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Optical and magnetic properties of Ni-implanted and post-annealed ZnO thin films

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Abstract

Single-crystalline ZnO thin films have been grown on sapphire substrates and implanted by 40 keV Ni+ ions with a dose of 0.25-1.25 × 1017 ions/cm2. After implantation the samples have been annealed at T = 1000°C for 30 minutes in air. Both as-prepared and annealed nickelimplanted ZnO samples have been investigated by ferromagnetic resonance (FMR), vibrating sample magnetometry (VSM), scanning electron microscopy (SEM), and optical techniques. SEM studies reveal that the surface of non-implanted ZnO thin film is very smooth, while microcracks are present in the Ni-implanted ZnO samples. Annealing after implantation recovers the surface of the implanted ZnO. Energy dispersive X-ray spectroscopy shows that the Ni concentration increases with increasing the implantation dose. Optical measurements of the Ni-implanted ZnO thin films indicate that annealing results in formation of a new phase. This phase is attributed to NiO that appears due to redistribution and oxidation of the implanted Ni ions in the ZnO matrix. Magnetic measurements show that both as-implanted and annealed samples exhibit roomtemperature ferromagnetism. VSM data indicate that annealing procedure results in decreasing the magnetic moment per Ni atom and higher coercivity at low temperatures. Magnetic-resonance studies reveal highly anisotropic FMR signal in the as-implanted Ni:ZnO samples starting from the dose of 0.5 × 10 17 ions/cm2. We also observe a step-wise increase of the effective magnetization at the dose of 1.0 × 1017 ions/cm 2, which is explained by magnetic percolation of the Ni nanoparticles. Narrow resonance signals with unusual angular dependence are observed in magnetic-resonance studies of the annealed Ni:ZnO samples, which have been related to the formation of a system of non-percolated NiO-coated Ni nanoparticles as a result of annealing in air. We did not observe experimental evidence for intrinsic ferromagnetism in the Ni-implanted ZnO thin films. © Springer-Verlag 2011.

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