

p-type properties of Ga-ZnO thin films by nitrogen implantation

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Recently, p-type properties of ZnO thin films with various doping elements, such as N, As and P, have been widely studied for thin film transistors. In this work, Ga doped ZnO (Ga-ZnO) thin films have been deposited on glass and sapphire substrates by pulsed DC magnetron sputtering. The growth temperature of Ga-ZnO thin films was changed from room temperature to 500 °C with the thickness of 200 nm. The Ga-ZnO thin films obtained at the temperature of 300°C was shown n-type properties with highly crystal quality. Those thin films were implanted with nitrogen in the proton accelerator. The implantation contents of nitrogen were changed with 10^{16} , 10^{17} and 10^{18} cm⁻³. The ion beam energy of accelerator was fixed 90 keV. The electrical properties of N and Ga co-doped ZnO thin films were measured by Hall effect measurements using van der Pauw method. The nitrogen implanted Ga-ZnO thin films of 10^{16} cm⁻³ were shown n-type properties of low quality. The Nitrogen implanted Ga-ZnO thin films of 10^{17} cm⁻³ was shown the unstable p-type properties, while that of 10^{18} cm⁻³ was shown the insulator characterization due to rich N. The nitrogen co-doped ZnO thin films with insulator characterization were annealed with the temperature of 500 °C during 10 min. in vacuum atmosphere. The electrical properties was changed from insulator to typical p-type properties since the unstable lattice with rich N doping was relaxed during annealing process. The corresponding carrier density, mobility and resistivity was 2.6×10^{17} cm⁻³, 2 cm²/Vs, and 17.4 Ωcm, respectively. Those p-type properties were maintained with highly stability during several month.