Chemical Vapor Deposition and Characterization of
Phosphorus-Nitride (P₃N₅) Gate Insulator for An Inversion-Mode InP MISFET
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A new gate insulating film consisting of P₃N₅ was formed on an InP surface by a new CVD technique. This film is characterized by a constituent V column atom (P) which is also the constituent atom of the semiconductor substrate and by an oxygen-free compound. Very high resistivity (5x10¹⁵Ω·cm), ohmic conduction at the electric field intensity up to 8x10⁶V/cm, surface state density as low as 2x10¹²/cm²·eV near the conduction band edge, and passivation effect to any alkaline and acid etchants are the characteristic features of the new insulating film. This paper demonstrates the P₃N₅ CVD technique, the deposition temperature effect, the MIS interface and MISFET characteristics.

After in-situ HCl vapor etching for elimination of InP native oxide layer¹, the reagents (PH₃(10% in N₂):NH₃=1:1) are introduced to the reactor system with three temperature zones as shown in Fig.1. Spatial separation of the deposition zone (Temperature:T₃) from the P₃N₅ synthesis zone (T₄) was effective to prevent the substrate thermal degradation, since it requires very high temperature above 860°C to obtain P₃N₅. The T₄ only affected the film deposition rate (90Å/hr at 860°C and 800Å/hr at 900°C). On the other hand, the change in T₃ resulted in remarkable changes in the quality of the insulating film and MIS interface characteristics.

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Fig.1. Temperature profile for P₃N₅ CVD.

Fig.2. J-E curves of P₃N₅ CVD film.
Coexistence of the ohmic conduction (for lower $E$) and Poole-Frenkel (higher $E$) conduction is seen in the $J-E$ curves (Fig. 2). The maximum field intensity $E_0$ for which the ohmic conduction dominates increases with $T_D$ up to $500-550^\circ C$. Further increase in $T_D$, however, decreases $E_0$. Highest $E_0$ of $8 \times 10^6 V/cm$ was obtained for $T_D=500-550^\circ C$. It should be noted that, in the conventional CVD films on III-V compounds, Poole-Frenkel conduction covers the almost entire range of applied field.

The surface state density distribution, $N_{SS}$, over the band gap was estimated from 1 MHz C-V curve by using Terman method. Reduction of $N_{SS}$ distribution was monotonic with lowering $T_D$ (Fig. 3). $N_{SS}$ value of $2 \times 10^{12}/cm^2\cdot eV$ is one order of magnitude lower than that of CVD Al$_2$O$_3$-InP interface. The other effect of $T_D$ on $N_{SS}$-Energy curve is a deformation of the so-called V shaped distribution: The curve became flatter with increased $T_D$.

An n-channel inversion-mode InP MISFET was fabricated by using 700 Å thick $P_3N_5$ gate insulator (Fig. 4). The effective electron mobility measured on this device was $1000-1640$ cm$^2/V \cdot $sec.

At the conference, the drifting behavior of the MISFET and $\mu$-wave characteristics will be also presented.

References