Temperature dependent photoluminescence characteristics of MBE grown Eu-doped ZnMgO thin films

Juby Alphonsa Mathew *, A. Wierzbicka, A. Lysak, M. Stachowicz, J. M. Sajkowski, Y. Zhydachevskyy, A. Kozanecki

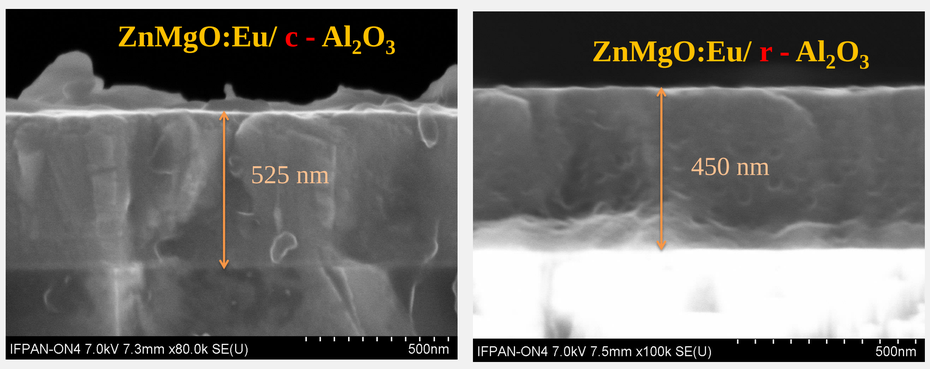
Institute of Physics Polish Academy of Sciences, Aleja Lotnikow 32/46, 02-668, Warsaw, Poland

***Corresponding author: mathewja@ifpan.edu.pl**

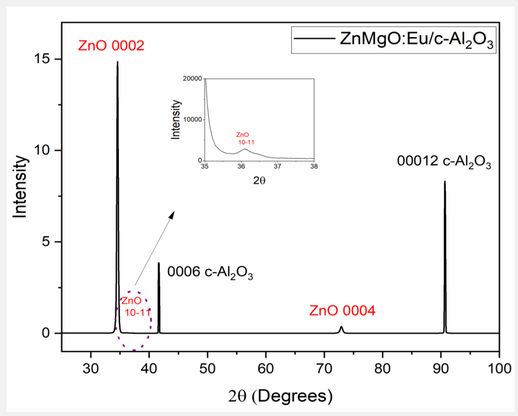
ABSTRACT

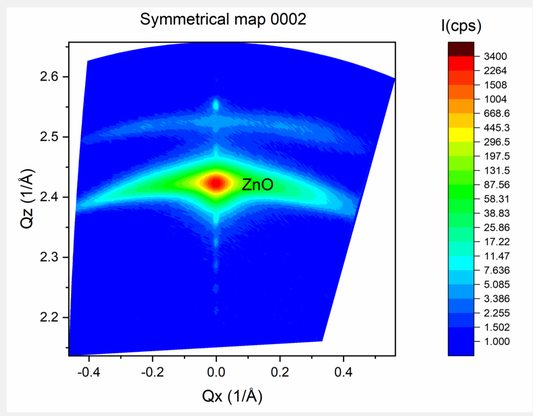
Oxide-wide-bandgap semiconductors are suitable hosts for rare earth ions owing to their availability at low cost, ease of synthesis, chemical stability, and, above all, due to the tunability of their optical and electrical properties. It is known that the bandgap of $Zn_{1-x}Mg_xO$ increases with the Mg alloying content, x. The photo-excitation-emissions of Eu ions are expected to be modified when doped inside a tunable wide bandgap material like $Zn_{1-x}Mg_xO$. Our studies have showed that the optical activity of Europium is increased by an order of magnitude when around 10% fractional Mg is alloyed to ZnO in comparison to Eu doped pure ZnO matrix [1, 2]. However, the exact nature of Eu ion optical sites in the ZnMgO host is unknown. In this project, we explore the nature of Eu optical sites in $Zn_{0.87}Mg_{0.13}O$ thin films at a doping level around 0.5 ± 0.1 at.% . Eu doped $Zn_{0.87}Mg_{0.13}O$ thin films were grown on c- and r-oriented Al_2O_3 by Plasma assisted Molecular Beam Epitaxy, under the same ambient experimental conditions. Low temperature PL and PL Excitation analysis were performed to explore the temperature dependent activity of Eu optical sites. HR-XRD studies confirmed hexagonal wurtzite crystal structure for Eu doped ZnMgO films. Sample grown on c-Sapphire was preferentially oriented in 0002 direction. Eu: ZnMgO/C-Sapphire was found to have dominating red Eu luminescence in comparison to Eu: ZnMgO/r- sapphire which was oriented along 11- 20 direction.

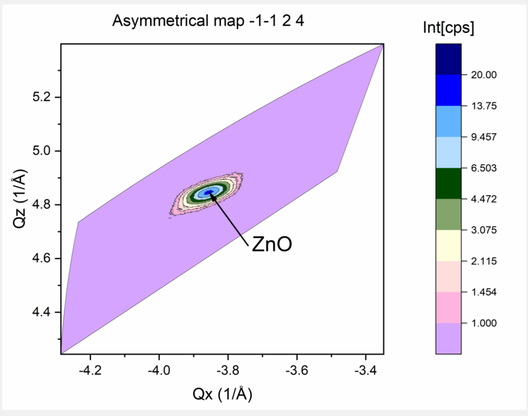
SEM Analysis

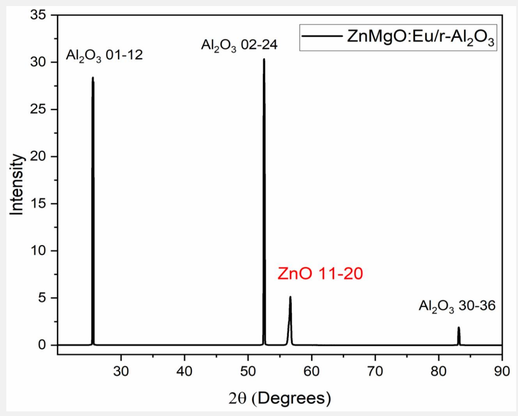


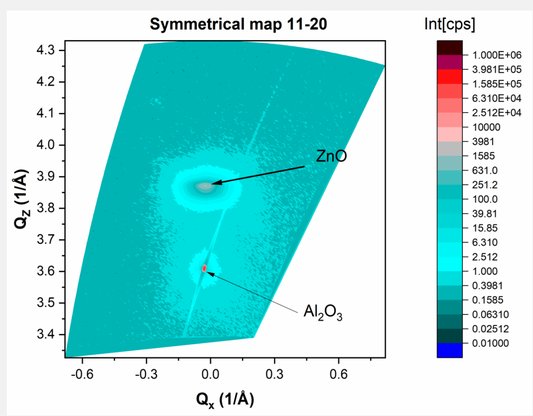
High- resolution XRD Analysis

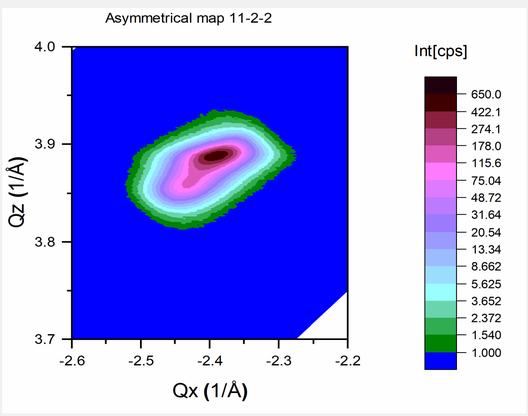




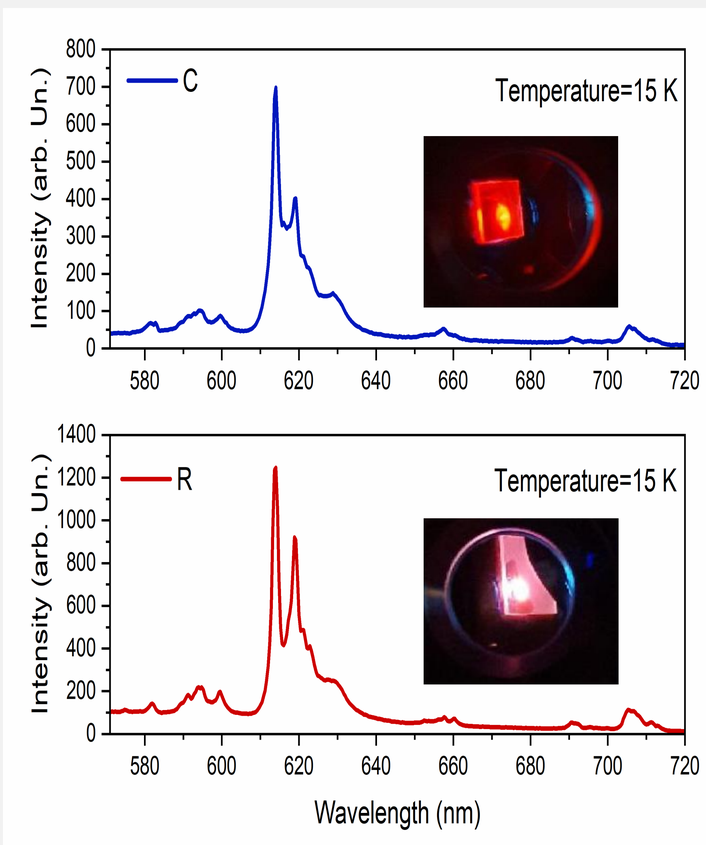


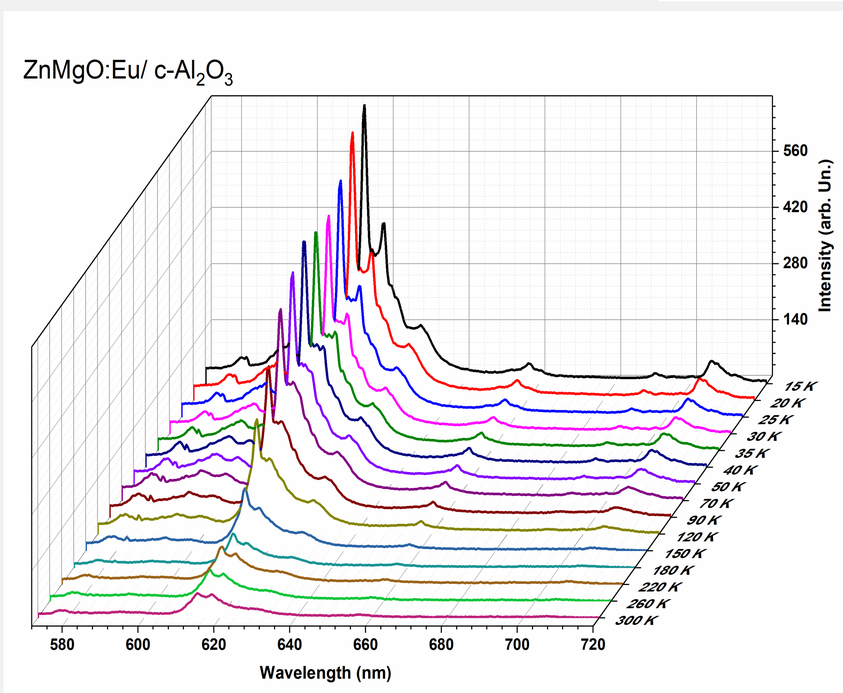


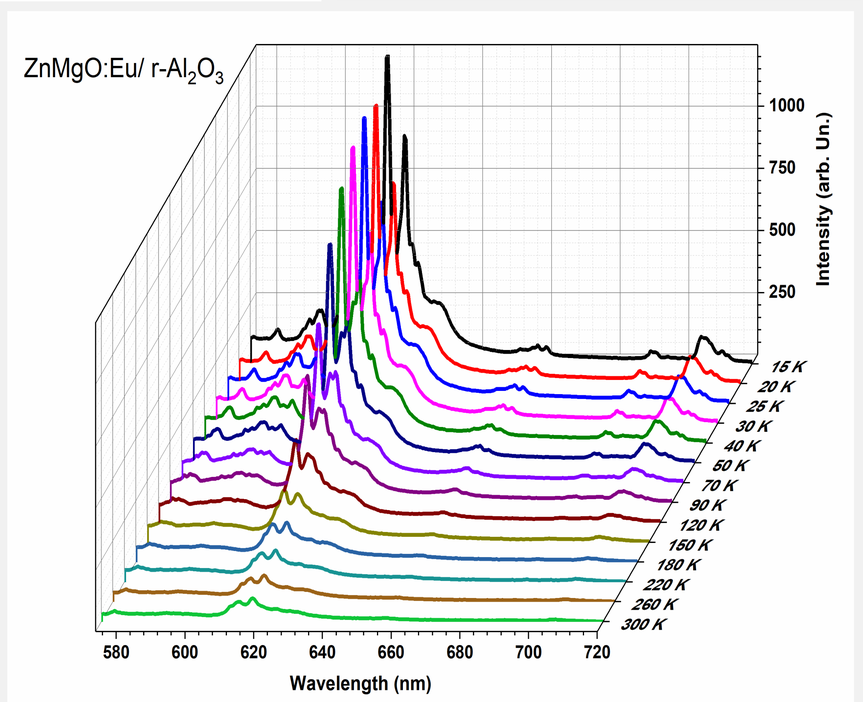




LT-PL Analysis







Samples	Line Positions (in nanometers) of $^5D_0$ to ^7F_J transitions of Eu^{3+} at 15 K		
	J=0	J=1	J=2
ZnMgO:Eu/c- Al_2O_3	581.0, 582.8	589.4, 592.5, 594.3, 599.8	613.8, 616.1, 619.0, 621.4, 623.0, 628.8
ZnMgOEu/r- Al_2O_3	574.9, 582.0	589.2, 591.2, 594, 599.6	614.0, 616.9, 618.8, 621.2, 622.8, 629.2

REFERENCES

1. J. A Mathew et.al., *Journal of Luminescence* 251, (2022) 119167
2. A. Kozanecki, et al., Appl. Phys. Lett. 119, (2021) 112101
3. K. Binnemans. Coordination Chemistry Reviews 295 (2015) 1–45

Acknowledgement

This work was supported by the Polish National Science Centre under the project number UMO-2019/35/B/ST8/01937

Summary

- Oxygen PA-MBE is an effective tool to develop Europium activated luminescent oxide materials.
- Eu doped $Zn_{0.89}Mg_{0.11}O$ films retained the hexagonal Wurtzite crystalline nature of ZnO with c (0002) plane and a (11-20) plane development on c- and r- oriented sapphire substrates respectively.
- Lattice Parameters of hexagonal ZnMgO:Eu thin films were calculated accurately as, c= 5.1837 Å, a= 3.2640 Å on c- plane Al_2O_3 and c= 5.2005 Å, a= 3.2450 Å on r- plane Al_2O_3.
- Low temperature PL analysis were performed in the range from 15K to 300K.
- The number of sublevels of a $^{2S+1}L_J$ term were 2, 4, and 6 for J=0, 1, and 2 respectively in the PL spectra at 15 K.
- Eu^{3+}, when occupied in a crystal lattice with hexagonal symmetry, is known to have 1, 2, and 3 sublevels corresponding to J= 0,1, and 2 levels. Hence the above observation points out to the presence of two different Eu^{3+} optical centers in wurtzite ZnMgO:Eu crystals.