Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2026

Enhancement of surface hardness using nitrogen and helium ion implantation

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Keywords : surface hardness, ion implantation, reinforced layer

1. Introduction

The surface hardness of most commercial products can be enhanced by coating, high-temperature sintering, and ion implantation. The ion implantation method has the advantage of being able to dramatically increase surface hardness by maintaining the shape of the product even after the process without peeling off the hardness reinforced layer.[1-3] However, the disadvantage is that the depth of strengthening hardness after the process is very thin at a level of hundreds of nm, so the effect of the enhanced surface layer cannot be fully utilized. In the case of general surface reinforced coatings, the performance of the coating layer is utilized by forming a thickness of 1um or more. If the implantation depth is increased to the level of 1 um, it can be used industrially. Most metal materials can use nitrogen ion implantation to enhance surface hardness, and to inject nitrogen ions into a metal material at 1um level requires more than 500 keV of energy. Ion implanters of 500keV and above are not suitable for industrial applications due to high construction costs and limited increase in beam current. The 200keV class accelerator is relatively low in construction costs and can easily extract high-current ion beams, so it can be applied as an industrial surface treatment method. This study is a basic study of industrial surface treatment technology to increase the depth of nitrogen injection by implanting nitrogen ions and helium ions with 30 keV energy into the metal surface.

2. Methods and Results

In this section some of the techniques used to improve the surface hardness are described. The techniques include a SRIM simulation, ion implantation, and nano indentation method.

2.1 SRIM simulation

The depth profiles of the implanted ions were calculated by SRIM(Stopping and Ranges of Ions in Matter) code[4]. In this study, 20 keV-N_2^+ and 30 keV-He ion beam were implanted into silicon wafer. The projected range of 20 keV-N_2^+ ion beam was about 30 nm. The vacancy distribution of 30 keV-He^+ beam was shown in Fig 1. The most vacancies were distributed around 300 nm below the surface. In case of cocktail beam implantation, we can implant 30 keV-N_2^+, 30 keV-N^+, 30 keV-He^+ ion beams into the target material simultaneously. When we use the cocktail beam, the reinforced depth can be increased by ion mixing and radiation enhanced diffusion effect.

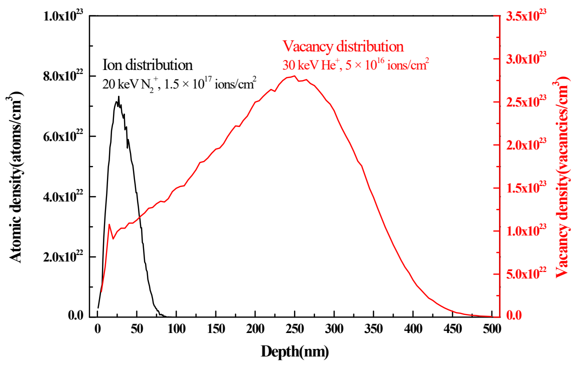

Figure 1. calculated depth profiles ion and vacancy distribution. (red) 30 keV-He, (black) 20 keV-N_2^+

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2.2 Ion implantation

The ion implantation process was conducted using the 30 kV ion implanter at KOMAC. The implanter is capable of implanting various ion species with fluence below 10^8 ions/cm^2. The implanter is also called the ultra-low fluence ion implanter.

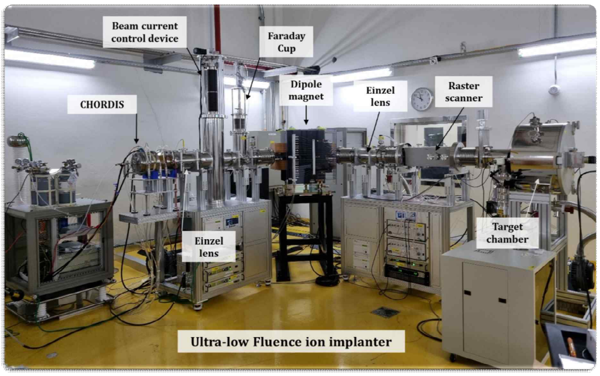


Figure 2. 30 kV ion implanter at KOMAC

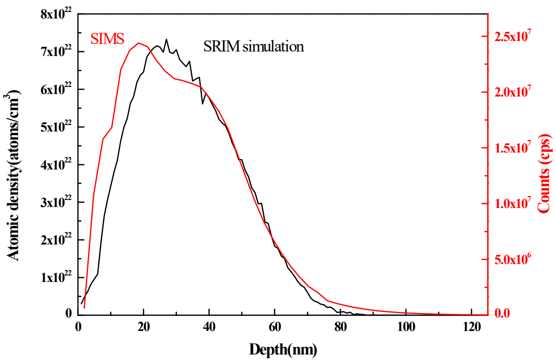
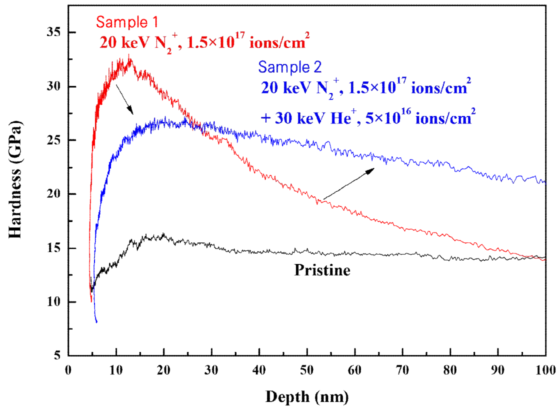


Figure 3 (red) SIMS result and (black) SRIM simulations of 30 keV-N_2^+ implanted silicon wafer

20 keV-N_2^+ and 30 keV-He^+ ions were implanted into silicon wafers. The depth profiles of implanted silicon were observed using SIMS measurements as shown in Fig 3. The calculated and observed depth profiles showed similar behavior.

2.3 Nano indentation

The surface hardness of each sample was observed using the ultra-nano indentation at KOMAC. The surface hardness of sample 2 was slightly reduced compared to sample 1 by helium ion implantation. However, the thickness of reinforced layer of sample 2 was 2.5 times increased than that of sample 1.



3. Conclusions

We tried to increase the depth of surface reinforced layer using nitrogen and helium ion implantation method. According to the ultra-nano indentation results, the depth of surface reinforced layer can be increased using the ion implantation method. In our research, we first implanted nitrogen ion beam and then implanted the helium ion beam. We are planning to use the cocktail ion beam technique to improve the surface hardness of the commercial products.

REFERENCES

[1] R. Pratap, M.H.N. Beshai, and R.T. Dhamejani, Surface hardness enhancement of titanium by an ion implantation technique, Thin Solid Films Vol.146, Issue 3, p. 33, 1987.

[2] D. H. Lee, B. Park, D. B. Poker, L. Riester, Z. C. Feng, and J. E. E. Baglin, Surface hardness enhancement in ion-implanted amorphous carbon, *J. Appl. Phys.* 80, 1480–1484 (1996).

[3] E. H. Lee, M. B. Lewis, P. J. Blau, and L. K. Mansur, Improved surface properties of polymer materials by multiple ion beam treatment, J. Matt. Research 6, 610, 1991.

[4] J. F. Ziegler, J. P. Biersack, "SRIM-2000, 40: The Stopping and Range of Ions in Matter", IBM-Research, Yorktown, NY 2000.

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