Simulation of SEM images taking into account local and global electromagnetic fields

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Predicting and understanding image formation in SEM is an important and practical task. Advanced Monte Carlo methods can simulate electron scattering in solids and thus predict SEM images made using backscattered or true secondary electrons, or both. To improve accuracy of simulations, trajectories of secondary electrons in the presence of local and global electromagnetic (EM) fields should be taken into account. Local electrical fields are produced by charging of a sample by the electron beam. Global EM fields are produced by electron lenses as well as by detector and additional elements under voltage.

We report here the development of a simulation tool with unique capabilities to comprehensively model the SEM signal. The simulation involves:

- Electron scattering inside a 3D sample using advanced Monte-Carlo model
- E-fields formed by a potential applied to detectors and additional elements as well as local E-fields due to sample charging
- Deflection of primary beams due to local and global fields and their landing points; trajectories of secondary electrons in the presence of EM fields until they reach a detector
- Charge and discharge of the sample

Examples of electrical fields and trajectories in these fields are demonstrated in Figure 1 for the local area of the resist lines on silicon. Here the field is due to sample charging. In Figure 2, the field is shown in the area of the SEM chamber. The voltage was applied to the ring electrode above the sample.

Measured and simulated SEM images in the presence of global electrical fields and local charging are presented and compared. The results were compared for SEM imaging of high aspect ratio contact holes in silicon dioxide in the presence of charging. Here, the bottom of the hole needs to be visible. A pre-charge of the surface was used in order to enhance secondary electrons from the bottom of the hole. Good agreement of simulated of measured data was demonstrated.

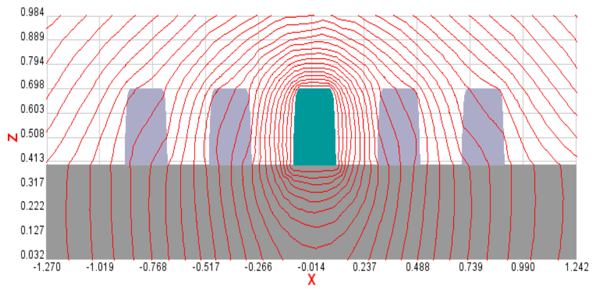

Fig.1.a. Local E-field due to sample charging (the central line is charged).

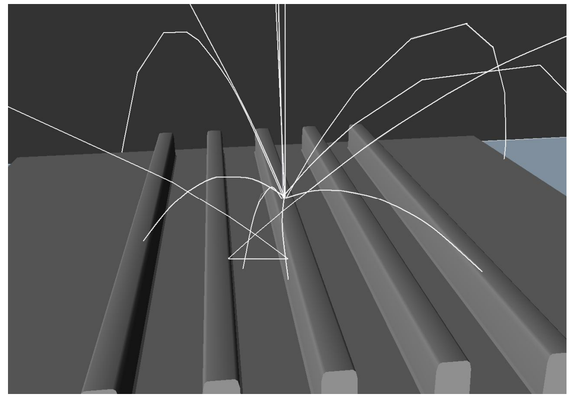

Fig.1.b. Electron trajectories in the local E-field due to sample charging.

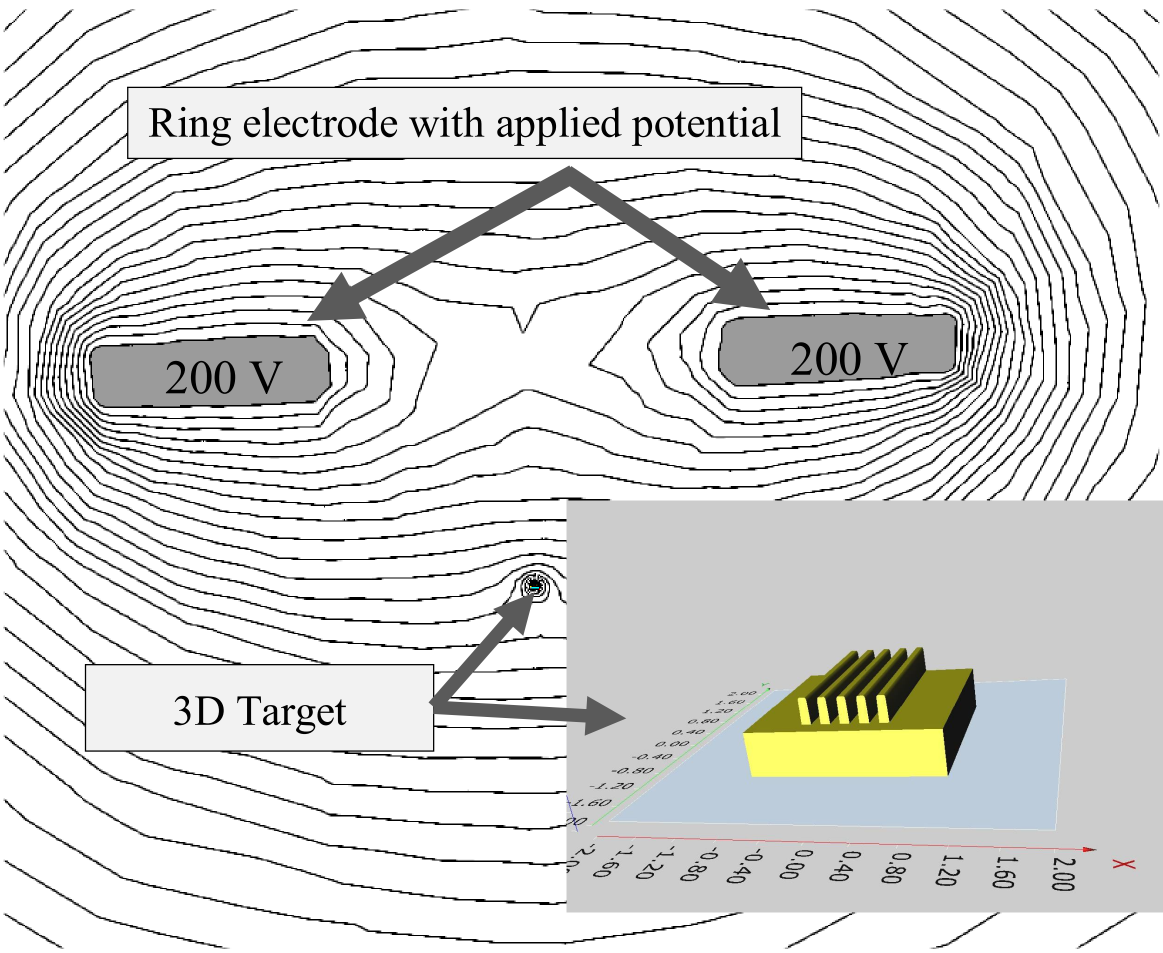

Fig.2. Equipotential lines of the global E-field formed by the ring with applied voltage.