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ORIGINAL RESEARCH

Luminescence properties of Tb^{3+}, Eu^{3+} ions doped silicon dioxide

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Europium (Eu^{3+}) and Terbium (Tb^{3+}) singly doped and double doped with Silicon dioxide (SiO_2) is synthesized successfully by the sol-gel process. A xenon lamp light source with wavelength, λe= 370 nm is used for exciting the sample. The excitation spectra of Eu3+ ion may show applications in the area of UVB, near UVA and green light regions. Magnetic-dipole transition ($^5D_0 \rightarrow {}^7F_1$) is the dominant transition in emission spectra of Eu^{3+} ion. The emission spectra of Tb^{3+} ion reveal four strong emission peaks at 488nm, 545nm, 586nm and 623nm due to the transitions of $^5D_4 \rightarrow {}^7F_6$, $^5D_4 \rightarrow {}^7F_5$, $^5D_4 \rightarrow {}^7F_4$ and $^5D_4 \rightarrow {}^7F_3$ respectively with the transition $^5D_4 \rightarrow {}^7F_5$ (green emission) as the most intense. The excitation of their co-doped spectra also evident that there is transfer of energy from Tb^{3+} ion to Eu^{3+} ion in silicon dioxide.

Keywords : emission, europium, excitation, silicon dioxide, terbium

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Introduction

Rare earth elements have many applications as a result of their unique spectroscopic properties, including long lifetime, numerous narrow and well-separated bands, and significant effective shifts from excitation to emission wavelength.[1-5] They can serve as ideal candidates for donors and acceptors when studying energy transfer (ET). Since energy migration between RE ions improves the emission intensity, lifetimes, quantum efficiencies. Interaction between luminescent ions that involve f-f transitions only with enhanced emission from one species. Energy transfer process has gained much technological importance in the fields of optoelectronics and photonics owing to its technological application point of view. The ET between Tb and Eu have attracted much attention because the emission bands of Tb^{3+} have overlap with some emission bands of Eu^{3+} and Tb^{3+} can act as a donor for the emission of Eu^{3+}. The energy transfer process from Tb^{3+} to Eu^{3+} has been observed in different materials host such as $LaPO_4$,[6] Gd_2O_3,[7] $YTaO_4$,[8] $A_3Tb(PO_4)_3$ (A=Sr, Ba) and $Ca_3Tb_2Z_3O_{12}$ (Z=Si, Ge),[9] $Sr_3B_2O_6$,[10] $Ca_2Ga_2SiO_7$,[11] zinc aluminoborosilicate,[12] lead borate,[13] metaphosphate,[14] aluminosilicate,[15] zinc phosphate glass[16]. However, there is no report on Tb^{3+} ion, Eu^{3+} ion doped pure SiO_2, therefore, we performed such experiment in liquid form. The results of Eu^{3+} ion:SiO_2 excitation confirmed that this is useful for sterilizing, disinfecting, killing bacteria and viruses and solid-state lighting devices. The excitation spectra of Tb:Eu:SiO_2 also revealed that there is transfer of energy from Tb^{3+} ion to Eu^{3+} ion in SiO_2 host.

Materials and Methods

The sol-gel process has been utilized for preparing 0.50 mol % of Tb^{3+} ion and 0.5 mol% Eu^{3+} ion doped with SiO_2. TEOS is used as main source of SiO_2. Terbium (III) nitrate hexahydrate and Europium (III) nitrate hexahydrate were separately first dissolved in 5 ml of methanol and deionized water. After that, 3 ml of SiO_2 is added in dropwise and stirrer for 1 hour. Next, the sample emission and excitation spectra were recorded in F-4700 Fluorescence Spectrometer.

Results and Discussions

The PL excitation and emission spectra of ZnS of 0.5 mol % of Eu^{3+} ion is shown in Figure 1(a) and Figure

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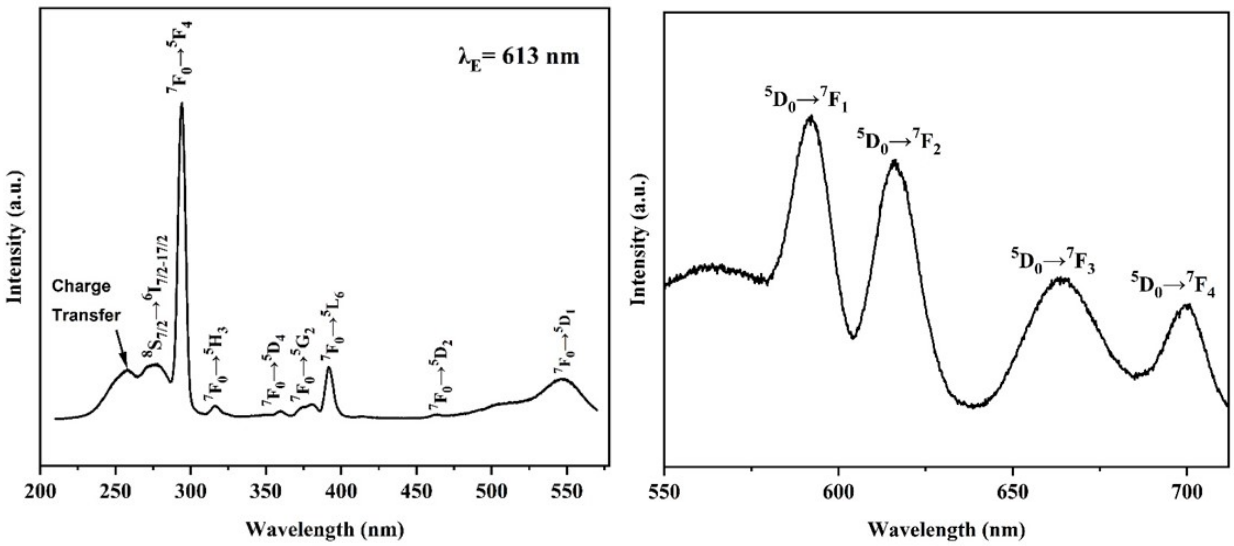

Figure 1. a. Excitation spectra of Eu^{3+} ion (0.5 %) in SiO_2 **b.** Emission spectra of Eu^{3+} ion in SiO_2.

1(b). Figure 1(a) shows the excitation spectrum monitored at 613 nm which shows a sharp peak from 230- 580 nm due to the transition of $^8S_{7/2}\rightarrow{}^6I_{7/2\text{-}17/2}$ (275 nm), $^5F_0\rightarrow{}^5F_4$ (294 nm), $^5F_0\rightarrow{}^5H_3$ (316 nm), $^5F_0\rightarrow{}^5D_4$ (359 nm), $^5F_0\rightarrow{}^5G_2$ (380 nm), $^5F_0\rightarrow{}^5L_6$ (391 nm), $^5F_0\rightarrow{}^5D_2$ (463 nm), $^5F_0\rightarrow{}^5D_1$ (553 nm). Three prominent peaks were observed at 294 nm, 391 nm and 553 nm which indicates that this Eu^{3+} ion:SiO_2 could be excited by the middle UV (UVB), near UV (UVA) light and green light[17] which may find applications sterilizing, disinfecting, killing bacteria and viruses and solid-state lighting devices. Since the position of the $O^{2-}\rightarrow Eu^{3+}$ charge transfer band typically locates in the 200–300 nm range, the broad band from 257 nm is primarily caused by the charge transfer transitions of the ligand O^{2-} atom to Eu^{3+} ions. Figure 1(b) represents the emission spectra under excitation with an UV light source with wavelength 370 nm. The spectra consist of four broad peaks at 578 nm, 593 nm, 613 nm, 653 nm and 703 nm which corresponds to transitions of $^5D_0\rightarrow{}^7F_0$, $^5D_0\rightarrow{}^7F_1$, $^5D_0\rightarrow{}^7F_2$, $^5D_0\rightarrow{}^7F_3$, and $^5D_0\rightarrow{}^7F_4$ respectively. The emission at around 578 nm and 593nm may be assigned to magnetic-dipole allowed transition which obeys the selection rule $\Delta J = 1$[18] which is independent of the local environment of the host lattice. $^5D_0\rightarrow{}^7F_0$ transition is also used for determining the environment in which the Eu^{3+} ions are bonded. The emission bands correspond to $^5D_0\rightarrow{}^7F_2$ (613 nm), $^5D_0\rightarrow{}^7F_3$ (653 nm) and $^5D_0\rightarrow{}^7F_4$ (703 nm) were a transition enabled by an electric dipole, and its intensity is hypersensitive to the variation of the bonding environment of the Eu^{3+} ions. The main causes of

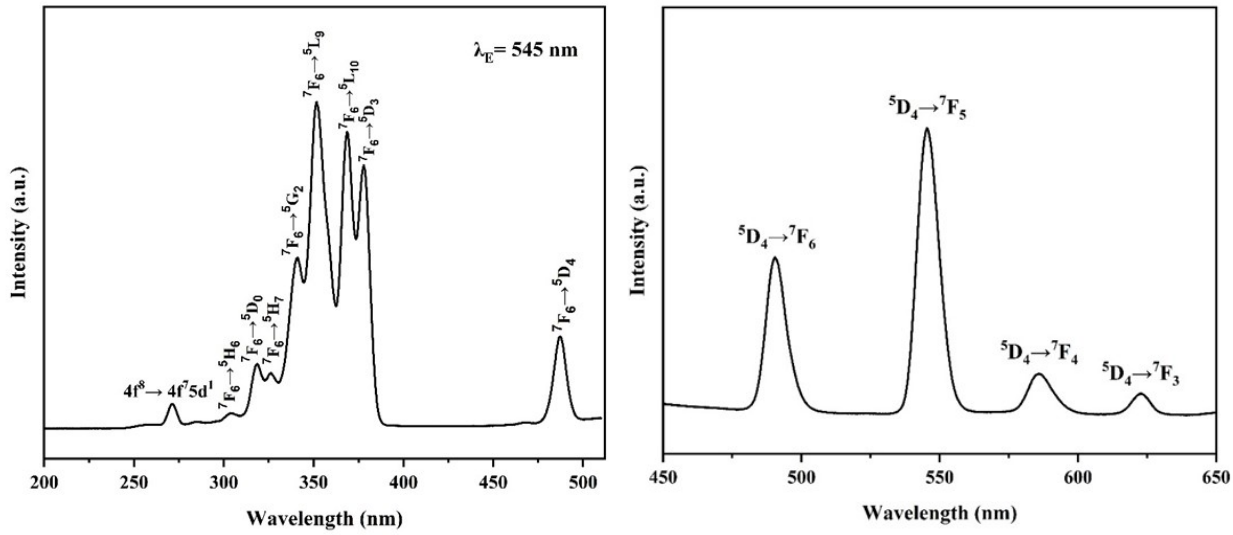

Figure 2. a. Excitation spectra of Tb^{3+} ion in SiO_2 **b.** Emission spectra of Tb^{3+} ion in SiO_2.

electric dipole transitions are the lack of a centre of symmetry and the mixing of $4f^5$ orbitals with the opposite parity orbital.[19] These transitions appear due to charge imbalance between Zn^{2+} and Eu^{3+} ions. Here, the magnetic-dipole transition $^5D_0 \rightarrow {}^7F_1$ (593 nm) is more dominant than the electric-dipole transition $^5D_0 \rightarrow {}^7F_1$ (613 nm), indicating that the most of Eu^{3+} locate at the inversion symmetry center in SiO_2.[20]

Figure 2(a) shows the excitation spectrum of Tb^{3+} ion (0.5%) when monitored at 545 nm which reveals several prominent peaks between 200-500 nm due to the transitions of ground state $^7F_6$ to the different excited states of Tb^{3+} i.e., at 303 nm (5H6), 319 nm ($^5D_0$), 326 nm (5H7), 341 nm ($^5G_2$), 352 nm (5L9), 368 nm ($^5L_{10}$), 378 nm ($^5D_3$) and 486 nm ($^5D_4$) respectively.[17] The sharp band observed at 275 nm is due to the spin allowed ($(4f^8 \rightarrow 4f^7 5d^1)$) and spin forbidden ($4f^8 \rightarrow 4f^7 5d^1$) transitions of Tb^{3+} ion. Figure 2(b) represents the emission spectra Tb^{3+} ion by exciting an UV light source wavelength 370 nm. The spectra reveal four strong emission peaks at 488nm, 545nm, 586nm and 623nm due to the transitions of $^5D_4 \rightarrow {}^7F_6$, $^5D_4 \rightarrow {}^7F_5$, $^5D_4 \rightarrow {}^7F_4$ and $^5D_4 \rightarrow {}^7F_3$ respectively. As expected, the transition from $^5D_4 \rightarrow {}^7F_5$ (green emission) is the most intense and has the highest affinity for both electric-dipole and magnetic-dipole-induced transitions.[21] It is also sensitive to the nature of the surrounding atoms. No emission was observed from higher level of $^5D_3$ due to cross-relaxation effect.

The inset of Figure 3(a) depicts the excitation spectrum of Tb(0.5%) : Eu(0.5%) co-doped by monitoring of Tb^{3+} emission wavelength at 545 nm. The spectrum shows similar spectra observed for Tb^{3+} ion alone, no extra peaks of Eu^{3+} excitation were observed suggesting that there is no transfer of energy from Eu^{3+} to Tb^{3+} ion. The excitation spectrum of Tb (0.5%): Eu (0.5%) co-doped by monitoring of Eu^{3+} emission at 613 nm is shown in Figure 3(a). The spectrum reveals new prominent peaks different from Eu^{3+} (see Figure 1(a)) because of the combination of spin allowed/ spin forbidden ($4f^8 \rightarrow 4f^7 5d1$) of Tb^{3+} and $O^{2-} \rightarrow Eu^{3+}$ charge transfer band of the Eu^{3+} ion. Because of this several peaks were observed at 303, 317, 351 nm due to the $^7F_6 \rightarrow {}^5H_6$ and $^7F_6 \rightarrow {}^5D_0$ transitions of Tb^{3+} and at 375, 393, 414, 463 and 553 nm due to $^5F_0 \rightarrow {}^5D_3$, $^5F_0 \rightarrow {}^5D_2$, $^5F_0 \rightarrow {}^5D_1$, $^5F_0 \rightarrow {}^5G_2$ and $^5F_0 \rightarrow {}^5L_6$ transitions of Eu^{3+} respectively. Therefore, it is evident that the co-doped sample excitation spectrum contains every characteristic of the single-doped Tb^{3+} ion and Eu^{3+}ion. When the co-doped excitation spectrum is compared to the single doped glasses, the two match precisely in terms of spectrum summation (see Figure 1(a) and 2(a)). Consequently, energy transfer from the Tb^{3+} to Eu^{3+} ions is clearly demonstrated by the presence of the Tb^{3+} [22] excitation peaks among the various photo-stimulation paths for the activation of the Eu^{3+} (613 nm) $^5D_0 \rightarrow {}^7F_2$ transition. The Eu^{3+} excitation spectra and Tb^{3+} emission is also highlighted for direct comparison (see Figure 3(b)). Figure 3(b) reveal that there is strong overlap between Eu^{3+} excitation peaks $^5F_0 \rightarrow {}^5L_6$ (391 nm), $^5F_0 \rightarrow {}^5D_2$ (463 nm), $^5F_0 \rightarrow {}^5D_1$ (553 nm) and Tb^{3+} emissions peaks $^5D_4 \rightarrow {}^7F_6$ (488 nm), $^5D_4 \rightarrow {}^7F_5$ (545 nm) and respectively clearly manifest the confirmation of possible transfer of energy from Tb^{3+} to Eu^{3+} in SiO_2 host.

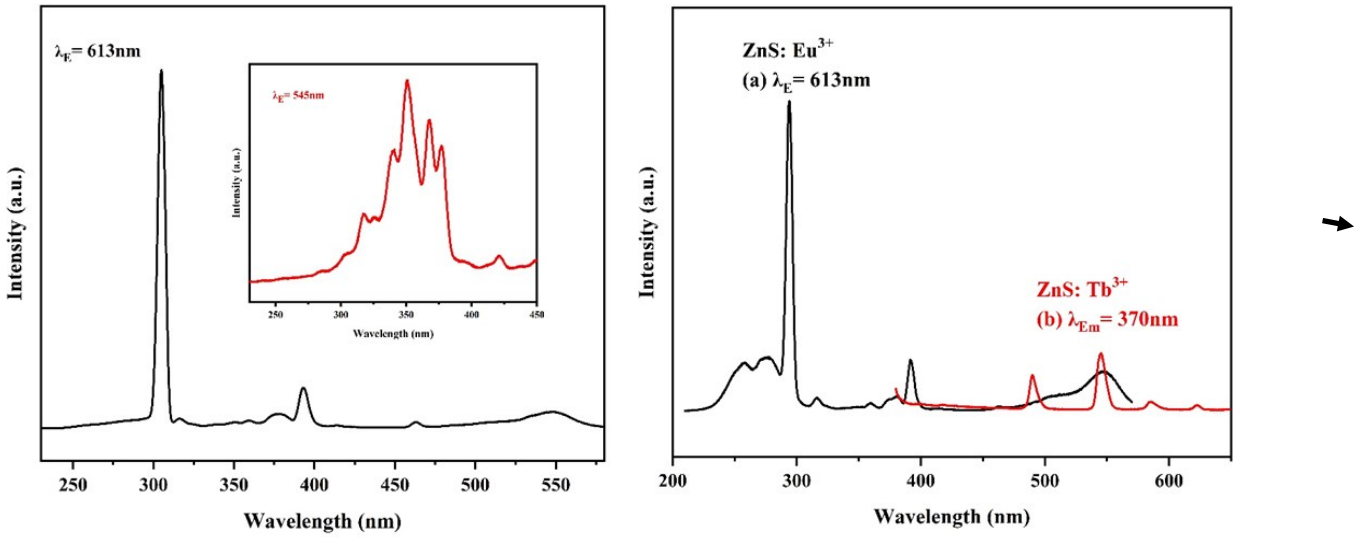

Figure 3. a. Excitation spectra of Tb:Eu:SiO_2 at λ_E= 613 nm and λ_E= 545 nm **b**. Spectral overlap between Tb emission and Eu excitation in SiO_2.

Conclusion

The excitation and emission spectra of a single phase of Eu^{3+} ion and Tb^{3+} ion doped and co-doped with silicon dioxide have been studied. Eu^{3+} ion excitation spectrum three prominent peaks were observed at 294 nm, 391 nm and 553 nm which indicates this may find applications sterilizing, disinfecting, killing bacteria and viruses and solid-state lighting devices. Tb^{3+} ion emission spectra confirmed that green emission as the most intense and this transition has the highest affinity for both electric-dipole and magnetic-dipole-induced transitions. It is also evident that the co-doped sample excitation spectrum contains every characteristic of the single-doped Tb^{3+} ion and Eu^{3+}ion. The co-doped sample has characteristics peaks due to the combination of spin allowed/ spin forbidden of Tb^{3+} and $O^{2-} \rightarrow Eu^{3+}$ charge transfer band of the Eu^{3+} ion which clearly confirmed the transfer of energy from Tb^{3+} ion to Eu^{3+} ion.

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Conflict of Interest

The author declares there is no conflict of interest.

References

1. Ralte, L., Dawngliana, K.M.S., Fanai, A.L., Rai, S. (2023). Effect of ZnS nanoparticles in photoluminescence properties of Tb^{3+} ion doped silica glass for photonic applications. *Applied Physics A*, **129**, 751. https://doi.org/10.1007/s00339-023-07037-7
2. Suthanthirakumar, P., Arunkumar, S., Marimuthu, K. (2018). Spectroscopic properties and excited state dynamics of Sm^{3+} ions in zinc telluro-fluoroborate glasses. *Journal of Luminescence*, **202**, 289–300. https://doi.org/10.1016/j.jlumin.2018.05.069
3. Kumaresh, A., Kumar, A.R., Ravikumar, N., Madhusoodanan, U., Panigrahi, B.S., Marimuthu, K., Anuradha, M. (2016). Structural and photoluminescence studies on europium-doped lithium tetraborate (Eu:$Li_2B_4O_7$) single crystal grown by microtube Czochralski (μT-Cz) technique. *Chinese Physics B*, **25**(5), 058105. https://doi.org/10.1088/1674-1056/25/5/058105
4. Puia, L., Rai, S. (2024). Structural and Spectroscopic Studies of Sm^{3+} Ions Doped ZnS Nanoparticle in Silica Glass Matrix. *Indian Journal of Science and Technology*, **17**(9), 773–779. https://doi.org/10.17485/IJST/v17i9.2939
5. Yu, C.C., Liu, X.M., Yu, M., Lin, C.K., Li, C.X., Wang, H., Lin, J. (2007). Enhanced photoluminescence of Ba_2GdNbO_6: Eu^{3+}/Dy^{3+} phosphors by Li^+ doping. *Journal of Solid State Chemistry*, **180**(11), 3058–3065. https://doi.org/10.1016/j.jssc.2007.08.028
6. Singh, K., Marikumar, R., Vaidyanathan, S. (2018). Trivalent rare-earth activated hexagonal lanthanum fluoride (LaF_3:RE^{3+}, where RE = Tb, Sm, Dy and Tm) nanocrystals: Synthesis and optical properties. *Luminescence*, **33**, 897–906 https://doi.org/10.1002/bio.3488
7. Zhu, X., Zhou, Z. (2017). Photoluminescence and energy transfer mechanism of a novel tunable color phosphor Na_2MgSiO_4:Tb^{3+}, Eu^{3+}. *Journal of Luminescence*, **188**, 589–594. https://doi.org/10.1016/j.jlumin.2017.05.003
8. Puia, L., Dawngliana, K.M.S., Khan, U., Rai, S. (2022). Synthesis and Spectral Characteristics of RhB and Rh6G Dyes and their Mixture in Solid Matrix. *Indian Journal of Pure and Applied Physics*, **60**(10), 883–891. https://doi.org/10.56042/ijpap.v60i10.62440
9. Dawngliana, K.M.S., Lalruatpuia., Ralte, L., Rai, S. (2024). Effect of ZnS nanoparticles on the optical properties of Sm^{3+} ions in silicate matrix. *Journal of Non-Crystalline Solids*, **632**, 122871. https://doi.org/10.1016/j.jnoncrysol.2024.122871
10. Dawngliana, K.M.S., Lalruatpuia., Fanai, A. L., Rai, S. (2022). Optical basicity and electronic polarizability of Sm^{3+} -doped silica glass prepared by sol–gel process. *Materials Today: Proceedings*, **65**(5), 2572–2577. https://doi.org/10.1016/j.matpr.2022.04.784
11. Luo, Y., Liu, Z., Wong, H. T., Zhou, L., Wong, K. L., Shiu, K. K., Tanner, P. A. (2019). Energy Transfer between Tb^{3+} and Eu^{3+} in $LaPO_4$: Pulsed versus Switched-off Continuous Wave Excitation. *Advanced Science*, **6**, 1900487. https://doi.org/10.1002/advs.201900487
12. Van Tuyen, H., Nguyen, M.S. (2017). Luminescence properties and energy transfer of Tb^{3+}–Eu^{3+} co-doped $Sr_3B_2O_6$ phosphors. *International Journal of Modern Physics B*, **31**, 1750128. https://doi.org/10.1142/S0217979217501284
13. Zhu, D., Li, J., Guo, X., Li, Q., Wu, H., Meng, L., Liu, Z. (2019). Controlled synthesis of Tb^{3+}/Eu^{3+} Co-Doped Gd_2O_3 Phosphors with enhanced

red emission. *Molecules*, **24**, 759. https://doi.org/10.3390/molecules24040759

14. Nan, S., Hong, F., Xu, H., Dou, J., Liu, G., Dong, X., Wang, J., Yu, W. (2020). Luminescence properties and energy transfer of Tb^{3+}, Eu^{3+} co-doped $YTaO_4$ phosphors obtained via sol–gel combustion process. *Journal of Materials Science: Materials in Electronics*, **31**, 13688–13695. https://doi.org/10.1007/s10854-020-03926-2
15. Paterlini, V., Piccinelli, F., Bettinelli, M. (2019). Tb^{3+} Eu^{3+} energy transfer processes in eulytite $A_3Tb(PO_4)_3$ (A=Sr, Ba) and silico-carnotite $Ca_3Tb_2Z_3O_{12}$ (Z=Si, Ge) materials doped with Eu^{3+}. *Physica B: Condensed Matter*, **575**, 411685. https://doi.org/10.1016/j.physb.2019.411685
16. Puia, L., Dawngliana, K.M.S., Rai, S. (2024). Spectroscopic investigation of Pr^{3+} doped ZnS nanoparticle in silica glass matrix prepared by sol–gel method. *Applied Physics A*, **130**, 812. https://doi.org/10.1007/s00339-024-07963-0
17. Rawat, K., Vishwakarma, A.K., Jha, K. (2022). Multicolor emission and energy transfer dynamics in thermally stable $Ca_2Ga_2SiO_7$:Tb^{3+}/Eu^{3+} for warm w-LEDs application *Optics & Laser Technology*, **145**, 107455. https://doi.org/10.1016/j.optlastec.2021.107455
18. Zheng, X., Yang, M., Wang, G., Zhou, W., Zhang, J., Yu, L., Wang, P., Qiu, Z., Li, C., Lian, S. (2020). Luminescence tuning of Tb/Eu Co-doped zinc aluminoborosilicate glasses for white LED applications. *Ceramics International*, **46**(17), 26608–26615. https://doi.org/10.1016/j.ceramint.2020.07.129
19. Pisarska, J., Kos, A., Sołtys, M., Żur, L., Pisarski, W. A. (2014). Energy transfer from Tb^{3+} to Eu^{3+} in lead borate glass. *Journal of Non-Crystalline Solids*, **388**, 1–5. https://doi.org/10.1016/j.jnoncrysol.2014.01.019
20. Said, H., Omrani, R.O., Ruiz Arana, L., El Bahri, D., Boussen, S., Bouzidi, C., Terraschke, H., Hamzaoui, A. H., M'nif, A. (2019). The effect of silica additive on the structural and luminescence properties of Eu^{3+}/Tb^{3+} co-doped metaphosphate glasses. *Journal of Molecular Structure*, **1192**, 42–48. https://doi.org/10.1016/j.molstruc.2019.04.087
21. Zhu, C., Chaussedent, S., Liu, S., Zhang, Y., Monteil, A., Gaumer, N., Yue, Y. (2013). Composition dependence of luminescence of Eu and Eu/Tb doped silicate glasses for LED applications. *Journal of Alloys and Compounds*, **555**, 232–236. https://doi.org/10.1016/j.jallcom.2012.12.052
22. Caldino, U., Álvarez, E., Speghini, A., Bettinelli, M. (2013). New greenish-yellow and yellowish-green emitting glass phosphors: Tb^{3+}/Eu^{3+} and Ce^{3+}/Tb^{3+}/Eu^{3+} in zinc phosphate glasses. *Journal of Luminescence*, **135**, 216–220. https://doi.org/10.1016/j.jlumin.2012.10.013
23. Som, S., Mitra, P., Kumar, V., Kumar, V., Terblans, J.J., Swart, H.C., Sharma, S.K. (2014). The energy transfer phenomena and colour tunability in Y_2O_2S:Eu^{3+}/Dy^{3+} micro-fibers for white emission in solid state lighting applications. *Dalton Transactions*, **43**, 9860–9871. https://doi.org/10.1039/C4DT00349G