

Added new ion species and upgrade of control and measurement system for metal ion beam at KOMAC

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1. Introduction

The metal ion beam facility has a bernas-type ion source for the research of materials science and engineering in the KOMAC (Korea Multi-purpose Accelerator Complex) [1]. The bernas ion source can be extract various type of metal ions such as Cu, Fe, Cr, and Co up to 150 keV energies. The metal ion species are generally used metal chloride which have low vapor pressure temperature. The new ion species which Titanium (Ti), Magnesium (Mg), Manganese (Mn) and Chlorine (Cl) have been successfully extracted and verified for graphene growth, coloring of jewels and bio materials research purposes. Also we upgrade the control system of metal ion beam facility and measurement system for increasing the accuracy of fluences.

2. Methods and Results

The metal ion irradiation system consists of a bernas ion source, a mass separation magnet, an acceleration tube, a magnetic quadrupole doublet, a raster scanner and a target chamber. The target chamber has four faraday cups for measuring the ion fluences. The maximum energy of various ions are 150 keV and maximum extraction current is about 1 mA. At present, Chromium(Cr⁺), Cobalt(Co⁺), Iron(Fe⁺), and Copper(Cu⁺), Magnesium(Mg⁺) and Titanium(Ti⁺) ions are provided [2]. The operation properties of the new ion species are updated as shown in table 1.

Table 1. Operation table of new ion species

Ion Species	Mg ⁺	Cl ⁺	MgCl ⁺	Mn ⁺	Ti ⁺
Crucible Temp. (°C)	640	350-680	640	600	450
Crucible Power (W)	600	50-600	640	360	120
Vacuum Pressure (torr)	5.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}	3.0×10^{-5}	2.0×10^{-5}
Arc Current (A)	~0.4	~0.6	~0.4	~0.6	~0.2

2.1 RBS and SIMS data of new ion species.

The Mg and Ti ions extraction was published at last year [2]. But these implanted ions are not verified with a Rutherford Back Scattering (RBS) analysis and a Secondary Ion Mass Spectroscopy (SIMS) analysis. The Mg and Ti ions implantation are verified with the RBS

and the SIMS analysis in this report add to new a Cl⁺ and a Mn⁺ ion species.

The 100 keV Mg⁺ ion was implanted in the GaN wafer samples. In order to verify the implantation of Mg⁺ ions, the SIMS analysis method was used instead of the RBS analysis method, because it has a large error value in detecting a low atomic number materials. The SIMS analysis was performed in the National Nanofab Center. As shown figure 1, the Mg⁺ ions are implanted about 100 nm depth in the GaN. The ion range value is in agreement with the SRIM simulation [2]. The Mg ion beams can be used to study as a biocompatible materials.

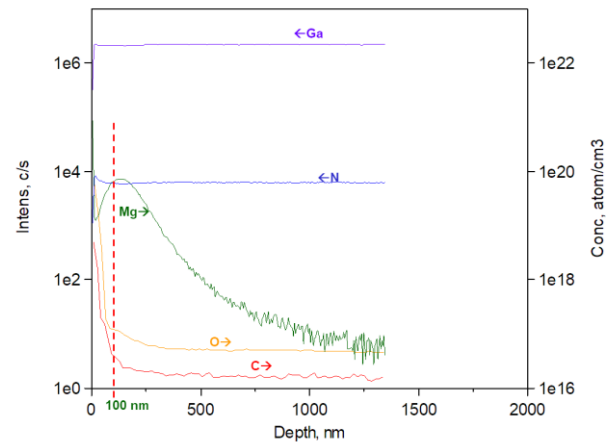


Fig. 1. Depth profile of the Mg⁺ ions implanted GaN

As shown in Fig. 2 the Ti⁺ ions are implanted in the Si wafer samples. The total number of Ti⁺ ions are 1.68E17 ions/cm² in the Si wafer. The RBS analysis was performed in the Korea Institute of Science and Technology (KIST). The Ti ion beams can be used to study as a graphene growth.

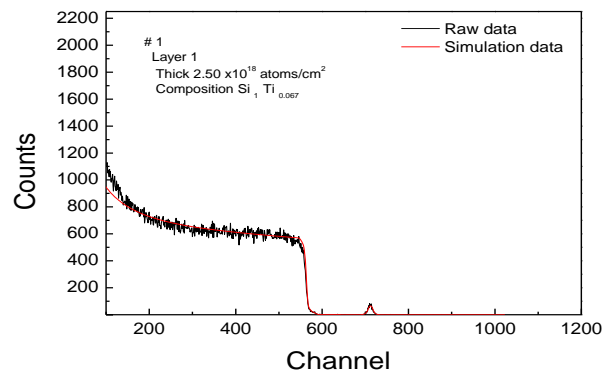


Fig. 2. 30 keV Ti⁺ ions are implanted in the Si wafer. Total number of Ti⁺ ions are 1.68E17 per unit area (cm²).

As shown in Fig. 3 the Cl^+ ions are implanted in the Si wafer samples. The total number of Cl^+ ions are $5.00\text{E}16$ ions/ cm^2 in the Si wafer. The Cl^+ ion beams can be used to study as a fast neutron detector.

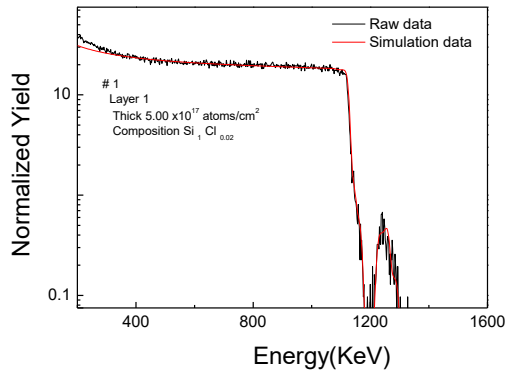


Fig. 3. 50 keV Cl^+ ions are implanted in the Si wafer. Total number of Cl ions are $5.00\text{E}16$ per unit area (cm^2).

As shown in Fig. 4 the Mn^+ ions are implanted in the Si wafer samples. The total number of Mn^+ ions are $2.56\text{E}16$ ions/ cm^2 in the Si wafer. The Mn ion beams can be used to study as coloring of jewels.

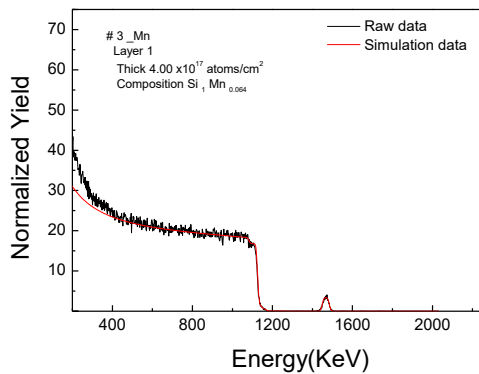


Fig. 4. 50 keV Mn^+ ions are implanted in the Si wafer. Total number of Mn^+ ions are $2.56\text{E}16$ per unit area (cm^2).

2.2 Control and Measurement system upgrade

Previous control system has not include fluence measurement function. And power and vacuum control performed in a single monitor. The monitoring graph of powers of devices and utilities couldn't display. In this works the control system attached fourth monitor direct recognize the beam operation variables about the fluence measurement, the power and vacuum control, and monitoring as shown in figure 5. The measurement display consist with in-situ current measuring, auto stop function, error calculation, total fluence measuring and irradiation time prediction function.

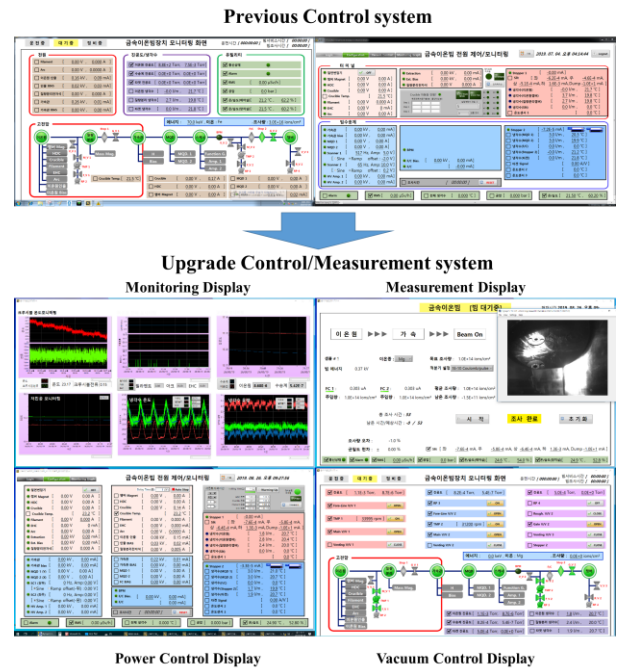


Fig. 5. Upgrading a control, measurement and monitoring system of metal ion beam facility.

Previous fluence measurement are performed that the charge from Faraday cup was converted to voltage signal which it fed into digital oscilloscope (SL1000 Yokogawa.Ltd) as shown in Fig. 5. This system could not in-situ measure the ion fluence. Also it is not coupled with the beam control system hence the possibility of human error was increased by manual controlling of desired ion fluence.

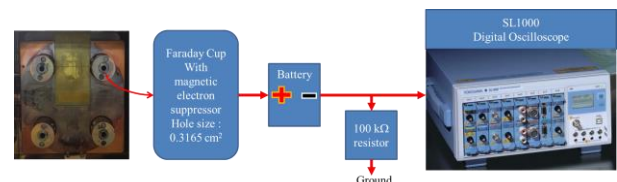


Fig. 6. Voltage integration method for measuring the ion fluence.

To improve the measurement system, the digital oscilloscope was replaced by the current integrator (Ortec 439) for in-situ measuring of ion fluence as shown in figure 6. This system was also automatically operated with the beam stopper when the ion fluence matched the desired ion fluence which helps to reduce the possibility of human error.

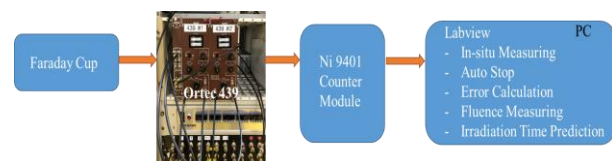


Fig. 7. Current integration method for measuring the ion fluence.

3. Conclusions

We have successfully verify Mg, Ti, Mn, and Cl ion implantation by the RBS and SIMS analysis methods with the metal ion beam. Also we upgrade control and measurement system for enhancing the efficiency of operation and increasing accuracy of the ion implantation fluence. We plan to verify the measurement system with the RBS analysis.

REFERENCES

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- [2] C.Y. Lee, et al, Titanium and Magnesium Ion Beam Extraction in a Metal Ion Beam Facility, Transactions of the Korean Nuclear Society Autumn Meeting, 2018.