Reduction of Leakage Current Through Interface Between Ga_2O_3 Epitaxial Layer and Substrate by Mg/Fe Implantation

○Sandeep Kumar, Takafumi Kamimura, Chia-Hung Lin, Yoshiaki Nakata, Masataka Higashiwaki

National Institute of Information and Communications Technology

E-mail: sandeep@nict.go.jp, mhigashi@nict.go.jp

Ga_2O_3 field-effect transistors (FETs) have shown tremendous potential for their possible applications in the field of power and RF electronics. Recently, a technical problem with Ga_2O_3 epitaxial structures that unwanted Si impurities accumulate at an interface between the epitaxial layer and the substrate is often discussed. This phenomenon results in formation of undesirable leakage current path in a buffer layer of the Ga_2O_3 FET, leading to poor turn-off and breakdown characteristics. In this work, we attempted to address the interface leakage issue by means of Mg- or Fe-ion implantation doping into Ga_2O_3 native substrates for compensation of the unintentionally doped (UID) Si donors prior to the subsequent epitaxial growth and succeeded in significantly reducing the interface leakage current by the Fe implantation.

We prepared a total of four samples with two different dopants (Mg or Fe) and two different densities (2×10^{18} or 2×10^{19} cm^{-3}). First, Mg or Fe ions were blanket implanted into a near-surface region of a semi-insulating Ga_2O_3 (010) substrate, followed by annealing at 950°C for 30 min in N_2 to recover crystal damage caused by the implantation process and activate the implants. Then, a UID Ga_2O_3 layer with a target thickness of 1.2 μm was grown on the Mg- or Fe-implanted Ga_2O_3 substrate by ozone molecular bean epitaxy (MBE). Ohmic electrodes with specific contact resistances of less than 1×10^{-5} $\Omega\cdot cm^2$ were fabricated on the MBE-grown UID Ga_2O_3 layer by processes of high-density Si-ion implantation doping, activation annealing of the implanted Si donors at 950°C, Ti/Au deposition, and rapid thermal annealing at 470°C. Test structures with circular ohmic metal pads as shown in Figs. 1(a) and (b) were used for electrical conductivity measurement. Two-terminal current–voltage (*I*–*V*) characteristics of the Mg- and Fe-implanted samples are presented in Fig. 2. Irrespective of the doping density, both the Mg-implanted samples revealed relatively large leakage current of over 1 mA/mm at ±5 V. A similar level of leakage current to those of the Mg-doped samples was observed for the sample with Fe=2×10^{18} cm^{-3}; on the other hand, the sample with Fe=2×10^{19} cm^{-3} exhibited about four orders of magnitude lower leakage current than those of the other three samples. These results could be due to a difference in the implant density distribution around the interface that was confirmed by secondary ion mass spectrometry.

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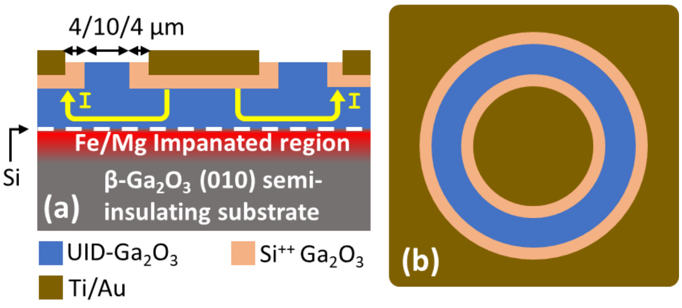

Fig. 1 (a) Cross-sectional and (b) plan-view schematics of test structures. Si at the interface and current flow through the interface are shown with a white dashed line and yellow arrows, respectively.

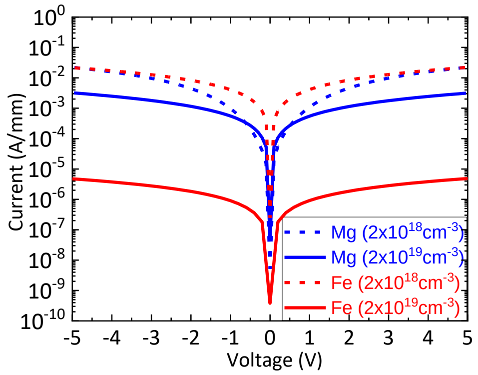

Fig. 2 *I*–*V* characteristics of Mg- and Fe-doped samples.