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A—5—2 LOW TEMPERATURE SILICON NITRIDE DEPOSITION USING MICROWAVE-EXCITED ACTIVE NITROGEN

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A new silicon nitride deposition technology has been developed using a microwave excitation (2.45GHz) instead of the conventional rf discharge (13.56MHz) (1,2) and applied to a passivation film for LSI. The deposition method is one of applications of the microwave plasma etching method which was previously reported(3).

The experimental apparatus is shown in Fig. 1. Active nitrogen is produced by the microwave excitation (power; 680 watt) of N_2 alone in a quartz tube through a waveguide. The microwave excitation enables us to obtain a stable discharge for higher pressure of N_2 as compared with rf discharge. Active nitrogen and SiH_4 are carried through the different tubings into the deposition chamber, which is exhausted by a mechanical vacuum pump (950 l/min). The silicon nitride film is deposited on 3-inches wafers on a heating stage (from 50°C to 350°C) by a reaction between active nitrogen and SiH_4 in the chamber.

Recently, the similar method to the present one was reported by using SiI_4 instead of SiH_4(4).

The films were deposited at 350°C, as otherwise stated. A pyrolytic silicon nitride film (Si_3N_4) as a reference material was deposited by thermal decomposition of SiH_4 and NH_3 at 790°C. We used 1%, 3%, 12% and 20% SiH_4 diluted by N_2.

In Fig. 2, the growth rates of the film for the different concentrations of SiH_4 are plotted as a function of nitrogen concentration, $R_p = P_{N_2}/P_{SiH_4}$, where P_{N_2} and P_{SiH_4} are the partial pressure of N_2 and SiH_4, respectively. The growth rate increases with increase in R_i and the concentration of SiH_4.

Figure 3 shows dependence of refractive index (R_i) on R_p for the different concentrations of SiH_4. R_i shows maxima at R_p =1.5, 6 and 9 for 1%, 3% and 12% SiH_4, respectively, and decreses rapidly with increse in R_p, while R_i tends to saturate for 20% SiH_4. Maximum value of R_i is 1.95 (R_i of pyrolytic Si_3N_4 film is about 2.0).

Infrared spectra shows their typical absorption peak of Si-N bond around 850 cm^{-1}, which coincides with that of pyrolytic Si_3N_4. The absorption peak at 850 cm^{-1} is broader, as the deposition temperature is lower. Consequently, the films prepared by the present method under the typical condition is confirmed to be the silicon nitride.

Figure 4 shows Arrhenius plots obtained in the temperature range from 50°C to 350°C. The plots show two regions of different slope. The activation energies of reaction between active nitrogen and SiH_4 are 0.6 Kcal/mole in a range from 150°C to 350°C and 2.3 Kcal/mole in a range from 50°C to 150°C, respectively. The low activation energies imply that the deposition is limited by gas supply. The uniformity depends on the flow direction of active nitrogen and SiH_4.

A weak, visible luminescence has been observed during deposition in the chamber. As shown in Fig. 6, a spectrum of the luminescence shows the broad band characteristic in a wave-length range from 400 nm to 800 nm and the line spectra below 430 nm. The line spectra below 400 nm were assigned to the emissions from silicon atoms. Some of those in a range between 400 nm and 430 nm were emissions from nitrogen atoms. It is concluded that SiH_4 is dissociated into silicon atoms by reaction with active nitrogen in gas phase at room temperature.

This silicon nitride film shows a good blocking effect against Al corrosion. The film was deposited on Al patterns with 6 μ spacing. Stress testing was performed at 85°C with relative humidity of 85% and biasing voltage of 20 volts between two Al-stripes. Al corrosion was not observed after 24 hours.

References

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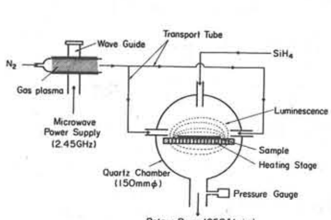

Fig.1. Schematic diagram of the deposition apparatus.

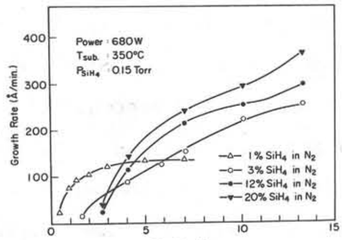

Fig.2. Growth rate as a function of $R_p=P_{N_2}/P_{SiH_4}$ for different concentration of SiH_4.

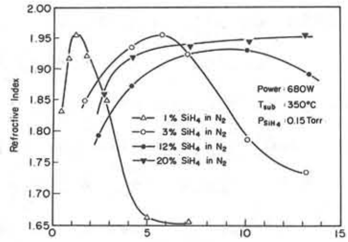

Fig.3. Refractive index (R_i) as a function of $R_p=P_{N_2}/P_{SiH4}$ for different concentrations of SiH_4.

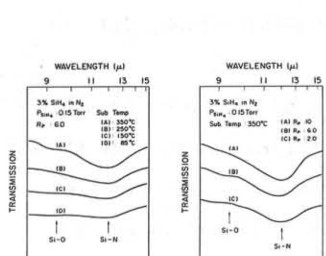

Fig.4. Transmission spectra of the films which were grown at different temperatures and R_p.

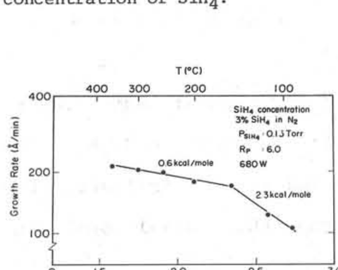

Fig.5. Temperature dependence of growth rate of the silicon nitride.

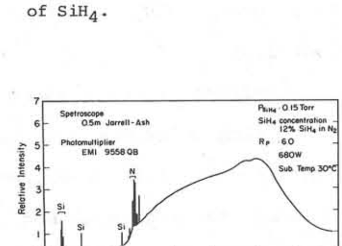

Fig.6. Emission spectrum from reaction between SiH_4 and active nitrogen.