Impact Objectives

- Develop a metallic solution ion source for use in constructing unknown functional materials
- Research opportunities to identify new materials for use as ion sources utilising electrospray ionisation (ESI) methods

A revolution in materials-driven fabrication processes

***Junior Associate Professor Masashi Nojima** has shared details of his exciting breakthroughs using selective elemental ion beams*

Can you tell us how you came to study focused ion beams?

My research began with my doctoral thesis on the 'Study on local analysis by nano-beam SIMS'. I completed this at The University of Tokyo in 2003, investigating instrumentation on focused ion beam-secondary ion beam mass spectrometry (FIB-SIMS). I learned about FIBs and their cross-sectioning abilities and secondary ion generations, mechanism and trajectories. I eventually developed a novel methodology of 'shave-off depth profiling'. The shave-off depth profiling introduced cross-sectioning processes of FIB and secondary ion generations in SIMS. My technique was revealed in an ion migration process within the interface between metal and polymer materials in an IC package. It is restricted by the physical abilities of the FIB. Generally, FIBs are generated by liquid metal ion source (LMIS) ionisation and are therefore expensive as the LMIS components are made from pure liquid metals or alloys. The high cost of working with LIMS inspired me to consider possible options for a low-cost ion beam source. I believed that if I could replace the liquid metals or alloys with a solution of metals, I would be able to create a valid FIB source and thus gain a cheap and plentiful supply of this vital component! The inspiration led me to invent a metallic solution ion source.

You are interested in material informatics, focused ion beam and thin film formation. What are some of the big gaps in knowledge you are hoping to address?

Material informatics has opened new avenues for the composition of different materials. The National Research Council of the USA defined as, 'Characterization describes those features of composition and structure (including defects) of a material that are significant for a particular preparation, study of properties, or use, and suffice for the reproduction of the material'. This definition highlights the way for us to reproduce materials from the informatics field as well as helping better understand the structures that define the physical properties of materials. While the field of material informatics is still in the data science stages and is far from the reproduction stage, I believe the gaps between these stages can be bridged by considering how we supply and reproduce composition materials. Metallic ion sources can elementally provide only typical materials as their constructed blueprints. The ion beam from metallic ion sources is elementally selected by our original mass separator and may reconstruct the ordered structures of materials.

Who will benefit from your findings?

This study will help us to realise the ultimate fabrication process ruled on periodic law. The mass separators can principally control ionic weights determined by periodic law and the existence of isotopes. Our original mass separator can be installed in the stream of ion beams and selected elements from the metallic solution ion source. This technique can revolutionise the materials-driven fabrication process to the periodic driven fabrication process. I believe the realisation of our project goals will represent a kind of revolution for academic and industrial studies in this area.

How are you developing fabrication processes in collaboration with industry?

We have support from the Toshiba Electric Devices & Storage Corporation and KIOXIA Corporation in a collaboration aiming to develop fabrication processes for new generation power and memory devices. We are also discussing the possibilities of this metallic ion source with specialists from the Japan Society for the Promotion of Science (JSPS) R026 committees on Future Design and Advanced Measurement and Analysis. We applied for a patent pending from the Tokyo University of Science in October 2021. This technique has possible importance in creating leading standards and potentially changing the world of fabrication processes. ●

Photograph showing metallic solution ion sources

Focusing on ion beams

*Ion beams play an important role in electronics manufacturing. A team from the **Research Institute of Science and Technology** at the **Tokyo University of Science** is looking into ways to produce a metallic solution ion source for ion beams*

Ion beams for any applications are basically a stream of charged particles. Ion beams should be optimised using different sources to suit the needs of the application. 'The technology of metallic solution ion beams can be applied to reproducing elemental structures as an elemental driven micro-dimensional 3D printer,' explains Junior Associate Professor Masahi Nojima, from the Research Institute of Science and Technology, Tokyo University of Science in Japan. Nojima is interested in creating a new generation of ion beams and has so far already succeeded in developing techniques for producing new focused ion beams (FIBs).

Nojima's most recent work is based on the development of a metallic solution ion source and will be used in constructing unknown functional materials by using ion beams made up of specific elements. Simply put, this process works rather like a micro-dimensional 3D printer. Where users wish to create a particular object with their printer, it is first necessary to assemble the components (elements) needed to create that object. 'A metallic solution ion source firstly selects elemental source by our originally developed mass separator,' explains Nojima. The metallic solution ion source can reconstruct original structures using elementally selected materials and can then control both scanning speed and the area of the ion beam to construct a copy of the original.

Developing the mass separator, which generates elementally selected ion beams

FULL BEAM AHEAD

'Ion beam techniques have been developed in industrial processes such as ion implanting, micro-machining and ion assisted deposition, and all of these developments help us make progress in pushing the boundaries of materials informatics,' outlines Nojima. FIBs are a powerful type of processing, with high current density and stability, and they are also able to be focused to within a few nanometres. 'However, ion sources of FIBs are quite restricted, as they require liquid metals such as gallium (Ga) or bismuth (Bi) or alloys such as AuGe (gold-germanium),' clarifies Nojima. His project is supported by grants from the JSPS KAKENHI, as well as support from the academic incentive system of the KIOXIA Corporation 2021 and the Toshiba Electric Devices & Storage Corporation 2021, and seeks to open up new materials for use as ion sources utilising electrospray ionisation (ESI) methods.

The research aims to create new generations of ion beams and seeks to harness the elements of FIBs primarily created from LMIS by field ionisation processes. 'The ESI with mass separation technique can open the new generation ion beam technology,' he observes. Nojima explains that they can now replicate materials using just the blueprints from materials informatics fields and this is to create unidentified complex materials.

A FITTING SOLUTION

The team has had some encouraging results. 'I have displayed the result of mass separating metallic ion solution ion beams on random conditions,' Nojima confirms. However, he has also experienced several challenges in achieving his target. Introducing dissolved materials directly into vacuum chambers has proved to be a real obstacle to Nojima's progress. 'For the first trial of metallic solution into a vacuum chamber, the turbo molecular vacuum pump was nearly crushed,' he states. Furthermore, the metallic solutions lead to deposits forming on top of the capillary. 'Thus, it is vital to develop an exact recipe for the metallic solutions as well as designing these for the shapes of the capillary to overcome these difficulties,' confirms Nojima. ●

Project Insights

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