Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2012

Effect of wetting durability on Al surface by high current ion beam treatment

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1. Introduction

Aluminum and aluminum alloys have been considered as one of the most important materials in various industries [1]. However, poor wettability of Al limits its use for industrial applications. Therefore, many researchers have tried to improve the surface properties of Al by conventional methods such as polymer coating or plasma treatments. However, due to the water-soluble property of a polymer coating or low energy of plasma treatment, the wetting performance gradually deteriorates with increasing time and numbers of wet/dry cycles. Ion beam technology has been extensively used for decades to modify the surface properties of materials because of its much technological superiority to the conventional diffusion and coating methods [2]. The previous experiments results provided wettability of ion beam treated Al surface [3]:

(1) The contact angle of hydrophobic aluminum surfaces were remarkably up to around 20º by ion beam treatment.

(2) We obtained results that formation of AlN layer and thickness effect to wettabilty of Al surface through XPS and AES analyses.

However, the wettability mechanism on Al by ion beam treatment is not proved certainly. formation of compressive stress is not well understood [7]. This is partly caused by the difficulty of quantifying important parameters such as ion energy and flux in many experiments. Therefore in this study, it was anticipated main factors that affect wetting durability through XPS and SEM/EDX analysis and many literatures.

2. Methods and Results

2.1 Ion beam treatment and wetting durability

Ion beam treatments were performed for pure aluminum (Al 1050) to investigate the surface wettability in previous study. Nitrogen ion beam treated into aluminum with a dose range 5E17 ~ 1.5E18 ions/cm^2 at the irradiation energy of 20 ~ 50keV. During the ion beam experiment, the vacuum pressure was kept at a below 3x10^{-5} Torr to optimize operation conditions. And the current density of ion beam is measured by Faraday cup and was kept at high flux range of 24~40μA/cm^2. As a result, the contact angle of untreated Al was about over 80° and just after nitrogen ion beam treated Al was about below 10°. After 30 days, the contact angle was increased 26° under atmosphere environment. Also, the contact angles were kept about 20°±5º in the 500 wet/dry cycles; high temperature-high humidity and high temperature-low humidity cycling conditions.

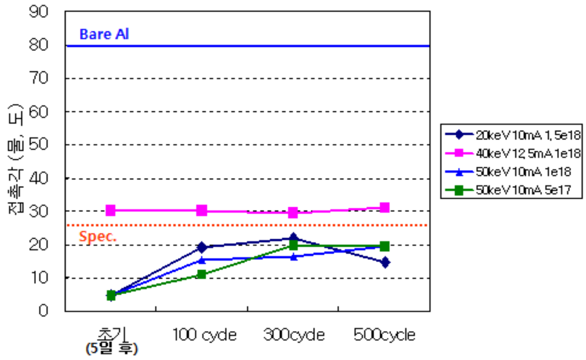

Fig. 1. Result of wetting durability at 500 wet/dry cycle test.

2.2 Comparison between low and high dos ion beam irradiation

The formation of AlN film by nitrogen ion beam treatment of an Al was identified with XPS analysis in previous experiments. Compressive stress arises when a growing AlN film is bombarded by atoms or ions which energies of tens or hundreds of electron-volts [4]. AlN films often exhibited a large compressive stress that can be increased by high current ion beam treatment in figure 2.

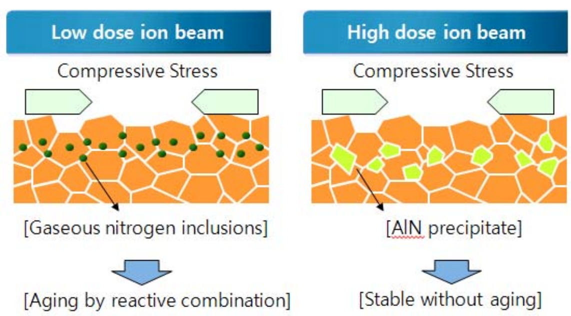

Fig. 2. Comparison between low and high dose ion beam irradiation

In case low dos ion beam irradiation, nitrogen ion could be existed by gaseous nitrogen inclusions and affects aging effect by reactive combination. But in case high dose ion beam treatment, nitrogen ion could be existed by AlN precipitate and it is more stable than low dos irradiation.

2.3 The hydrophilic mechanism by decomposition

The mechanism and kinetics of the hydrolysis reaction of A1N have been extensively studied [5, 6]. A simplified representation of the reactions taking place in neutral water is ;

$$A1N + 2H_2O \rightarrow AlO(OH)_{amorphous} + NH_3 \qquad (1)$$

As the NH_3 raises the pH according to

$$NH_3 + H_2O \iff NH_4^+ + OH^- \qquad (2)$$

Formation of crystalline bayerite, $Al(OH)_3$, becomes favorable at room temperature ;

$$AlO(OH)_{amorphous} + H_2O \rightarrow Al(OH)_{3,crystalline} \qquad (3)$$

Thus, the stability of the A1N precipitate with respect to hydrolysis in water can be evaluated by recording the ΔpH with time.

2.3 The formation of nano-structured surface

The surface morphology of AlN film was studied by high resolution SEM(Scanning Electron Microscopy) at an accelerating voltage of 15kV. Significant variations of morphology were observed in the AlN film irradiated at 40keV, 1E18 ions/cm^2 in figure 3. Figure 3 shows a smooth and bare surface of the non-irradiated sample, and no obvious structures were observed at that scale. The contact angle on the bare surface is about 80 degree. After ion beam irradiation, the surface which is below 10 degree, exhibits a nanostructure composed of compact nanoshperes with diameter of 10~50nm.

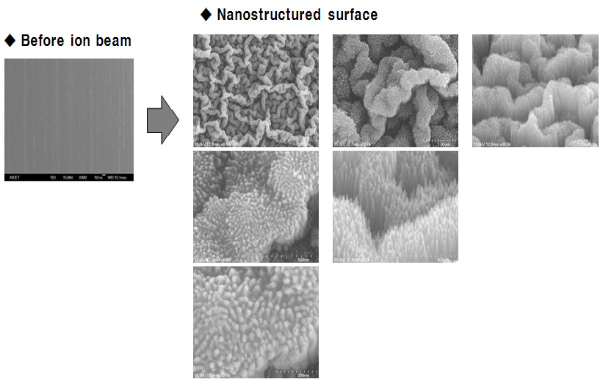

Fig. 3. The change of surface morphology before and after ion beam irradiation.

500 wet/dry cycle tests were performed to identify more detail morphology and nanoshperes arrays with sharp tips were regularly arranged on the surface in figure 4. It could be anticipated nanostructure after ion beam treatment affect wetting durability on Al surface.

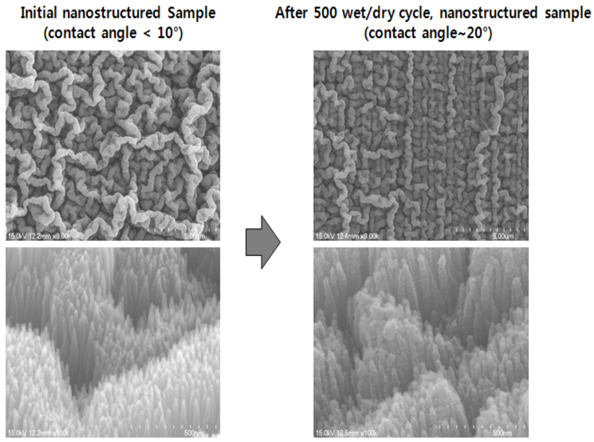

Fig. 4.The change of surface morphology after 500 wet/dry cycle test.

3. Conclusions

A high-current and high-dose nitrogen ion beam was irradiated on aluminum surface to investigate effect of wetting durability.

(1) Nitrogen ion beam irradiation affects AlN precipitate formation and it is more stable without aging effect.
(2) The mechanism and kinetics of the hydrolysis reaction of A1N
(3) After ion beam irradiation, the surface through SEM analysis exhibits a nanostructure composed of compact nanoshperes.

We anticipated main factors which affect wetting durability in this study. But the effect of nitrogen ion beam treatment on the wettability behavior of Al must be investigated further.

4. Acknowledgement

This work is supported by the Ministry of Education, Science and Technology of the Korean Government.

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