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SEMI-INSULATING POLYCRYSTALLINE SILICON (SIPOS) FILMS APPLIED TO MOS INTEGRATED CIRCUITS

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Semi-Insulating Polycrystalline Si (SIPOS) films grown by the chemical vapor reactions of N_2O and SiH_4 in nitrogen ambient were investigated, and showed various applicable properties to the semiconductor devices. The semiconductor surfaces passivated with SIPOS films are very stable under bias-temperature stress and have high parasitic threshold voltages for both N- and P-type Si substrates in the structure of Metal-Oxide-SIPOS-Si. SIPOS films were applied to the passivation of C/MOS-ICs and the integrating density was improved as a result of removing channel stopper regions and the electrical stabilities were also improved. In this paper, the growth and properties of SIPOS films and the proposal about a new passivation technology of MOS-ICs are described.

The growth and properties of SIPOS films. SIPOS films are grown by chemical vapor reactions of N_2O and SiH_4 in nitrogen ambient over the temperature range 600 to 700°C. Fig.1 shows the oxygen concentration and the depositin rate of SIPOS films as a function of the flow-rate ratio of N_2O to SiH_4 gas. The oxygen concentration in SIPOS films can be precisely controlled by changing $(N_2O)/(SiH_4)$ ratio. Electron microscopy reveals that the grain size of SIPOS films is about ~ 100, 200~300, and 500~ 600 Å, corresponding to the growth temperature 600, 650, and 700°C, respectively, and become amorphous-like with increasing the oxygen concentration. Fig.2 shows the infrared transmission spectra of SIPOS films for various oxygen concentrations before and after annealing. Before annealing, the absorption peak due to Si-O stretching bonds shifts from 10.0 to 9.6 μm with increasing the oxygen concentration, which indicates that the films contain SiO, Si_2O_3, or something between the two. After annealing at 1100°C for 60 min. in nitrogen ambient, the absorption peak shifts to 9.3 μ m corresponding to the absorption of the SiO_2 bonds.

Electrical resistivities of undoped and boron(or phosphor)diffused SIPOS films are shown in Fig.3, and electrical conductivities of undoped SIPOS films are shown in Fig.4 as a function of reciprocal temperatures. The electrical resistivities of undoped SIPOS films can be controlled over the range 10^7 to 10^{10} (ohm-cm) by changing the oxygen concentration, so that SIPOS films have applicable characteristics as high resistive materials or semi-insulating materials. By the diffusion of boron or phosphor into SIPOS films, the electrical resistivities lower to $10^{-3} \sim 10^{-1}$ (ohm-cm), so that impurity diffused SIPOS films are applicable to the gate electrode, or the wiring materials of the MOS integrated circuits.

Basic electrical characteristics for passivation films are examined by using Metal-Oxide-SIPOS-Si structure. Fig.5 shows the C-V characteristics of M-O-SI.-Si capacitors. The inversion layers are not induced in the surface region of both N- and P-type Si under rather strong electric field. Fig.6 shows the temperature dependence of the leakage current of the reverse biased drain junctions. Values of the leakage current are relatively large compared with that of the junctions passivated with SiO_2, but it can be said that SIPOS films are satisfactorily applicable to the passivation of MOS devices for practical use. Fig.7 shows the stabilities under bias-temperature stress, and SIPOS films show excellent passivating effects.

Application to C/MOS-ICs. The cross sectional view of C/MOS-inverter passivated with SIPOS films is shown in Fig.8. The integrating density is improved because C/MOS-ICs passivated with SIPOS films need no channel stopper regions in both P-well and N-type Si substrate. The characteristics about input frequency vs. maximum operating voltage of the dynamic gate type C/MOS flip-flop circuits are examined, and the effects of leakage current on the electrical characteristics of C/MOS-ICs are shown in Fig.9.

The mechanisms of the leakage current and its infuluences on the electrical characteristics of C/MOS-ICs will be discussed in detaile.

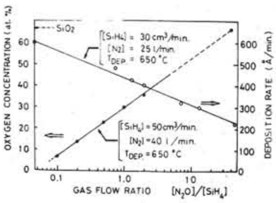

Fig.1 Oxygen concentration and deposition rate of SIPOS films vs. gas flow ratio $(N_2O)/(SiH_4)$.

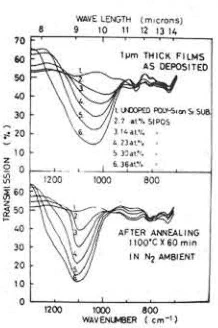

Fig.2 Infrared transmission spectra of 1 m thick SIPOS films before and after annealing

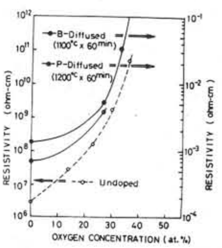

Fig.3 Electrical resistivities of both undoped and boron (or phosphor) diffused SIPOS films.

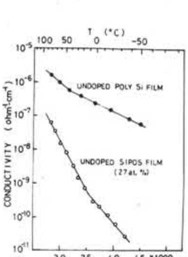

Fig.4 Electrical conductivities of undoped SIPOS films vs. 1/T.

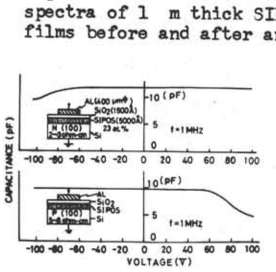

Fig.5 C-V characteristics M-O-SIPOS-Si capacitors.

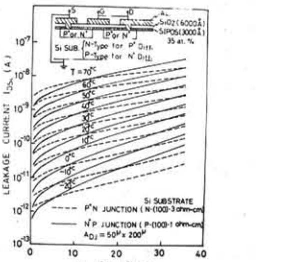

Fig.6 Temperature dependense of the leakage current of the reverse biased drain junctios of M-O-SIPOS-Si FET.

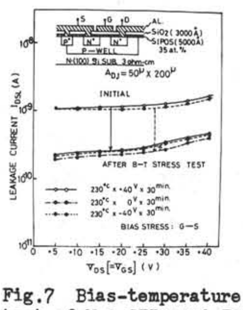

Fig.7 Bias-temperature stress test of M-O-SIPOS-Si FET.

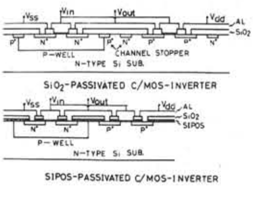

Fig.8 The cross sectional view of the C/MOS inverter passivated with SIPOS films.

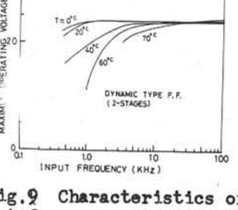

Fig.9 Characteristics of input frequency vs. maximum operating voltage of the C/MOS dynamic gate type Flip-Flop.