HIGH ENERGY Xe^+ ENHANCED ADHESION OF Al AND Ag FILMS ON OPTICAL GLASS

Zhang Tonghe (张通和), Liu Yili (刘伊犁), Sun Yinguan (孙寅官)
and Shang Shixuan (尚世铉)

(Beijing Normal University, Beijing 100875, China)

(Received January 1989)

ABSTRACT

The samples consisting of 100nm Al or Ag film on optical glass substrate were irradiated by a beam of Xe 5×10^{15} to 2×10^{16} cm^{-2} with energy 320 keV. The adhesion of films on substrates was tested by Xe^+ irradiation. Optical character was measured by spectrophotometer. The ion mixing amount was measured by RBS. The results showed that after ion irradiating the adhesion of the film on the glass is enhanced. The adherent strength is greater than 10 kg/cm^2. The thermal stability of the films is good. The irradiated film is more optically efficient, the surface is smooth and rendered more corrosion resistance. The mechanism of the film adhesion was discussed.

Keywords: High energy Xe^+ Bombard Al and Ag films Ion beam enhanced adhesion

Ⅰ. INTRODUCTION

Recent reports of enhanced adhesion of metal films to various substrates after irradiation with ion beam have stimulated speculation concerning the mechanism involved[1,2]. A principal question is whether the bonding results from mixing produced by low energy irradiation[3] or from electronic effects produced at the interface by high energy beams[1], electron beam[4] or ultraviolet irradiation[5]. In this paper the enhanced by Xe^+ irradiation adhesion was studied, the optimum adhesion conditions were found, and the mechanism of the enhanced adhesion was also discussed.

Ⅱ. EXPERIMENTS AND METHODS

The Al or Ag films (100nm) were evaporated and condensed as a 100nm film on optical glass. The surface of the glass was cleaned carefully. Irradiation of samples was carried out in the 400 keV heavy ion implantor of Beijing Normal University. Beam of 320keV Xe^+ was used. The Xe^+ flux is about (2–3) $\mu A/cm^2$.

RBS analysis is performed by the Ionex General Tandem which provides a beam of

2 MeV He ions. The enhanced adhesion threshold doses were determined using scotch tape test[6].

In order to measure adhesion strength of film to glass, the bar was adhered to the film. The spring balance was hanged up on the bar. The weight hanged up on the spring balance and indicated the adhesion strength of film.

The optical character of enhanced adhesion films was measured by a spectrophotometer of 365 type.

In order to measure the adhesion strength of the films, the bar with 1 cm diameter was adhered on the irradiating film by adhesion. The measured results showed that if the beam is higher than $5\times10^{15}cm^{-2}$, the adhesion strength is greater than 10 kg/cm^2.

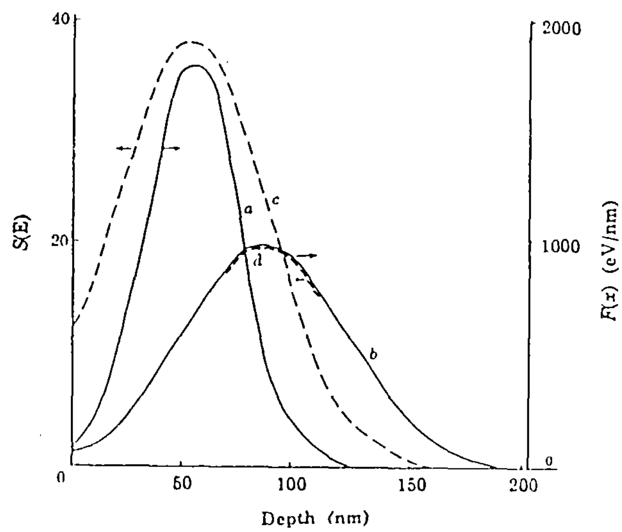

Fig.1 The relations between deposited energy function $F(x)$ of 320 keV Xe^+ and thickness of Ag (curve *a*) and Al (curve *b*) film, the relations of transmission sputtering coefficent $S(E)$ to thickness of Ag (curve *c*) and Al (curve *d*) film

The determination of enhanced adhesion condition is as follow: The choice of Xe^+ ion energy, with which to produce the film interfacial damage, is dictated by the production of ballistic cascade mixing. So that the Xe^+ average damage depth should be equal to the thickness of the film. That is, the peak of Xe^+ deposited energy function $F(x)$ in the film should locate in the interface[7]:

$$F(x)=\gamma(E)/[(2\pi)^{1/2}\triangle(x)]\exp[-(x-(x)_D)^2/(2\triangle(x)^2)] \quad (1)$$

$\gamma(E)$ is an estimated energy deposited in atomic processes and given by $\gamma(E)=E/[1+Kg(\varepsilon)]$, where $K=0.13372^{2/3}A^{0.5}$, $g(\varepsilon)=3.4008\varepsilon^{1/6}+0.40244\varepsilon^{3/4}+\varepsilon$, $\varepsilon=E/[86.931Z^{1/3}]$, E in eV. Here Z and A are the atomic and mass numbers, the $(x)_D$ and $\triangle(x)$ are the average damage depth and straggling of damage. The calculated results are shown in Fig.1. The transmission sputtering coefficients $S(E)$ are calculated by the following equation[8]:

$$S(E) = 0.042\gamma\ (E)/[NE_d\ (2\pi\ )^{1/2}\triangle(x)]\exp\ [-(d-(x)_D)^2/2\ \triangle(x)^2] \qquad (2)$$

where N is Al or Ag atomic density (cm^{-3}), E_d is the atomic bonding energy, d is thickness of the film. The others are the same as Eq.(1). The calculating $S(E)$ of Al and Ag are indicated by curve c and d in Fig.1.

It can be seen from Fig.1 that if 320 keV Xe^+ is used, the optimum thicknesses of Ag and Al are 53nm and 86nm, respectively. If the optimum thicknesses are used, the maximum $S(E)$ (atoms/ion) and deposited energy at the interface can be obtained.

Ⅲ. RESULTS AND DISCUSSIONS

1) Ion flux Xe^+ ion fluxes are 1, (2- 3) and 6μ A/cm^2 for the films enhanced adhesion. If the Xe^+ flux is lower than 3μ A/cm^2, a good quality of enhanced adhesion films can be obtained. But when the flux 6μ A/cm^2 is used, the films will tarnish and crackle.

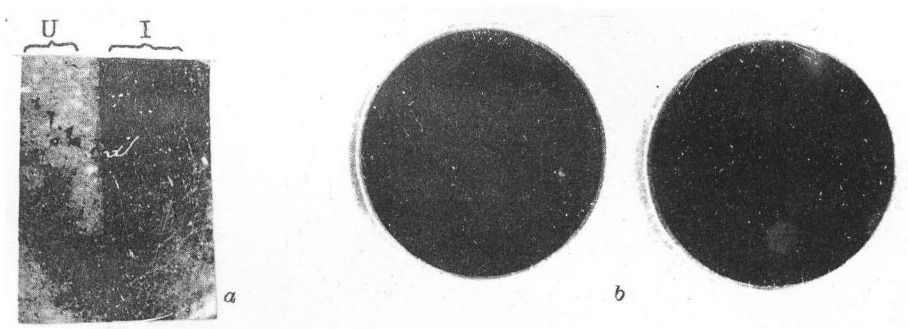

Fig.2 Photographs of Ag films (100nm)

a After scotch tape test, areas *U* and *I* are unirradiation and irradiation regions respectively; *b* After irradiated by 320 keV Xe^+ to a dose of $1.4\times10^{16}cm^{-2}$

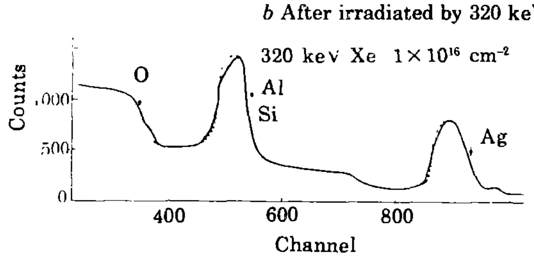

Fig.3 The results of RBS analysis before (dotted line) and after (solid line) Xe irradiating at 320 keV to dose of 1.4×10^{16} cm^{-2} for Al+Ag film on glass

2) The determination of enhanced adhesion ion doses The films were easily removed from unirradiated areas by scotch tape. It was also readity removed from area when the irradiated dose is less than $5\times10^{15}cm^{-2}$ (Fig.2*a*). If $1.4\times10^{16}cm^{-2}$ of the dose is used, the good quality of enhanced adhesion films is obtained. It is shown in Fig.2*b*. But when $2\times10^{16}cm^{-2}$ of the dose is used, the film will be tarnished gradually. And when the dose is greater than $2\times10^{16}cm^{-2}$, the film surface will be cracky.

3) RBS measurements The results of RBS analysis before (dotted line) and after (solid line) Xe^+ irradiation are shown in Fig.3. The area between dotted and solid curves of the Fig.3 indicates the Al or Ag recoil atom amount in glass. It can be seen that the Al and Ag have migrated into glass. Ballistic mixing is seen for the case of Al or Ag on glass. The migrated amount of Al into the glass is greater than that of Ag.

4) The optic character of the films The light transmission efficiencies of the films are shown in Fig.4. The results from the light transmission measurements of the film show that the light transmission efficiency increases with increasing of dose. The transmission efficiency increases to 5 per cent when the dose of $3.5\times 10^{16}cm^2$ is used. The results are shown in Fig.5.

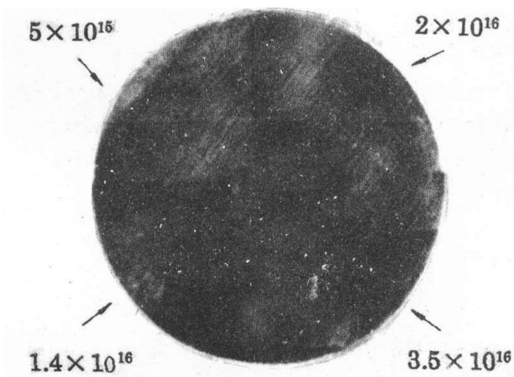

Fig.4 Photograph of appearance for Ag film on optic glass after irradiating 100 nm thick film with 320 keV Xe^+ to doses ranging from 5×10^{15} to 3.5×10^{16} cm^{-2}

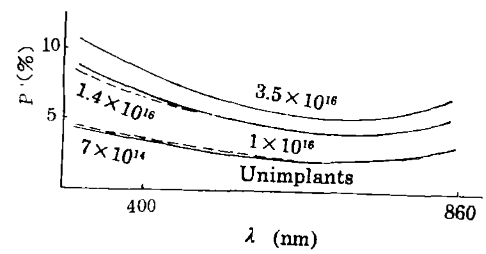

Fig.5 The relation of light transmission ratio P of Al or Ag film on glass to light wavelength λ

Ⅳ. CONCLUSIONS

Adhesion can be enhanced between Al or Ag films and substrates by Xe^+ irradiation. The optimum flux is less than 3 $\mu A/cm^2$. Optimum adhesive Xe^+ dose is $1.4\times 10^{16}cm^{-2}$. Therefore the enhanced adhesion of the films is suitable for soft collision. If the hard collision is used, the crackle will appear in the films.

REFERENCES

[1] T.A.Tombrello, *Nucl. Instr. Meth.*, **218** (1983), 679.
[2] A.E.Berkowitz *et al.*, *Nucl. Instr. Meth.*, **B7/8** (1985), 877.
[3] J.E.E.Baglin and G.J.Clark, *Nucl. Instr. Meth.*, **B7/8** (1985), 881.
[4] D.K.Sood *et al.*, *Nucl.Instr. Meth.*, **B7/8** (1985), 893.
[5] I.V.Mitchell *et al.*, *Appl. Phys. Lett.*, **45** (1984), 137.
[6] P.Mazzoldi and G.W.Arnold eds., Ion beam modifacation of insulators, Elsevier, Amsterdam, 1987, Chapter 15.
[7] P.Sigmund, *Physics Review*, **108** (1969), 383.
[8] P.Sigmund, *Rev. Roum. Phys.*, **17** (1972), 823.