BIO Web of Conferences **129**, 04029 (2024) https://doi.org/10.1051/bioconf/202412904029
EMC 2024

Investigation of electron-beam-induced charging in a dolomite needle using off-axis electron holography

Dr. Fengshan Zheng[1], Mrs Ingrid McCarroll[4], Dr Vadim Migunov[3], Dr Marco Beleggia[5], Prof Giulio Pozzi[6], Prof Julie Cairney[4], Prof Rafal Dunin-Borkowski[2]
[1]South China University of Technology, Guangzhou, China,
[2]Forschungszentrum Jülich, Jülich, Germany, [3]RWTH Aachen University, Aachen, Germany, [4]The University of Sydney, Sydney, Australia, [5]Technical University of Denmark, Denmark, Denmark, [6]University of Modena and Reggio Emilia, Modena, Italy

The phenomenon of electron-beam-induced charging of specimens in the transmission electron microscope (TEM) is attracting increasing attention, both for fundamental reasons and because it has a strong influence on image contrast and quality, in particular when studying insulating and (cryo-)biological specimens [1], in which it is responsible for the bee-swarm or Berriman effect [2-4]. Electron-beam-induced charging is generally believed to result from secondary electron emission from specimen surfaces as a result of primary electron bombardment. However, the underlying physics is not yet fully understood.

Recent developments in off-axis electron holography in TEM offer the possibility to directly map charge density distributions in materials in real space [5, 6] as a function of parameters such as dose (rate), applied voltage and specimen temperature.

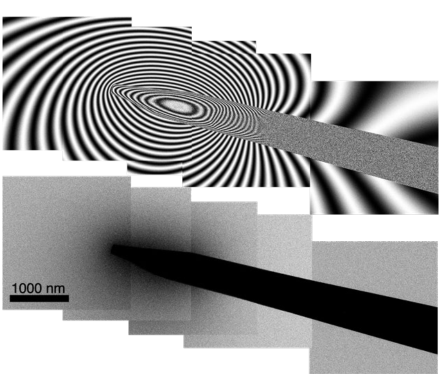
Figure 1 shows a measurement of electron-beam-induced charging of a needle-shaped specimen recorded at 300 kV using off-axis electron holography in the TEM at an electron dose rate of approximately 0.9 e-/Å2/s. The needle contains an apex of insulating dolomite (CaMg(CO3)2) and a W base. These two regions are separated from each other by Pt, which was deposited in a focused ion beam scanning electron microscope. The phase contour map shows that the needle is charged at its apex. The contours suggest the presence of a dipole-like charge distribution along the length of the needle. Asymmetry in the phase contour map results primarily from the influence of the perturbed reference wave. There is neither a dose-rate nor a total dose dependence of charging in this needle (not shown).

Surprisingly, a decrease in the reconstructed amplitude is visible in the vacuum region around the apex region. Although this observation is suggestive of a time-dependent charging and discharging process, no double exposure effects are visible in the recorded holograms in the form of Moiré fringes. Secondary electron emission alone may not be sufficient to interpret this result. Coincidence measurements between secondary electrons and electron energy-loss spectra may help to determine the physical origin of secondary electron emission in such samples. Parameters that include the distance to surrounding regions of the specimen and microscope, the presence of surface contamination, the specimen temperature, the presence of residual gas in the TEM column and the voltage applied to the specimen should be varied systematically in such experiments, in order to understand their influence on electron-beam-induced charging and to unravel the underlying physics of charging during illumination by high-energy electrons (and photons) [7].

References:
[1] Russo, CJ. et. al., Ultramicroscopy 187, 43-49 (2018).
[2] Dove, DB, Journal of Applied Physics 35, 1652-1653 (1964).
[3] Drahoš, V. et. al., Czech J Phys 15, 760–765 (1965).
[4] Berriman, JA. et. al., Ultramicroscopy 116, 106–114 (2012).
[5] Zheng, F. et al., Journal of Electron Spectroscopy and Related Phenomena 241, 146881 (2020).
[6] Zheng, F. et al., Ultramicroscopy 241, 113593 (2022).
[7] The authors acknowledge the European Union for funding through the Marie Curie Initial Training Network Grant No. 606988 under FP7-PEOPLE-2013-ITN) and National Natural Science Fund (No. 52373226).

Figure 1 Electron-beam-induced charging of a needle-shaped specimen recorded using off-axis electron holography. The needle contains dolomite ($CaMg(CO_3)_2$) in the apex region, a W base and Pt in between. The electron dose rate is 0.9 e$^-$/Å^2/s. Upper panel: Electron holographic phase contour map obtained from reconstructed phase images. The phase contour spacing is 2π radians. Lower panel: Amplitude image reconstructed from off-axis electron holograms. Each image is stitched together from results obtained from 5 aligned off-axis electron holograms.

Graphic:



Keywords:

Electron holography, specimen charging