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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 effetcs 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 phosphrous vapor pressure during deposition processes, which yielded excellent performances of InP-MISFET.

The features of an experimental apparatus were described in elesewhere[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 exsisted in a preparation chamber. Phosphrous (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} Ω 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}min 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}min 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 μm. The effective mobility μ_{eff} and transconductance g_m increased with decreasing N_{ss}min (Fig.3), and excellent results of as high as μ_{eff}=2560 $cm^2V^{-1}sec^{-1}$ and g_m=10$mSmm^{-1}$ were obtained. Utilization of neutral activated oxygen to get high quality SiO_2 is useful to fabricate MISFET's with high performances.

References

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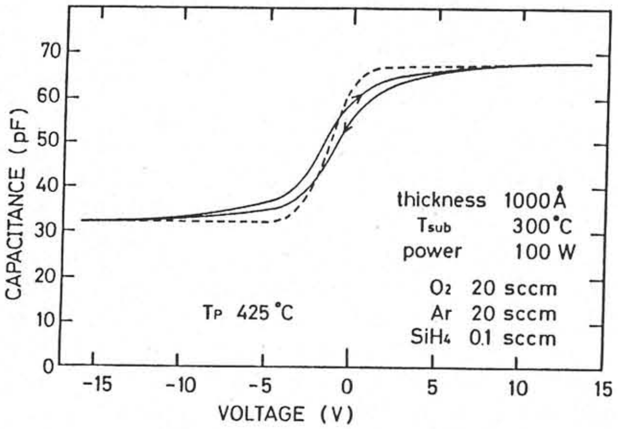

Fig.1

Typical capacitance-voltage characteristic of n-InP MIS diodes using SiO_2 deposited with P vapor pressure.

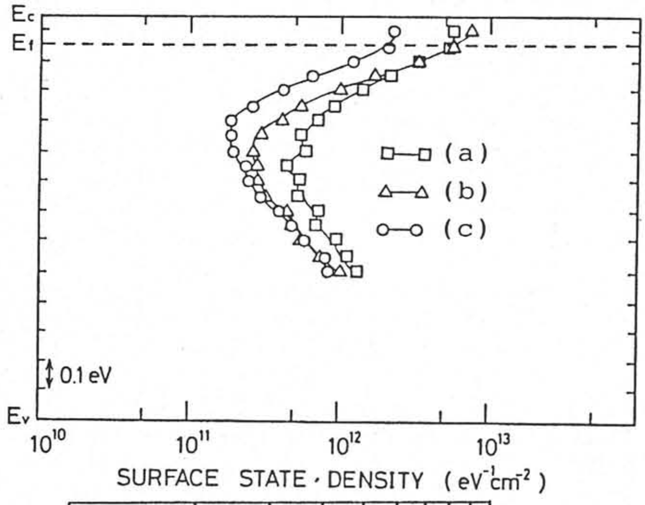

Fig.2

Interface state density between SiO_2 and n-InP.
(a)Deposited without P pressure.
(b)Deposited with P Pressure.
(c)Insertion of native oxide between SiO_2 and InP

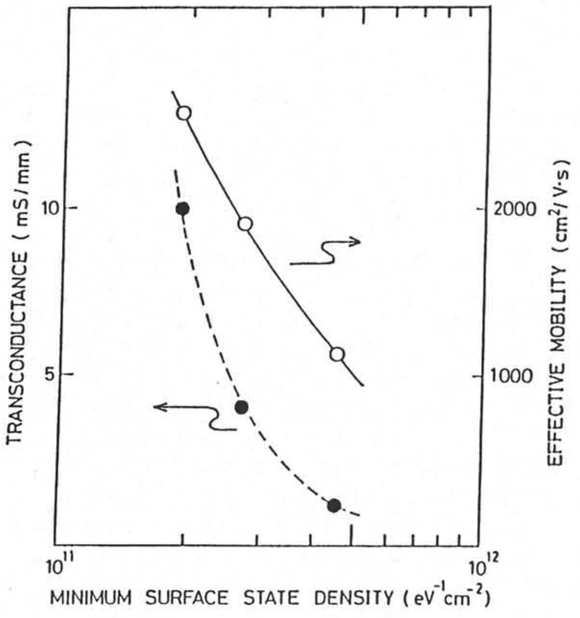

Fig.3

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