RESEARCH

Detection and enhancement of latent fingerprint by powder method using bio-synthesized spherical-shaped bismuth oxychloride nanoparticles

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ABSTRACT

Green fluorescent nanoparticles Bi0.95Tb3+0.5Li0.3OCl were successfully synthesized through the solution combustion method using Mimosa pudica as a biofuel. The nanoparticles, annealed at 10000°C for three hours, were characterized by X-ray diffraction, revealing a BODY CENTERED CUBIC structure. When excited with a 980 nm diode laser, the phosphor emitted a green color. The energy gap of the

INTRODUCTION

he transfers of energy from host materials to Rare Earth (RE) materials has captured the attention of researchers due to its potential applications in display devices, biological imaging, temperature sensing, lasing, phosphor industries, forensic science, water purification, photochemical reactions, and the production of vitamin D [1-4]. The frequency conversion characteristics of RE materials eliminate background interference caused by low autofluorescence from the background [5-7]. Just like DNA, each human being has a unique ridge pattern on their fingers, making fingermark detection crucial in forensic science for crime investigation. However, fingermarks obtained from crime scenes need to be enlarged and developed using suitable techniques as they are not visible to the naked eye [8-12]. Various visualization techniques, such as cyanoacrylate fuming, ninhydrin spraying, and silver nitrate soaking, have been utilized [13-16]. However, many of these techniques are not effective in enhancing latent ridges on multicolor background surfaces due to background auto-fluorescence that hinders achieving high contrast. The powder dusting technique is a simple and fast method for visualizing and revealing latent fingermarks [17-20]. Recently, luminescent nano powders have been utilized as fingermark detecting agents due to their nano size and superior adhesion efficiency, sparking nanophosphor was estimated to be 3.64eV using diffuse reflectance spectra. High contrast latent fingerprints were developed on porous and semi-porous surfaces by exciting the phosphors with a 980 nm diode laser. These fingerprints were compared with a commercially available green luminescent fingerprint. The synthesized nano phosphor proved to be a viable alternative to traditional luminescent powders for forensic applications, offering a simple, fast, highly sensitive, and eco-friendly method for detecting and enhancing fingermarks related to forensic materials.

Key Words: Bio mediated synthesis; Latent fingerprint; Electron microscopy

significant interest among researchers. The current research utilized Mimosa Pudica (M.P.) extract as a fuel in the synthesis of Bi0.95Tb3+0.5Li0.3OCl using the solution combustion method. This paper presents the use of a green combustion method to create Bi0.95Tb3+0.5Li0.3OCl, employing the low-cost and readily available M.p. plant gel as a fuel. Additionally, the synthesized nanophosphor was characterized, and its potential applications in forensic science were investigated.

Experimental

<u>Synthesis</u>: All the chemicals utilized in the present work was of high purity and was used directly without any additional purification steps. Bismuth nitrate pentahydrate [Bi(NO₃)3.5H₂O], ammonium chloride (NH₄Cl), and concentrated nitric acid were combined in precise proportions and mixed thoroughly in deionized water. The dopants terbium nitrate [Tb(NO₃)3(99.9%)] and Lithium nitrate [LiNO₃], along with the plant extract used as a fuel were dissolved in a solution previously prepared [21]. The solution containing the reactants was poured into a 300 ml cylindrical Pyrex Petri dish. This dish was then placed in a muffle furnace set at a temperature of 400°C \pm 100°C. The reaction mixture experienced thermal dehydration and self-ignition, releasing gases like oxides of nitrogen and carbon. The flame spread throughout the mixture, causing the decomposition of the reactants

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Choudhary

and the subsequent formation of the desired product. The artistic mechanism of formation of Bi0.95Tb3+0.5Li0.3OCl nanoparticle is shown in figure 1.



Figure 1) Mechanism for the formation of Bi0.95Tb3+0.5Li0.3OCl nanoparticles

The final product was then heated to 1000°C for 3 hours to achieve its final form, which was then analyzed using various techniques such as X-ray diffractometer, Scanning Electron Microscope (SEM), and energy dispersive X-ray spectroscopy analysis to gather information on its structure, surface composition, and the origin of its green color.

Forensic applications for fingerprint detection: To verify the solidity and its phase, the nanoparticles were examined using P-XRD (XRD, Shimadzu 7000). Field Emission Scanning Electron Microscopy (FESEM-Supra 55, Carl Zeiss was a 980 nm diode laser.

A variety of flat surfaces were selected for the finger prints experiments. These surfaces ranged from those that were not absorbent and had a single-color background (such as aluminum foil and glass) to those that were multi-colored (like plastic, mobile screens, and the edge of a steel knife). Before applying the finger prints, the donor's hands were thoroughly washed and then gently pressed onto these surfaces using moderate force. The nanophosphor solution was then used to create the latent Finger prints by carefully spreading the powder on the surfaces and any excess powder was cleaned off with a soft brush, following the traditional powder brush technique. The process was carried out in real-time using a Nikon D3100 camera with an AF-S Nikkor 50 mm f/1.8G ED lens and a 380 nm UV light for capturing images of the finger prints.

RESULTS AND DISCUSSION

For structural characterization of both as-synthesized and annealed nanoparticles XRD pattern has been obtained as shown in figure 2.



Figure 2) X-ray Diffraction (XRD) pattern of Bi0.95Tb 3+0.5 Li0.3OCl nanoparticles (a) annealed at 1000° C and (b) as-synthesized and (c) reference peaks of sample matched with JCPDS Card No. 43-1014

The RXD pattern show that peak position was obtained at (211), (222), (400), (411), (332), (440), (622), (444), (662) and (840) corresponding

to various diffraction angles of (20) equal to 20.28°, 28.49°, 33.07°, 35.16°, 42.95°, 47.54°, 56.57°, 59.22°, 77.03° and 79.26°. The figure shows that for annealed nanoparticles, intensity sharpness is very prominent. The obtained XRD has been matched with JCPDS File No. 43-1014, which confirm the absence of any extra peak due to secondary phases and impurity. Debye–Scherrer formula has been used for estimating the particle size [22].

$$d = \frac{0.9\gamma}{\beta cos\theta}$$

The FWHM value β corresponds to the half diffraction angle θ , where λ represents the wavelength of diffracted X-ray for Cu-K α radiation with a value of 0.154 nm. The average crystallite size was determined to be approximately 30 nm for the as-synthesized sample and 45 nm for the annealed sample (1000°C for 3 h). Analysis of the XRD curve reveals a decrease in the sharpness of the diffraction peak for the annealed sample, indicating an increase in particle size.

The absorption features and the source of the green color in the developed nanophosphor semiconductor were investigated using Diffuse Reflectance Spectroscopy (DRS). The DRS spectra of the nanophosphor that was synthesized are depicted in figure 3.



Figure 3) Energy band gaps of Bi0.95Tb3+0.5 Li0.3OCl nanophosphors

The absorption peak at approximately 366 nm was linked to the transition from valence bands to conduction band. In this research, DRS data was utilized to determine the band gap of Bi0.95Tb3+0.5Li0.3OCl nanophosphor. The Kubelka-Munk function F (R^{∞}) and photon energy were calculated based on the relevant equations [23].

$$F(R_{\infty}) = \frac{(1-R_{\infty})^2}{2R_{\infty}}$$
$$hv = \frac{1240}{\lambda}$$

The reflection coefficient of the sample denoted by R^∞ and the absorption wavelength represented by λ were utilized to calculate the energy gap. This was achieved by creating a plot of F(R)2 versus a certain parameter, and then extrapolating the linear fitted region to F(R)2=0, as illustrated in figure 3. The resulting band gap values were recorded in table 1.

TABLE 1

Absolute electronegativity, calculated CB edge, calculated VB position and band gap energy for Bi0.95Tb3+0.5Li0.3OCI nanophosphors at the point of charge

Bi₀.95Tb ³⁺ ₀. 5 Li _x OCI	Absolute Electronegativit y X (eV)	Calculate d CB Position (eV)	Calculate d VB Position (eV)	Band Gap Energy , <i>E</i> g (eV)
0.3	6.34	0.02	3.66	3.64

The observed variations in the energy gap values are closely linked to the level of structural order and disorder present within the lattice structure. These factors can influence the distribution of intermediary energy levels within the band gap [24]. It is important to note that the values of Eg are significantly influenced by the methods of preparation and the experimental conditions employed. These factors can either promote or hinder the formation of structural defects, thereby impacting the degree of structural order-disorder in the material and consequently, the number of intermediary energy levels within the band gap.

The Conduction Band (CB) and Valence Band (VB) edges were employed to examine the impact of dopants on the electronic configuration of the BiOCl host. These values were determined using the following equation

$$E_{cb} = X - E^{c} - \frac{1}{2}E_{g}$$

 $E_{vb} = X - E^{c} + 0.5E_{g}$

The semiconductor's conduction band edge at the point of zero charge is denoted as ECB, while X represents the absolute electronegativity of the semiconductor, which is approximately 3.64 eV [25]. Additionally, EC signifies the energy of free electrons on the hydrogen scale, which is around 4.5 eV, and Eg represents the optical energy band gap. The band gap configurations of phosphors composed of Bi0.95Tb3+0.5Li0.3OCl can be visualized in figure 4.



Figure 4) The band gap structures of Bi0.95Tb3+0.5 Li0.3OCl nanophosphors

The energy levels of the Conduction Band (CB) and Valence Band (VB) for nanoparticles of Bi0.95Tb3+0.5Li0.3OCl have been determined and documented in table 1.

FESEM analysis was carried out on the synthesized sample to detect particle size. Particle size plays an important role for the detection of finger print as irregular shaped or bigger particle sized may not stick to the ridges of finger marks [26]. The average particle size obtained from FESEM image figure 5 is close to 40 nm of uniform spherical shape. The uniformity and small particle size obtained in present work is highly suitable for developing uniform and bright ridge pattern of the finger mark. During image recording with SEM, it was observed that sample get heated due to striking electron leading to sticking of particles with each other and therefore, defocused image was recorded.



Figure 5) FESEM image of Bi0.95Tb3+0.5 Li0.3OCl and particle size distribution obtained using image J software

For optical characterization, 980 nm diode laser excitation has been used to obtain visible region emission spectra under variable pump power, as shown in figures 6 and 7 [27-29]. The intensity of green color was found increasing with increasing pump power density and with help of insitu camera, good intensity green color has been recorded as shown in figure 6.



Figure 6) Visible region emission spectra under variable pump power at 550 nm and green color of emission when excited with laser diode of 980 nm



Figure 7) Weak Emission spectra at 667 nm and 757 nm wavelength The prominent emission was obved at 550 nm and weak emission peak corresponding to 667 nm and 757 nm figure 7. The optical properties of this compound are explored, revealing efficient energy transfer from Tb3+ to Bi3+ ions. Under excitation, Tb3+ ions absorb energy and transfer it to Bi3+, resulting in enhanced emission from Bi3+. The presence of Li+ ions is found to modify the crystal structure, facilitating this energy transfer process. The emission spectrum exhibits characteristic peaks corresponding to Bi3+ and Tb3+ ions, confirming

Choudhary

the energy transfer mechanism. A typical emission peak at 550 nm attributed to 5D4 7F5 transmission of Tb3+ and weak peaks at 667 nm and 757 nm attributed to 5D4 7F3 and 5D4 7F2 transmission respectively. The observed color coordinate of emission spectra was obtained using Go CIE software represented in figure 8.



Figure 8) CIE color coordinates (x,y) for Bi0.95Tb3+0.5 Li0.3OCl nanophosphors in green zone

The CIE color coordinate are estimated to 0.30 and 0.69 with 99% color purity. With increasing pump power, the ratio of green to red color ratio was found increasing (Figure 9).



Figure 9) Variation of color ratio of green and red with pump power. Therefore, the present sample is ideal for finger mark detection as CIE plot shows almost complete absence of other colors particularly for higher pump density.

FP detection using Bi0.95Tb3+0.5 Li0.3OCl nanophosphors: Various surfaces such as glass slides, aluminum foil, and aluminum chocolate wrappers have been utilized in the identification of marked fingerprints of volunteers using Bi0.95Tb3+0.5Li0.3OCl nanophosphors. In order to ensure high contrast and minimal background interference during the development of latent fingerprints, it is crucial that the photoluminescence intensity of the nanoparticles remains high. Achieving optimal sensitivity and selectivity requires the nanoparticles to be of small size and possess suitable adherence properties. Furthermore, a detailed investigation was conducted on the sensitivity, contrast, selectivity, and background interference of the developed fingerprints. Figure 10 displays fingerprints dusted with Bi0.95Tb3+0.5Li0.3OCl nanoparticles, showcasing clear and bright images, aiding in the identification of individual finger marks.



Figure 10) FPs developed by Bi0.95Tb3+0.5LixOCl (x=0.3 mol%) NP photographed under on semi-porous paper with different background colors

Figure 11 (a, b) shows the finger marks developed on the aluminum foil and chocolate wrapping sheet which has bright green images without background interference. Figure11(c, d) shows the finger marks developed with Bi0.95Tb3+0.5 Li0.3OCl nanoparticles on stainless steel knife edge and steel lock under UV light exposure clearly evident for the fine ridge details with better contrast. Further, similar procedure was adopted to analyze the ridge patterns on the mobile phone display screen and PET bottle surfaces figure 11(e, f).



Figure 11) Latent FPs stained by Bi0.95Tb3+0.5 Lix OCl (x=0.3 mol%)nanophosphor on the surface of (A) aluminium foil, (B) chocolate wrapping sheet, (C) steel knife handle, (D) steel lock, (E) mobile screen and (P) pet bottle

Identifying finger marks on semi-porous paper with varying background colors can be a challenging task that is commonly faced. The Bi0.95Tb3+0.5Li0.3OCl nanoparticles created were found to be effective in staining the paper surfaces, allowing for the clear identification of the finger marks with intricate details and a noticeable contrast between the ridges of the finger marks and the background, as illustrated in figure 12.



Figure 12) High-resolution fluorescence images of latent fingerprints stained by Bi0.95Tb3+0.5 LixOCl(x=0.3 mol%) nanophosphor. The images indicate different fingerprint patterns including (**A**) whorl (**B**) arch, and (**C**), loop

CONCLUSION

Bi0.95Tb3+0.5Li0.3OCl nanophosphors in powder form were produced through an environmentally friendly method known as solution combustion synthesis. These nanophosphors exhibited

Choudhary

semiconducting properties, with an energy gap falling within the 3.64 eV range. When excited by a 980 nm laser diode, the synthesized nanophosphor emitted a vibrant green color, as evidenced by the emission spectra on the CIE plot. Featuring a powerful green emission and a fine particle size, this phosphor has successfully revealed legible fingermarks in upconversion mode various surfaces such as aluminium foil, chocolate wrapping sheet, steel knife handle, steel lock, mobile screen and pet bottle. The comparison between fingermarks developed using upconversion phosphor and commercial green luminescence powder has clearly demonstrated the superior quality of the synthesized nano-sized upconversion particles. This study highlights the potential of optimized Bi0.95Tb3+0.5Li0.3OCl nanoparticles as versatile fluorescent labels, particularly for the easy detection of fingerprints on a wide range of materials, thus opening up practical applications in forensic sciences.

REFERENCES

- 1. Blasse G, Grabmaier BC, Blasse G, et al. A general introduction to luminescent materials. Springer Berl Heidelb. 1994.
- Zhang M, Wang J, Ding W, et al. A novel white light-emitting diode (w-LED) fabricated with Sr 6 BP 5 O 20: Eu 2+ phosphor. Appl Phys B. 2007; 86:647-51.
- Pollnau M, Gamelin DR, Lüthi SR, et al. Power dependence of upconversion luminescence in lanthanide and transition-metalion systems. Phys Rev B. 2000; 61(5):3337.
- Feldmann C, Jüstel T, Ronda CR, et al. Inorganic luminescent materials: 100 years of research and application. Adv Funct Mater. 2003;13(7):511-6.
- Rangari VV, Dhoble SJ. Synthesis and photoluminescence studies of Ba (Gd, Ln) B9O16: Eu3+ (Ln= La, Y) phosphors for n-UV LED lighting and display devices. J rare earths. 2015; 33(2):140-7.
- VijaySingh SB, Murali A, Rao JL, et al. Electron paramagnetic resonance and photoluminescence investigation on ultravioletemitting Gadolinium-in-doped CaAl12O19 phosphors. Chim Acta A. 2015;139:1-6.
- Xie HH, Wen Q, Huang H, et al. Synthesis of bright upconversion submicrocrystals for high-contrast imaging of latent-fingerprints with cyanoacrylate fuming. RSC adv. 2015;5(97):79525-31.
- Choi MJ, Smoother T, Martin AA, et al. Fluorescent TiO2 powders prepared using a new perylene diimide dye: applications in latent fingermark detection. Forensic sci int. 2007;173(2-3):154-60.
- Moret S, Bécue A, Champod C. Functionalised silicon oxide nanoparticles for fingermark detection. Forensic sci int. 2016; 259:10-8.
- Wang M, Li M, Yu A, et al. Rare earth fluorescent nanomaterials for enhanced development of latent fingerprints. ACS appl mater interfaces. 2015;7(51):28110-5.
- Saif M, Shebl M, Nabeel AI, et al. Novel non-toxic and red luminescent sensor based on Eu3+: Y2Ti2O7/SiO2 nanopowder for latent fingerprint detection. Sens Actuators B: Chem. 2015; 220:162-70.
- Singh SK, Kumar K, Rai SB. Multifunctional Er 3+-Yb 3+ codoped Gd 2 O 3 nanocrystalline phosphor synthesized through optimized combustion route. Appl Phys B. 2009; 94:165-73.

- Fung TC, Grimwood K, Shimmon R, et al. Investigation of hydrogen cyanide generation from the cyanoacrylate fuming process used for latent fingermark detection. Forensic sci int. 2011; 212(1-3):143-9.
- Tahtouh M, Kalman JR, Reedy BJ. Synthesis and characterization of four alkyl 2-cyanoacrylate monomers and their precursors for use in latent fingerprint detection. J Polym Sci A: Polym Chem. 2011; 49(1):257-77.
- Kendall FG, Rehn BW. Rapid method of super glue[®] fuming application for the development of latent fingerprints. J forensic sci. 1983; 28(3):777-80.
- 16. Sodhi GS, Kaur J. Powder method for detecting latent fingerprints: a review. Forensic sci int. 2001; 120(3):172-6.
- Saif M. Synthesis of down conversion, high luminescent nanophosphor materials based on new developed Ln3+: Y2Zr2O7/SiO2 for latent fingerprint application. J Lumin. 2013; 135:187-95.
- Burt JA, Roland Menzel E. Laser detection of latent fingerprints: difficult surfaces. J Forensic Sci. 1985; 30(2):364-70.
- Bullock E. Honours Thesis, University of Technology, Sydney 98 (2006)
- Darshan GP, Premkumar HB, Nagabhushana H, et al. Effective fingerprint recognition technique using doped yttrium aluminate nano phosphor material. J colloid interface sci. 2016; 464:206-18.
- Tiwari SP, Mahata MK, Kumar K, et al. Enhanced temperature sensing response of upconversion luminescence in ZnO-CaTiO3: Er3+/Yb3+ nano-composite phosphor. Spectrochim Acta A: Mol Biomol Spectrosc. 2015; 150:623-30.
- 22. Choudhary N. Detection and enhancement of latent fingerprint by powder method using bio-synthesized spherical-shaped Bismuth Oxychloride nanoparticles.
- Shivakumara C, Saraf R, Halappa P. White luminescence in Dy3+ doped BiOCl phosphors and their Judd-Ofelt analysis. Dyes Pigments. 2016; 126:154-64.
- 24. Morales AE, Mora ES, Pal U. Use of diffuse reflectance spectroscopy for optical characterization of un-supported nanostructures. Rev mex fis. 2007; 53(5):18-22.
- Ryu J, Park HY, Kim K, et al. Facile synthesis of ultrasmall and hexagonal NaGdF4: Yb3+, Er3+ nanoparticles with magnetic and upconversion imaging properties. J Phys Chem C. 2010; 114(49):21077-82.
- Tiwari SP, Kumar K, Rai VK. Plasmonic enhancement in upconversion emission of La 2 O 3: Er 3+/Yb 3+ phosphor via introducing silver metal nanoparticles. Appl Phys B. 2015; 121:221-8.
- 27. Park W, Lu D, Ahn S. Plasmon enhancement of luminescence upconversion. Chem Soc Rev. 2015; 44(10):2940-62.
- Auzel F. Upconversion and anti-stokes processes with f and d ions in solids. Chem rev. 2004; 104(1):139-74.
- Naik R, Prashantha SC, Nagabhushana H, et al. Mg2SiO4: Tb3+ nanophosphor: auto ignition route and near UV excited photoluminescence properties for WLEDs. J alloys compd. 2014; 617:69-75.