} , nm), transition probability (A), calculated, experimental branching ratios (β_R) and stimulated emission cross-section ($\sigma_p^E \times 10^{-22} \text{ cm}^2$) for the $^4F_{9/2} \rightarrow ^6H_{15/2}$, $^4F_{9/2} \rightarrow ^6H_{13/2}$ transitions of the Dy^{3+} doped borophosphate glasses and compared with the similar studies. CIE (1931) chromaticity diagram for various pumping wavelengths of emission spectra has been plotted and found that the prepared glasses suitable for WLED applications.

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STRUCTURAL AND OPTICAL PROPERTIES OF THULIUM DOPED TELLURITE GLASSES

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Thulium doped tellurite glasses ($\text{TeO}_2\text{-ZnO-BaCO}_3\text{-BaF}_2\text{-Tm}_2\text{O}_3$) with thulim concentration varying upto 2 mol% were synthesized using melt-quenching technique. Basic characterisations were carried out on these samples to confirm the glassy nature and understand their other properties. Physical properties like density and molar volume were found to increase with thulium addition. Differential Scanning Calorimetry was used to elucidate the thermal stability of these glasses. Presence of hydroxyl impurities even with the addition of barium fluoride was identified through FTIR spectra. Raman Spectra, used to understand the structure of these glasses showed three distinct bands at 768 cm^{-1} , 681 cm^{-1} and 453 cm^{-1} which varies with dopant addition indicating the structural network modifications occurring in these doped systems. Photoluminescence spectra reveal distinct emission at 1856 nm and 1464 nm corresponding to the ${}^3\text{F}_4$ ${}^3\text{H}_6$ & ${}^3\text{H}_4$ ${}^3\text{F}_6$ transition of thulium respectively. Observed properties of these glasses show that they can be utilised as optical fiber materials for transmission in the infrared region.

SPECTROSCOPIC ANALYSIS OF Sm^{3+} IONS DOPED BOROTELLURITE GLASSES FOR REDDISH-ORANGE LASER APPLICATIONS

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The spectroscopic behavior of Sm^{3+} ions in $(40-x)\text{B}_2\text{O}_3+30\text{TeO}_2+20\text{BaO}+10\text{SrO}+x\text{Er}_2\text{O}_3$ ($x=0.1, 0.25, 0.5, 1, \text{ and } 3$ in wt%) borotellurite glasses have been studied to understand the effect of Sm^{3+} ions concentration on the local symmetry around Sm^{3+} ions to analysis the luminescence and excited dynamics of Sm^{3+} ions. The absorption measurements have been used to calculate the bonding parameter values and experimental oscillator strengths for each observed transitions. Judd-Ofelt (JO) theory has been implemented to get information about the local structure around Sm^{3+} ions in the chosen matrix using the experimental oscillator strength values obtained from the intensities of the absorption band transitions. The higher Ω_4 parameter values reveals that the present glasses possess higher rigidity around the Sm^{3+} ions and less Ω_2 values implies the less covalent characteristic nature and higher symmetry of the local field environment of the Sm^{3+} ions in the prepared glasses. Further, Ω_2 intensity parameter values are found to decrease with the increase in Sm^{3+} ions concentration, which indicate the more symmetry around the Sm^{3+} ions. Luminescence spectra of the Sm^{3+} ions doped present glasses were recorded by monitoring an excitation at 405 nm which exhibits $^4\text{G}_{5/2} \rightarrow ^6\text{H}_J$ ($J=5/2, 7/2, 9/2$ and $11/2$) intra-4f transitions through an efficient energy transfer process. The greater the intensity of the $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{9/2}$ electric dipole allowed transition, more the asymmetry nature around the Sm^{3+} ions and all the prepared glasses exhibit higher symmetry, since the intensity of $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{9/2}$ transition is found to be lower than the $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{7/2}$ transition. The obtained lower magnitude of the R/O asymmetry ratio emphasis the higher symmetry of the ligand field around Sm^{3+} ions thus suggest the less distorted environment around the Sm^{3+} ions and it is in good accordance with the lower Ω_2 and negative bonding parameter values. The JO parameter values have been used to derive the other radiative parameters such as transition probability (A), stimulated emission cross-section and branching ratios (β_R) for the emission transitions. The transition probability of the $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{7/2}$ transition is found to be higher in magnitude which in turn leads to have higher σ_p^E value for the $^4\text{G}_{5/2} \rightarrow ^6\text{H}_{7/2}$ transition compared to other excited state transitions for all the prepared glasses. The luminescence quenching of Sm^{3+} ions emission were observed beyond 0.5wt% of Sm^{3+} ion concentration. The quenching occurs because of nearest neighboring excited Sm^{3+} ions as a result of non-radiative decay through the energy transfer process between excited and unexcited Sm^{3+} ions via various cross-relaxation channels. Thus concentration-quenching mechanism can be explained by fitting the experimental decay curves to the Inokuti-Hirayama model and the nature of interaction takes place between Sm^{3+} ions for energy transfer through cross-relaxation is found to be dipole-dipole in nature.

THERMAL AND OPTICAL STUDIES OF SAMARIUM DOPED GERMINATE GLASSES FOR FIBER LASER AND AMPLIFIER APPLICATIONS

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Optical fibers based on heavy metal oxide glasses possess good environmental stability and moderate optical loss in comparison with fluorides based optical fibers, which makes them suitable for fiber laser and amplifier applications. Bismuth-germinate glasses are used significantly for applications in non-linear optics, optical switching and second harmonic generation especially because of their high linear and nonlinear refractive indices, high thermal expansion coefficient, low glass transition temperature, and excellent infrared transmission. Present work reports the thermal, structural and optical properties of Sm³⁺-doped germinate glasses. Germinate glasses with the glass composition 40GeO₂ – 20Bi₂O₃ – 20Na₂O₃ – 10Gd₂O₃ – 10BaO – xSm₂O₃ (x = 0.05, 0.1, 0.5, 1.0, 1.5, 2.0, 2.5) were prepared by usual melt quenching method. These glasses have been characterized through XRD, TG-DTA, FTIR, UV-VIS-NIR techniques. Results of these interesting glasses were presented during the conference.

**SPECTROSCOPIC PROPERTIES OF Er³⁺ IONS-INDUCED
ZINCBOROPHOSPHATE GLASSES FOR MID-INFRARED LASER
MATERIALS**

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Erbium doped ZBP glasses belonging to the $40\text{ZnO}+(30-x)\text{B}_2\text{O}_3+30\text{P}_2\text{O}_5+x\text{Er}_2\text{O}_3$ (where $x=0.2$ to 1.0 mol%) were prepared by using conventional melt-quenching technique. In order to understand the structural properties of Er_2O_3 on the prepared glasses, the density and refractive index are calculated and reported. The X-ray diffraction (XRD) analysis confirms the amorphous nature of the prepared glass samples. The FTIR spectra of glasses samples shows, a new absorption band indicating Er-O band vibration with the addition of erbium ions when compared with pure glass. Judd-Ofelt intensity parameters have been calculated from the optical absorption spectra and follows the trend $A_2 > A_4 > A_6$. These parameters are used to calculate radiative properties such as radiative transition probability (A_R), stimulated emission cross-section (σ_e) and branching ratios (β_R). The spectroscopic quality factor A_4/A_6 has been calculated for the (1 mol%)ZBP:Er³⁺ glass and compared with the other glasses, that makes our glasses are suitable for laser operation. The luminescence decay curves exhibit single exponential nature for all the concentrations.

**EFFECT OF ALKALINE EARTH METAL OXIDES ON
SPECTROSCOPIC AND LUMINESCENCE PROPERTIES OF Eu^{3+}
DOPED ZINC BORATE GLASSES FOR ACTIVE PHOTONIC
APPLICATIONS**

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Alkaline earth zinc borate glasses have been prepared and characterized. The effect of alkaline earth metal ions and Eu^{3+} content on the structure of zinc borate glasses was analyzed by the band structure of IR spectra. From the absorption spectra, the bonding and J-O intensity parameters are evaluated, which reveals the covalent nature of Eu-O bonds in the present glass matrix. The J-O parameters and the asymmetry ratio derived from $f-f$ transitions of the Eu^{3+} ion gives information on the local symmetry around the impurity ions. The calculated radiative parameters like radiative lifetime (τ_R) and luminescence intensity branching ratio (β_R) are compared with the measured values for $^5\text{D}_0$ level. The potentiality of present Eu^{3+} doped alkaline earth zinc borate glasses produces bright red luminescence at 612 nm due to $^5\text{D}_0 \rightarrow ^7\text{F}_2$ emission transition in laser host materials and also has significance in the development of emission rich optical systems.