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B—6—1 Preparation and Characterization of Reactively-Sputtered Amorphous Si:H Films*

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Introduction What is the essential difference in properties between glow-discharge amorphous Si:H films (GD-a-Si) and reactively-sputtered ones (SP-a-Si)? Presumably no one gives a clear answer because SP-a-Si[1,2] has not yet been well characterized compared with GD-a-Si[2,3,4]. The purpose of this report is to present the first systematic map of the structural and electronic properties of SP-a-Si film for various deposition conditions and to point out the strong correlation between both properties in connection with those of GD-a-Si films.

Experimental SP-a-Si films were prepared in diode-type sputtering system (NEVA FP-46) by varying deposition parameters. Used parameters are listed in Table 1, among which H_2 concentration (x vol. %) in Ar-H_2 sputtering gas, substrate temperature (T_s), RF power and gas pressure (P_G) are important. Emission spectra of RF plasma were monitored during deposition, giving information on deposition kinetics. For all the samples prepared, film density, ir vibrational spectra (600-3000 cm^{-1}), optical transmission spectra (0.4-2.6 μm), dark- (σ_d) and photoconductivity ($\Delta\sigma_p$) were measured.

Bonded H and Ar in films From the experimental data on film density and ir spectra we determined the content (at.%) of bonded hydrogen and the medium wave number (ν_m) of stretching mode absorption for Si-H complexes. The medium ν_m gives a measure of the absorption ratio of SiH_2 to SiH modes[5]. Both quantities are shown in Fig.1(a) and (b) as a function of T_s for different H_2 concentrations (x), which shows that the amount of bonded H as well as its environment can be widely controlled. EPMA traces have shown that more than 5 at.% of Ar atoms are involved in SP films depending on preparation parameters.

Optical gap and photoconductivity Figure 2 shows optical gap E_o vs. T_s for samples prepared for different H_2 concentrations (x). E_o was graphically determined using the empirical relation $\sqrt{\alpha h\nu} \propto (h\nu - E_o)$. Figure 3 shows E_o as a function of bonded H content in the films, which is replotted from the data of Figs.1(a) and 2. E_o increases drastically from 1.1 to 2.0 eV with an increase in bonded H content. Thermal effect is another factor shifting E_o to higher energies. Figures 4 and 5 show σ_d and $\Delta\sigma_p$ vs. T_s for the samples used in the above experimants. σ_d keeps decreasing with increasing x up to 40%, while $\Delta\sigma_p$ takes a maximum value at x=20%. Figure 6 shows spectral response of $\eta\mu\tau$, that is, $\Delta\sigma_p$ normalized to the absorbed photon flux, where η is quantum efficiency, μ electron mobility and τ electron life time. The data suggest that surface recombination prevails in photoconduction process.

Connecting the above results with other annealing studies, conclusions are summarized into following items: (1) The amount of bonded H and its environments can be controlled by varying H_2 concentration in Ar-H_2 sputtering gas, T_s, RF power and P_G. (2) E_o is mainly determined by the amount of bonded H, and to a lesser degree by thermal stabilization. (3) Photoconductivity is strongly correlated with the absorption ratio of SiH_2 to SiH modes as well as bonded H content. (4) Ar

atoms involved in SP films play the role of steric hindrance against H diffusion, so SP films are more stable than GD films at high temperatures. These results are discussed in comparison with those of GD-a-Si:H.

References
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Table 1 Deposition Conditions

Gas	Target	Substrate	T_s	RF Power	P_G	P_{base}
$Ar+x\%H_2$ $0 \leq x \leq 40$	c-Si (5-15Ω-cm)	C#7059 c-Si(ir)	RT-300°C	100-300W	7-50mtorr	3×10^{-7}torr

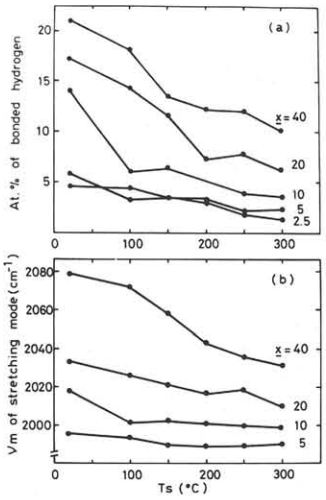

Fig. 1

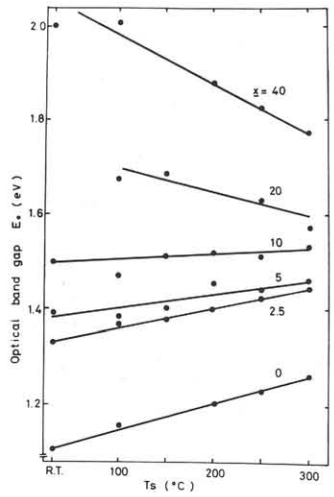

Fig. 2

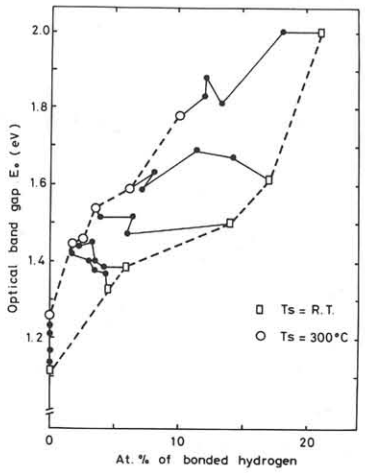

Fig. 3

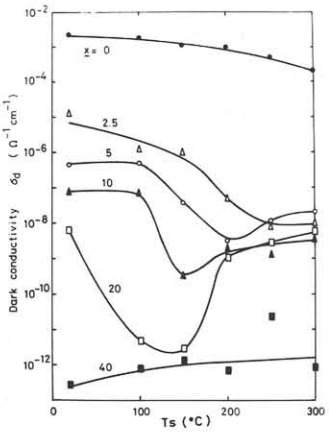

Fig. 4

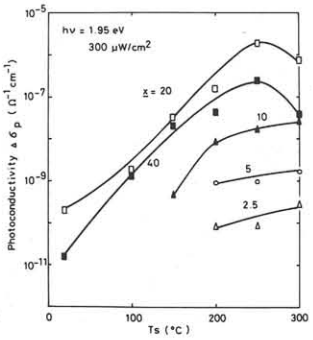

Fig. 5

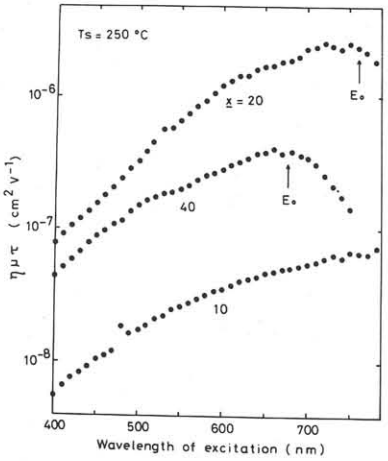

Fig. 6

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