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Neutron Transmutation Doping and Radiation Hardness for Solution-Grown Bulk and Nano-Structured ZnO

E. Flitsiyan[a], C. Swartz[a], R.E. Peale[a], O. Lupan[a,b], L. Chernyak[a], L. Chow[a], W.G. Vernetson[c], Z. Dashevsky[d]

[a] Department of Physics, University of Central Florida, Orlando, FL 32816-2385, USA
[b] Department of Microelectronics and Semiconductor Devices, Technical University of Moldova, 2004 Chisinau, Republic of Moldova.
[c] Department of Nuclear and Radiological Engineering, University of Florida, Gainesville, Florida, 32611
[d] Department of Materials Engineering, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel

ABSTRACT

It is shown that solution-grown ZnO nanostructures exhibit enhanced radiation hardness against neutron irradiation as compared to bulk material. The decrease of the cathodoluminescence intensity after irradiation at a neutron dose of 6×10^{16} cm^{-2} in ZnO nanostructure is nearly identical to that induced by a dose of 1.5×10^{14} cm^{-2} in bulk material. The damage introduced by irradiation is shown to change the nature of electronic transitions responsible for luminescence. The change of excitonic luminescence to the luminescence related to the tailing of the density of states caused by potential fluctuations occurs at an irradiation dose around 6×10^{16} cm^{-2} and 5×10^{14} cm^{-2} in nanostructured and bulk materials, respectively.

Hall measurements before and after annealing determined the effect of dose on resistance, mobility, and carrier concentration. Annealing decreased the sheet resistance, increased the mobility, and increased carrier concentration for all doses. While the concentration of carriers in the control sample increased 200-fold after annealing, the increase was ~1000-fold for the irradiated samples. Annealed irradiated samples showed a maximum carrier concentration increase of about 60x over the unirradiated sample. Interestingly, neutron irradiation increased the mobility even in the un-annealed samples.

INTRODUCTION

ZnO is much more resistant to radiation damage than other common semiconductor materials, such as Si, GaAs, CdS and GaN[1,2]. Together with excellent optical and electrical properties, ZnO devices are therefore promising for space applications[1]. Difficulties in p-doping have been the main obstacle to realizing ZnO photonic devices. Better understanding of donor and acceptor behavior[6,7] is needed for development of ZnO *p-n* junctions. Knowledge of material property dependence on irradiation and thermal treatment is similarly important. The previous irradiation studies in ZnO were focused either on effects of electron or proton bombardment[2,3] or ion implantation.[4,5] Recently electrochemical nanostructuring of bulk GaN has been shown to enhance its radiation hardness against high energy heavy ion irradiation.[6] In this paper, effects of neutron irradiation with respect to transmutation doping and optical properties in bulk and nanostructured ZnO are studied.

EXPERIMENT

ZnO nanorods were grown on quartz and Si substrates using facile and soft aqueous solution method without catalysts, templates and seeds. The synthesis route used here differs slightly from ordinary aqueous solution route. The substrates were cleaned in dilute HCl solution for 10 min and then rinsed in de-ionized (DI) water. Then the substrates were rinsed in ethanol/acetone (1:1) mixture, DI water, and dried in nitrogen, which gave uniformly wet-able

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