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Preparation of high photosensitive a-SiGe:H alloys from glow-discharge plasma

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Development of longer wavelength-light sensitive material is pressing need to get a high conversion efficiency in amorphous silicon based solar cell. However, different from a-Si:H, a-SiGe:H film prepared from the conventional glow-discharge decomposition of SiH_4/GeH_4 mixture shows a quite inferior photosensitivity. It arises from a low-density network structure, i. e., hydrogen evolution at a low temperature range ($T_{peak} < 400C$), dominant $(SiH_2)n$ infrared absorption and a high density of Ge dangling bonds ($>10^{17}$ cm^{-3}). This paper describes the first success of the preparation of high photosensitive a-SiGe:H films through two different glow-discharge techniques; (1) from SiH_4/GeH_4 mixture using a triode reactor (method A), and (2) from $SiH_4/GeH_4/H_2$ mixture using a diode reactor (method B).

Table 1 summarizes the deposition conditions of our methods A and B, as well as the conventional technique using a diode reactor with SiH_4/GeH_4 mixture.

In the method A, we used a triode reactor which is schematically indicated in Fig.1. SiH_4/GeH_4 glow-discharge plasma is produced between the cathode and the mesh electrode, and various kinds of radicals generated in the bulk plasma diffuse into a plasma-free space below the mesh, where short reaction-lifetime radicals are scavenged via collision with parent gas molecules. Therefore, in this method, only long lifetime radicals are able to reach onto the film-growing surface. Longer lifetime means lower reactivity of the radicals, in other words, ;larger surface diffusion coefficient of the adsorbates, resulting in a sufficient structural relaxation of the network structure. Actually, ir absorption spectra of these films show less amount of $(SiH_2)n$ configuration and their thermal evolution curves of H are shifted to higher temperature ranges compared to those of the conventional films (Diode-SiH_4/GeH_4), as shown in Fig.2. Figure 3 shows dark and photoconductivities of a-SiGe:H films prepared by the method A (Triode; solid lines) in comparison to those of the conventional films (Diode-SiH_4/GeH_4; dashed lines), plotted against their optical bandgap E_0. The photoconductivity of the triode films is higher by around two orders of magnitude than that of the diode films in the range of $1.4 < E_0 < 1.7$eV, while their dark conductivity is kept at the same level as low as the diode films. ESR measurements indicate that the density of Ge dangling bonds in the triode films is reduced down to $\simeq 10^{16}$ cm^{-3}, being consistent with high photoconductivity of those films.

Data points indicated by "star" marks in the figure represent the results of a-SiGe:H films prepared by the method B (Diode-$SiH_4/GeH_4/H_2$) under a carefully-selected plasma

parameters which were determined on the basis of deposition chemistry. These films also show a high photoconductivity comparable to the triode films. It should be noted that the deposition rate for the method B is around 1A/sec which exceeds that for the method A. Recently, Oda et al reported high photoconductive a-SiGe:H:F from $SiF_4/GeF_4/H_2$ mixture[1] However, at least from the view points of factory-scale production technology, F is and undesirable element because of its strong chemical reactivity. This is another motivation of the present work. Deposition chemistry will be also discussed in the talk.

Table 1. Plasma parameters of each deposition

Reactor	Starting gas	Flow rate	Pressure	Power dens.	Ts
Triode	SiH_4/GeH_4	5-20sccm	25mTorr	0.5-1W/cm2	250
Diode	$SiH_4/GeH_4/H_2$	3-5	200-400	0.1-0.3	300
Convent.	SiH_4/GeH_4	5-10	10-50	0.01-1	250

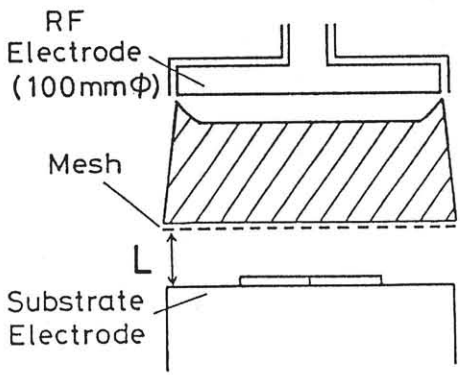

Fig.1. Triode reactor used.

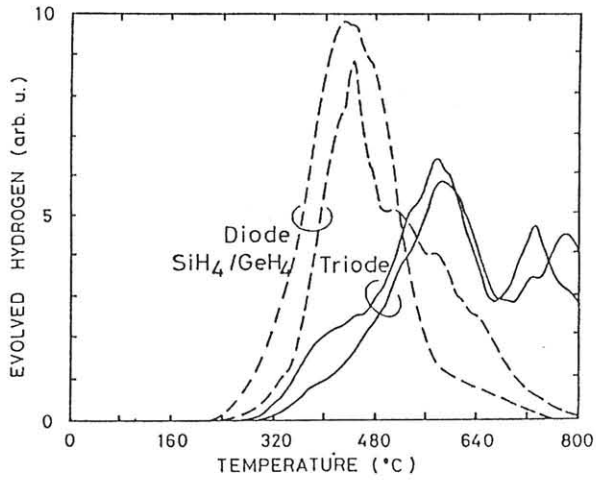

Fig.2. H_2-effusion curves of a-SiGe:H from conventional diode and triode reactors.

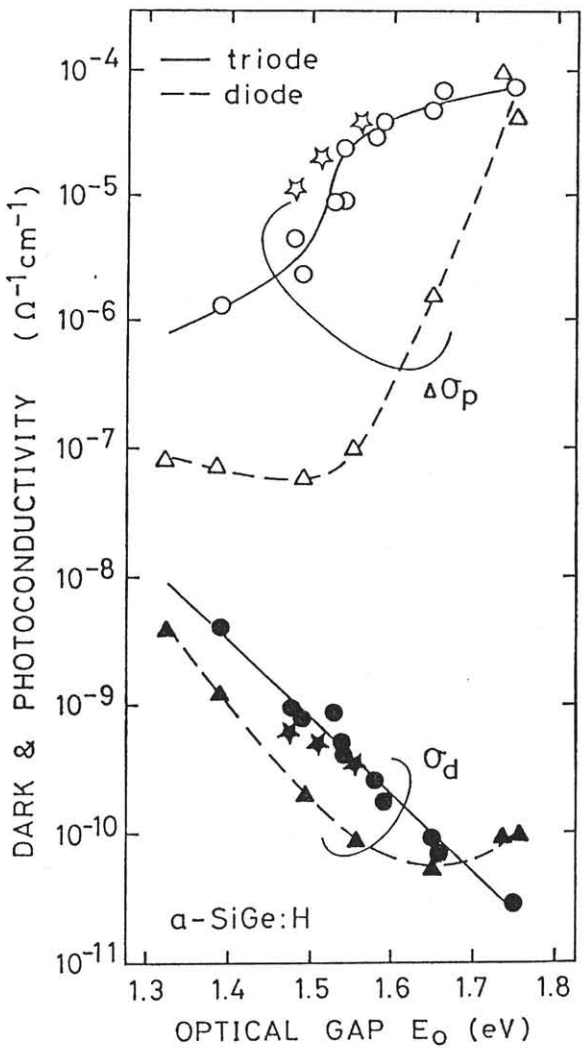

Fig.3. Dark and photoconductivities of a-SiGe:H films.

1) S.Oda et al; Tech. Digest Int'l PVSEC-1 (1984) Kobe, p.429.