Low Interface State Density SiO$_2$ on InP by Indirect Plasma CVD with Phosphorous Stabilization

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In order to achieve a stable operation of InP-MISFET, high quality surface passivation is strongly required. Indirect Plasma CVD has been expected to get insulator/semiconductor interfaces with low state density, since utilization of neutral activated species can eliminate the bombardment effects of energetic particles. In this study, the source gas of SiH$_4$ was found to be decomposed effectively by neutral activated oxygen generated in microwave plasma, and high quality SiO$_2$ was achieved at low temperatures of 300-400°C. The electronic properties of SiO$_2$/InP interfaces could be improved very much by supplying phosphorous vapor pressure during deposition processes, which yielded excellent performances of InP-MISFET.

The features of an experimental apparatus were described elsewhere[1]. High density oxygen plasma was generated by microwave (2.45GHz) power of 100W at pressures of 0.1-3Torr. Plasma probing analysis revealed that electrons and ions were confined in the plasma region, and no charged particles existed in a preparation chamber. Phosphorous (P) vapor pressure was supplied utilizing sublimation of red P heated in a small quartz tube connected to a preparation chamber. The relative amount of introduced P was monitored by mass spectroscopy.

The source gas of SiH$_4$ was introduced into a preparation chamber, and it was found that SiH$_4$ was not decomposed by plasma directly. The activated oxygen species have long diffusion length of 30-50cm, and can diffuse far away from the plasma region[2]. By mass-spectroscopy, the peaks of SiH$_n$(n=0-3) decreased when the activated oxygen was introduced, which showed that SiH$_4$ reacted with the neutral activated oxygen. The resistivity and the breakdown field of SiO$_2$ deposited at 300-400°C were 10$^{16}$ $\Omega$ cm and 10 MVcm$^{-1}$, respectively, which were comparable to those of the thermally grown SiO$_2$.

Electronic properties of SiO$_2$/InP interface were analyzed using Al/SiO$_2$/n-InP MIS diodes. Typical capacitance-voltage characteristic is shown in Fig.1 when P vapor pressure was supplied during deposition. The hysteresis width was as narrow as 1 V. The deposited SiO$_2$ included P in a content of about 10 at%, which might prevent P vacancy generation at the interface. The minimum interface state density $N_{ss}$ decreased from 4.5x10$^{11}$ to 2.7x10$^{11}$ eV$^{-1}$cm$^{-2}$ with P stabilization as shown in Fig.2. Further improvement was obtained introducing surface oxidation process by activated oxygen under P vapor pressure before SiO$_2$ deposition. Creation of native oxide[3] of InP was revealed by Auger electron spectroscopy, and the lowest $N_{ss}$ of 1.9x10$^{11}$ eV$^{-1}$cm$^{-2}$ was achieved (Fig.2). On semi-insulating InP, MISFET was fabricated whose $n^+$ source and drain regions were made by ion implantation of Si$^+$. Gate length and width was 20 and 500 $\mu$m. The effective mobility $\mu_{eff}$ and transconductance $g_m$ increased with decreasing $N_{ss}$ (Fig.3), and excellent results of as high as $\mu_{eff}$=2560 cm$^2$V$^{-1}$sec$^{-1}$ and $g_m$=10mSmm$^{-1}$ were obtained. Utilization of neutral activated oxygen to get high quality SiO$_2$ is useful to fabricate MISFET's with high performances.
References

Fig. 1
Typical capacitance-voltage characteristic of n-InP MIS diodes using SiO2 deposited with P vapor pressure.

Fig. 2
Interface state density between SiO2 and n-InP.
(a) Deposited without P pressure.
(b) Deposited with P pressure.
(c) Insertion of native oxide between SiO2 and InP.

Fig. 3
Effective mobility and transconductance of InP-MISFET as a function of minimum interface state density.