MERIT Internship Report

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1st year of Ph.D. / MERIT-WINGS 10th
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Abstract of internship

・Host company: Mel-Build Corporation
・Implementation period: 2022/11/7 ~ 2022/11/25, 2022/12/5 ~ 2022/12/16
・Research topic: Development of damage reduction method using FIB sample stage equipped with Peltier device

Research background

Focused ion beam (FIB) is a widely used technique for preparing transmission electron microscopy (TEM) samples with high throughput by irradiating a converged gallium ion beam onto the sample. However, due to the knock-on and higher sample temperature caused by gallium ion irradiation, sample damage, such as the formation of the secondary defect and the mixing of gallium, has long been a problem [N. I. Kato, J. Microsc., 53 (2004)]. On the other hand, recent developments in TEM sample holders and micro-electromechanical systems (MEMS) allowed precisely controlled *in situ* TEM mechanical testing to be conducted [T. Sato, et al., Nat. Commun., 13 (2022)]. However, since FIB is used when attaching the sample to the MEMS device, developing a FIB sample stage compatible with the MEMS device is required for high throughput fabrication.

Mel-Build Corporation, mainly engaged in developing electron microscope-related equipment, has developed and commercialized the FIB sample stage equipped with Peltier device to cool down to -90 ℃. Performing FIB sample fabrication with cooling (cryo-FIB) would suppress the formation of secondary defects and the mixing of gallium. In addition, Mel-Build's precision machining and design technologies can be used to develop the FIB sample stage equipped with Peltier device compatible with MEMS device. In this internship, I set the following two research topics related to my doctoral research on *in situ* TEM mechanical testing methods using MEMS devices.

① Investigation of a method to reduce ion beam induced damage of single-crystalline gold sample using FIB sample stage equipped with Peltier device.
② Development of FIB sample stage equipped with Peltier device for MEMS device.

Activity description

About the first research topic, to evaluate the effect of cryo-FIB on sample damage of single-crystalline gold, two samples were prepared; one was fabricated by FIB at room temperature, and the other one was fabricated at -90 ℃ with the FIB sample stage equipped with Peltier device. As a result of TEM observations, the thin region of the sample fabricated at room temperature showed significant contrast due to dislocations, while the other one showed significant contrast due to precipitations. This difference would be due to the suppression of gallium diffusion, resulting in local gallium enrichment and precipitated alloy with gold.

About the second research topic, the FIB sample stage equipped with Peltier device for MEMS device was designed using Fusion360 published by Autodesk. In the design process, I considered maximizing the contact area between the sample stage and the Peltier device to increase the cooling efficiency, providing an area for fixing the conductor to *in situ* FIB mechanical tests by applying voltage from outside of FIB, and installing a mechanism to tilt the sample stage from outside of FIB to increase the throughput. As a result, I succeeded in designing a sample stage capable of cooling, mechanical testing, and externally tilted in FIB. This newly designed sample stage will be machined and applied to future research.

Feeling through the internship

Through this internship, in addition to gaining scientific knowledge by tackling the research topics I set, I was able to experience the best part of manufacturing from the viewpoint of equipment development. Moreover, I gained a bird's eye view of manufacturing from the viewpoint of business because of working closely with the CEO, and I strongly felt the importance of industry-academia collaboration. The most significant knowledge I gained through this internship was that participating in activities in different industrial fields are beneficial for advancing my research area. In the future, I would like to actively collaborate with people in different fields and cultivate a bird's eye view.

Acknowledgments

I would like to express my sincere gratitude to every staff at Mel-Build corporation for warmly hosting me for this internship. I deepened my understanding of the industrial field by sharing the work and knowledge with every staff cultivated. In particular, I would like to express my deepest gratitude to Mr. Hiroya Miyazaki, who guided company management and machine design, and Dr. Takashi Gondo, who guided equipment operation and experimental methods. I would also like to thank my supervisor, Prof. Naoya Shibata, my assistant supervisor, Prof. Takeshi Yanagida, and all professors and administrators involved in this MERIT program for providing me with this precious internship opportunity.