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Characterizations of fluoridated GaAs surface under remote SF_6 plasma

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Although the advantage of using GaAs metal insulator semiconductor field effect transistors (MISFETs) for high-speed and low-power consumption integrated circuit applications has been known for about 30 years, there are only a few reports of actual inversion layers in a GaAs surface. Recently, epitaxial growth of group IIA fluoride(CaF_2 and SrF_2) films on GaAs substrates by MBE has been reported. However, electrically and chemically stable insulators fabricated on GaAs substrates have not been obtained despite the use of various technologies, such as thermal, plasma, chemical oxidation, and deposition techniques. In this study, some fluoridation characteristics of a GaAs surface obtained using a new remote plasma flooridation technique with SF_6 gas. The advantage of SF_6 gas over fluorine are nonflammability, nontoxicity and simplicity of the process.

The fluoridation experiments were performed at temperatures ranging from 270 ℃ to 300 ℃ and at an operating pressure of 0.6 Torr. Highly doped p^+-type GaAs(100) wafers were employed for calculation of the dielectric constant. The wafers were cleaned in organic solvents and dipped in an $(NH_4)_2S_x$ solution for 15 minutes to passivate the GaAs surface in order to reduce the surface contamination due to oxygen. The chemical composition and existence of some elements in the films were studied by RBS and SIMS. The thickness and refractive indices of the films were measured using ellipsometry at a wavelength of 632.8 nm. The electrical properties of the film were determined from the current-voltage(I-V) and capacitance-voltage characteristics of Al-fluoride-GaAs(MIS) capacitors fabricated by thermal evaporation of Al. The gate area was 3.5×10^{-4} cm^2.

Fig. 1 shows the relationship between film thickness and fluoridation time for three temperatures. Fig. 2 shows the RBS spectra of untreated GaAs wafer and a fluoridaed sample. As shown in Fig. 2, the composition of F:Ga of the film was estimated to be about 3.0(that is , GaF_3) and no sulfur from SF_6 was detected by RBS and SIMS. Fig. 3 shows the C-V characteristics of MIS capacitors with fluoridated film on Si-doped GaAs(100) substrate fabricated at 285 ℃ measured at 1 MHz. The C-V curve indicates accumulation implies that the Fermi level is not pinned in the upper half of the band gap. It is also shown that C-V curves were shifted in the positive direction from the ideal curve indicating a carrier injection type of hysterisis.

We have demonstrated that gallium fluoride films can be grown by the RF remote SF_6 plasma fluoridation of GaAs(100) at temperature below 300 ℃. RBS and SIMS showed that the

GaF_3 films had almost stoichiometric composition while sulfur and arsenic fluoride were not detected in the fluoridated films. The as-grown films exhibited a current density of less than 1 uA/cm^2 and a resistivity of more than 5×10^{12} Ω-cm at a breakdown field of 1MV/cm. The refractive index of as-grown films was 2.0~2.3, and the typical value of the dielectric constant was about 5.5 as derived from 1 MHz C-V measurements. The minimum interface state density is estimated to be around 1×10^{12} $cm^{-2}\cdot eV$.

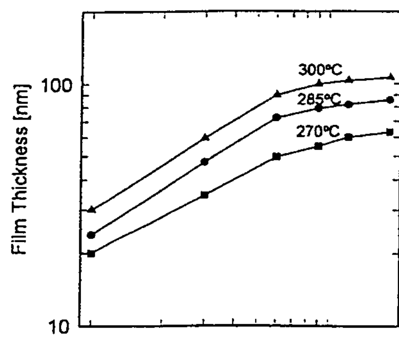

Fig. 1. Film thickness vs fluoridation time for film obtained at three temperatures using 200 sccm of SF_6 gas at a pressure of 0.6 Torr, and a power of 50W.

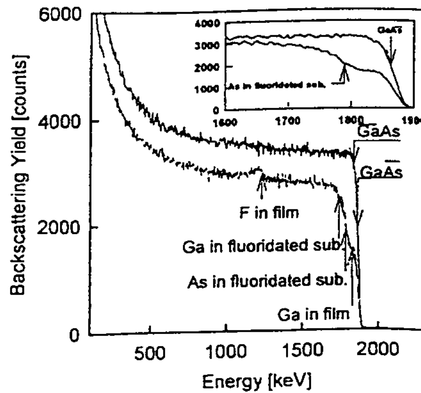

Fig. 2. RBS spectra of a fluoridated sample (lower) and untreated GaAs wafer(upper).

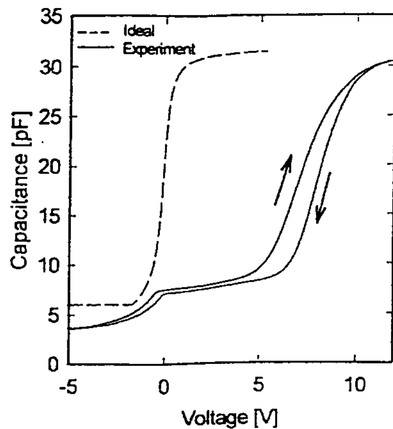

Fig. 3. 1 MHz C-V characteristics of a MIS capacitor. The dashed curve shows an ideal high-frequency characteristic.(thickness : 54 nm, capacitor area : 3.14×10^{-4} cm^2, substrate carrier concentration : 5.8×10^{15} cm^{-3}).