Department of Electrical, Electronic and Computer Engineering	Key words	Electron optics, aberration corrector, differential algebra, electron microscopy, electron tomography, Ultra high voltage electron microscopy

Doctor of Eng. / Professor

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Education

Department of Electronic Engineering, Faculty of Engineering, Osaka University
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Professional Background

Assistant Professor, Associate Professor, Center for UHVEM, Osaka University
Chairperson, Committee on Electron and Ion Beam Science for Nanotechnology, JSAP
Secretary, Electro-Optical Design Technology Research Group, JSM

Consultations, Lectures, and Collaborative Research Themes

Electron optics (including aberration theory), electron microscope instruments, electron tomography (CT)

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Main research themes and their characteristics

「Development of aberration correction optical system with symmetric line currents (SYLC)」

Electron optics is an academic field that studies the characteristics of electromagnetic lens systems such as electron microscopes. Aberration correction technology could dramatically improve the performance of electron microscope. On the other hand, since it needs a very complicated and expensive multipole system, more simple aberration corrector is desired for SEM. We have been researching aberration correctors for both spherical and chromatic aberrations at low cost. To be simple configuration, we proposed symmetric line currents (SYLC) which consists of several parallel lines arranged on the optical axis in rotational symmetry. We shown that the magnetic field closely equivalent to a hexapole field. The SYLC can be construct spherical aberration corrector. Because the SYCL does not use magnetic poles, there is essentially no influence of nonuniformity or hysteresis of the magnetic material, and the manufacturing cost and controllability may be improved.

We also developed a new aberration analysis method using the differential algebra. The differential algebra is a mathematical method that can efficiently obtain the aberration coefficients. We are applying this to model analysis of aberration correctors. We will analyze the corrector of higher-order aberrations of 5th order or higher and chromatic aberrations. Therefore, we aim to develop a high-resolution electron optical system in the extremely low energy (100V to 1kV) range suitable for CD-SEM.

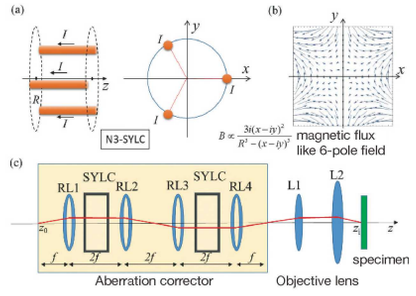
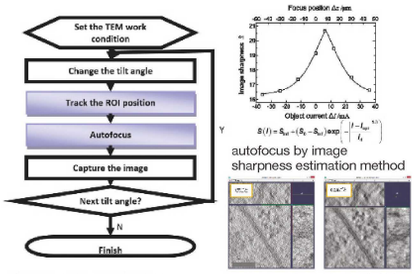


Fig.1 Spherical aberration corrector with SYLC. Three parallel lines are placed in axisymmetric position, which gives the magnetic field close to 6 poles.

「Automation of tomography in ultra high voltage electron microscopy」

Ultrahigh voltage electron microscope tomography is an important technology for three-dimensional (3D) observation of materials science, semiconductor fields, and biological samples, in particular, for a thickness of 1 μm or more. In tomography, a large number of images must be taken during rotating a sample with small tilt angle increments. Manual observation is a time-consuming task. Therefore, useful information can be acquired within a limited observation time, if possible, to automatic acquisition. It was realized by feeding back the position of field of view and the focus from the images captured by the digital CMOS camera to the lens system, the deflection system, and the sample-position-control system of the electron microscope. For focusing, a high-speed autofocus is realized to estimate the focusing position where the maximum image sharpness by using an empirical formula. We implemented a practical software that enables tomography tilt-series acquisition within 30 minutes if the tilt-step is every 2 degrees in the range of ±60 degrees for biological samples. We will extend the target sample to semiconductor or rod-shape samples.



Automatic image acquisition sequence

Reconstruction images. (left) by 60 tilt-images, (right) by 600 tilt-images.

Fig.2 Ultra high voltage electron tomography. Automatic image acquisition sequence with autofocus by image sharpness estimation method, reconstructed tomographic image (bottom right)

Major academic publications

Shahedul Hoque, Hiroyuki Ito and Ryuji Nishi, Spherical aberration correction with an in-lens N-fold symmetric line currents model, Ultramicroscopy, 187, (2018)135-143

R. Nishi and A. Takaoka, Stigmatic condition for electrostatic core-lens by using diagram of axis intercept, Optik, 123, 16 (2012) 1492-1496,

R. Nishi, S. Hoque, H. Ito, and A.Takaoka, Investigation of electromagnetic-SYLC for chromatic aberration correction, CPO-10, (2018) p.14