

# Brief Papers

---

## Magnetic and Structural Properties of Co Ion-Implanted GaN

Woochul Kim, Hee Jae Kang, Suhk Kun Oh, Sangwon Shin, Jong-Han Lee, Jonghan Song, Sam Kyu Noh, Sang Jun Oh, and Chul Sung Kim, *Member, IEEE*

**Abstract**—A GaN epilayer was grown on  $\text{Al}_2\text{O}_3$  substrate by metal-organic chemical vapor deposition, and  $\text{Co}^+$  ions with a dose of  $3 \times 10^{16} \text{ cm}^{-2}$  were implanted into GaN at  $350^\circ\text{C}$ . The implanted samples were postannealed at  $700^\circ\text{C}$ – $900^\circ\text{C}$  to recrystallize the samples and to remove implantation damage. We have investigated the magnetic and structural properties of Co ion-implanted GaN by using X-ray diffraction (XRD), superconducting quantum interference device (SQUID) magnetometer, and X-ray photoelectron spectroscopy (XPS). XRD results did not show any peaks associated with the second phase formation, and only the diffraction from the GaN layer and substrate structure were observed. The temperature dependence of magnetization taken in zero-field-cooling and field-cooling conditions showed the features of superparamagnetic system in films annealed at  $700^\circ\text{C}$ – $900^\circ\text{C}$ . The magnetization curves at 5 K for samples annealed at  $700^\circ\text{C}$ – $900^\circ\text{C}$  exhibits ferromagnetic hysteresis loops, and the highest residual magnetization ( $M_R$ ) and coercivity ( $H_c$ ) of  $M_R = 1.5 \times 10^{-4} \text{ emu/g}$  and  $H_c = 107 \text{ Oe}$  were found in the  $800^\circ\text{C}$  annealed sample. XPS measurement showed the metallic Co  $2p$  core levels and the metallic valence band spectra for as-implanted and  $700^\circ\text{C}$ – $900^\circ\text{C}$  annealed samples. From these, it could be explained that the magnetic property of our films originated from Co and CoGa magnetic clusters.

**Index Terms**—Ion implantation, magnetic semiconductor.