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Image Processing for Phase Imperfections in Electron Holography

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Introduction

Electron holography has been used for observing an electric field or a magnetic field. However, the disconnection of interference fringes cause phase errors in the phase images reconstructed from electron holograms. In some cases, a strange contrast, where the contrast reverses abruptly from white to black especially in the thick regions of the specimen, may occur in a directly reconstructed phase image [1]. There are two types of such abrupt reverses. One is a jump of 2π in the phase during the digital reconstruction process; however, the phase can be unwrapped and connected smoothly after such a jump. The other is caused by the disconnection of interference fringes due to the weakness of the electron-wave amplitude. A correction technique has been proposed to reduce the influence of distortions on the reconstructed phase. This proposed technique will be illustrated with experimental results.

Experimental Procedure

In our proposed method, the interference pattern of an electron hologram is captured by a CCD camera attached to the bottom of a Hitachi field-emission electron microscope HF-2000. First, we reduce the influence of Fresnel diffraction and noise by using a low-pass filter, retaining only those interference fringes that contain useful phase information. Then, we binarize the electron hologram to extract interference fringes by using a binarization algorithm. Finally, we correct the failed interference fringes, which are mainly disconnected or incorrectly connected, by cut-and-reconnect processing performed using MATLAB (MathWorks). Thus, we obtain a reconstructed phase image without any phase error.

Results and Discussion

The interference pattern of an electron hologram for a CeO_2 specimen captured by a CCD camera is shown in Fig.1a. The reconstructed phase image obtained directly from the electron hologram (Fig.1b) shows some phase imperfections. A binary image of the interference fringes that contain phase information can be used to reconstruct the phase images; nevertheless, imperfections in the interference fringes, viz. disconnected and incorrectly connected fringes, occur in the binary image, as shown in Fig.1c. The disconnected and incorrectly connected points on the interference fringes occur generally in the areas with abrupt intensity variations or a rather low intensity, and such points always appear in pairs. The reconstructed phase image (Fig.1d) obtained from the hologram (Fig.1c) shows some phase imperfections since the interference fringes are not corrected. We corrected the distorted interference fringes by cut-and-reconnect processing performed using MATLAB and then smoothed the corrected interference fringes by using a median filter, as shown in Fig.1e. The reconstructed phase image (Fig.1f) obtained from the corrected interference fringes shows that the phase error has been drastically reduced.

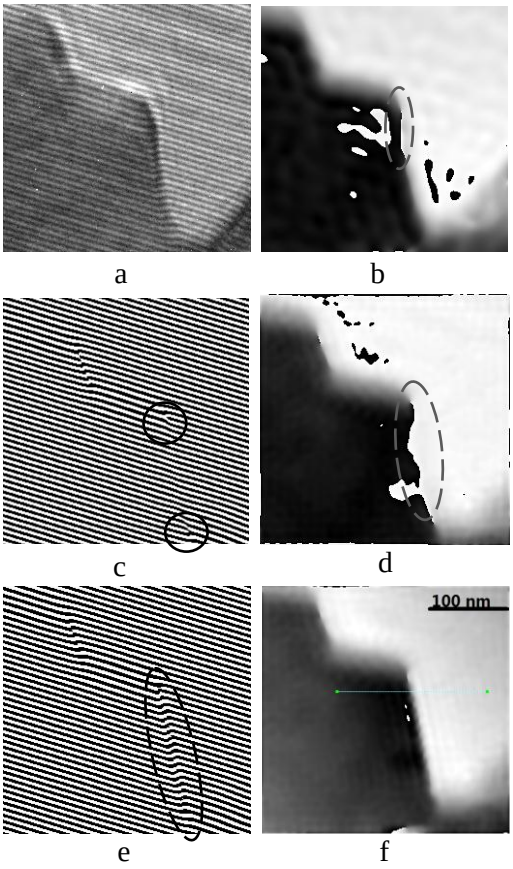

Fig. 1. Images showing processing method: a. original electron hologram of CeO_2; b. directly reconstructed phase image; c. binary image of interference fringes; d. reconstructed phase image of c; e. image showing connected interference fringes; f. reconstructed phase image of e.

References

[1] T.Tanji, K.Urata, K.Ishizuka, Q.Ru and A.Tonomura, Ultramicroscopy, 49, 259-264 (1993)