Effects of Fresnel Corrections for Phase-Shifting Electron Holography

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Phase-shifting electron holography [1] is a useful technique for detecting a small phase change of an electron wave. In this method, however, Fresnel diffraction at an electron biprism causes two kinds of problems to the reconstructed phase. One is the influence on the amplitude of the electron wave, i.e. Fresnel fringes, resulting in non-uniform contrast of interference fringes. The non-uniform fringes bring numerical phase errors in reconstructed images. In order to remove the phase errors, we calculated the envelopes of the fringes, and normalized the non-uniform contrast. [2] The other problem is that Fresnel diffraction directly distorts the phase of the electron waves. We prepare the reference holograms that were taken in a vacuum without specimens, and then correct the distortion by subtracting the reconstructed phase of the reference holograms from that of holograms. [2] In this report, we evaluate the effects of the above correction methods (Fresnel corrections) using a computer simulation and show the possibility of observing a very small amount of electric charges.

In this simulation, we assumed a charged latex sphere placed on a uniform carbon film. We also assumed that the size of the sphere was 60 nm in diameter and that the amount of electric charges was +5 e ($e = 1.6 \times 10^{-19}$ C). Figure 1(a) shows an interference micrograph directly calculated from the phase changes due to the electric charges. Figure 1(b) shows the simulated hologram of this sphere. In this Fig. 1(b), we considered the influence of Fresnel diffraction, quantum noise and electron-wave coherency. [3] Figure 1(c) shows the interference micrograph reconstructed without Fresnel corrections from 100 holograms and 100 reference holograms. Figure 1(d) shows the micrograph with Fresnel corrections. These interference micrographs are phase-amplified by a factor of 300.

In Fig. 1(c), the phase errors due to Fresnel diffraction obscure the electric field. Using Fresnel corrections, however, the phase errors decreased to 5% of those in Fig. 1(c) and the phase-measurement precision reached $2\pi / 410$ rad. Consequently, the electric field can be observed as shown in Fig. 1(d).

References

[1] Q. Ru, G. Lai, K. Aoyama, J. Endo and A. Tonomura, Ultramicroscopy **55**, (1994) 209-220.

[2] K. Yamamoto, I. Kawajiri, T. Tanji, M. Hibino and T. Hirayama J. Electron Microsc. **49**, (2000) 31-49.

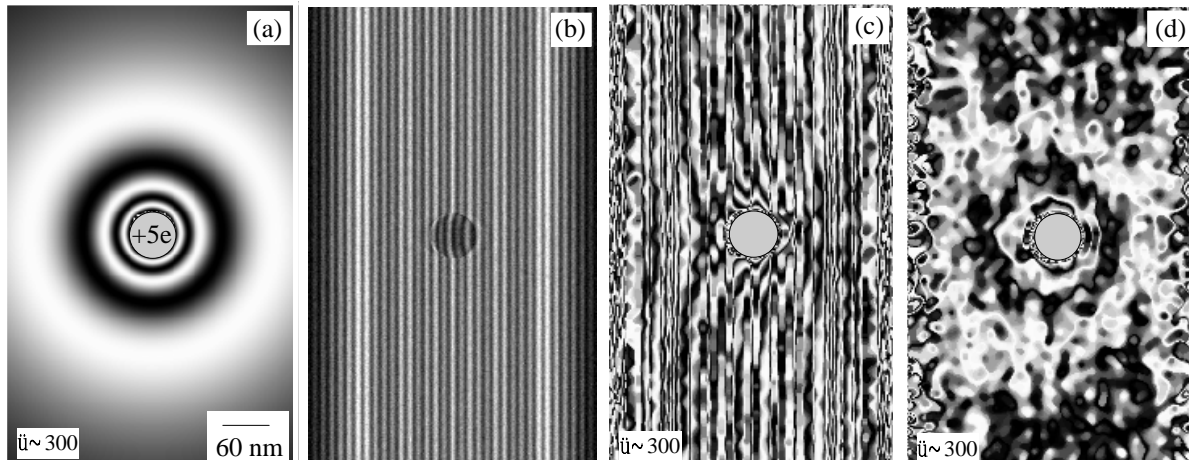[3] K. Yamamoto, T. Tanji and M. Hibino, Ultramicroscopy **85**, (2000) 35-39.

Fig. 1(a)   Interference micrograph of a charged latex sphere. It is directly calculated from the phase change due to positive charges of 5 electrons. Phase-amplified factor is 300. (b) Simulated hologram of the sphere. The influence of Fresnel diffraction, quantum noise and electron-wave coherency are considered. (c) Interference micrograph reconstructed from 100 holograms and 100 reference holograms without Fresnel corrections. (d) Interference micrograph with Fresnel corrections.