

Biprism in condenser system for coherent two-beam illumination of an object

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1. Goals

- Illuminate specimen with two overlapping coherent waves by means of electrostatic biprism [1] in C2 aperture
- Understand the condenser optics with integrated biprism
- Control interference fringe spacing and width of interference field

2. Motivation

Illumination of a specimen with two overlapping coherent electron waves is a prerequisite for one of the possible realisations of the circular dichroism experiment in TEM (Ref. [2] and a poster in this conference).

3. Instrumentation

A Philips CM200 microscope is used for experiments. Its condenser system is quite complicated (Fig. 1). It consists of two condenser lenses (C1, C2), minicondenser lens (MC) and upper part of the objective lens (OC).

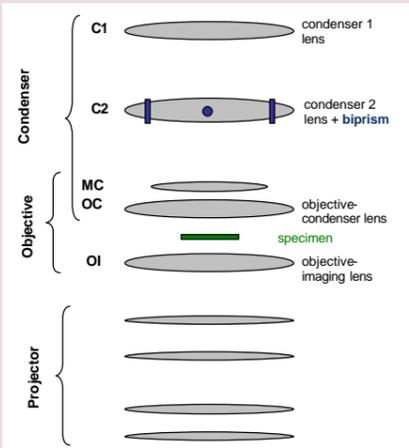


Fig. 1 Scheme of electron microscope illumination system (Philips CM 200).

Unfortunately, it is not possible to position the biprism arbitrarily in the column. The C2-aperture part of the column has to be used. This means that the biprism is located in the middle of the C2 lens. We express the complicated biprism-condenser system by an equivalent simple model (Fig. 2), whose parameters a , b generally depend on the excitation of C1, C2 and MC lenses, on the extraction voltage of the FEG gun, and on the gun lens voltage.

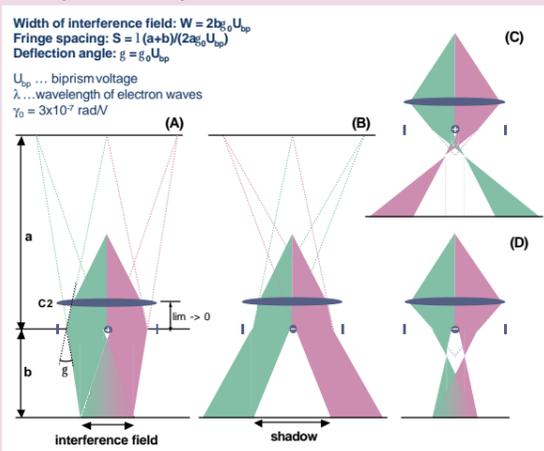


Fig. 2 Beam paths in a biprism. Four possible combinations are shown: crossover below/above biprism with negative/positive biprism voltage.

4. Problems

- Due to biprism charging, its actual voltage is not known (offset of up to 250 V)
- Complicated illumination system with unknown parameters (focal lengths, distances)
- Condenser and objective are not independent (Fig. 1)

5. Experimental results

For extraction voltages 3.8kV - 4.2kV, given biprism voltage and

- for given excitation of C1, C2 lenses, fringe spacing and width of interference field (width of biprism shadow) do not depend on gun lens voltage.
- for given gun lens voltage, and given excitation of C2 lens, fringe spacing and width of interference field (width of biprism shadow) do not depend on excitation of C1 lenses.

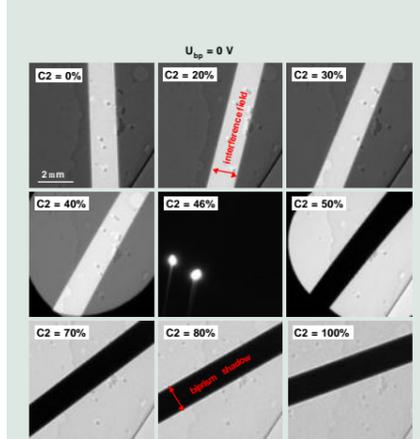


Fig. 3 Interference field and shadow of the biprism at nominal biprism voltage of 0V for various excitations (in % of maximal current) of C2 lens.

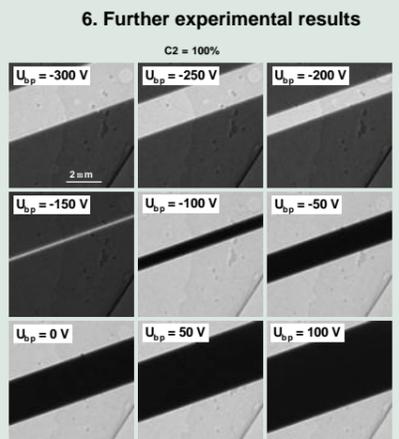


Fig. 4 Interference field and biprism shadow for maximum excitation of C2 lens and various nominal biprism voltages.

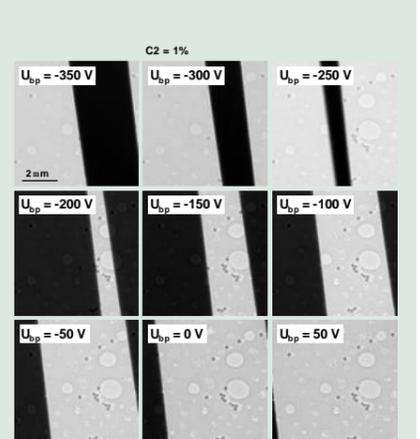


Fig. 5 Interference field and biprism shadow for minimum excitation of C2 lens and various nominal biprism voltages.

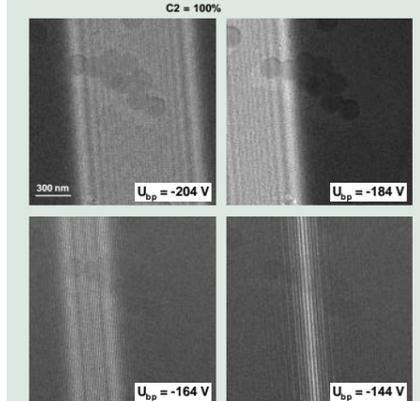


Fig. 6 Latex spheres illuminated by two overlapping plane electron waves at various biprism voltages. The coherent superposition of the waves gives rise to interference fringes.

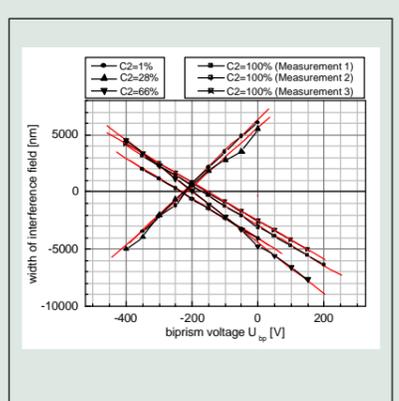


Fig. 7 Width of interference field (negative for biprism shadow) as a function of the nominal biprism voltage at various excitations of the C2 lens. Red lines are linear regressions.

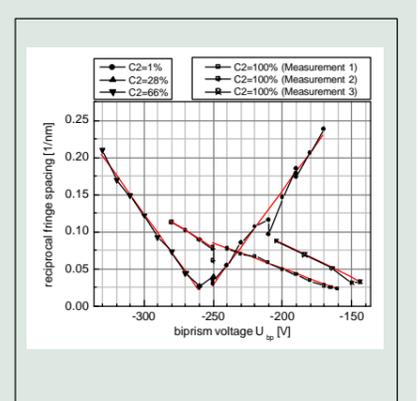


Fig. 8 Reciprocal fringe spacing as a function of the nominal biprism voltage at various excitations of the C2 lens. Red lines are linear regressions.

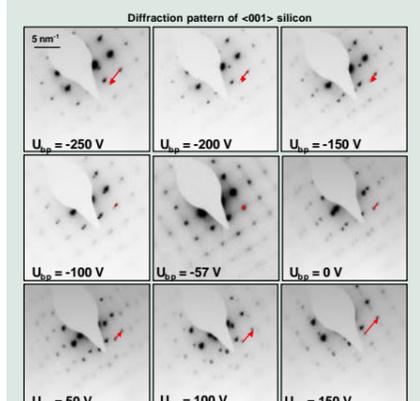


Fig. 9 Diffraction pattern (negative) of <001> silicon at various biprism voltages (at C2 = 46%). Red arrows mark splitting of the diffraction spots due to the two illuminating waves.

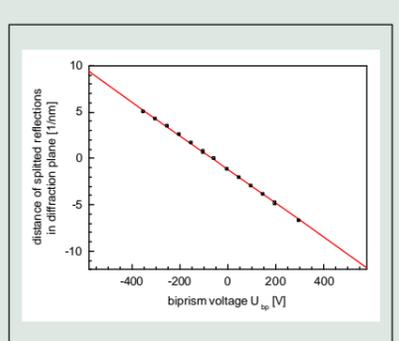


Fig. 10 Distance of splitted reflections in the diffraction pattern of <001> silicon as a function of biprism voltage. The red line is linear fit with slope of 0.018 nm⁻¹/V. The values on x-axis are shifted by 57 volts to the right, cf. Fig. 9. In Fig. 9, the distance of splitted reflections is zero for U_{bp} = -57V because of charging of the biprism.

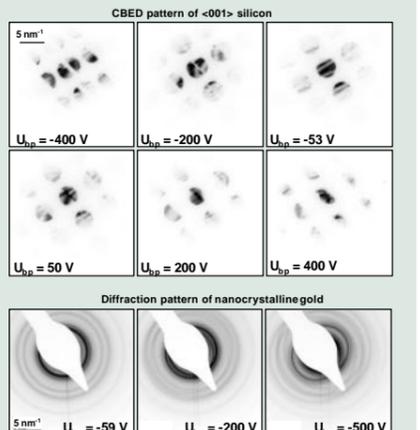


Fig. 11 CBED pattern of <001> silicon (upper) and diffraction pattern of nanocrystalline gold (lower) at various biprism voltages.

7. Summary

- Fringe spacing is indirectly proportional to the biprism voltage, interference field width is directly proportional to the biprism voltage. It is in accordance to the simple model in Fig. 2.
- Depending on the excitation of the C2 lens, the crossover is above the biprism (C2 < 47%, Fig. 2A, 2B) or below the biprism (C2 > 47%, Fig. 2C, 2D).
- Parameters a , b do not depend, within the experimental errors and problems with biprism charging, on the C1 & C2 excitation, the gun lens voltage and the extraction voltage.
- Deflection angle recalculated to the back focal plane is proportional to the biprism voltage with a slope of 0.018 nm⁻¹/V.
- Interference fringes with spacings of 5 nm to 40 nm and reasonable contrast of 5% to 40% can be obtained.

8. Acknowledgements

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9. References

[1] G. Möllenstedt, H. Düker, Zeitschrift für Physik 42 (1955) 41
 [2] C. Hébert, P. Schattschneider, Ultramicroscopy 96 (2003) 463