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Modeling Contrasts in Variable Pressure Scanning Electron Microscopes

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Charge Contrast Imaging (CCI) is a new imaging mode that has been discovered recently using the GSED Secondary Electron (SE) detector in the ESEM[1, 2.] CCI allows to image non-conductive specimens with details about the structures of these materials that are not seen with conventional SE and Backscattering Electron (BSE) imaging modes. CCI was also observed in a Hitachi S-3500N VP-SEM with the Shah detector[3]. The Hitachi ESED detector is a variation of the Shah detector which allow the observation of CCI[4].

Despite the incredible amount of new information that CCI gives, there is still a huge controversy concerning the mechanisms of CCI. It is believed that CCI are obtained when there is an optimal charge compensation allowing to map the surface potential differences of the materials, giving an enhanced sensitivity in SE emission. However, this explanation still remain speculative and dedicate and elaborate research must be performed in order to understand the mechanisms of CCI. It is clear that CCI is related with the charging of non-conductive materials that accumulate charges when irradiated by incident electrons.

The modeling of charging is a very difficult task because it is very difficult, if not impossible, to predict the trap charge density because of the drift mobility of electrons and ions, their recombination rate and their trapping by detects like vacancies, dislocation and grain boundaries. This is very unfortunate because once the trapped charge density is known, it is easy to solve numerically the Poisson equation to obtain the electrical field inside and outside the materials. With the knowledge of the electric field, electron trajectories inside the materials and ions trajectories in the gas could be computed and their effect on CCI could be estimated. In the case of the gas, the ion production rate and the drift velocity of ions must be known in order to compute accurately the electric field in the gas.

Since the trapped charge density is difficult to compute in a solid, it should be measured experimentally. It is possible to compute an X-Ray spectrum by assuming the strength of the electric field inside the material[5]. By comparison between experimental X-Ray Spectra with simulated ones at different values of the electric field, it could be possible to determine the electric field inside the material and hence the trapped charge density. Figure [1] shows simulated X-Ray spectra of Gibbsite at incident electron energy of 30 keV for maximum electric field of 0, 3 and 5 V/nm. In order to compare the experiment to these simulations, a Gibbsite specimen with a conductive coating must be used. Also, the measurement should be performed under vacuum conditions. Even if this it not the representative case of ESEM or VP-SEM, it is a good starting point to understand charging and hence, CCI. We are currently working to generalize this analysis to the case of non coated specimen under vacuum as well as under gas pressure.

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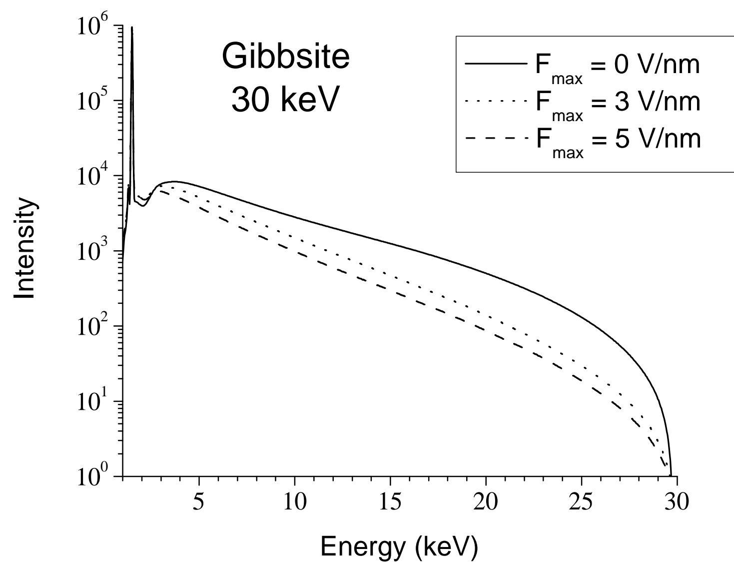

Figure 1 Simulated X-Ray spectra for Gibsite at 30 keV. The maximum electric field is ranging between 0 to 5 V/nm.

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