Discrepancies Between AES and SRIM in Nitrogen Implantation to Al Alloy

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1. Introduction

Many researches on improving characteristics of Al alloy which has hard and light properties have been carried out. One of the Al treatment techniques is the implantation which can make ions penetrate into the anticipated depth. Also, it doesn't impair samples, for normal temperature process is possible. In this study we implanted nitrogen ions into the Al alloy samples using the mass-separable implanter(in PEFP) with changing energy and fluence. To analyze elements depth profile, AES(Auger Electron Spectroscopy) was used and its results were compared with SRIM simulation. We found out differences between results of the SRIM and AES. Also we commented on this reasons.

2. Methods and Results

In the section the method of the experiment and the feature of the ion implanter are introduced. Also, we compare the result of AES to that of SRIM calculation.

2.1 Samples

As a target material, used was Al6061 which is the one of Al-Mg-Si alloys. The samples were cut to the size of 1 ㎝ × 1 ㎝. For a pre-treatment, T6(thermal treatment) was performed to all samples. After T6, polished samples were cleaned up by alcohol solution using a ultrasonic washer for 5 minutes.

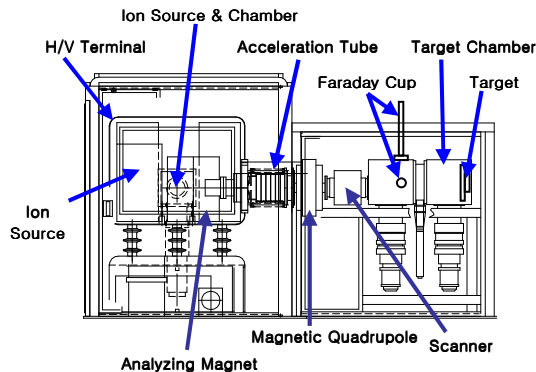### 2.2 Excperimental Device

Figure 1. The layout of the ion implanter with a mass analyzer.

Once extracted beam from the ion source(Modified Bernas type) passed through the analyzing magnet which separates N^+ ions from others, the beam is accelerated, passing through the acceleration tube. The accelerated beam passes through the quadrupole magnet and the scanner.

2.3 Measurement and Conditions

The beam current was measured by the X- and Y-axis Faraday cups in front of the target. Each faraday cup has a 5 mm hole and a pair of permanent magnets confining secondary ions. In the target vacuum chamber base pressure was 2×10^{-7} torr and working pressure was 2×10^{-6} torr. To prevent the samples from annealing, target temperature was kept below 60 ℃ during implantation.

2.4 Simulation

SRIM 03' code was used to calculate the penetration depth and to forecast the ion distributions in the Al target. The components of Al6061 were input respectively. Two energy variables(50 keV, 100 keV) were taken and the number of incident ions was 1×10^5.
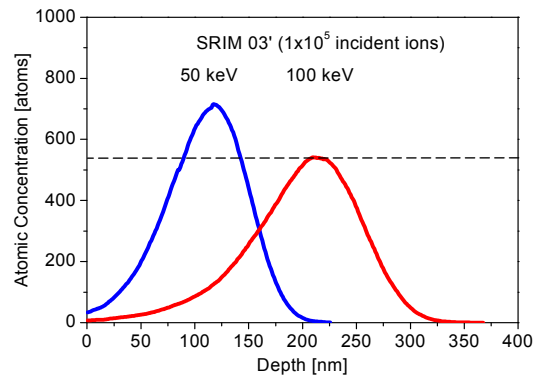

Figure 2. SRIM calculation result at 50keV and 100keV with 1×10^5 incident ions.

As shown in the Figure 2, in the condition of different energies the peak of the 100 keV curve showed a lower value than that of 50 keV in spite of the same fluence. It is due to the energy spread which increases as the ion energy increases.

2.5 AES analysis

Ulvac-Perkinelmer PHI 4300 was used for AES equipment. For depth profiling, Ar sputtering(3 kV, 15 mA) was used with a 12 s interval and electron beam(5

kV, 250 μA/cm^2) was used for scanning. AES shows information on the concentration distribution of nitrogen and on the depth profile of each element.

In Figure 3, the 50keV curve has a flat region in the top while the 100keV curve hasn't it. The flat region represents saturation of solid solution, which is due to the atomic ratio of the aluminum nitride(AlN) formation. In addition, at the ion energy of 100 keV, the average depth of ion distribution is about 260nm in depth which is deeper than that of SRIM's(Figure 2.). This discrepancy can be explained as the following.
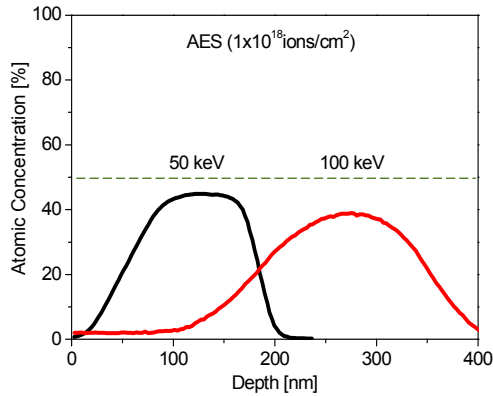

Figure 3. AES result at 50 keV and 100 keV, 1×10^{18} ions/cm^2.

First, the incident ion with 100 keV can induce larger irradiation damage in the material and it makes much more lattice defect. And solid solution tends to diffuse to this damaged direction[1], which is called "Radiation Enhanced Diffusion". Because the re-coupling time of the vacancies and interstitial solid solution is longer than the time of chain collisions, defects remain after the collisions. Then, microscopically intensive heat induced by the collisions spreads around. At this time, the solid solution can spread as the defect diffuses because of momentary thermal effect.

Second, intensive high temperature increases diffusion rate, which is due to the cascade collision. The first collision between incident ions and target atoms produces recoiled atoms which may make second collision with neighboring atoms. At the end of collision process, the kinetic energy of the atoms is transformed to thermal energy and the thermal energy spreads around into the collision region. For diffusion rate is proportional to temperature, microscopically intensive heat can induce rapid rate of diffusion. Also, it is reported that this tendency increases as incident ion fluence increases[2].

Last, as shown in the figure 4, atomic concentration stopped at around 45% with forming a flat region, which represents that atomic concentration rate doesn't increase anymore in spite of the increased ion fluence. It is called "Solid Solution Saturation". When AlN composition is formed, atomic concentration ratio tends to match the rule of stoichiometry[3] rather than makes

a narrow and high peak in the nitrogen depth distribution. It means, that is, solute diffusion in solid.
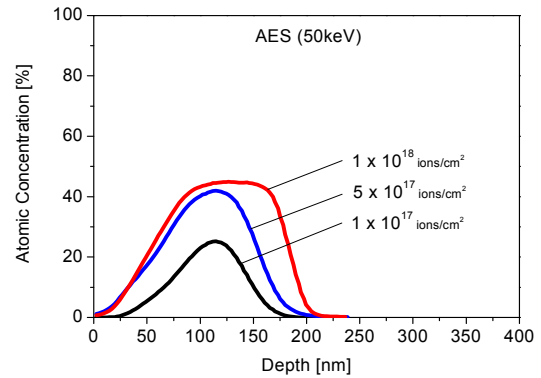

Figure 4. AES result at 50 keV with various fluences : 1×10^{17} ions/cm^2, 5×10^{17} ions/cm^2 and 1×10^{18} ions/cm^2.

3. Conclusion

In this study, we could observe different results between AES analysis and SRIM calculaution. To explain this discrepancy we exemplified some theories; radiation damage, diffusion rate of the solid solution by instant temperature rising, solid solution saturation by the stoichiometrical rule. we observed discrepancies between AES analysis and SRIM simulation. As a result of this study, we conclude that such discrepancy would be increased as the ion fluence rises.

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