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Nitrogen Ion Implantation in Pure Aluminium

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Abstract

In this study nitrogen ion implantation at doses from 4×10^{17} to 1×10^{19} ions/cm^2 and energy of 80 keV in pure aluminium is investigated. By means of x-ray diffractometry the phase composition was characterized. Nitrogen and aluminium nitride distribution in samples at different doses was analyzed using SIMS. Hardness of samples before and after implantation was tested by Vickers instrument. The SEM technique has been used for topographical studies of samples in different conditions. The results show that the hardness of samples after ion implantation process and because of formation of aluminium nitride phase increases dramatically, but above the dose of 5×10^{18} ions/cm^2 it decreases.

Keywords:

aluminium, nitrogen ion implantation, XRD, SIMS, Hardness Vickers

1. Introduction

It has been established that ion implantation is a technique for producing a modification in the structure of metals by formation of new crystalline phases, metastable or amorphous , and thus to improve the surface properties. In the past few years, implantation of nitrogen in aluminium has been widely investigated, both in the semiconductor and tribology fields because of the potential application of the nitride formed (passivation of semiconductor surfaces, transmission of surface acoustic waves, piezoelectric materials etc.). Tribological properties such as handness, friction, wear and corrosion can be improved [1-10]. The importance of aluminium nitride is because of its extreme handness, its electrical insulating properties (a band gap approximately 6.3 eV wide) and its high melting point (about 2400 ℃).

The results in the literature about the formation of AlN after nitrogen ion implantation are few and partly contradictory [11]. In the following study the effects of nitrogen ion implantation in pure aluminium is investigated.

2. Experiments and results

In the experiments the samples with 2 mm thickness made of pure aluminium (99.96 % purity) were used. The samples were implanted by using 80 keV ion implanter and unseparated nitrogen beam. The increase of the sample temperature was ensured solely by incoming ion beam without any additional heating. Implantation of aluminium samples performed at doses of 5×10^{17}, 1×10^{18}, 5×10^{18} and 1×10^{19} ions/cm^2.

The phase composition of nitrogen-implanted samples was analyzed using x-ray diffraction in the $\Theta-2\Theta$ mode and λ = 1.5418 Å of CuK$_\alpha$ radiation. The presence of nitride in all implanted samples was revealed by the spectrum of Fig. 1 as AlN in (111), (200), (220), (311) and (222) planes with wurtzite structure.

The effect of nitrogen implantation in microhandness properties of samples was tested by using Vickers instrument (see Fig. 2). It can be concluded that the hardness of samples improves after nitrogen ion implantation and extend of improvement increases with dose. The maximum hardness appears at a nitrogen ion dose

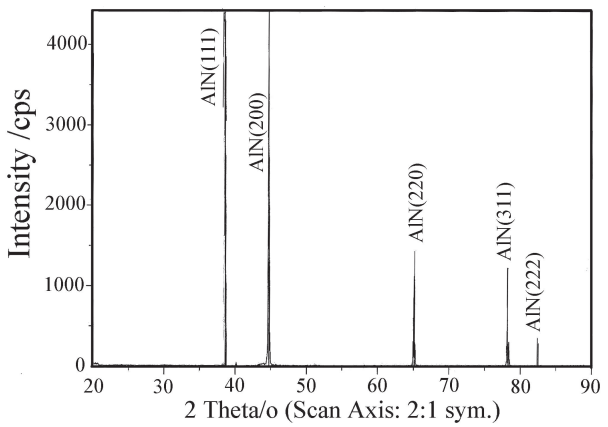

Fig. 1 XRD analysis of a typical sample implanted at dose of 5×10^{18} ions/cm^2

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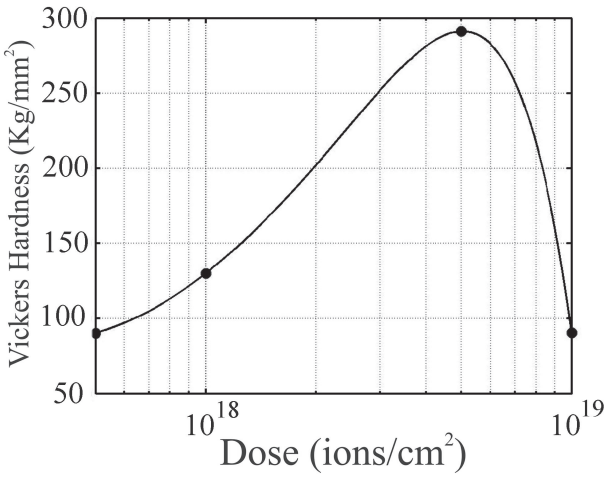


Fig. 2 Microhardness versus different nitrogen ion dose

of 5×10^{18} ions/cm^2. Over this dose, the hardness decreases. This may caused by defects due to the excess ion irradiation.

Nitrogen and aluminium nitride distribution in implanted samples were obtained by using secondary ion mass spectrometry technique (SIMS) . The experiments performed by SIMS CAMECA IMS-6F at Plasma Physics Research Center of Islamic Azad University. These profiles are shown in Fig. 3 (a) to 3 (c). One can observe that the shape of the nitrogen distribution in Fig. 3 (a) is Gaussian for lowest dose. For higher doses, the distributions became larger. These profiles also confirm that by increasing the nitrogen ion dose penetration depth of nitrogen decreases which could be because of enhancing the formation of aluminium nitride phase (AlN) that dose not allow nitrogen ions to penetrate more. This latter result, can be confirmed by comparison of Fig. 3 (a) to 3 (c) from the distribution of nitrogen and aluminium nitride in aluminium for samples implanted at various ion doses.

Figure 4 show the SEM images of unimplanted and nitrogen-implanted samples at different doses. It can be clearly seen that when the implantation dose increase, the surface morphology changes dramatically.

3. Conclusion

The results obtained in the present work can be summarized as follows. These experiments confirm the formation of the desired aluminium nitride precipitates by nitrogen ion implantation in pure aluminium. It was found that nitrogen implantation into aluminium was effective in enhancing the hardness of the aluminium surface, which is attributed to the formation of the crystalline AlN produced by nitrogen implantation. The hardness increasing did not continue at nitrogen ion dose above 5×10^{18} ions/cm^2. It could be caused by increase of defects at higher dose. SIMS analysis showed that by increasing the ion dose the penetration depth of nitrogen implanted ions decrease.

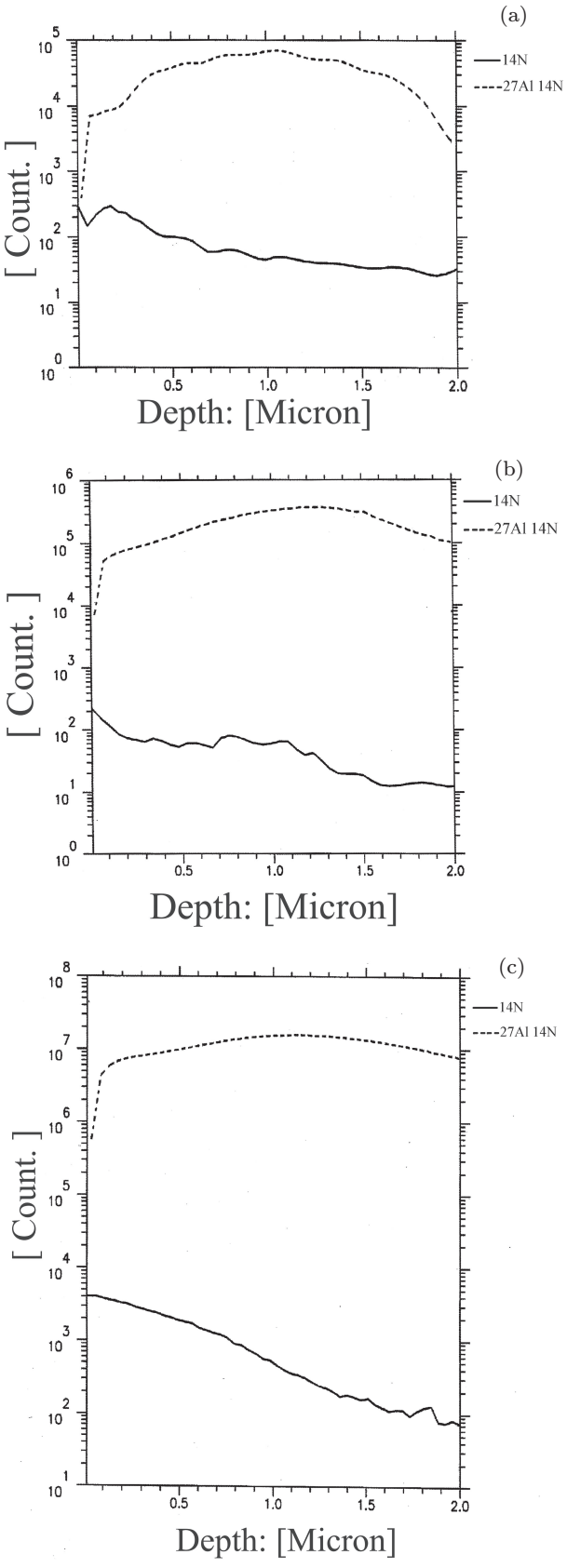
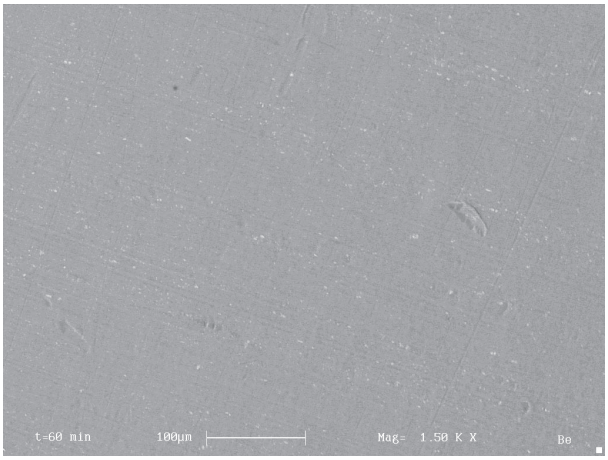
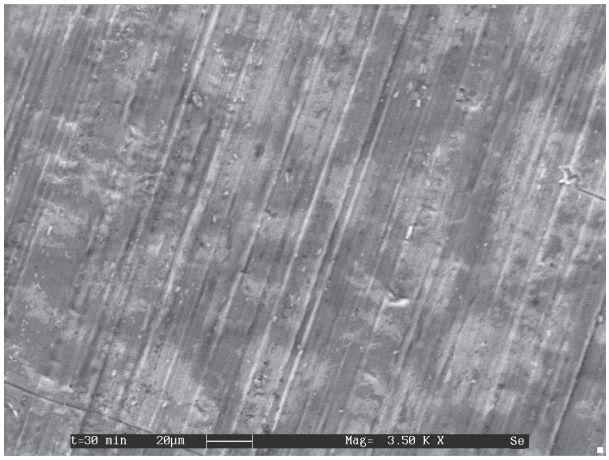


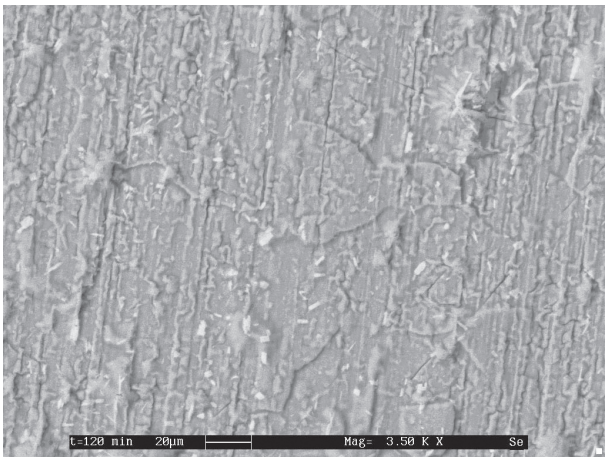
Fig. 3 SIMS analysis shows nitrogen and aluminium nitride distribution in samples implanted at doses of (a) 5×10^{17}, (b) 1×10^{18} and (c) 1×10^{19} ions/cm^2.



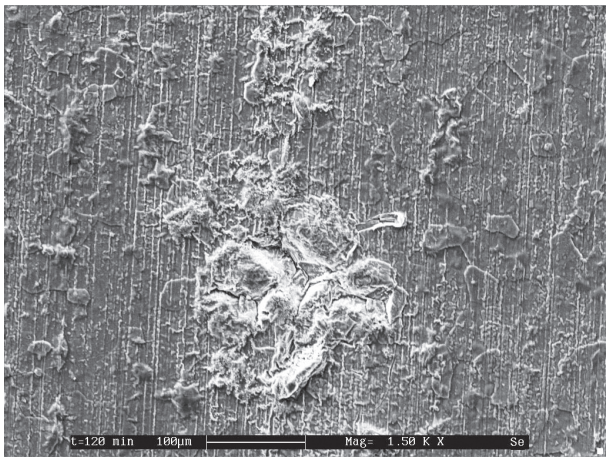
(a)



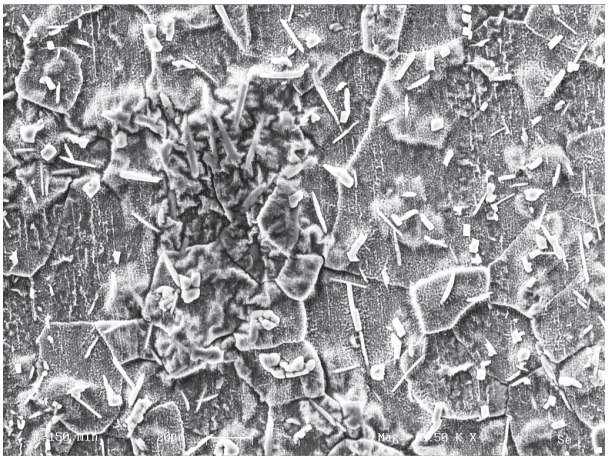
(b)



(c)



(d)



(e)

Fig. 4 SEM images presenting the surface of Al samples with increasing fluencies of nitrogen ions : (a) unimplanted Al, (b) Al implanted up to 4×10^{17} ion/cm^2, (c) 1×10^{18}, (d) 5×10^{18} and (e) 1×10^{19} ion/cm^2. The magnification is 3500x.

Acknowledgements

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