New Possibilities Opened by Advanced Electron Holography

Toshiaki Tanigaki

Research and Development Group, Hitachi, Ltd., Saitama, 350-0395, Japan

Functional materials and devices supporting our life are constructed on the basis of electromagnetic properties emerged from fundamental atomic arrangements. Thus high-resolution observation of electromagnetic field is important to understand mechanism of its function. Electron holography using interference of electron wave is one of quantitative microscopic techniques to visualize electromagnetic fields at nanometer scale. The idea invented by Dennis Gabor has been developed to the practical level by employing cold field emission gun (cold-FEG). Recently we have developed several technologies to expand the possibilities of electron holography.

In electron holography, object wave passing through the sample and reference wave passing through reference area such as vacuum are overlapped to form interference pattern called hologram. Even after the coherence degree between the object and reference waves was improved by cold-FEG, the long standing problem in this method was that the observable area was limited near the edge of the sample. To overcome this problem, split-illumination electron holography (SIEH) employing multiple biprisms has been developed (Figure 1) [1]. In this method, a coherent electron wave is separated into two coherent waves using biprism placed in the illumination system of the electron microscope. After the object and reference waves passing through distant position on the sample plane, they are overlapped using biprisms in the imaging system. The distance between the object and reference waves on the sample plane became controllable and the area locating far away from the sample edge became observable. We also developed advanced SIEH without Fresnel fringes for precise phase measurements [2].

For observing three-dimensional (3D) electromagnetic fields, we developed 3D electron holographic technology using sample rotation holder. The dedicated holder has two axes which can rotate a sample in 360 degree. The holder without missing wedge can provide precise tomography results. Using the developed method, the sample has two magnetic vortex cores were reconstructed [3]. The obtained results were confirmed as one of the stable conditions by micromagnetic simulations.

For pushing the limit of spatial resolution in electron holography, 1.2-MV aberration corrected cold-FE transmission electron microscope (TEM) has been developed. This is the first ultra-high-voltage TEM equipped with an aberration corrector. By improving stability of high-voltage, electric circuit, electron gun and environment around the microscope, the resolution of 43 pm has been realized at the high-resolution observation conditions, in which the sample is placed in high magnetic field of the objective lens [4]. Under the field-free observation condition, in which the sample is placed out side of the magnetic field of the objective lens for observing magnetic sample, the spatial resolution has been reached 0.21 nm [5]. The observation of magnetic field at atomic resolution using electron holography is expected to be realized.

The electron holographic technologies have been improved and became more...
practical and powerful. The developed technologies open new possibilities to visualize electromagnetic fields in and around the sample under varieties of conditions, which was difficult to be achieved using conventional electron holography.

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References


FIG. 1. Schematics of split-illumination electron holography. (a) Conventional electro holography. (b) Idea of split-illumination electron holography. (c) Detailed optics of split-illumination electron holography.