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Avalanche Multiplication Factor and Quantum Efficiency of Te-doped a-Se HARP Target

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1. Introduction

The avalanche characteristics of the a-Se HARP(High-gain Avalanche Rushing amorphous Photoconductor) target are dependent on a-Se layer thickness and applied electric field of the HARP target [1]. The a-Se photoconductive layer is doped with Te to improve quantum efficiency of the a-Se HARP target. Te doping concentration and thickness of Te-doped a-Se layer are important parameter on the avalanche characteristics of the Te-doped a-Se HARP target.

In previous report [2,3], avalanche characteristics and spectral responses of 0.4μm-thick Te-doped a-Se HARP target for a solid state image sensor were investigated. In this paper, the effect of thickness of the Te-doped a-Se HARP target on the avalanche multiplication factor, quantum efficiency, and light-transfer characteristics are investigated.

2. Experiment

The schematic structure of the Te-doped a-Se HARP target was shown in previous report [2]. The hole blocking layer (GeO_2 and CeO_2), a-Se photoconductive layer, Sb_2S_3 electron blocking layer were deposited on the glass substrate by vacuum evaporation method. Te-doped a-Se layer was sandwiched in the a-Se HARP photoconductive target. Te doping concentration and thickness of Te-doped a-Se layer were 15wt.% and 60nm, respectively. And thickness of Te-doped a-Se HARP target was changed from 0.4 to 8μm. Also the Te-doped a-Se HARP target was combined with conventional electron optics tube to investigate the avalanche characteristics.

3. Results and Discussion

Figure 1 shows the photocurrent for blue incident light and dark current of the Te-doped a-Se HARP target. The photocurrent increases at higher electric field than the threshold field for the avalanche multiplication [4]. Increasing thickness of the Te-doped a-Se HARP target, the photocurrent increases by the avalanche multiplication within the a-Se photoconductive layer. On the other hand, the dark current was suitably suppressed by the blocking layer. Then it largely increases by the avalanche breakdown at a high electric field.

The avalanche multiplication factor of the Te-doped a-Se HARP target is shown in Fig. 2. The avalanche

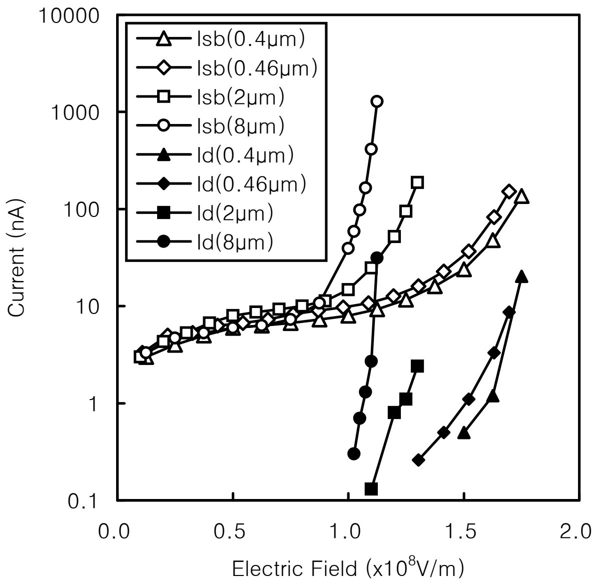

Fig. 1. Photocurrent and dark current of the Te-doped a-Se HARP target.

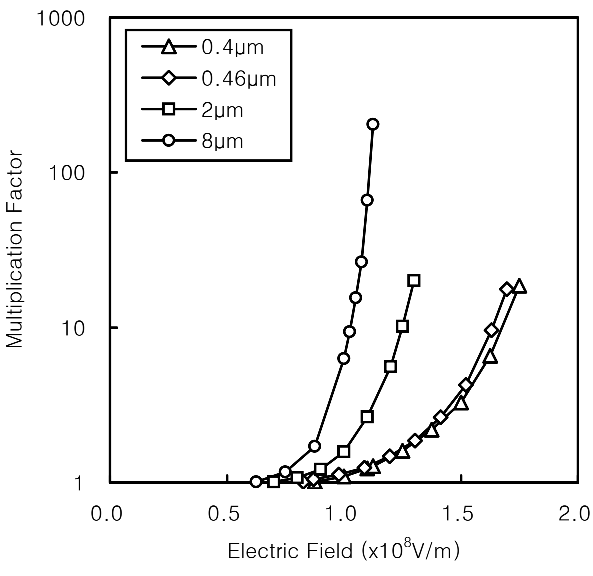

Fig. 2. Avalanche multiplication factor of the Te-doped a-Se HARP target.

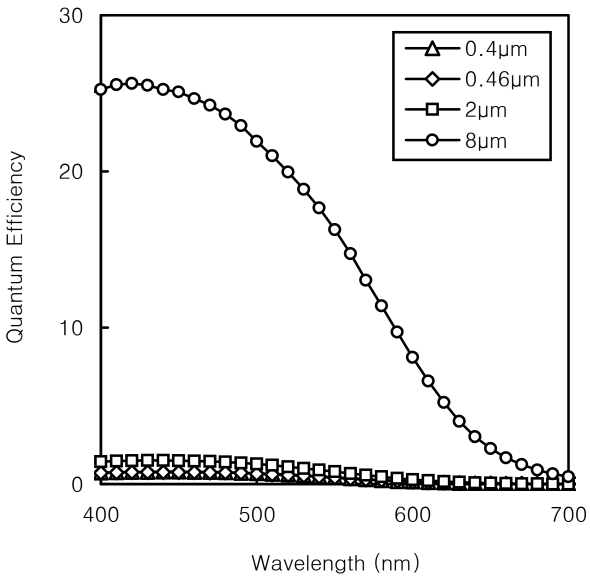

Fig. 3. Quantum efficiency of the Te-doped a-Se HARP target at $1.1x10^8$V/m.

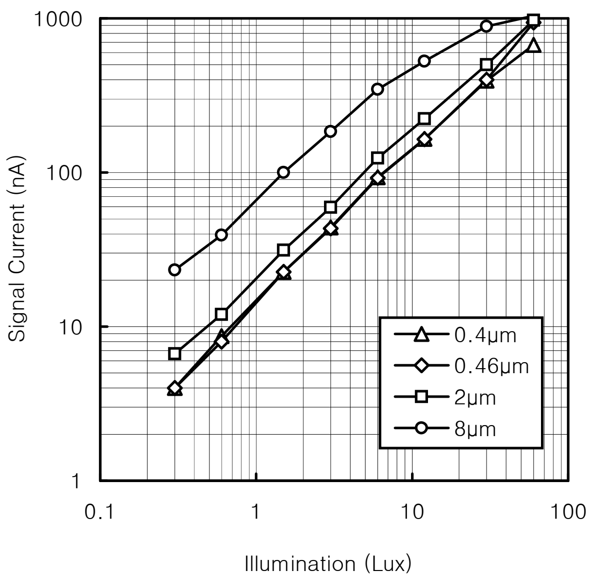

Fig. 4. Light-transfer characteristics of the Te-doped a-Se HARP target at $1x10^8$V/m.

multiplication factor calculated from the photocurrent at blue light exponentially increases with increasing electric field. In the 8μm-thick target, the avalanche multiplication factor largely increases over $0.88x10^8$V/m in contrast with 0.4μm-thick HARP target.

In the a-Se HARP target, the excess noise factor and signal to noise (SN) ratio are dependent on the avalanche multiplication factor. M. Kubota et al. [5] measured the SN ratio in the 2μm HARP tube under UV light condition, and obtained the excess noise factor. If the excess noise factor of the a-Se HARP target is calculated by the McIntyre's equation [6], it increases with increasing avalanche multiplication factor. This is different from the result by M. Kubota et al. To examine the excess noise factor of the a-Se HARP target effectively, it is necessary to investigate the relation between the excess noise factor and the avalanche multiplication factor.

Figure 3 shows the quantum efficiency of the Te-doped a-Se HARP target at $1.1x10^8$V/m. In the 8μm-thick HARP target, it was more higher than thin HARP target under 2μm. This increase of the quantum efficiency in the visible region is caused by the increase of the avalanche multiplication at a high electric field. Also the quantum efficiency at long wavelength region is extended to 700 nm by Te doping.

The light-transfer characteristics of the Te-doped a-Se HARP target at $1x10^8$V/m was investigated. As shown in Fig. 4, the γ value of the 0.4μm-thick a-Se HARP target was about 1. Then the γ value slowly decreases with increasing thickness of the Te-doped a-Se HARP target. It is considered that this change of the light-transfer characteristics affects the dynamic range and excess noise factor. The change of the excess noise factor by increasing avalanche multiplication factor was explained by the condition of $\gamma<1$ at avalanche multiplication region as one of factors [5].

4. Conclusions

The avalanche multiplication factor and quantum efficiency of the Te-doped a-Se HARP target were investigated. Te doping concentration and thickness of the Te-doped layer within the a-Se HARP target were 15wt.% and 60nm, respectively. And thickness of the Te-doped a-Se HARP target was changed from 0.4 to 8μm. The avalanche multiplication factor at blue incident light increases with increasing thickness of the Te-doped a-Se HARP target. In the 8μm-thick target, the quantum efficiency was more higher than thin HARP target under 2μm. The γ value slowly decreases with increasing thickness of the Te-doped a-Se HARP target.

Acknowledgement

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