Examination of Sample Contamination in SEM

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Contamination is one of the most common problems in imaging with a scanning electron microscope (SEM). The contamination is causing a degradation of resolution and contrast due to the electron beam induced deposition (EBID) of a hydrocarbon layer. In this study we are developing an SEM-device-independent method to characterize contamination in order to evaluate useful prevention strategies. It is found that not only the commonly used methods such as plasma/ozone cleaning, heat treatment or cryo traps reduce the contamination, but also a clever choice of the image acquisition parameters might reduce the contamination in the area of interest.

Contamination becomes visible in the SEM quite easily as a change of contrast, which is, unfortunately, not a direct measure of the thickness of the contamination layer. Therefore we use a 3D-imaging of the contamination with an atomic force microscope (AFM). For the reason of comparability, all measurements are done with standard parameters: Si-specimen, 5 um field of view (FOV), 1 kV, 200 pA, working distance 5 mm, 760 ns dwell time per pixel at 1024 x 768 pixels and a total acquisition time of 1 hour. As an example, figure 1 shows the contamination of a Schottky field-emission SEM without any of the commonly used prevention strategies. As the next step we determined on two different types of SEMs (Schottky and cold field-emission) that the use of a cold trap reduces the contamination by a factor of about ten. The size of the cooling plate, the distance to the sample and the cooling time prior to SEM recordings affect the efficiency of the trap.

To further reduce the contamination it is worth to regard its origin. Modern SEMs are greatly improved regarding contamination by using oil free pumping, load locks and improved materials providing an almost hydrocarbon free environment. Thus the main source of contamination is the specimen itself. Since the contamination does not stop even during typical acquisition times as for mappings, it is clear that the surface diffusion of molecules is involved in the whole process. Fig. 1 shows that the contamination happens mainly at the frame boarder due to the diffusion of hydrocarbons from outside areas. Following this observation, the image acquisition rates must influence the contamination rate. Ideally it should be possible to collect any contamination at the frame border having a low contamination area in the center of the FOV where high resolution and high contrast images might be captured. As an example, figure 2 shows the influence of the dwell time per pixel on the contamination, whereas all further acquisition parameters remain unchanged. By stepwise increasing the dwell time from 220 ns to 185 us the contamination is also increasing. From the AFM measurements we determined the FWTM of the frame border and the width of the low-contamination area in the center in relation to the complete FOV ranging from 88% to 31% [Fig. 2]. Obviously, it is advantageous in terms of contamination to scan images at short dwell times together with frame averaging.

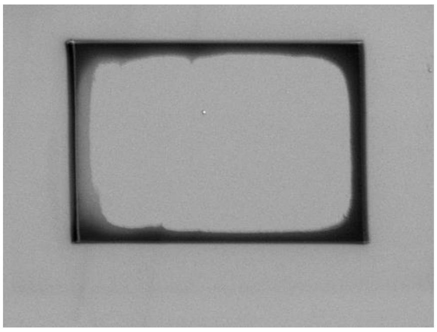

Fig. 1a: Inlens SE image of a contaminated area (width 5um)

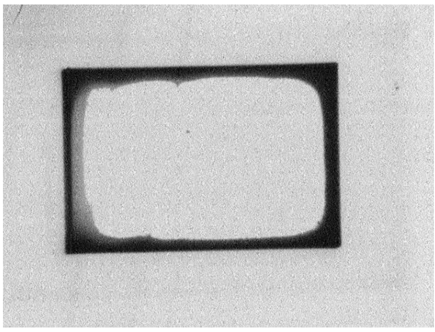

Fig. 1b: BSE image of the same area

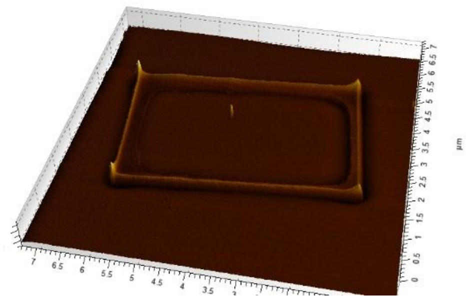

Fig. 1c: AFM image of the same area

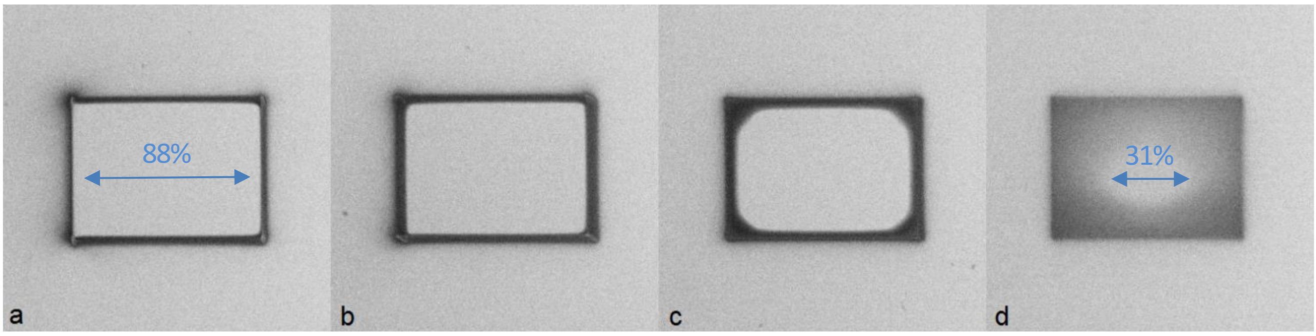

Fig.2: High angle BSE images; acc. voltage 1 kV

Different dwell times: 220 ns [a], 760 ns [b], 12 us [c], 184 us [d]

AFM data of the width of the contamination free inner part in relation to the full frame width (FWTM):

88% @ 220ns, 82% @ 760ns, 82% @ 12us, 31% @ 184us

Ref.

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2. R.F. Egerton, P. Li, M. Malac, Radiation damage in the TEM and SEM, Micron, **35**, 399,(2004)