Improved imaging mode for electron holography at medium resolution

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Electron holography has become a reliable tool for dopant profiling in semiconductor industry [1]. Up to now, large field of view and medium resolution have been required in order to adapt to the object structures of interest. With shrinking device structures, resolution has to be improved, while preserving a reasonable holographic field of view.

Medium resolution and a large field of view up to 1 µm are easily achieved by operating the microscope with the Lorentz Lens instead of the usual objective lens. However, whereas the Lorentz Lens provides an acceptable field of view, the holographic lateral resolution is limited to ~10 nm. Using the objective lens with a standard setup will provide a better resolution, but only a field of view of 30 nm, which is still too narrow to cover the modern small semiconductor devices. Therefore, we are searching for new paths of rays achievable by special combination of the objective lens and the diffraction lens, which provide the needed field of view and lateral resolution.

In order to obtain an optimized setup for holography, the parameters determining field of view, lateral resolution and noise properties of the phase signal [2] are most important. In particular the following parameters have to be considered carefully: hologram width, fringe spacing, contrast of the interference fringes and coherent current over the area of interest.

These parameters have been investigated for the double lens system formed by objective and diffraction lens with the biprism inserted in the Selected-Area-Diffraction aperture. Considering the holographic setup in Fig. 1, hologram width w_{hol} and fringe spacing s_{hol} are given as [3]:

$$w_{hol} = \frac{2\gamma\,|b|\,f_{obj}}{|a+b|} - \frac{2\,r\,f_{obj}}{a} \qquad \text{and} \qquad s_{hol} = \frac{\lambda\, f_{obj}}{2\gamma\, a} \ .$$

The distances a and b are given in Fig. 1, f_{obj} is the focal length of the objective lens, r is the radius of the biprism, and γ is the deflection angle at a specific biprism voltage. In particular, distance b denotes the position of the 1st intermediate image plane.

Apart from the deflection angle only the position of the 1st intermediate image plane hence distance b is freely adjustable by the operator. Thus we apply the free lens control function of our microscope to adjust the excitation ε_{dif} of the diffraction lens hence change distance b. With the biprism negatively or positively biased, four different imaging modes with different properties have been found. The experimental results have been compared to calculations on a simple optical model using thin lens-approximation. An optimum setup for holography with an extended field of view of 210 nm and a lateral resolution of 3 nm has been derived (Fig. 2). This field of view is seven times larger than in the normal HRTEM-setup and five times smaller than in the normal Lorentz Lens setup.

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1. W. D. Rau, P. Schwander, F. H. Baumann, W. Höppner, A. Ourmazd: “Two-Dimensional Mapping of the Electrostatic Potential in Transistors by Electron Holography”, Phys. Rev. Let. **82** (1999), p2614-2617.
2. H. Lichte: “Performance limits of electron holography”, Ultramicroscopy **108** (2008), p256-262.
3. H. Lichte: “Electron holography: optimum position of the biprism in the electron microscope”, Ultramicroscopy **64** (1996), p79-86.

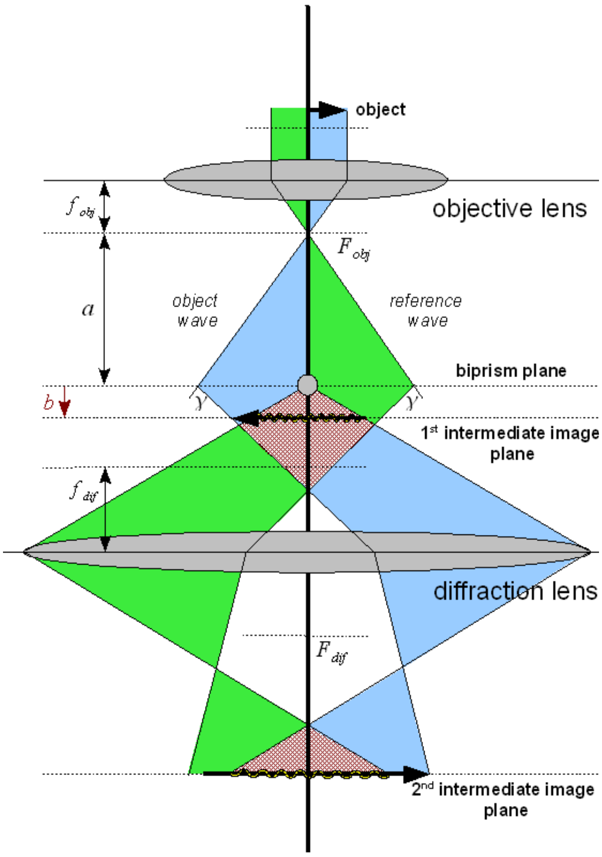

Figure 1. Scheme of the common holographic setup using the objective lens. The 1st intermediate image is slightly shifted downstream, where the positive biprism inserted in the selected area aperture yields the image plane hologram. The diffraction lens is adjusted such that the image-plane hologram finally appears in the given 2nd intermediate image plane. Field of view and resolution are variable only in a small range, mostly suitable for high-resolution holography. A gap to medium-resolution Lorentz holography remains inaccessible.

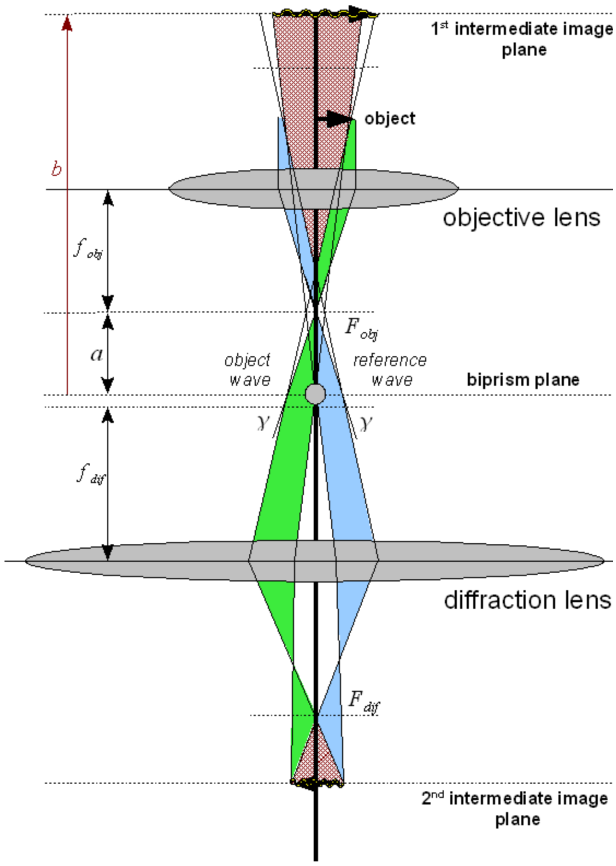

Figure 2. Scheme of the modified holographic setup. Focal length of objective lens is increased in order to create a virtual 1st intermediate image. There, at comparably small positive biprism voltage, the image-plane hologram is built up. The diffraction lens has to be adjusted such that this hologram is transferred into the given 2nd intermediate image plane. Field of view and resolution are variable in a wider range allowing bridging the gap between Lorentz holography and high-resolution holography.

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