B—6—3 Chemical Vapor Deposition and Characterization of Phosphorus-Nitride (P_3N_5) Gate Insulator for An Inversion-Mode InP MISFET

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A new gate insulating film consisting of P_3N_5 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 ($5\times10^{15}\Omega$ cm), ohmic conduction at the electric field intensity up to 8×10^{6}V/cm, surface state density as low as $2\times10^{12}/cm^2$.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 P_3N_5 CVD technique, the deposition temperature effect, the MIS interface and MISFET characteristics.

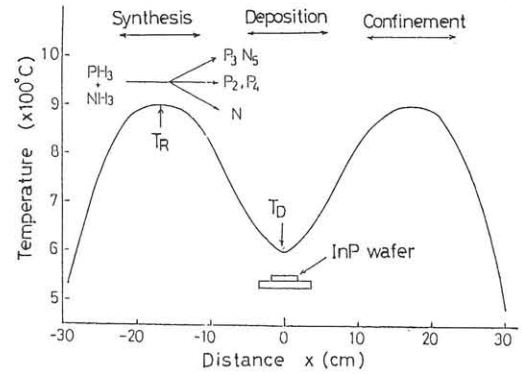

Fig.1. Temperature profile for P_3N_5 CVD.

After in-situ HCl vapor etching for elimination of InP native oxide layer[1], the reagents (PH_3(10% in N_2):NH_3=1:1) are introduced to the reactor system with three temperature zones as shown in Fig.1. Spatial separation of the deposition zone (Temperature:T_D) from the P_3N_5 synthesis zone (T_R) was effective to prevent the substrate thermal degradation, since it requires very high temperature above 860°C to obtain P_3N_5. The T_R only affected the film deposition rate (90Å/hr at 860°C and 800Å/hr at 900°C). On the other hand, the change in T_D resulted in remarkable changes in the quality of the insulating film and MIS interface characteristics.

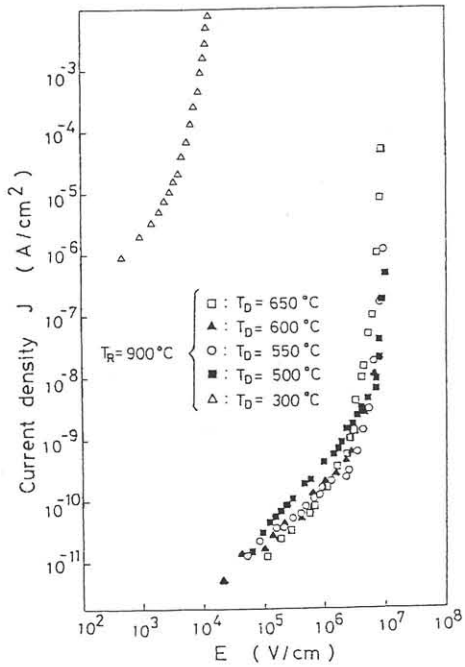

Fig.2. J-E curves of P_3N_5 CVD film.

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°C . Further increase in T_D, however, decreases E_0. Highest E_0 of 8×10^6 V/cm was obtained for T_D=500-550°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 2×10^{12}/cm^2·eV is one order of magnitude lower than that of CVD Al_2O_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.

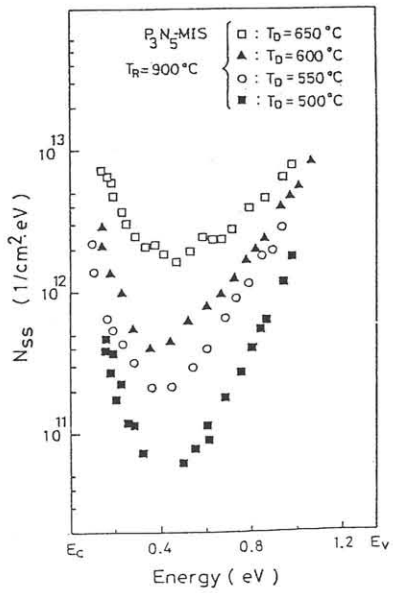

Fig.3. Surface state density distribution.

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·sec.

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

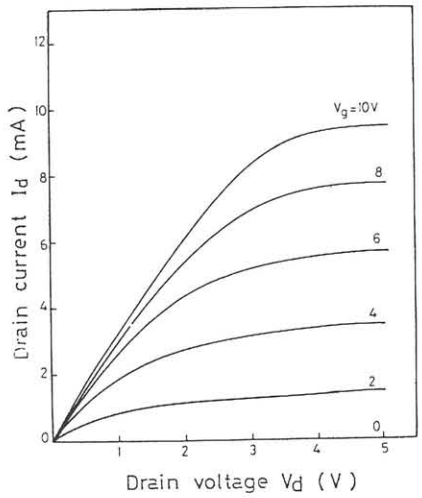

Fig.4. Drain current I_d vs drain voltage V_d.

References

1) Y. Hirota, M. Okamura and T. Kobayashi, J.Appl.Phys. 53,539 (1982).

2) D. L. Lile, D. A. Collins, L. G. Meiners, and L. Messik, Electron. Lett. 14, 657 (1978).