Detection of angular distribution of signal electrons in low-voltage SEM

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In an UHV apparatus designed in our institute, a low-energy SEM (a scanning LEEM) is realized by adding a cathode-lens attachment to a SEM [1]. Our aim is redesign the LESEM in the apparatus to allow the detection of the angular distribution of signal electrons. For this we have to separate the signal electrons from the primary beam with a Wien filter [2] and project the image of the back-focal plane of the objective lens on an area-sensitive detector (a back-illuminated CCD [3]). For this we have to design a new electrostatic optics working in UHV.

The proposed arrangement of the system is schematically shown in Figure 1. The crossover of the primary 5 keV electron beam from a Schottky gun is imaged with the electrostatic objective lens/cathode lens on the specimen, where it is scanned with a two-stage deflection system. The beam aperture must be placed above the Wien filter so that it does not limit the signal beam. The signal electrons are deflected with a Wien filter from the microscope axis and the back-focal plane of the objective lens is imaged with transport lenses on the detector.

The Wien filter is producing magnetic dipole fields the eight poles of equal size, which are electrically insulated and serve also as electrodes for electrostatic dipole field. This arrangement guarantees a perfect overlap of the two mutually perpendicular dipole fields. The Wien filter is stigmatic for the primary beam if we superimpose a suitable electrostatic quadrupole field component on its electrodes. For our application the deflection of the signal beam can be as low as 10 degrees. The primary beam then obtains a slight angular chromatic deflection below $\varepsilon \approx 0.01$ mrad/eV in a dispersion direction given by the electrostatic dipole field. For a parallel beam entering the objective lens this would produce a deviation in this direction of $f \cdot \varepsilon \cdot \delta E$, where f is the focal distance on the side of the filter and δE the energy deviation. Thus, for high-resolution imaging, an intermediate crossover must be placed to a center of the Wien filter.

The objective lens works as a unipotential lens for the beam energy of 5 keV, and the conical shape of its outer electrode allows enough space in the sample region. In the low-energy mode we put high voltage on the insulated sample. This cathode lens allows decreasing of the beam landing energy on the sample without much sacrifice on spot size (at 30 eV landing energy the attainable resolution is just two times lower than the 6 nm expected for 5 keV). The diffracted and low-loss back-scattered electrons are accelerated into the lens and a diffraction pattern, whose size and position are almost independent of the beam energy on the sample, is formed in the back-focal plane. Figure 2 shows the maximum angle of electrons passing through given percentage of lens opening. The back-focal plane is then imaged with transfer lenses on the CCD element as a fast position-sensitive detector, whose output is then used to form the SEM image.

The properties of this sensor, a thinned back-side directly electron-bombarded sensor CCD 39-02 of Marconi with 80x80 pixels with 24 μm size, have recently been studied [3]. Its gain 300, large dynamic range of 59 dB and short integration time of 10 ms are obtained at room temperature for optimum electron energy of 4.2 keV. The chip with sensor will be placed in vacuum on a flange with multi-pin feedthrough, the electronics will be put on the flange outside vacuum [4].

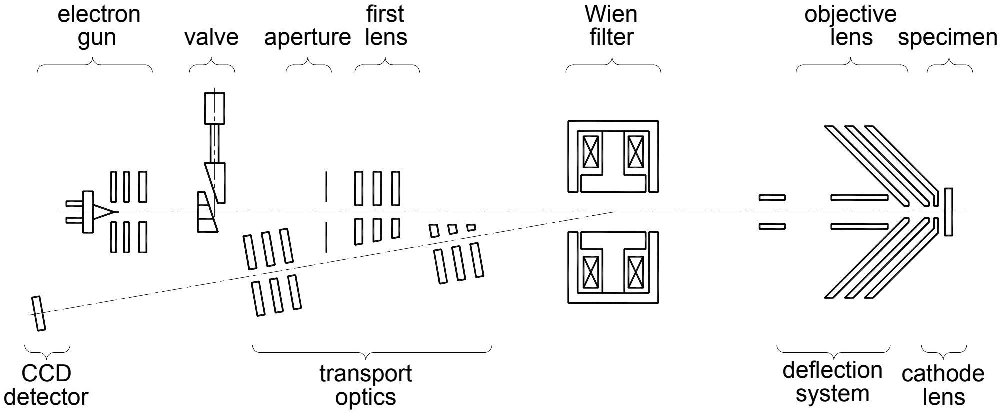

Figure 1. Schematic arrangement of low-energy SEM allowing the acquisition of angular distribution of signal electrons.

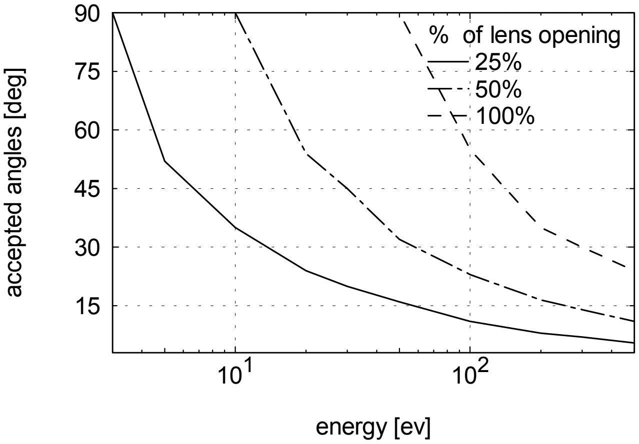

Figure 2. The dependence of angular range of diffracted and back-scattered electrons passing through given percentage of objective lens opening for a given energy on the sample.

1. I. Müllerová and L. Frank, Adv. Imag. Electron Phys. **128** (2003), p. 309.
2. B. Lencová and I. Vlček in "Proceedings of the 12th European Congress on Electron Microscopy", ed. L. Frank and F. Čiampor, (CSEM, Brno) (2000) Vol. III, p. I87.
3. M. Horáček, Review of Scientific Instruments **74** (2003), p. 3379.

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