B −2 −4 Optical and Electrical Properties of Nitrogen Doped a-Si:H Films for Solid State Image Pickup Devices

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Introduction A new type of solid state image pickup device with a photoconductive layer on top of a Si LSI scanner, has been proposed[1,2]. In order to successfully fabricate this type of sensor the follwing requirements have to be met: 1) The film must be deposited on top of the Si LSI without introducing any defects in the film itself and in the Si LSI circuit. 2) The film must withstand some heat treatment in the photoresist patterning process. 3) The film must have good photo-sensitivity over the whole visible region and good response characteristics in a low electric field.

We have chosen a reactively sputtered hydrogenated amorphous silicon (a-Si:H) as the photoconductive material to meet these requirements. In this paper, we report the optimization of deposition conditions, including the doping effect of nitrogen gas and the optical and electrical properties of the a-Si:H films.

Film deposition and evaluation We sputtered a-Si:H films onto glass substrates using a diode sputtering apparatus. The sputtering atmosphere was hydrogen and argon. The sputtering target was high purity poly-silicon (5 nines). The film was 3 μm thick and was deposited onto a Ta electrode. The upper transparent and semi-transparent electrodes were ITO film deposited by sputtering and Au thin film deposited by vacuum evaporation, respectively. The sample geometory is shown in Fig. 1. Photoelectric properties were evaluated by measuring dark and photo currents when the film was irradiated by 450 nm illumination at a power density of 20 μW per cm^2.

Experimental results In contrast to the vidicon type pickup tube, our a-Si:H film can be either n-type or p-type. First, we optimized the RF sputtering conditions. The optimized results are as follows: An RF power of 650 w, a total atmospheric pressure of $1x10^{-3}$ Torr and a partial hydrogen pressure of $1x10^{-4}$ Torr. Fig.2 shows the typical V-I characteristics of an a-Si:H film deposited under these optimized conditions. The photocurrent increases monotonically with the bias voltage until it reaches the saturation voltage, V_s. In this case V_s is 15 V, with the dark current remaining at a very low level, implying that the Au electrode acts as a Schottky barrier to form a blocking contact. By changing the direction of bias voltage, we could investigate the behavior of both types of photocarriers, i.e. electrons and holes. In this film, the photocurrent(I_{ph}) of both carriers saturates at almost the same V_s. Thus the operating voltage of this film

can be fairly low compared to other types of pickup tubes[3] . However, in order to use a-Si:H films in solid state imagers, it is preferable to operate this film at 10 V or less. We found that nitrogen doping is quite effective for this purpose. Fig.3 shows the V-I characteristics of 1% nitrogen doped film. As seen in this figure, the V_s of this film is as low as 5 V and I_d remains at a very low level. Fig.4 shows the saturation field as a function of nitrogen partial pressure. A sharp decrease in V_s is seen at a P_N of 1×10^{-6} Torr. From the value of the open circuit voltage, we conclude that the Fermi level shift is 0.2 eV toward the conduction band compared with that of undoped a-Si:H. The spectral response of this film shown in Fig.5, indicates a high quantum yield at shorter wavelengths. The response time of this film has been estimated by pulse driven LED (550 nm) illumination. Rise and fall times of 500 μS have been obtained. From these results, we expect good lag characteristics for solid state imagers using a-Si:H films.

Conclusion We have evaluated nitrogen doped n-type a-Si:H film as a photoconductive material for solid state image pickup devices and have found it to be quite satisfactory for this purpose.

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References

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2)Y.Terui et al., Proc. 1980 ISSCC, p.34

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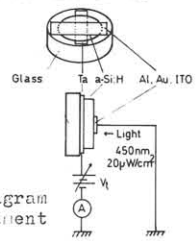

Fig. 1 Schematic diagram of V-I experiment

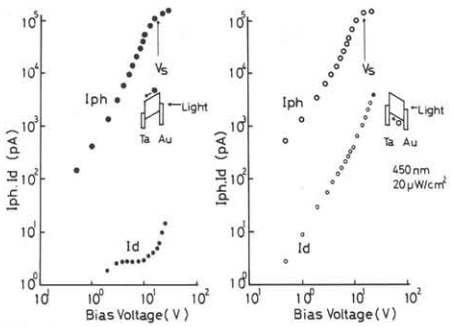

Fig.2 V-I characteristics of non doped a-Si:H film

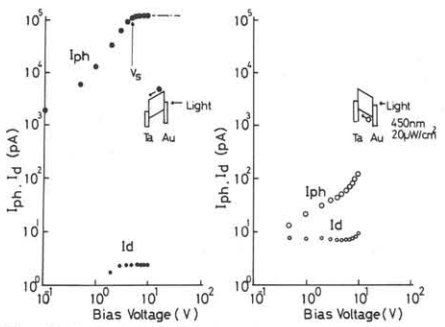

Fig.3 V-I characteristics of 1% nitrogen doped a-Si:H film

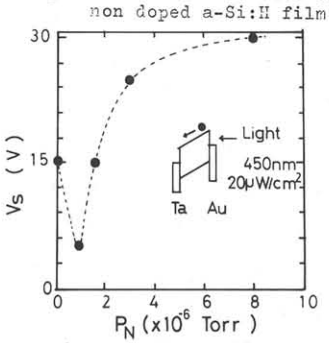

Fig. 4 Saturation voltage vs nitrogen doping

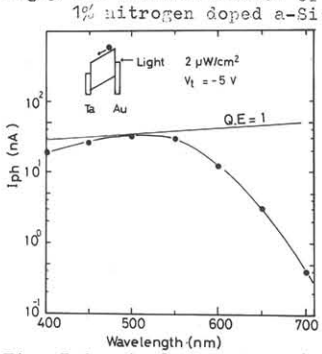

Fig. 5 Spectral response of nitrogen doped a-Si:H film