Ultraviolet emission properties of undoped and indium-doped bulk zinc oxide single crystals irradiated with gamma rays

Keito Shinohara[1]*, Verdad C. Agulto[1], Melvin John F. Empizo[1,2], Kohei Yamanoi[1], Erick John Carlo D. Solibet[2], Vallerie Ann I. Samson[3], Marilou Cadatal-Raduban[1,4], Toshihiko Shimizu[1], Roland V. Sarmago[2], Arnel A. Salvador[2], Masashi Yoshimura[1], Tsuguo Fukuda[5], and Nobuhiko Sarukura[1].
*lead presenter: shinohara-k@ile.osaka-u.ac.jp
1 Institute of Laser Engineering, Osaka University, Japan
2 National Institute of Physics, University of the Philippines Diliman, Philippines
3 Philippine Nuclear Research Institute, Department of Science and Technology, Philippines
4 School of Natural and Mathematical Sciences, Massey University, New Zealand
5 Fukuda Crystal Laboratory Co., Ltd., Japan

The effect of gamma-ray irradiation on the ultraviolet (UV, 3.26 eV) emission properties of undoped and doped bulk zinc oxide (ZnO) single crystals is investigated. Undoped and indium (In)-doped bulk ZnO single crystals with <0001> crystal orientation were sliced from large boules grown by hydrothermal method. These crystals were irradiated with gamma rays from a cobalt-60 (^{60}Co) source resulting in an absorbed dose of 1.6 kGy similar to our previous studies [1,2]. For the undoped ZnO crystal, grazing incidence x-ray diffraction (GIXRD) measurements indicate an in-plane lattice compression wherein the (100) reflection of the non-irradiated crystal is 27.812 °, while that of the irradiated crystal is 27.867 °. Although lattice compression is observed, the UV emission peak is not significantly shifted after irradiation. The UV emission linewidth only broadens toward lower energies which can be ascribed to the emergence of an additional peak centered around 2.97(1) eV and the presence of zinc interstitials (Zn_i) as shallow donors in ZnO. Moreover, the UV emission lifetime shortens to at least 0.18 ns which suggests increased defect density in the irradiated crystal. On the other hand, similar linewidth broadening and lifetime shortening are observed from the In-doped ZnO crystal. However, the emission lifetime shortening is more pronounced (~ 0.63 ns) due to a higher defect density from intentional doping. Our results demonstrate how gamma-ray irradiation affects the UV emission of ZnO and influences the carrier recombination dynamics in both undoped and doped crystals. From these findings, low-energy gamma-ray irradiation could be used as a post-growth treatment to tailor the excitonic emission lifetime of ZnO, especially for potential scintillator applications.

References

[1] Shinohara K, Empizo MJF, Cadatal-Raduban M, Yamanoi K, Shimizu T, Yoshimura M, Sarukura N, Murata T, Uy MA, Abe H, Yoshikawa A, Boulon G, Dujardin C. Radiation resistance of praseodymium-doped aluminum lithium fluorophosphate scintillator glasses for laser fusion experiments. Jpn J Appl Phys. 2023;62:010613.
[2] Empizo MJF, Yamanoi K, Abe Y, Shinohara K, Agulto VC, Arikawa Y, Shimizu T, Yoshimura M, Sarukura N, Fukuda T. Nanosecond alpha-ray response and gamma-ray radiation resistance of a hydrothermal-grown bulk ZnO single crystal. J Cryst Growth. 2021;570:126240.