Transport property of *a* Se:As films for digital x ray imaging

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The transport properties of amorphous selenium typical of the material used in direct conversion x-ray imaging devices are reported. The effects of As addition on the carrier mobility and recombination lifetime in amorphous selenium (*a*-Se) films have been studied using the moving photocarrier grating (MPG) technique 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. The transport properties for As doped *a*-Se films obtained by using MPG technique have been compared with the drift mobilities of holes and electrons obtained by time of flight (TOF) measurement.

Keywords: moving photocarrier grating, carrier mobility, recombination lifetime

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 film is added to enhance the thermal stability of the amorphous state. But a high As addition induces the undesirable hole traps in *a*-Se:As film The moving photo-carrier grating (MPG) technique allows us to determine the carrier mobility and recombination lifetime of electrons and holes in semiconductors[5-6]. Although hole and electron transport in a-Se is well documented, mobilities and lifetimes of hole and electron in a-Se:0.3% As photoconductors that have been used in current x-ray detectors are not clear [6]. In this paper, time-of-flight (TOF) of drifting electrons and holes in stabilized a-Se film was used to investigate electron and hole drift mobility

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.

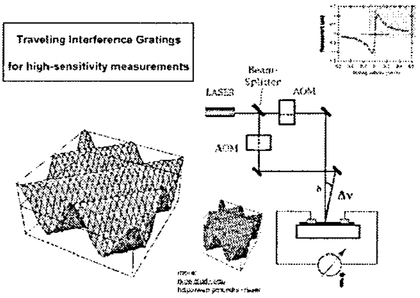

Fig.1. Experimental set-up for the moving photo carrier grating measurement

Fig. 2 shows the schematic diagram illustrating the principle of TOF measurement. A voltage was applied across the a-Se layer sandwiched between Au electrode and ITO electrode for collecting charges.

The applied bias (V) appeared across the thickness of a-Se layer since the external resistance is much less than the a-Se resistance. A short light pulse of 5nm from laser light source (350 nm) was employed to photogenerate free charges. The transit across a-Se layer produced a measurable current in the external circuit. The transient voltage, R_L, was monitored on an oscilloscope (LeCroy LC 334AM, USA) as a photo response signal.

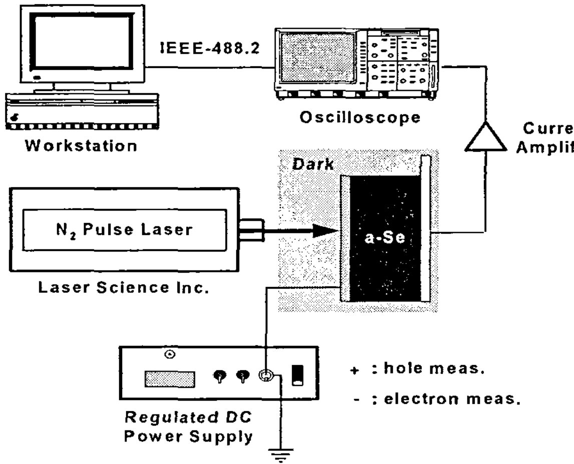

Fig. 2. The schematic diagram for TOF measurement

III. RESULTS AND DISCUSSIONS

MPG curves for a-Se:As film exhibit the different behavior compared with those for a-Si:H]. The inverted MPG curves in Fig. 3 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 [7].

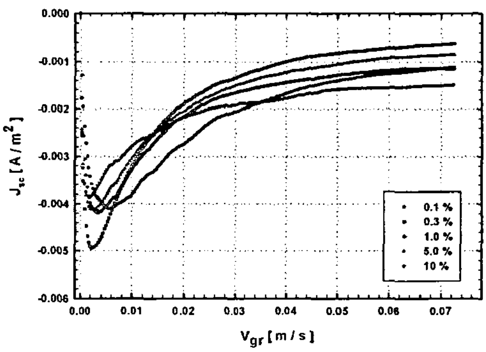

Fig. 3. Current density as a function of v_{gr}

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. [5]. 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 = 0.1, whereas electron drift mobility decreases as a function of As addition. The hole mobility decreases due to defect density of shallow traps when x exceeds 0.003, whereas hole mobility increases in low As addition $(x \le 0.03)$.

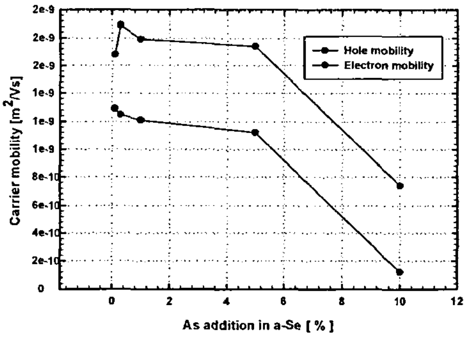

Fig.4. The electron and hole drift mobility as a function of As addition

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 exceeds 0.003 , whereas hole mobility increases in low As addition $(x \le 0.03)$.

The transient current TOF signals for a-Se layer (400 μm) are shown in Fig. 5 and Fig. 6. The transient TOF waveforms were taken after the application of 10 V/μm across the a-Se layer. The transient indicates that the electric field remains uniform across the a-Se film layer, suggesting the presence of hole and electron trapping within the a-Se layer. The transit time becomes dependent on applied electric field to raise charge collection as a theoretical anticipation value.

The transit times of hole and electron are 8.72 and 229.2 μs, respectively, at a voltage bias of 10 V/μm. TOF transient photocurrents exhibited similar behaviors with those in an a-$Se_{0.966}Te_{0.034}$ alloy photoreceptor film reported by J. A. Rowland and S. O. Kasap previously.

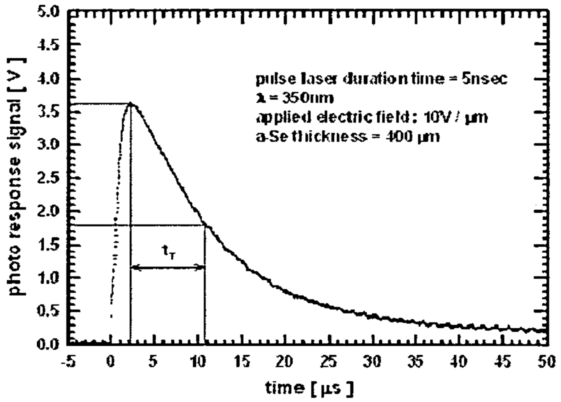

Fig. 5. Photo response signal of hole

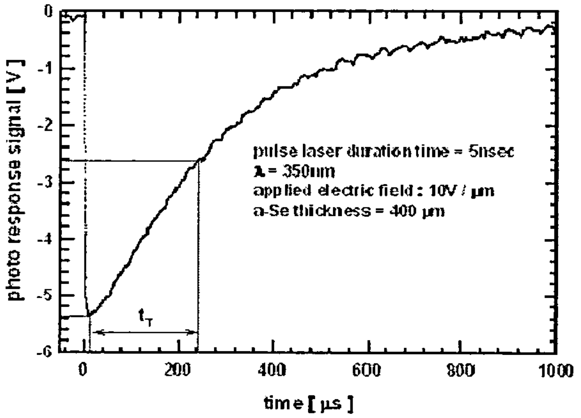

Fig. 6. Photo response signal of electron

3.2. Mobility

The relationship between charge-carrier mobility μ and the measured transit time t_T is given by:

$$\mu t_T E = L$$

$$\mu = \frac{L}{t_T E} = \frac{L^2}{t_T V} \quad (4)$$

The drift mobility of hole and electron exhibited observable field dependence up to 4 V/μm, as shown in Fig. 7 and 8.

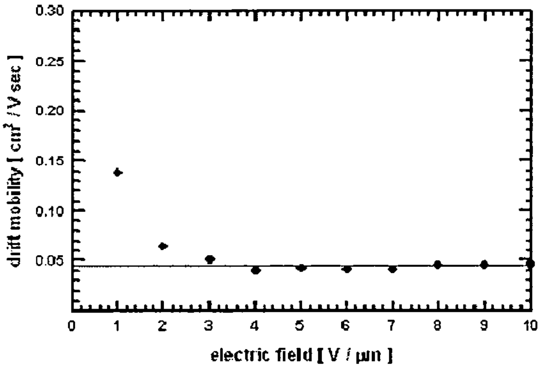

Fig. 7. The drift mobility of hole as a function of applied electric field.

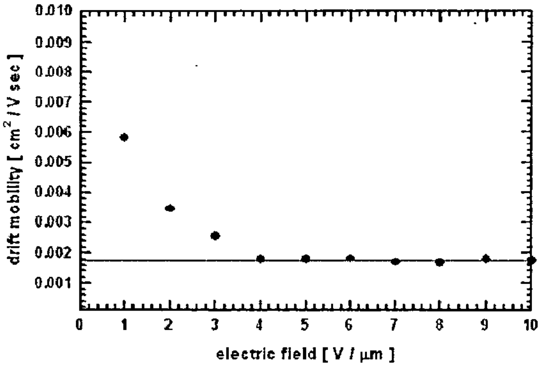

Fig. 8. The drift mobility of electron as a function of applied electric field

The drift mobility of hole and electron at 10 V/μm are 0.04584 and 0.00174 $cm^2V^{-1}s^{-1}$, respectively. The obtained drift mobility of hole is somewhat different from the value of 0.13 $cm^2V^{-1}s^{-1}$, reported previously by Kasap et al. After careful analysis, this apparent difference in hole mobility seems to be due to both the temperature dependence and doping quantity of stabilized a-Se film.

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