Advanced Ceramics Progress: Vol. 8, No. 3, (Summer 2022) 8-12

Materials and Energy Research Center
MERC

Contents lists available at ACERP

Advanced Ceramics Progress

Journal Homepage: www.acerp.ir

Original Research Article

Luminescence Investigation of Ce Doped ZnO/$CdWO_4$ Nanocomposite

Maryam Hajiebrahimi [a], Sanaz Alamdari [b,*], Omid Mirzaee [c,*], Mohammad Tajally [d]

[a] MSc Student, Faculty of Materials and Metallurgical Engineering, Semnan University, Semnan, Semnan, Iran
[b] Assistant Professor, Department of Nano Electronics, Faculty of Nanotechnology, Semnan University, Semnan, Semnan, Iran
[c] Professor, Department of Ceramic , Faculty of Materials and Metallurgical Engineering, Semnan University, Semnan, Semnan, Iran
[d] Associate Professor, Department of Industrial Metallurgy, Faculty of Materials and Metallurgical Engineering, Semnan University, Semnan, Semnan, Iran

* Corresponding Authors' Emails: s.alamdari@semnan.ac.ir (S. Alamdari); o_mirzaee@semnan.ac.ir (O. Mirzaee)
URL: https://www.acerp.ir/article_159415.html

ARTICLE INFO

Article History:

Received 22 September 2022
Received in revised form 1 October 2022
Accepted 24 October 2022

Keywords:

ZnO
$CdWO_4$
Ce Dopant
Nanocomposite
Emission
Optical Response

ABSTRACT

Novel luminous materials are always required in solid-state light-emitting diodes and displays applications. In this regard, the current study investigated the luminescence properties of cerium-doped zinc oxide/cadmium tungstate (ZnO/$CdWO_4$: Ce) nanocomposite particles under proton, laser, and gamma-ray excitations. The XRD results revealed the simultaneous existence of monoclinic CWO and hexagonal ZnO. Doped nanocomposite particles under proton/laser irradiations displayed significant luminescence in the blue-green region compared with the pure nanocomposite. In addition, Thermo-Luminescence (TL) study of the doped pellet showed a stronger glow peak at 350-400 °C. According to the TEM, the doped nanoparticles had an average diameter of 70-150 nanometers. The existence of Zn, O, Cd, W, and Ce elements in the composites was confirmed by the EDX technique. The obtained results showed that the produced ZnO/CWO: Ce nanocomposite particles could be promising materials to be used in optoelectronic devices.

https://doi.org/10.30501/acp.2022.363264.1102

1. INTRODUCTION

Luminescent materials have drawn considerable attention owing to their applications in photonic, displays, and screen devices. Within this energy sphere, it is recommended that a wide range of insulators be used with the band gaps that are doped with optically active ions capable of emitting a visible luminescence with high quantum efficiency for all excited phosphors [1,2]. Luminescent materials may take up energy and then release it as light. The process is called excitation and emission. The nature of the luminous substance is fixed by the physical form of the excitation energy. Many materials are able to both absorb and release different types of energy. In other words, they have the potential to serve in a variety of luminous media. Doping and modifications of the energy level structure in metal oxides are performed to enhance the optical behavior, hence desirable outcome. For instance, ZnO and $CdWO_4$ (CWO) are two oxide materials that have wide

Please cite this article as: Hajiebrahimi, M., Alamdari, S., Mirzaee, O., Tajally, M., "Luminescence Investigation of Ce Doped ZnO/$CdWO_4$ Nanocomposite", ***Advanced Ceramics Progress***, Vol. 8, No. 3, (2022), 8-12. https://doi.org/10.30501/acp.2022.363264.1102

applications in different industries [3-7]. Compared to the single structures, mixed oxide materials are characterized by different features due to the newly produced luminescence centers or defects. Although numerous studies have been conducted on ZnO and CWO nanostructures, only a few studies focused on the luminescence properties of ZnO/CWO [9-18]. Given that, the current study aims to prepare flexible scintillation Ce doped ZnO/CWO nanocomposite films and investigate ionization radiation sensitivity and photocurrent responses (under UV/alpha ray) [14]. In addition, this research discusses the luminescence properties of Ce doped ZnO/$CdWO_4$ nanocomposite particles under laser and gamma irradiation prepared through a simple method for photonic applications.

2. MATERIALS AND METHODS

Cadmium nitrate, ethylene glycol, sodium tungstate triethanolamine, sodium tungstate dihydrate, ethanol zinc acetate dihydrate, citric acid (99 %), (98 %), and cerium (III) nitrate hexahydrate were purchased from Merck and Sigma-Aldrich (99.99 % purity). First, ZnO NPs were synthesized via the sol-gel method, taking into account the instructions given in our previous work [10-13]. Then, $CdWO_4$ NPs were synthesized through the co-precipitation method [16]. Next, 25 cc of ethylene glycol was added to five grams of ZnO NPs containing 6.3 g of citric acid and deionized water. The synthesized CWO powder (1:1 ratio to ZnO) and cerium nitrate (2 at. %) were then added to the suspension, stirred again for three hours, and calcined at 600 ° C for four hours. Using a ^{60}Co gamma source, Thermo-Luminescence (TL) glow curve was recorded using a TLD reader for the prepared nanocomposite pellets. The luminescence characteristics of the nanocomposite were examined using a CW Nd: YAG laser excitation (1064 nm) linked to a focusing lens and a spectrometer. The produced nanocomposite particles were subjected to focused microbeam irradiation of protons with the energy of 2.2 MeV and current of 4 nA linked to the fluorescence spectrometer to assess Ion Beam-Induced Luminescence (IBIL).

3. RESULTS AND DISCUSSION

Figure 1 demonstrates the XRD pattern of the ZnO/CWO: Ce nanocomposite. According to the standard data, the crystal structure of wurtzite ZnO was revealed by the display of the primary ZnO peaks in the diffraction peaks of the pure ZnO (JCPDS card no. 36-1451 data) [5,10]. In addition, the diffraction peaks of the pure CWO sample can only be indexed as the monoclinic of $CdWO_4$, (JCPDS card no. 14-0676) [16]. X-ray powder diffraction analysis of a ZnO/CWO: Ce nanocomposite confirmed the simultaneous presence of both hexagonal ZnO and monoclinic CWO in the material [11].

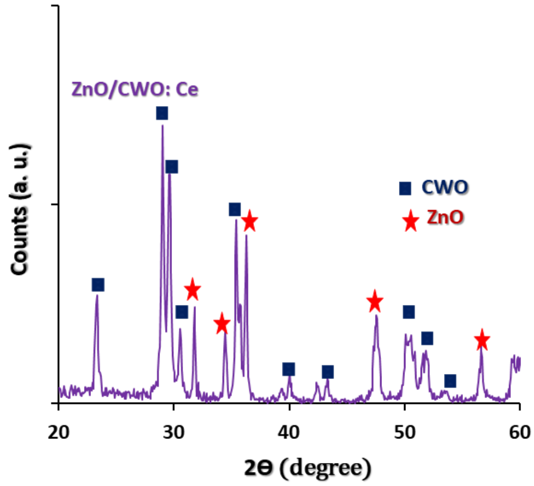


Figure 1. XRD pattern of CWO/ZnO: Ce

The morphology of the prepared doped nanocomposite was examined using the TEM image given in Figure 2. The prepared ZnO/CWO: Ce nanocomposite sample is composed of particles with spheroid, cubic, and rod-like morphologies with an average diameter of 70-150 nm.

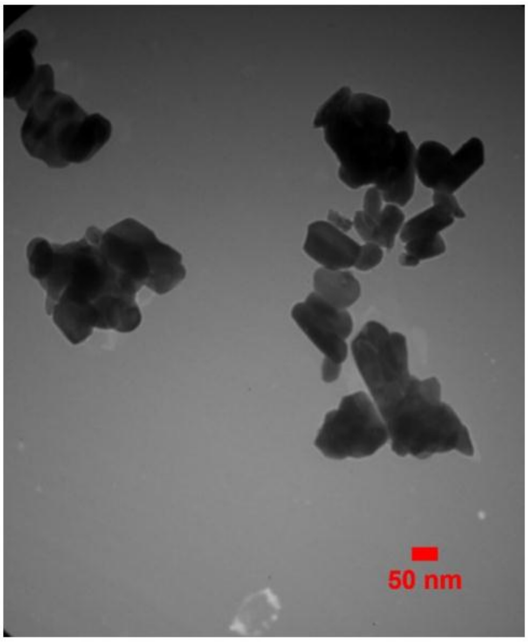
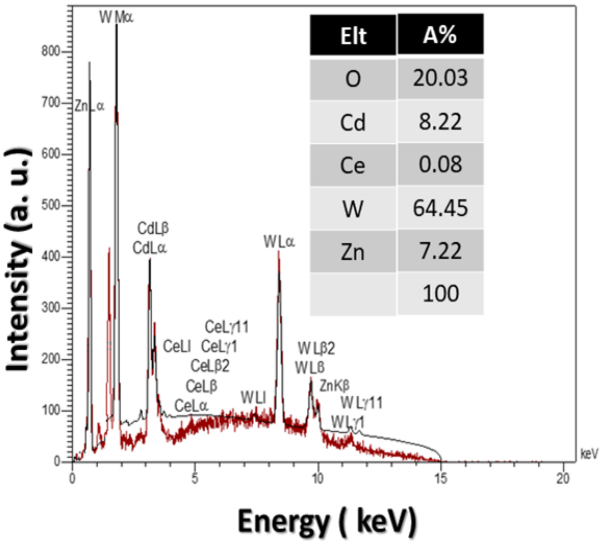


Figure 2. TEM images of the prepared doped nanocomposite particles

As observed in Figure 3, the EDX spectrum was used to verify the presence and relative abundance of the element of Zn, Cd, W, Ce, and O on the surface of the produced nanocomposite.



Elt	A%
O	20.03
Cd	8.22
Ce	0.08
W	64.45
Zn	7.22
	100

Figure 3. The energy-dispersive X-ray spectrum of the Ce doped nanocomposite

The optical properties of the synthesized samples were studied using ion beam/laser/gamma induced luminescence techniques. Figure 4 presents the schematic of the experimental setup under proton and CW Nd: YAG laser excitations (1064 nm).

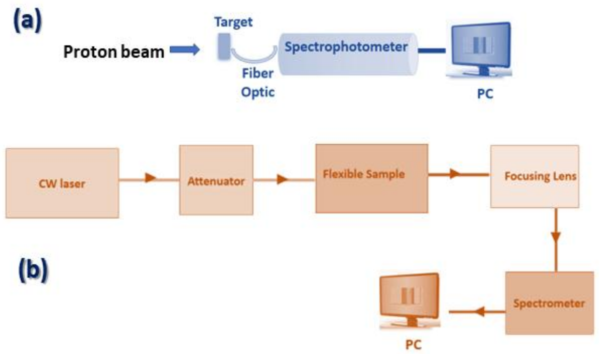


Figure 4. Brief schematic of the (a) IBIL and (b) Laser induced luminescence setups

Near-Band-Edge (NBE) emission in the ultraviolet and visible broadband emission in the visible range are both observed in luminescence spectra of ZnO [19-22]. The oxygen vacancies that generate a majority of the faults have a very low ionization energy. The band gap energy, band-to-band transitions, and exciton recombination of ZnO are the main reasons behind the formation of the UV emission peaks [22]. The major cause of the blue-green emission from the $CdWO_4$ structure is the $1A^1$-$3T^1$ transitions inside the WO^{6}_{-6} complex [12,20]. In general, the anion complex WO_4^{-2} emits powerful blue-green radiation due to the charge-transfer type electronic transitions between oxygen and WO_4^{-2} inside the complex [23].

Ce doping of the ZnO/CWO nanocomposite improved its luminosity. This enhancement may be attributable to the natural surface flaws of the host lattice, thus allowing for more efficient energy transfer to the Ce dopant. Ion Beam-Induced Luminescence (IBIL) characterization technique helps confirm the presence of impurities, flaws, and chemical compounds in the given material. As observed in Figure 5, when subjected to a focused proton beam, pure ZnO/CWO and Ce doped ZnO/CWO nanocomposites exhibit emission peaks at 500 nm. It is also observed that doped ZnO/CWO nanocomposite has the stronger luminesce than its counterparts. The luminescence spectra of the laser-excited prepared samples are given in Figure 6 according to which, the doped sample has stronger peaks than others in the 420-460 nm range as a result of the upconversion photon processes in the host ZnO/CWO. The scintillation and luminescence studies confirmed that ZnO/CWO: Ce could be a promising material to be used in lasers and other photonic devices.

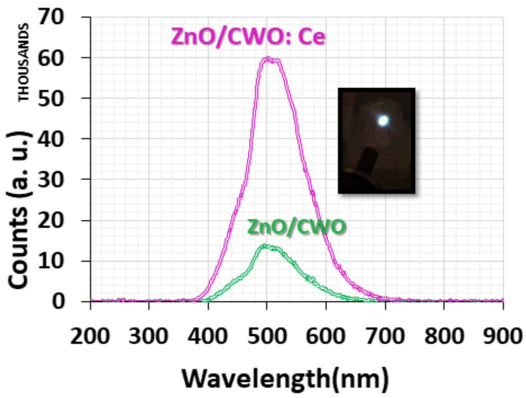


Figure 5. IBIL spectrum of pure and Ce doped ZnO/CWO nanocomposites

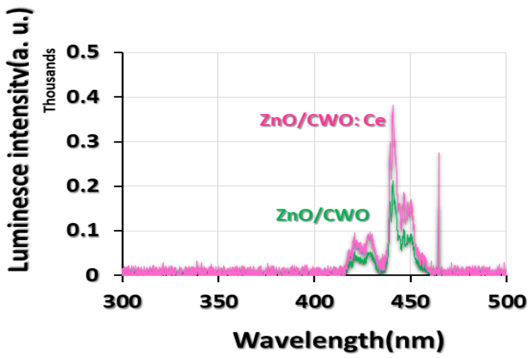


Figure 6. Luminescence spectrum of the pure and Ce doped ZnO/CWO nanocomposites under CW laser excitation

As observed in Figure 7, the prepared pellets were irradiated with ^{60}Co gamma rays, and TL properties were measured. In this figure, the TL emission curve of Ce Doped sample is stronger than the pure one, and its peaks are observed at 350-400 °C that could be related to luminescent centers. As shown in Figure 8, TL dose response of the synthesized doped pellet was studied over radiation absorbed dose. Here, the doped phosphor exhibits a nearly linear dose response.

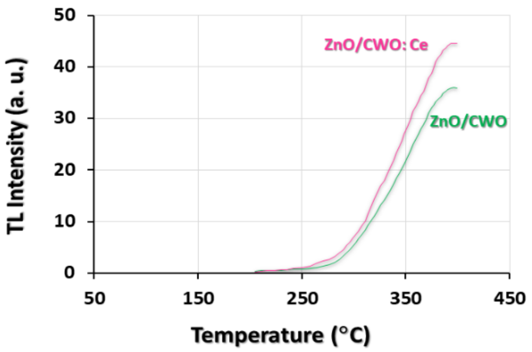


Figure 7. TL spectra of pure and Ce doped ZnO/CWO nanocomposite pellets

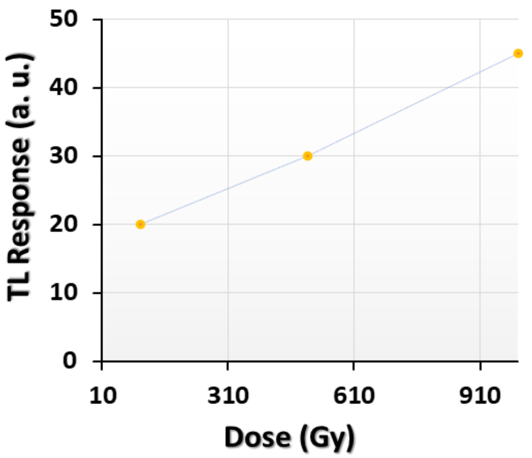


Figure 8. TL dose response of Ce doped ZnO/CWO nanocomposite pellet

4. CONCLUSION

In the present study, two mixes of pure and Ce doped oxide nanocomposites were successfully prepared via a simple method. The XRD results confirmed the simultaneous existence of both monoclinic CWO and hexagonal ZnO. Doped nanocomposite particles under proton/laser irradiations displayed significant luminescence in the blue-green region. TL study of the ZnO/CWO: Ce pellet showed a relatively strong glow peak at 350-400 °C. The presence of Zn, O, Cd, W, and Ce elements in the composites was confirmed using the EDX technique. Doped phosphor exhibited a nearly linear gamma dose response. According to the findings, the synthesized ZnO/CWO: Ce nanocomposite particles could be the appropriate potential components of optoelectronic devices.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Semnan University for the all support throughout this work.

REFERENCES

1. Enríquez-Sánchez, N., Vilchis-Nestor, A. R., Camacho-López, S., Camacho-López, M. A., Camacho-López, M., "Colloidal MnO_X NPs/Carbon sheets nanocomposite synthesis by laser ablation in liquids", ***Optics & Laser Technology***, Vol. 146, (2022), 107591. https://doi.org/10.1016/j.optlastec.2021.107591
2. Dey, S., Kar, A. K., "Effect of acceptor concentration in the FRET controlled photoluminescence of PMMA-ZnO nanocomposite for the application of PLED device", ***Optics & Laser Technology***, Vol. 136, (2021), 106811. https://doi.org/10.1016/j.optlastec.2020.106811
3. Alamdari, S., Ghamsari, M. S., Tafreshi, M. J., "Novel scintillation properties by entrapping ZnO: Ga nanocrystals in epoxy polymer", ***Progress in Nuclear Energy***, Vol. 130, (2020), 103495. https://doi.org/10.1016/j.pnucene.2020.103495
4. Al-Hiti, A. S., Al-Masoodi, A. H. H., Harun, S. W., Yasin, M., Wong, W. R., "Tungsten trioxide (WO_3) film absorber for generating soliton mode-locked pulses in erbium laser", ***Optics & Laser Technology***, Vol. 131, (2020), 106429. https://doi.org/10.1016/j.optlastec.2020.106429
5. Fortunato, E., Gonçalves, A., Pimentel, A., Barquinha, P., Gonçalves, G., Pereira, L., Ferreira, I., Martins, R. J. A. P. A., "Zinc oxide, a multifunctional material: from material to device applications", ***Applied Physics A***, Vol. 96, No. 1, (2009), 197–205. https://doi.org/10.1007/s00339-009-5086-5
6. Nunes, D., Pimentel, A., Gonçalves, A., Pereira, S., Branquinho, R., Barquinha, P., Fortunato, E., Martins, R., "Metal oxide nanostructures for sensor applications", ***Semiconductor Science and Technology***, Vol. 34, No. 4, (2019), 043001. https://doi.org/10.1088/1361-6641/ab011e
7. Ferreira, S. H., Morais, M., Nunes, D., Oliveira, M. J., Rovisco, A., Pimentel, A., Águas, H., Fortunato, E., Martins, R., "High UV and Sunlight Photocatalytic Performance of Porous ZnO Nanostructures Synthesized by a Facile and Fast Microwave Hydrothermal Method", ***Materials***, Vol. 14, No. 9, (2021), 2385. https://doi.org/10.3390/ma14092385
8. Tian, W., Li, J., "Size-dependent optical-electrical characteristics of blue GaN/InGaN micro-light-emitting diodes", ***Applied Optics***, Vol. 59, No. 29, (2020), 9225-9232. https://doi.org/10.1364/AO.405572
9. Liu, Z., Li, J. and Liu, X., "Novel functionalized BN nanosheets/epoxy composites with advanced thermal conductivity and mechanical properties", ***ACS Applied Materials & Interfaces***, Vol. 12, No. 5, (2020), 6503-6515. https://doi.org/10.1021/acsami.9b21467
10. Alamdari, S., Jafar Tafreshi, M., Sasani Ghamsari, M., "Preparation and characterization of gallium doped zinc oxide/polystyrene nanocomposite scintillator for alpha particles detection", ***Applied Physics A***, Vol. 125, No. 6, (2019), 450. https://doi.org/10.1007/s00339-019-2727-1
11. Alamdari, S., Ghamsari, M. S., Tafreshi, M. J., "Novel scintillation properties by entrapping ZnO: Ga nanocrystals in

epoxy polymer", ***Progress in Nuclear Energy***, Vol. 130, (2020), 103495. https://doi.org/10.1016/j.pnucene.2020.103495

12. Alamdari, S., Sasani Ghamsari, M., Lee, C., Han, W., Park, H. H., Tafreshi, M. J., Afarideh, H., Ara, M. H. M., "Preparation and Characterization of Zinc Oxide Nanoparticles Using Leaf Extract of Sambucus ebulus", ***Applied Sciences***, Vol. 10, No. 10, (2020), 3620. https://doi.org/10.1016/j.apradiso.2021.110050
13. Alamdari, S., Ghamsari, M. S., Tafreshi, M. J., "Optimization of Gallium concentration to improve the performance of ZnO nanopowders for nanophotonic applications", ***Ceramics International***, Vol. 46, No. 4, (2020), 4484-4492. https://doi.org/10.1016/j.ceramint.2019.10.175
14. Alamdari, S., Ara, M. H. M., Tafreshi, M. J., "Synthesize and optical response of ZnO/$CdWO_4$: Ce nanocomposite with high sensitivity detection of ionizing radiations", ***Optics & Laser Technology***, Vol. 151, (2022), 107990. https://doi.org/10.1016/j.optlastec.2022.107990
15. Lim, C. S., "Microwave-assisted synthesis of $CdWO_4$ by solid-state metathetic reaction", ***Materials Chemistry and Physics***, Vol. 131, No. 3, (2012), 714–718. https://doi.org/10.1016/j.matchemphys.2011.10.039
16. Ziluei, H., Azimirad, R., Larijani, M. M., Ziaie, F., "Preparation and optimization of $CdWO_4$-polymer composite film as an alpha particle counter", ***Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment***, Vol. 852, (2017), 85-90. https://doi.org/10.1016/j.nima.2017.01.015
17. Kumar, E. D., Thirumalai, K., Aravindhan, R., Swaminathan, M., Rao, J. R., Nair, B.U.,, "Visible light photocatalytic degradation of wattle extract: effect of mixing $CdWO_4$ over a semiconductive ZnO photocatalyst", ***RSC advances***, Vol. 5, No. 75, (2015), 60926-60937. https://doi.org/10.1039/C5RA06926B
18. Fatima, B., Siddiqui, S. I., Nirala, R.K., Vikrant, K., Kim, K. H., Ahmad, R., Chaudhry, S. A., "Facile green synthesis of ZnO-$CdWO_4$ nanoparticles and their potential as adsorbents to remove organic dye", ***Environmental Pollution***, Vol. 271, (2021), 116401. https://doi.org/10.1016/j.envpol.2020.116401
19. Yang, J., Gao, M., Yang, L., Zhang, Y., Lang, J., Wang, D., Wang, Y., Liu, H., Fan, H., "Low-temperature growth and optical properties of Ce-doped ZnO nanorods", ***Applied Surface Science***, Vol. 255, No. 5, (2008), 2646-2650. https://doi.org/10.1016/j.apsusc.2008.08.001
20. Rondinone, A. J., Pawel, M., Travaglini, D., Mahurin, S., Dai, S., "Metastable tetragonal phase $CdWO_4$ nanoparticles synthesized with a solvothermal method", ***Journal of Colloid and Interface Science***, Vol. 306, No. 2, (2007), 281–284. https://doi.org/10.1016/j.jcis.2006.10.064
21. Fatima, B., Siddiqui, S. I., Nirala, R. K., Vikrant, K., Kim, K. H., Ahmad, R., Chaudhry, S. A., "Facile green synthesis of ZnO–$CdWO_4$ nanoparticles and their potential as adsorbents to remove organic dye", ***Environmental Pollution***, Vol. 271, (2021), 116401. https://doi.org/10.1016/j.envpol.2020.116401
22. Ghamsari, M. S., Alamdari, S., Razzaghi, D., Pirlar, M. A., "ZnO nanocrystals with narrow-band blue emission", ***Journal of Luminescence***, Vol. 205, (2019), 508–518. https://doi.org/10.1016/j.jlumin.2018.09.064
23. Bardelli, L., Bini, M., Bizzeti, P. G., Carraresi, L., Danevich, F. A., Fazzini, T. F., Grinyov, B. V., Ivannikova, N. V., Kobychev, V. V., Kropivyansky, B. N., Maurenzig, P. R., "Further study of CdWO4 crystal scintillators as detectors for high sensitivity 2β experiments: Scintillation properties and pulse-shape discrimination", ***Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment***, Vol. 569, No. 3, (2006), 743-753. https://doi.org/10.1016/j.nima.2006.09.094
24. Alamdari, S., Haji Ebrahimi, M., Mirzaee, O., Jafar Tafreshi, M., Majlesara, M. H., Tajali, M., Sasani Ghamsari, M. Mohammadi, A., "Cerium doped Tungsten-Based Compounds for Thermoluminescence Application", ***Progress in Physics of Applied Materials***, Vol. 2, No. 1, (2022), 35-40. https://doi.org/10.22075/ppam.2022.27086.1028