The effects of As addition on the transport property of *a*-Se:As films using the moving photo-carrier grating technique

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The effects of As addition in amorphous selenium (*a*-Se) films on the carrier mobilities and the recombination lifetime have been studied using the moving photo-carrier grating (MPG) measurements. The electron and hole mobility, and recombination lifetime of *a*-Se films with arsenic (As) additions up to 1% have been obtained. We have found an increase in hole drift mobility and recombination lifetime, especially when 0.3% As is added into *a*-Se film, whereas electron mobility decreases with As addition due to the defect density from shallow traps.

Keywords: moving photocarrier grating, amorphous selenium, transport property

I. INTRODUCTION

While traditionally *a*-Se was employed in xerography [1], more recently this material has been used as the X-ray photoconductor in flat-panel X-ray image detectors [2]. The amorphous selenium film that is currently being studied for use an X-ray photoconductor is not pure *a*-Se but rather *a*-Se alloyed with 0.2-0.5% As (normally 0.3% As) and doped with chlorine (Cl) in the 10-20 ppm range, also known as stabilized *a*-Se[3-4]. A small amount of As in *a*-Se is added to enhance the thermal stability of the amorphous state. But it induces the undesirable hole traps in *a*-Se sample.

The mobility and the recombination lifetime of electrons and holes in semiconductors are important parameters that determine the performance of many devices, such as solar cells or thin film transistors [5].

The moving photo-carrier grating (MPG) technique allows us to determine the carrier mobilities and recombination lifetime of electrons and holes in semiconductors [6-7]. While a several MPG measurements have been carried out on the transport properties of amorphous silicon (*a*-Si) sample in the past, the transport phenomena for *a*-Se films has not been accomplished using MPG method yet.

II. EXPERIMENT

The experimental setup used for the MPG measurement is shown in Fig.1. Coherent laser beam is split into two parts which interfere at the surface of the sample under an angle δ . Thus, an intensity grating with spatial period $\Lambda = \lambda/[2\sin(\delta/2)]$ is created, where δ is the angle between the two laser beams, and λ is the laser wavelength.

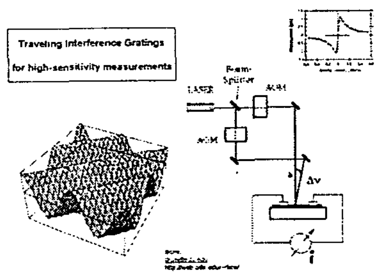

Fig.1. Experimental set-up for the moving photo carrier grating measurement

The MPG technique was applied to $a-Se_{1-x}As_x$ (x = 0.001, 0.003, and 0.01) films. The laser angles δ for *a*-Se samples were 17.1° and 33.2°.

III. RESULTS AND DISCUSSIONS

The short circuit currents measured for $a-Se(0.1\%As)$ samples as a function of υ_{gr} are plotted in Fig. 2. The inverted MPG curve of *a*-$Se_{1-x}As_x$ compared with the MPG curves of *a*-Si:H is due to the positive photocarrier charges, holes. The dominant mobility carriers are holes for *a*-Se films, whereas those are electrons for *a*-Si:H films [8]. The MPG fitting for the sign and the shape of $j_{sc}(v_{gr})$ allows the determination of the values of the carrier mobility and their recombination lifetime.

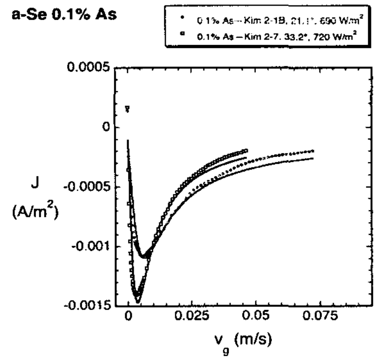

Fig. 2. Current density for a-Se:0.1%As film as a function of υ_{gr}

The maximum current density (minimum current density for *a*-Se) is proportional to the laser intensity [9]. Fig. 3 shows the maximum current densities per laser intensity, J/I_0 for $a-Se_{1-x}As_x$ films as a function of As addition in *a*-Se films. Measurement indicates that $a-Se_{0.997}As_{0.003}$ film exhibits the high efficiency in converting light into current density of three samples. The reason for this behavior is that a small amounts of As in *a*-Se film increase the thermal stability and the current density due to holes, but the electric characteristic of As doped *a*-Se film critically deteriorates when As addition exceeds 0.03%, due to the defect density of hole traps in $a-Se_{1-x}As_x$ films.

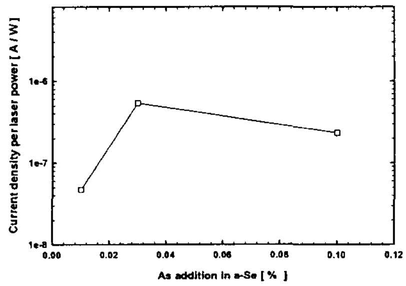

Fig. 3 Maximum current density per laser intensity as a function of As addition.

The carrier mobilities μ_n and μ_p are obtained by fitting the measured short circuit current to the theoretical expression derived by U. Haken et al. [6]. The electron and hole drift mobility for $a-Se_{1-x}As_x$ films are plotted as a function of As addition in Fig. 4. The hole drift mobility exhibits the apparent increase at the As addition of $x = 0.003$ between $x = 0.001$ and $x = 0.01$, whereas electron drift mobility decreases with As addition. The hole mobility decreases due to defect density of shallow traps when $x = 0.003$ exceeds, whereas hole mobility increases in low As addition in *a*-Se film.

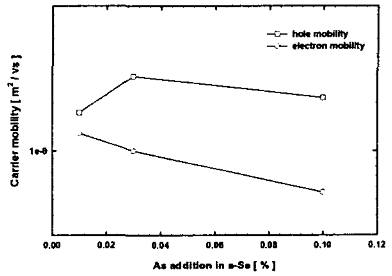

Fig. 4. The electron and hole drift mobility as a function of As addition

The dependence of the recombination lifetime on the As addition in *a*-Se films is shown in Fig. 5. We have found that τ_R increases up to As addition of $x = 0.003$ and decreases with larger As addition of $x = 0.01$. We assign this change to the contribution of two facts. On the other hand, a small additions of As in *a*-Se films up to $x = 0.003$ enhance the electric conductivity of $a-Se_{1-x}As_x$ films, while further As addition induces the undesirable hole traps in *a*-Se samples [4].

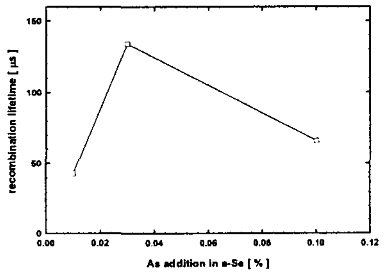

Fig. 5. The recombination lifetimes for *a*-Se:As films as a function of As addition

REFERENCES

[1] S. O. Kasap. J.A. Rowland, J. Matter. Sci., Vol. 11, p. 179, 2000.

[2] S. O. Kasap, J. Phys. D , Vol. 33, p. 2853, 2000.

[3] B. Fogal, R. E. Fohanson, G. Belev, S. O'Leary, S. O. Kasap, J. Non-Crystalline Solids, 299-302, 993-997, 2002.

[4] S. O. Kasap, V. Aiyah, A. Baillie, A. G. Leiga, J. Appl. Phys., Vol. 69(10), p. 7087, 1991.

[5] J. A. Schmidt, M. Hundhausen, and L. Ley, Physical Review B. Vol. 62(19), 13010, 2000.

[6] U. Haken, M. Haudhausen, and L. Ley, Physical Review B, Vol. 51, No. 16, p. 10579, 1995.

[7] M. Hundhausen, J. Non-Cry. Sol. Vol. 198-200, p. 146-152, 1996.

[8] J. A. Schmidt, M. Haudhausen, and L. Ley, Physical Review B, Vol. 64, p. 104201, 2001.

[9] C. Witt, U Haken and M. Hunhausen, Jpn. J. Appl. Phys. Vol. 33, No. 10A, p. L1386-L1388, 1994.