MERIT Internship Report

Department of Materials Engineering
D3 / MERIT 7th student
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- ## Implementation period

2021/9/1~2021/10/29

- ## Hosting company

EM Research and Development Department 2, EM Business Unit, JEOL Ltd.

- ## Research Topic

Development of efficient atomic-resolution imaging method using OBF STEM

- ## Background

A scanning transmission electron microscope (STEM) is a microscope that uses transmitted electrons through a sample with raster-scanning electron beams converged to sub-angstrom size. The STEM provides extremely high spatial resolution, but one of the major challenges in recent years has been the analysis of materials with low tolerance to electron irradiation (so called electron beam sensitive materials). For the observation of electron beam sensitive materials, low electron dose conditions are required to reduce irradiation damage, but at the same time, low-dose conditions cause the poor signal-to-noise ratio of the image.

In my doctoral course research, I was working on the development of a highly efficient STEM imaging method to enable observation of the beam sensitive materials. As one of the results of my research, I succeeded in developing the optimum bright-field (OBF) STEM method, which is about 70 times more efficient than conventional imaging methods. In response to the recent worldwide increase in demand for low-dose STEM observation, JEOL, which is a leading company on the electron microscopes, has decided to adopt the OBF imaging technique as a product. Therefore, as an opportunity to be involved in the product development and implementation of the OBF STEM method, we planned and conducted a MERIT internship at JEOL. Through this internship, we aimed to learn how the development of electron microscopes is carried out, how to work in the private company, and what the R&D field at JEOL is like.

• Activity description

The OBF STEM uses a segmented-type electron detector, which has become popular worldwide in recent years. In a segmented detector, the detector plane is divided into multiple channels, and STEM images are acquired from each area. The OBF STEM image is obtained by applying image processing to each of these simultaneously acquired STEM images, and the shape and number of channels affect the imaging characteristics. In this internship, we investigated the dependence of the detector geometry on the OBF STEM method from both experimental and computational aspects, and aimed to propose a more suitable detector for OBF imaging.

A common method to evaluate the imaging characteristics of electron microscopes is to calculate the phase contrast transfer function (CTF), which provides the spatial frequency characteristics of the imaging technique of interest. So far, the School of Engineering at the University of Tokyo has established a university-corporate collaboration office with JEOL, and the research and development of the segmented-type detector (segmented annular all-field detector: "SAAF" detector) has been conducted. Therefore, we performed CTF calculations of the OBF STEM for the SAAF detector developed at the University of Tokyo and the commercial version of SAAF at JEOL. At the same time, image simulations and experiments of the OBF STEM method using the above SAAF detectors were conducted at both JEOL and the University of Tokyo for comparison. As a result, it was found that the number of channels and the division shape of the SAAF detector have a significant effect on the OBF STEM imaging characteristics, which is especially important for the observation of heavy element atoms.

• Feelings through the internship

Through this internship, I was able to have an opportunity to come into contact with electron microscopes from the perspective of R&D, which I had never had the chance to know before. In addition, the way of spending time in a private company is very different from that in a university laboratory, and I strongly felt that being able to know the atmosphere of a private company would be a great source of inspiration for me in the future.

• Acknowledgements

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