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Anodic Oxidation of GaAs in Oxygen Plasma

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§1. Introduction

Insulator films with good dielectric and interface properties on GaAs surface are requested for surface passivation of GaAs devices, gate insulators of GaAs MIS devices and also planar technology in GaAs IC process. Thermal oxidation,(1) anodic oxidation in electrolyte(2) are commonly used for forming insulators on GaAs. Here we report a new low temperature oxidation process, that is, anodic oxidation in oxygen plasma.

§2. Experimental

The schematic diagram of the plasma anodization apparatus is illustrated in Fig. 1. The oxygen plasma (electron density $\simeq 10^{12}$ cm^{-3}, gas temperature $\simeq$1000 °C) is produced by high frequency (420KHz) electrodeless discharge in oxygen, whose pressure is about 0.1 - 0.4 Torr. GaAs wafer (mechano-chemically polished), to be oxidized, was etched by the mixture of H_3PO_4, H_2O_2, and H_2O whose volume ratio was 7 : 3 : 50, and was mounted on a quartz plate located below the center of the oxygen plasma at a distance of 10 cm at least in order to keep sample temperature below 200°C. The chip temperature in terms of the wafer position from the plasma generating region is illustrated in Fig. 2. The sample was biased at 10 - 200 V positive with respect to the plasma with a pair of Pt electrodes. Anodization can be done in either a constant-voltage or a constant-current mode.

§3. Results

These oxide films are easily dissolved in HCl or NaOH, uniform and glassy, and the thickness was measured by Tolansky method.

In the constant-voltage mode, the oxide film thickness is saturated after about one minute as shown in Fig. 3, and the sample current decreases with time. The saturated oxide thickness is approximately linear with the bias voltage, as far as for low voltages, and this slope is about 42 Å/V as shown in Fig. 4. When the bias voltage is higher than 60 V, the oxide film locally breaks down and the oxide thickness is not saturated with oxidation time, and becomes non-uniform. The oxidation rate and the saturated thickness depend on doping level and surface orientation of samples, plasma conditions and positions of samples.

In the constant-current mode, the oxide flim thickness is approximately in proportion to the oxidation time as shown in Fig. 5. The oxidation rate is about 9 Å/s when current density is about 8 mA/cm^2, and current efficiency is about 10%.

Electrical properties of these oxide films were evaluated by I-V, C-V, G-V characteristics of MOS structures. The resistivity and breakdown field strength are higher than $10^{12}\Omega$ cm and 10^6 V/cm, respectively. Typical C-V and G-V curves are shown in Fig. 6. These show the injection-type hysteresis and large frequency dispersion of accumulation capacitance.

§4. Conclusion

Anodic oxidation of GaAs in oxygen plasma has been carried out even at the room temperature and results a glassy film with uniform thickness over the whole chip.

Electrical properties of the film measured by MOS technique is still to be improved, but this technique is quite useful for forming an insulator film on GaAs surface.

References

(1) F. Koshiga & T. Sugano: Proc. 8th Conference on Solid State Devices, Tokyo, 1976 p. 465

(2) H. Hasegawa & H. L. Hartnagel: J. Electrochem. Soc. 123, 713 (1976)

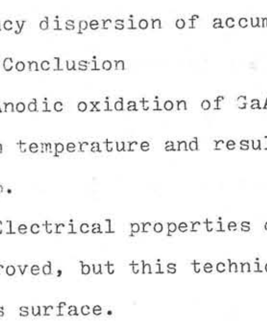

Fig.1. Schematic diagram of plasma anodization apparatus.

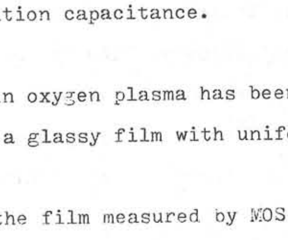

Fig.2. Chip temperature after two minutes vs. position from center of plasma.

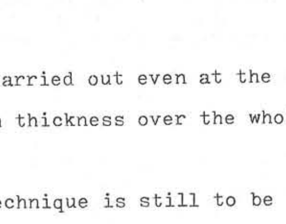

Fig.3. Oxide thickness vs. oxidation time in constant voltage mode.

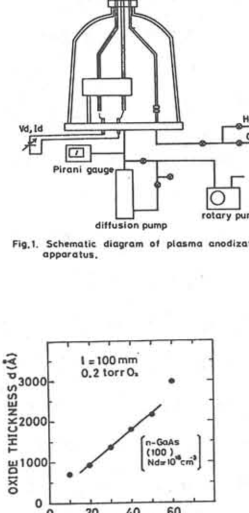

Fig.4. Saturated oxide thickness vs. bias voltage in constant voltage mode.

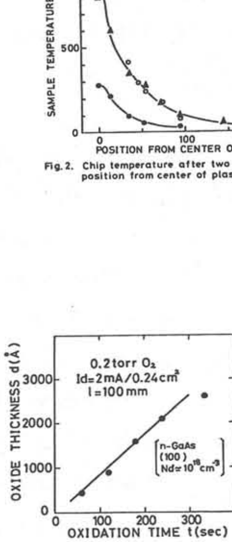

Fig.5. Oxide thickness vs. oxidation time in constant current mode.

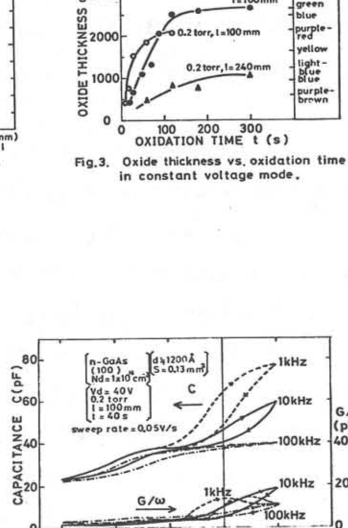

Fig.6. Typical C-V, G-V curves of MOS diode as a function of frequency.