Dependence on working distance of the acceptance of secondary and backscattered electrons in modern inlens SEM

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The modern in-lens type scanning electron microscopes (SEMs) have several detectors corresponding to secondary electron (SE) and backscattered electron (BSE) detectors. Such SEMs are customized for low energy electron beam observation as well as the high magnification observation. Typically, the construction of SEM is not disclosed, so that the performance of such detectors is not fully understood for the SEM users. Thus, the interpretation of SE and/or BSE images is not well developed so far. We have virtually designed an in-lens type SEM and different electron detectors, namely through-the-lens (TTL), under-the-lens (UTL) and chamber-type Everhart-Thornley (C-ET) detectors. Generating SEs and BSEs from the specimen, the electron trajectories are simulated and the acceptance maps and efficiencies of these detectors are deduced. [1] Fig. 1 shows the SE and BSE trajectories emitted from the specimen. Through such procedure, the performances of these detectors are revealed.

First, the simulation has performed with a standard condition (working distance; WD = 5 mm) for 1 kV electron beam operation. The SEs and high angle BSEs (emitted to vertical direction) are effectively introduced in the objective lens and detected by TTL detector. Middle angle BSEs are detected by UTL. Few electrons have come to C-ET. This situation shows that the typical condition of modern in-lens SEM as demonstrated by SEM suppliers. In this condition, TTL works as the SE & high angle BSE detector. Without some filter, the TTL image is formed by a mixture of these signals. Due to the detector sensitivity, UTL works as the middle angle BSE detector.

Second, another simulation has done with the long working distance (WD = 15 mm). Contrary to the first case, the low angle SEs & BSEs are no more introduced into the objective lens. Only high angle BSEs are deteted by TTL, so that TTL act as BSE detector. The C-ET collect half of SEs emitted to the direction of C-ET. Some fraction of BSEs emitted to the C-ET direction is also superimposed. UTL works as higher angle BSE detector.

These results are schematically presented in Fig. 2, showing the 3D angular map of SE and BSE acceptance for 3 detectors. After various simulations with different conditions, we have concluded that the WD is the key parameter for the sharing SEs and BSEs with plural detectors.

These simulations pave the way to understand SEM images created by various type of electron detectors.

[1] Agemura T, Sekiguchi T, Microscopy, 2018, 1-12; DOI: 10.1093/jmicro/dfx124

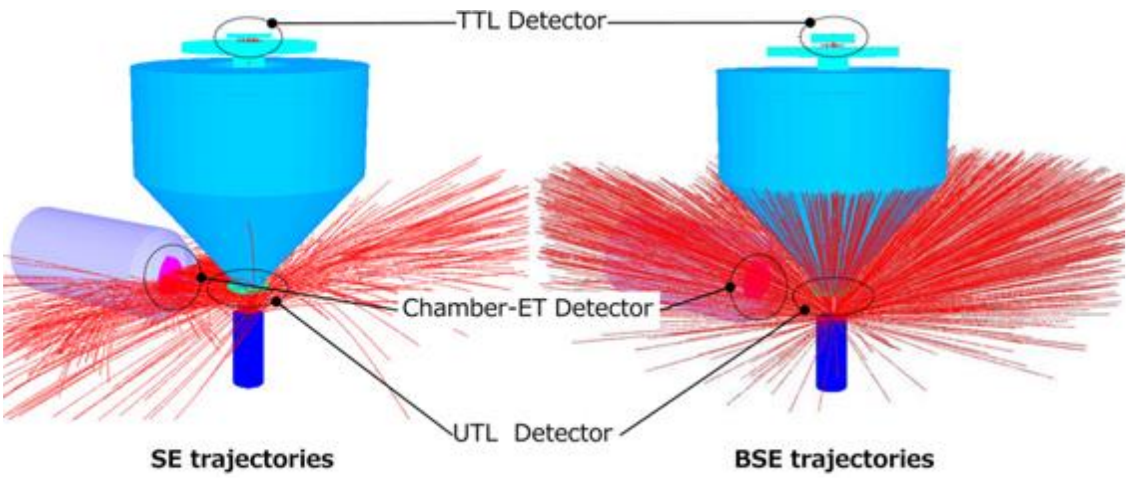

Fig. 1. SE and BSE trajectories in in-lens SEM.

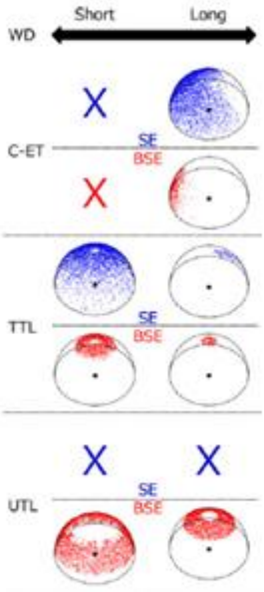

Fig. 2. 3D acceptance maps of 3 detectors with different WD.