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PHOTON ENERGY DEPENDENCE OF SW EFFECT IN *a*-Si : H FILMS*

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In order to explore the creation process of Staebler–Wronski (SW) defect in *a*-Si:H films. We investigated the effect of monochromatic light exposure with different photon energies: 2.54, 1.96, 1.17 and 0.95 eV. The experimental results show that threshold energy for SW defect creation is around 1.17 eV.

THE LIGHT-INDUCED metastable changes in the properties of *a*-Si:H films (Staebler–Wronski effect) have been drawing broad attention because of both the physics involved and its close relation to the stability of *a*-Si:H devices. Although several models to the account for the effect have been proposed [1, 2], many points still remain unclear.

Here we present the results obtained by exposure of undoped *a*-Si:H films to monochromatic light with different photon energies. A threshold photon energy for the creation of light-induced effects around 1.17 eV was observed, which is helpful towards the understanding of the microscopic process of the SW effect. Similar work was reported for P-doped *a*-Si:H and undoped *a*-Si:H [3].

Undoped *a*-Si:H films were deposited by glow discharge decomposition of 97.5% H_2 + 2.5% SiH_4 on quartz substrates held at 300°C. Co-planar Al electrodes with a gap of 0.1 mm were then evaporated. The photoconductivity was measured for samples in two states, namely samples annealed in vacuum at 180°C for 1 h (state A) and the same further exposed to light with various photon energies (state B). The sources used for light soaking were: Ar^+ laser (with photon energy of 2.54 eV), He–Ne laser (1.96 eV), YAG laser (1.18 eV) and YLiF laser (0.95 eV). A projector lamp with a band-pass filter (6000–9000 A) was also used as a "white light" source for comparison. Films 0.4 μm thick were used for Ar^+ laser radiation and films 2.3 μ thick for radiation with other sources were used to ensure that the radiation was absorbed through the whole sample thickness. To keep the density of absorbed photons approximately constant the incident power for Ar^+ laser and He–Ne laser was 40 mW cm^{-1} and was 100 mW cm^{-2} or higher for longer wavelength soaking light.

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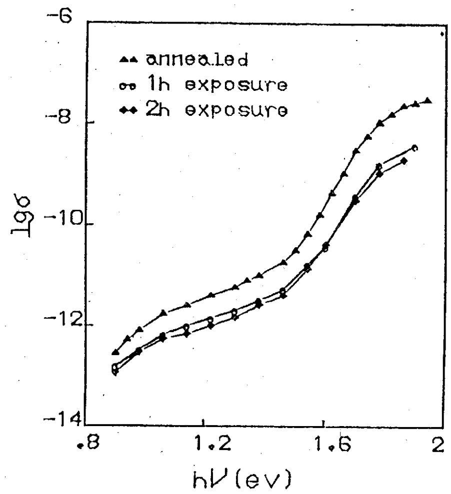

Fig. 1. Photoconductive spectra of *a*-Si:H annealed and exposed to Ar^+ laser.

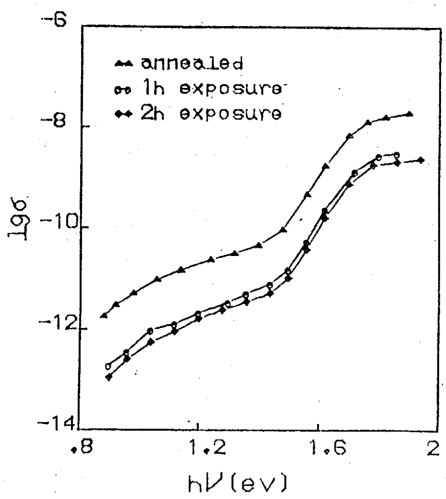

Fig. 2. Photoconductive spectra of *a*-Si:H annealed and exposed to He–Ne laser.

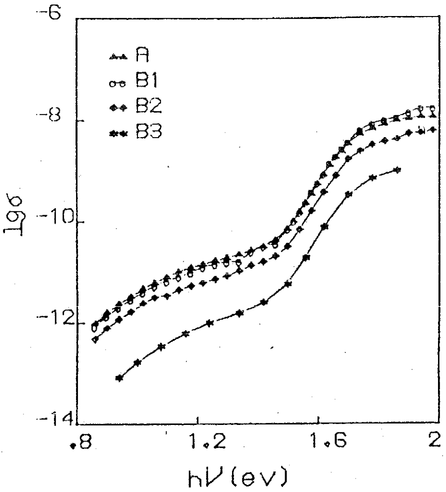

Fig. 3. Photoconductive spectra of a-Si:H. A: annealed at 180°C; B1: exposed to YLiF laser; B2: exposed to YAG laser; B3: exposed to white light.

From Fig. 1 and Fig. 2 we see that the changes of photoconductivity from state A to state B in both cases are comparable with that caused by white light radiation (Fig. 3, curve B3). It means that photons having energies greater than the gap energy are equally effective for the creation of light-induced defects.

Figure 3 shows the change of photoconductivity spectra of one sample exposed successively to YLiF laser (photon energy 0.95 eV), YAG laser (photon energy 1.17 eV) and white light (1.4–2.1 eV). No detectable change was seen after illumination with YLiF laser (curve B1), but a distinguishable decrease of photoconductivity was observed when the sample was exposed to YAG laser (curve B2) though the change is much smaller than that caused by white light (curve B3). This result seems to show that the threshold energy for SW effect is between 0.95 eV and 1.17 eV. In order to make sure of the change in photoconductivity with 1.17 eV radiation, further measurments were made on some 20 samples before and after exposing to YAG laser with different incident power ($100 \, mW \, cm^{-2}$ to $2 \, W \, cm^{-2}$) and different radiation time (2 min to 1 h). Most of the samples showed photoinduced changes, but to different extents. The photoconductivity generally decreased by a factor of 1.5–2. However, there were a few samples (5 samples) showing no change. This is understandable, if we allow for a sample-dependent fluctuation of the threshold energy.

It is interesting to note that the change of photoconductivity caused by 1.17 eV photon radiation did not obey the rule of photographic reciprocity. The change seems to saturate within several minutes and for most samples the saturate values ($G_A/G_B = 1.5–2$) were far lower than that caused by white light ($G_A/G_B = 10$). Prolonging radiation time or increasing light intensity did not move the change to a higher value. In other words, the 1.17 eV photons can create SW defects only under most favourable circumstances in a-Si:H network, where the SW defects could be created with the lowest energy requirement. Apparently, such circumstances are comparatively rare and are influenced by the material preparation conditions. This may explain the fluctuation of threshold energy mentioned above. And there is good reason to believe that the threshold energy for the creation of SW defects is very close to 1.17 eV in average circumstances.

The optical gap of our samples is 1.74 eV from the measurement of absorption coefficient, which gives an estimated separation between the valence and conduction band tails of about 1.19–1.24 eV. If the photon energy of 1.17 eV can be taken as the lower limit of the energy needed for exciting electron-hole pairs in the band tail states, it seems dubious that such an energy is enough to break a weak Si–Si bond in addition to driving a Si–H bond transposition. However, if the vibration mode of Si–H bond could become highly excited by multi-phonon relaxation during non-radiative recombination of electron-hole pairs, it would provide a good chance for the Si–H bond diffusion as an event independent of the weak bond breaking.

The existence of a threshold energy of 1.17 eV for SW effect is not consistent with the model of negative effective correlation energy, according to which we need an energy no more than 0.9 eV to induce SW effect for our samples.

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REFERENCES

1. H. Dersch, J. Stuke & J. Beichler, *Appl. Phys. Lett.* **38**, 456 (1981).
2. D. Adler, *J. Phys.* **42**, C4-3 (1981).
3. H. Okushi, M. Itoh, S. Yamasaki & K. Tanaka, *Technical Digest of the International PVSEC-1*, Japan, 413 (1984).