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Lifetime and Diffusion Coefficient of Carriers in X-Ray Irradiated a-Si:H

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Radiation effects in crystalline Si (c-Si) have been extensively studied by various investigators. However, little is known about the radiation effects in amorphous Si (a-Si:H). As the electrical properties of a-Si:H are greatly changed by optical illumination[1,2] in contrast to those of c-Si, the radiation effects in a-Si:H are expected to differ from those in c-Si. It is important to examine the radiation effects in a-Si: H for practical application of a-Si:H devices operating in various environments. We report here experimental results on the effect of X-ray irradiation on the carrier transport properties of a-Si:H.

The transient grating method was used to determine the lifetime and the diffusion coefficient of carriers. The excitation light (λ_L) is split into two beams which are made to intersect on the sample surface, and the interference of the two beams produces a transient grating of photo-excited carriers. The probe light (λ_P) is diffracted by this grating. The experimental apparatus was similar to those reported in ref. 2. As the excitation source, we used the second harmonies (λ = 532 nm, pulse duration = 6 ns) from a Q-switched Nd-YAG laser. The power density at the sample surface was about 100 MW/cm^2. The probe source was light from a Kr laser (λ_P = 647.1 nm) with a duration of 10 ms and a power density of about 10 W/cm^2.

Undoped a-Si:H film was prepared by rf glow discharge on a Corning 7059 glass substrate whose temperature was 250^{o}C. The thickness of the film was 0.57 μm. The sample was annealed in vacuum at 150^{o}C for 30 min. in the dark and was then exposed to X-rays from a Cu target X-ray tube operated at 40 kV and 30 mA through an Ni filter. The exposure rate of 20 ± 10R/s was estimated with film badges. X-ray irradiation was carried out in air for 76 hours, so that the total dose was about 5 x 10^6 R. The measurements were performed in vacuum at room temperature, because the sample may be affected by air. However, the effect of air is smaller than that of radiation. The properties of the sample left in air for a week are not very different from those of the annealed sample.

Figure 1 shows the inverse decay time constant 1/T of the diffraction intensity of the probe light as a function of $4\pi^2/\Lambda^2$ for several grating pitches Λ. The slope gives the diffusion coefficient D and the point of intersection with the ordinate gives the lifetime τ.[2] The values D = 2.2 x 10^{-2} cm^2/s and τ = 2.5 μs are estimated for the annealed sample, and D = 5.8 x 10^{-3} cm^2/s and τ = 0.6 μs for the X-ray irradiated sample. The values of D and τ for the sample irradiated for 4 hours are similar to those of the annealed sample.

The lifetime of carriers strongly depends on the density of localized centers near the Fermi level, which is related to the density of dangling bonds. Our results suggest that X-ray irradiation generates dangling bonds in a-Si:H in contrast to the case of c-Si. In c-Si, the photon energy of the X-rays is lower than the threshold energy for radiation damage.[3)] A reduction in electrical conductivity has also been observed in a-Si:H after exposure to light[1,2)] and a 3.5 MeV electron beam.[4)] This reduction has been attributed to the generation of dangling bonds. Our results are in qualitative agreement with the results of light and electron beam irradiation.

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References

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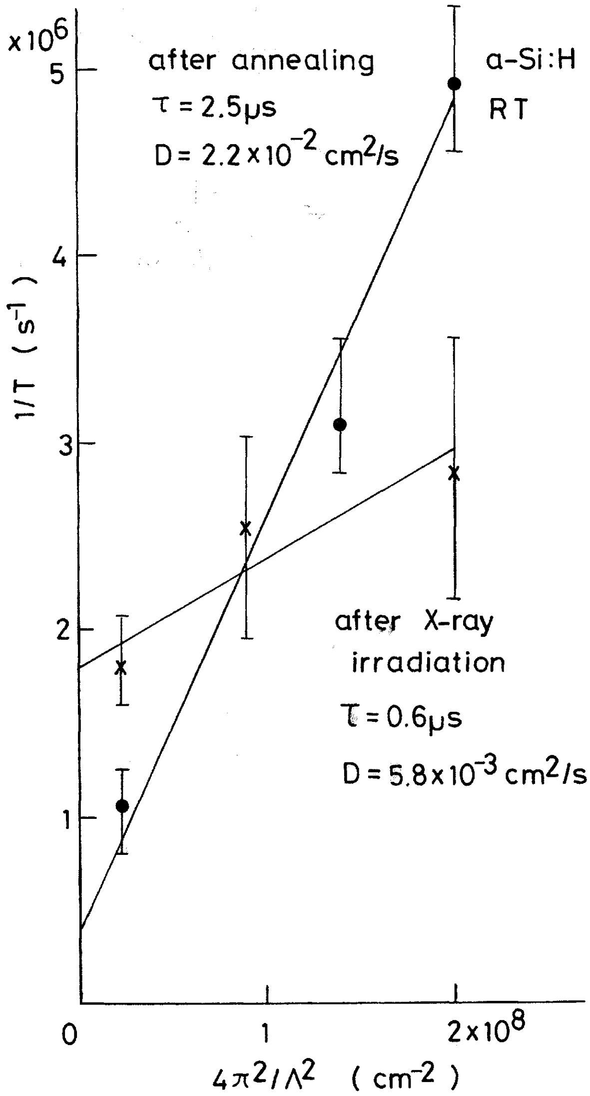
Figure caption

Fig. 1. Inverse decay time constant 1/T versus $4\pi^2/\Lambda^2$ for several grating pitches Λ after annealing (•) and after X-ray irradiation (x).

Fig. 1


x10^6
5
4
3
2
1
0
1
2x10^8
1/T (s^-1)
4π^2/Λ^2 (cm^-2)
after annealing
τ = 2.5μs
D = 2.2x10^-2 cm^2/s
a-Si:H
RT
after X-ray
irradiation
τ = 0.6μs
D = 5.8x10^-3 cm^2/s