Digest of Tech. Papers *The 11th Conf. (1979 International) on Solid State Devices, Tokyo*

A—1—9 Deposition of Silicon Nitride Films by High Rate Reactive Sputtering

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Silicon nitride, because of its high thermal and chemical stability, is attractive for use in passivating semiconductor surfaces. Then, we have silicon nitride films of high quality at a high deposition rate without the extreme rise of the substrate temperature by reactive sputtering using a planar magnetron type[1] of sputtering apparatus. The preparatory conditions, structure and optical, mechanical and electrical properties of the films will be briefly presented.

Figure 1 shows the arrangement of the sputtering apparatus used in this work. The electromagnet in the vacuum chamber is used to apply magnetic field parallel to the target surface. Another magnetic coil placed out of the vacuum chamber is used to control the strength of the magnetic field in the neighborhood of the end of the target, which is disk in diameter of 3 inches single crystal silicon. The specimen films 1000~6000 Å thick were formed on the substrates of Si wafers or slide glasses by sputtering in the atmosphere of argon-nitrogen mixture of total gas pressure P_t maintained in the vicinity of 8 mTorr. The partial nitrogen pressure P_{N_2} was varied between 1 and 8 mTorr.

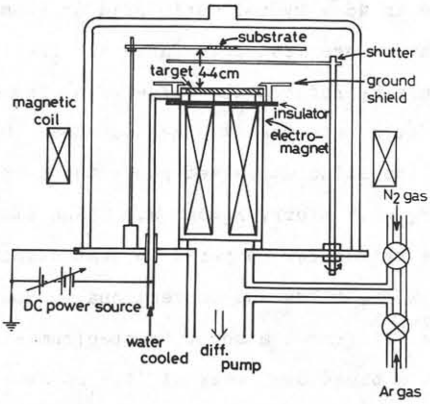

Fig. 1 The arrangement of planar magnetron sputtering apparatus.

Figure 2 shows dependence of the deposition rate R_d on P_{N_2} in the case of target power E_i of 350 W. Rd decreased with increasing P_{N_2} abruptly over the range of 4~5 mTorr. When reactive sputtering occured and some of the nitrogen gas entered into the films, P_t droped markedly. The dependence of R_d and the reduction of gas pressure ΔP_t on E_i are shown in Fig.3. R_d and ΔP_t increased almost in proportion to E_i. R_d in the case of E_i=880 W was about 1900 Å/min, of which value was higher

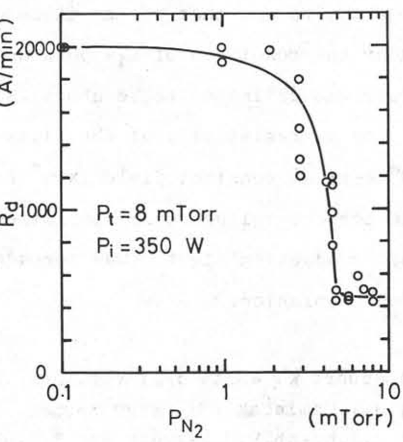

Fig. 2 Dependence of deposition rate R_d on partial nitrogen pressure P_{N_2}.

than that of plasma CVD and was about 10 times as high as that of conventional diode sputtering.

X-ray diffraction study showed that all the obtained films were amorphous. The transmittance spectra of the films deposited on slide glasses are shown in Fig.4. The absorption edge shifted to higher energies with increasing P_{N_2} and E_i. The films deposited at P_{N_2} above 4.8 mTorr seemed to be transparent.

The refractive index n and the etch rate in 48 % hydrofluoric acid at room temperature are listed in Table 1. The increase E_i reduced the value of n. The minimum etch rate was attained to about 40 Å/min for the films deposited under the condition of P_{N_2}=6.5 mTorr, P_i=360 W. These etch rate were rather low compared to that obtained on CVD Si_3N_4 films and conventionally sputtered ones.[2~4] Infrared absorption spectrum exhibited a broad Si-N peak at 11.5 µm and did not change significantly with the E_i and P_{N_2}. The stress latent in the films was compressive and that of the films deposited under the condition of E_i=350 W and P_{N_2}=6.5 mTorr was estimated to be about 2×10^9 dyn/cm^2.

The dc resistivity of the films was about 10^{16} Ω-cm at constant field 2×10^6 V/cm and the current-voltage characteristics showed that conduction might occur through Frenkel-Poole emission.[5]

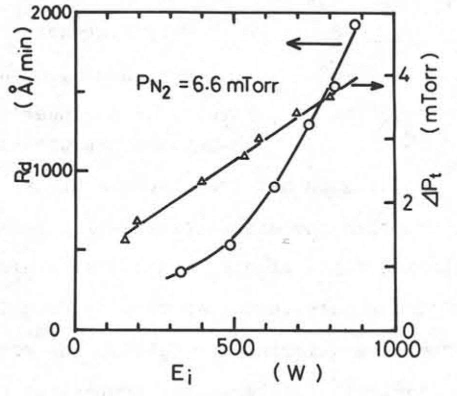

Fig. 3 Dependence of Rd and Pt on target power E_i.

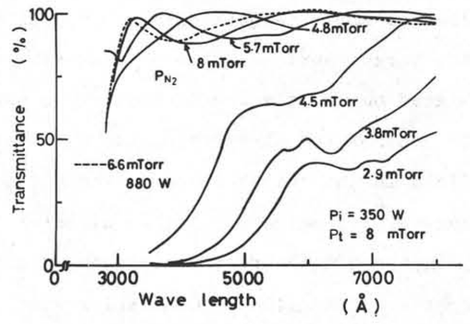

Fig. 4 Transmittance of the silicon nitride films deposited on slide glass.

Table 1

P_{N_2} (mTorr)	E_i (W)	n at λ = 6328Å	etch rate in 48 % HF (Å/min)
4.5		2.14	600
4.8		2.05	42
5.7	350	2.06	66
6.6		2.10	40
8.0		2.09	70
	360	2.10	40
6.6	530	2.06	85
	820	2.03	115

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