In the past years, considerable attention has been drawn to imaging of non-conducting samples without prior application of conductive coating. Conditions of low voltage microscopy allow such observation with its main benefits: sensitivity to the surface details and possibility to reach charge balance under which the charging of the sample is diminished [1, 2].

Uncoated non-conducting samples often exhibit undesirable charging that prevents the observation of finer details. This effect can be suppressed by using specific landing energy for which the total flow of electrons from the sample equals the charge coming into the sample. An example of the charge balance for nylon fibers is shown in Figure 1: a) exhibits positive charging effects, b) is an illustration of charge balance at 1200 V in agreement with [2], whereas c) has visible signs of accumulation of negative charge.

Conditions for charge flow equilibrium for the non-conducting materials generally lie in low voltage region [2]. To maintain the quality of imaging, preserving high resolution at low acceleration voltages is crucial. In Figure 2, we present images taken in low voltage regime. In Figure 2 a) uncoated polystyrene balls are shown. At 4.2 kV we can see fine details of their surface roughened by etching. The resolution at low voltages can be enhanced in the Beam Deceleration Mode (BDM) [3]. Figure 2 b) shows the structure of TiO₂ imaged with the BDM at 800 V. In this mode, the electrons are maintained at higher energy during their path through the column and they are decelerated just after they leave the objective lens. BDM supports further lowering of landing energy, automatically to 50 eV and manually to 0 eV. Figure 2 c) shows para-hexaphenyl imaged at 20 eV. These images were taken by an ultra-high resolution microscope MAIA [4] by TESCAN, which has guaranteed resolution 1.4 nm at 1 kV.

Secondary electrons reveal sometimes surprising amount of details when primary beam interacts only with surface layers of material [1]. In Figure 3, the comparison of cracked oxidized copper imaged at acceleration voltages a) 20 kV, b) 10 kV and c) 2 kV is given. As can be seen in Figures 3 a) and 3 b), the shapes and edges of larger structures are well distinguishable and coarse surface is visible. Figure 3 c), taken at 2 kV, shows detailed structure of the studied object. In comparison with Figures 3 a) and 3 b), in Figure 3 c) the edges lose brightness and the contrast of surface cracks and contours is predominant.

References:

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Fig. 1: Charging artifacts of nylon fibers at acceleration voltages a) 900 V, b) 1200 V and c) 1500 V. Dark areas and lines in a) are an evidence of positive charging while localized brighter areas in c) are due to negative charging. Image b) at critical voltage shows least charging artifacts.

Fig. 2: a) Uncoated polystyrene balls at 4200 V, b) TiO$_2$ with BDM at 800 V and c) Fiber-like structure of Para-hexaphenyl imaged at 20 V with BDM. Lowering the acceleration voltage makes fine surface details of the presented non-conducting samples clearly visible. Such details are frequently obscured when high acceleration voltages are used.

Fig. 3: Oxidized surface of copper imaged at different acceleration voltages, a) 20 kV, b) 10 kV and c) 2 kV, thus shrinking the interaction volume. The contrast is gradually changed, especially at the edges of surface cracks and contours.