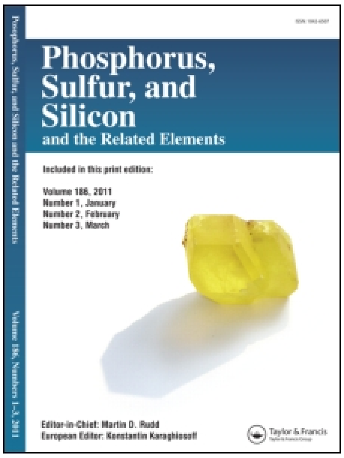

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Electrical Properties of Silver Photodoped Amorphous Red Phosphorus

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ELECTRICAL PROPERTIES OF SILVER PHOTODOPED AMORPHOUS RED PHOSPHORUS

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ABSTRACT Effects of photodoping and thermal doping of silver into sputtered amorphous red phosphorus films (a-P_{red}) on the electrical properties are studied. The d.c. electrical conductivity of the photodoped a-P_{red} at room temperature is about 1×10^{-5} Scm^{-1} which is a very high value comparing with that of the undoped a-P_{red} (1×10^{-14} Scm^{-1}). The activation energy for the conduction of the photodoped a-P_{red} is lower than that of the a-P_{red}. In contrast, the activation energy of the thermally doped a-P_{red} is essentially the same as that of the undoped a-P_{red}. SEM-EDX analyses show that colloidal silver was deposited in the thermally doped a-P_{red} but not in the photodoped a-P_{red}. It seems that the photodoping involves the ionization process of silver by illumination, i.e., $Ag^0 \longrightarrow Ag^+ + e^-$.

1. INTRODUCTION

Light induced reaction between silver and amorphous chalcogenides called "photodoping" has been reported by many investigators[1]. Some investigators have shown the possibility of technical application of this phenomenon but the mechanism is not known yet[2].

In our previous papers, the authors reported that amorphous red phosphorus film (a-P_{red}) was found to show photodarkening, photodoping and photobleaching effects; a-P_{red} is not chalcogen element but pnictide element[3]. It is known that these effects are commonly observed in amorphous chalcogenide alloys.

The objects of this work are to investigate the effects of silver doping into a-P_{red} on the electrical conduction and to elucidate the mechanism of the doping.

2. RESULTS AND DISCUSSION

2.1 Photodoping in amorphous red phosphorus

Amorphous red phosphorus films were deposited on a 0.5 mm thick Pyrex glass substrate by r.f. sputtering technique, and subsequently silver was evaporated onto the as-sputtered a-P_{red} films. The specimen of the a-P_{red} films with the silver thin layer was employed for examining the photodoping effect. Illumination was carried out by 500W Xe-arc-lamp with an IR cut-off filter in order to avoid the thermal influence.

The diffusion of silver into the a-P_{red} films was monitored by the recovery of optical transmission as shown in figure 1.

The gradual increase in the transmission was observed during illumination. The transmission increase observed here was caused by the decrease in thickness of the silver layer, from which silver diffuses into the a-P_{red} film on illumination.

This result was directly confirmed by measuring the depth profile of silver in the photodoped film, using secondary ion mass spectroscopy (SIMS). It was found in this experiment that silver photodoping takes place in the a-P_{red}, in which no concentration gradient of silver is observed. (fig.2)

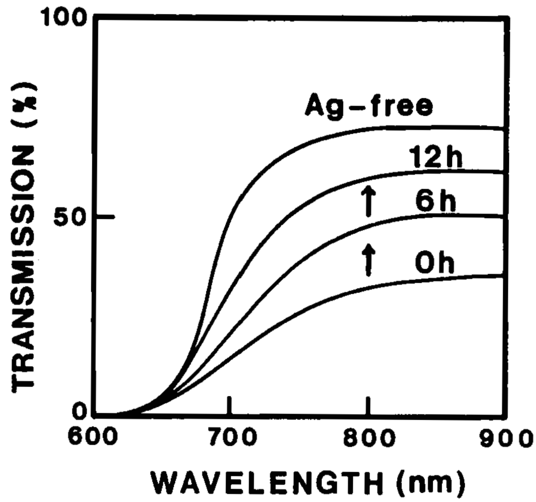

FIGURE 1 Changes in optical transmission of Ag-evaporated a-P_{red} film.

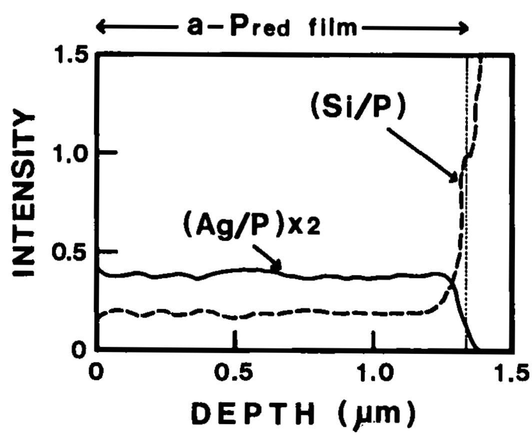

FIGURE 2 Depth profile of the silver photodoped a-P_{red}. (SIMS)

2.2 Effects of silver doping on the electrical conductivity

Figure 3 shows the relation between the electrical conductivity (σ) and the inverse temperature (1/T). The conductivity of the as-sputtered a-P_{red} film is 1×10^{-14} Scm^{-1} at room temperature. The activation energy is about 0.85 eV, which is the same as that of thermally silver-doped specimen.

On the other hand, the conductivity and the activation energy for the photodoped specimen are markedly changed, respectively, as seen in figure 3. The conductivity of silver photodoped specimen at room temperature is 1×10^{-5} Scm^{-1} which is much higher than that of the a-P_{red}, and the activation energy is about 0.35 eV.

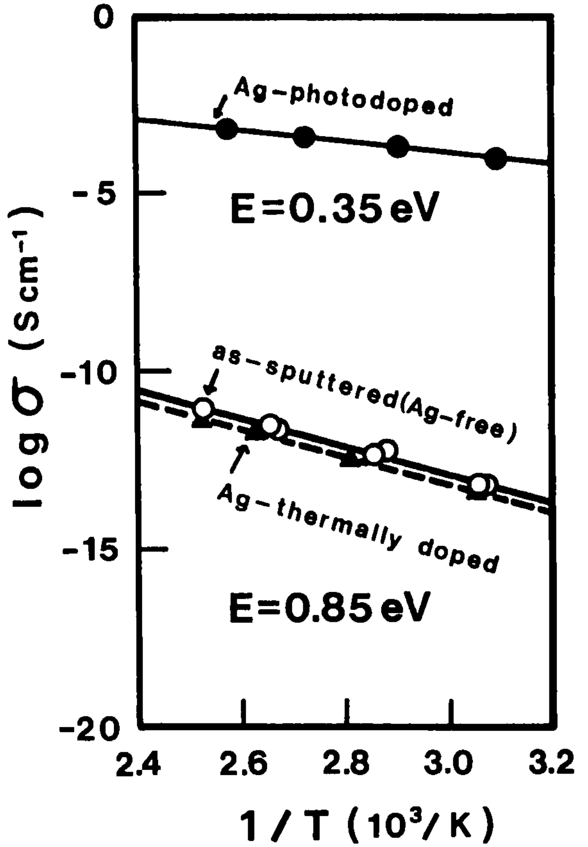

FIGURE 3 log σ vs 1/T plots

2.3 Observation of silver doped a-P_{red} by SEM-EDX

Figure 4 shows SEM micrograph and results of the silver concentration analysis by EDX along the indicated cross line in the photo for thermally silver-doped a-P_{red}. The patterns like snow-crystal observed by SEM were found by EDX to consist of colloidal silver. It is deduced that atomic silver (Ag^0) diffuses into the a-P_{red} and subsequently associates with each other to form colloid, so as to decrease the surface energy. This supports the results that the activation energy for the thermally silver-doped specimen is essentially the same as that for undoped specimen.

However, no colloid was observed in the photodoped a-P_{red}.

These results suggest that the thermally doped species is Ag^0 and the photodoped species is Ag^+. (fig.5)

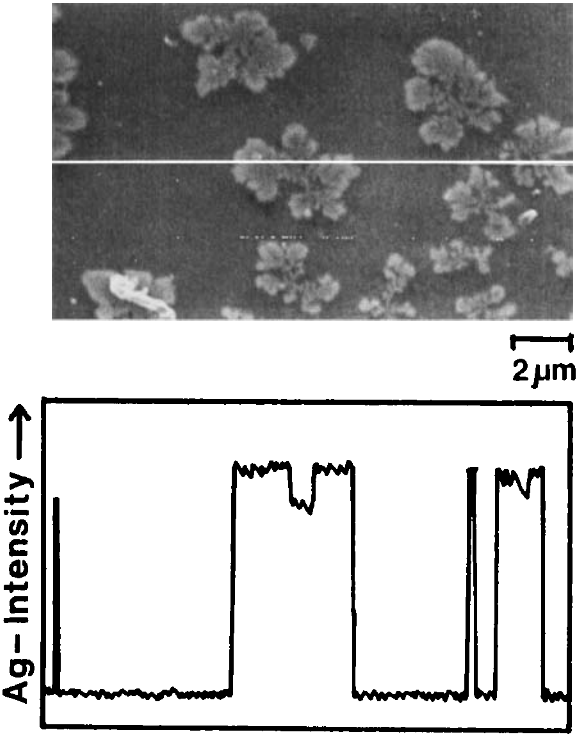

FIGURE 4 SEM-EDX analysis

$$Ag^{\circ} \xrightarrow{h\nu} Ag^{+} + e^{-}$$

ion

$$Ag^{\circ} \xrightarrow{\Delta H} (Ag^{\circ})_n$$

colloid

FIGURE 5 Mechanisms of silver doping

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[REFERENCE]

1) I.Shimizu, H.Sakuma, H.Kokado and E.Inoue, Bull.Chem. Soc. Jpn, 46, 1291 (1973)
2) A.E.Owen, A.P.Firth and P.J.S.Ewen, Phil.Mag.B, 52, 347 (1985)
3) K.Kawashima, H.Hosono and Y.Abe, J.Non-Cryst.Solids, 95-96 741 (1987)