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Angle and Energy Selective Electron Imaging With an Immersion Lens Cryo-SEM

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Over the last few decades, the use of scanning electron microscopy (SEM) for the characterization of materials has shifted from the simple imaging case to a more complex, multi-modal imaging and analysis environment. Beam surface interaction results in a broad range of effects that can be distinguished by appropriate angular and energy selection in the detection process. These signals can be collected simultaneously and even be mixed in real time. The result is a customized contrast that facilitates the interpretation of the acquired images.

The usefulness of secondary electron (SE) imaging - showing for example topography contrast - and backscattered electron (BSE) imaging - giving mass and channelling contrasts - as well as the analytical possibilities such as energy dispersive spectroscopy (EDS), electron backscattered electron diffraction (EBSD) and wavelength dispersive spectroscopy (WDS) is widely recognised. However, more information can be extracted from the sample by contrast “engineering.” This is achieved by selecting those electrons that optimize the image content for a specific application. Sensitive samples give further side conditions upon electron bombardment. For imaging cryogenically-fixed specimen, high yield detection is extremely important to minimize the dose used for image acquisition because of the delicate nature of the specimen.

The aim of the current work is to show the possibilities in image acquisition by selectively detecting different solid angles and energies of both SE and BSE signal. To optimize the detection geometry it is important to be able to fully model the detection set-up, including the 3D fields. In Figure 1 we give an example of the simulated electron paths for high-yield TLD (Through-the-Lens Detection) of the SE signal in immersion mode. We demonstrate that various contrast mechanisms can be utilised by employing the in-lens detectors as well as segmented detector in combination with microscope parameters such as specimen bias and immersion field conditions.

In addition we demonstrate how the detection efficiency of various energies of the SE signal can be optimized using a magnetic immersion field in combination with stage bias as shown in Figure 2. Experimental results can also be compared with simulations, to yield a greater understanding of the origin of signals and their correlation with specific features of the specimen. For cryogenically fixed specimen this enables extreme resolution imaging without the need to create replicas.

References
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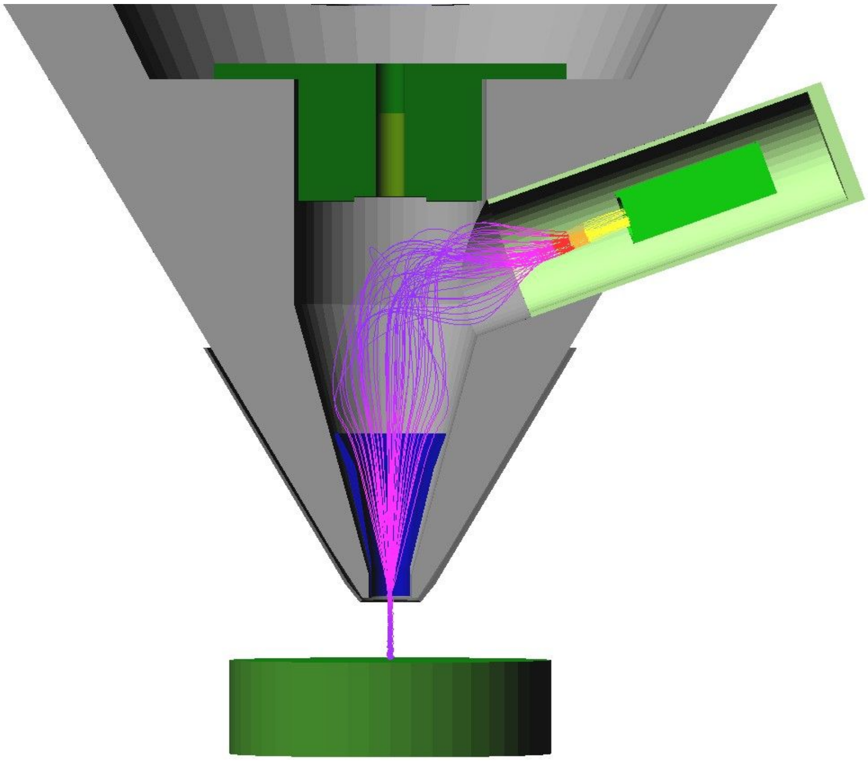

Figure 1 Simulated electron paths towards in-lens detector in High-Yield SE detection mode.

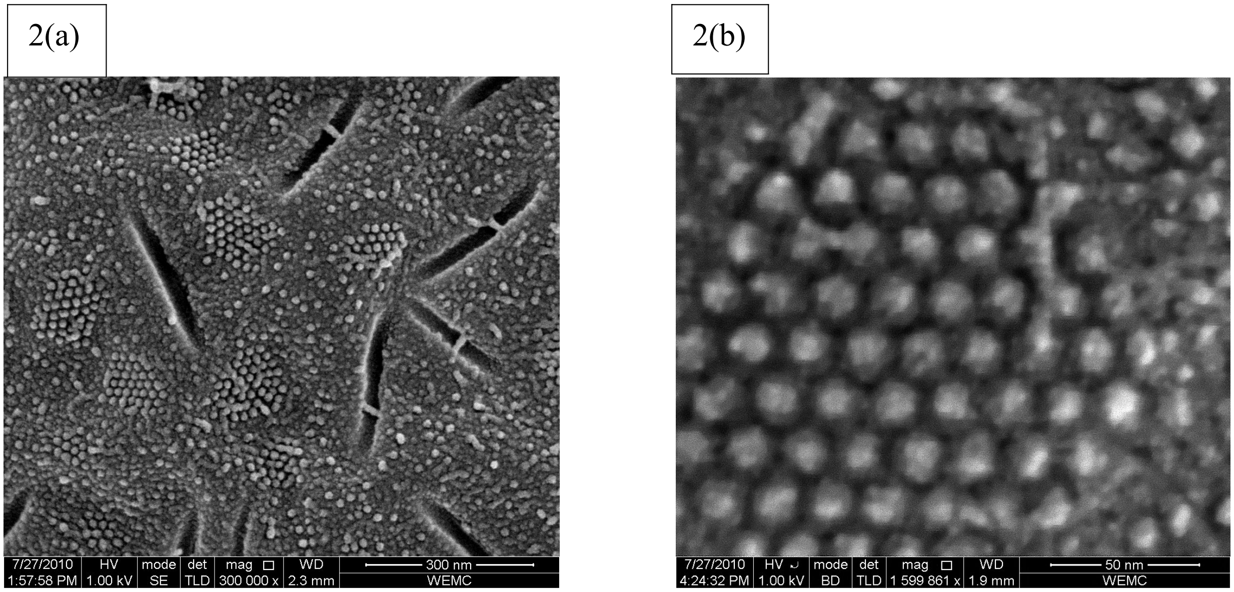

Figure 2 (a) SE image of Yeast, Cryo-fixed and Ir Coated sample showing the effectiveness of SE detection in immersion mode. Note the transmembrane particles in the nuclear membrane. (b) High-Yield SE detection mode using immersion field and beam deceleration of the same region as in (a). Image courtesy Dr A. V Aelst, WEMC, Wageningen University, the Netherlands