Type of presentation: Poster

IT-1-P-2835 Projector lens and CCD camera distortions in a Hitachi HF-3300 TEM

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In a transmission electron microscope (TEM) the projector lenses are known to introduce large-scale distortions. The magnification and the rotation in the image can vary up to 5% and 2° across the field of view [1]. Therefore the accurate mapping of any physical field (strain, magnetic or electric field) using high resolution TEM or holography requires the calibration of those distortions. The method used here does not add noise to the phase image and alleviates the need for a reference hologram.

We have investigated the projector and the CCD camera distortions on a recently installed aberration-corrected HF-3300 Hitachi TEM (I2TEM-Toulouse). The distortions were measured using off-axis electron holograms acquired in the vacuum. A double biprisms setup was used to remove the Fresnel fringes [2]. The voltages of the biprisms were set so that the interference pattern fills entirely the 4k Gatan CCD camera. Two holograms with a different orientation of the biprisms were acquired in order to reconstruct the 2D strain field using geometrical phase analysis (GPA) [3]. Before GPA calculation, the reconstructed phase images were fitted using a 4th order polynomial to remove the noise.

The influence of the magnification and the values of P1 and P2 was investigated. It was found that the distortions are mainly dependent on the value of P2. Fig. 1 shows the strain field obtained for 4 different values of P2. Increasing P2 is equivalent to "zoom" into the distortion pattern. The variations across the image are then lower for high values of P2. At a nominal magnification of ×1.5M (P2 is equal to 5.3 A) the mean dilatation Δ_{xz} varies from 0 to 3% and the rigid body rotation ω_{xz} varies from 0 to 1° from the center to the corner of the image.

According to the theory [1], Δ_{xz} and ω_{xz} should be circular shaped. However it can be noted that the rotation image is slightly triangular shaped. After analysing the ronchigram of the camera provided by Gatan [4] we found that this is due to the low frequency distortions of the camera (see Fig. 2 after correction of the camera distortions). We then created an artificial ronchigram for correcting both the projector and the camera distortions. The procedure will be detailed during the presentation. Fig. 3(a) is an example of dark-field hologram acquired on a SiGe layer grown by epitaxy on a Si substrate. Without correction (Fig. 3(b)) the reconstructed phase image exhibits some variations in the substrate and the phase ramps in the layer are slightly distorted. Those artifacts are removed after correction (Fig. 3(c)).

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[2] K Harada et al, Appl. Phys. Lett. **84(17)** (2004), 3229–3231
[3] MJ Hÿtch et al, Ultramicrosopy **74** (1998), 131–146
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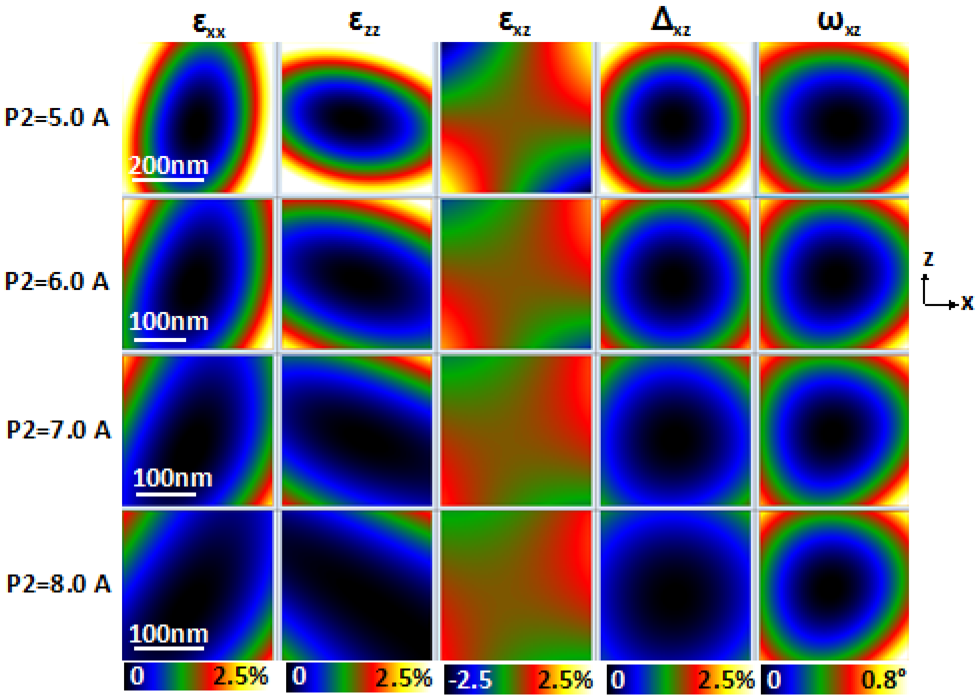

Fig. 1: Distortions of the projector lenses as a function of the displayed value of P2. The strain field was calculated by geometrical phase analysis after fitting the phase images reconstructed from the holograms. From left to right are shown the horizontal ε_{xx}, the vertical ε_{zz}, the shear ε_{xz} strain, the mean dilatation Δ_{xz} and the rotation ω_{xz}.

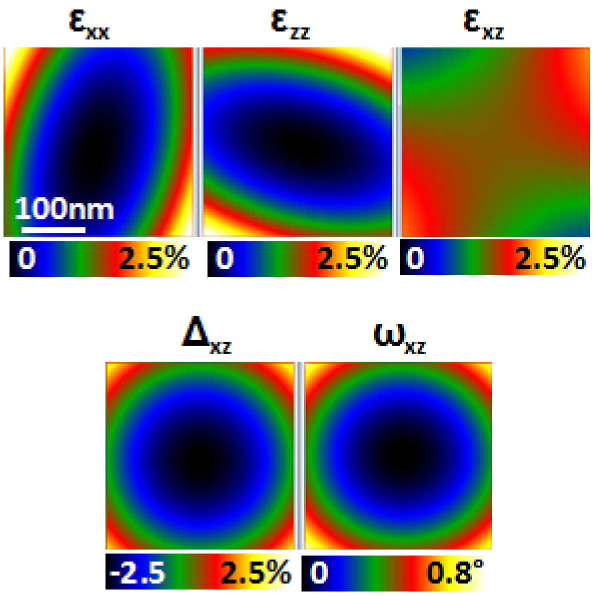

Fig. 2: Distortions (for P2 = 6.0 A) obtained after correcting the phase images with the CCD camera ronchigram.

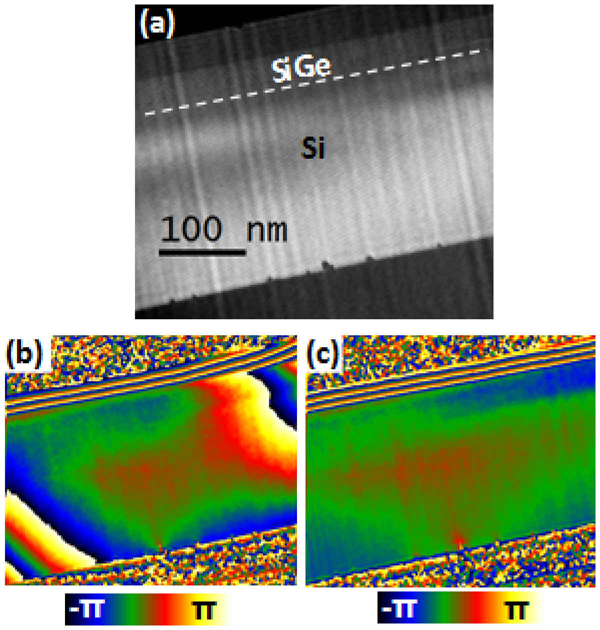

Fig. 3: (a) (004) dark-field electron hologram of a SiGe layer epitaxially grown on a Si substrate. (b) Phase image reconstructed from the hologram without correction. (c) Phase image reconstructed with correction of the projector and camera distortions.