

In-situ measurement of electron beam-induced surface potentials in a scanning electron microscope

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In a scanning electron microscope (SEM) interaction of the electron beam with non-conductive parts of samples, such as insulators or floating (un-grounded) metallic contacts, causes local charge accumulation. This can lead to image artefacts which may obscure the interpretation of nm-scale features. Therefore, it is imperative that charging phenomena are understood, quantified and mitigated in-situ in SEM.

Empirical measurement of sample surface charging in SEM is thus a necessity to validate theoretical understanding of charging and demonstrate the efficacy of mitigation strategies. Since secondary electron (SE) detection is already employed in SEM imaging and the SE energy spectrum is sensitive to the local surface potential, we aim to use SE energy spectra to quantify sample surface potentials and thereby measure the presence of charge on the sample.

We use the through-the-lens detector of our NovaNanoLab-600 SEM as a low pass energy filter to obtain the SE spectra as described in [1]. When applying a bias voltage to a thin Ruthenium film we observe clear shifts and changes in the measured SE spectrum (Fig. 1a). Negative biasing shifts the SE spectra to the right while positive biasing shifts them to the left and flattens the peak. On a mixed sample of rectangular 300 nm wide electrically floating Ruthenium contacts (charging) and equally sized grounded Ruthenium contacts (non-charging), both embedded in an insulating Si_3N_4 layer (charging) deposited on a Si substrate, clear material- and charge-dependent spectral changes can be seen (Fig. 1b). Fig. 1c shows a SEM image of the contacts on the semiconductor sample. Floating Ru (H) refers to horizontal floating Ru contacts, which are parallel to the imaging scan direction, experiencing more positive charging than the vertical Floating Ru (V) contacts which are perpendicular to the scan direction. The difference between horizontal and vertical floating Ru plugs is caused by the difference in exposure time per scanline leading to a difference in accumulated charge. The flattened SE spectrum of the more positively charged Floating Ru (H) agrees with the positive-bias curves in Fig 1a. The insulating Si_3N_4 layer also charges but its surface potential and SE spectrum cannot be directly compared to those of Ru due to its different composition and secondary electron yield. However, clear differences between SE spectra from Ru and Si_3N_4 can be observed.

These initial results show that charging phenomena can be clearly identified by SE energy spectra and can potentially be quantified too.

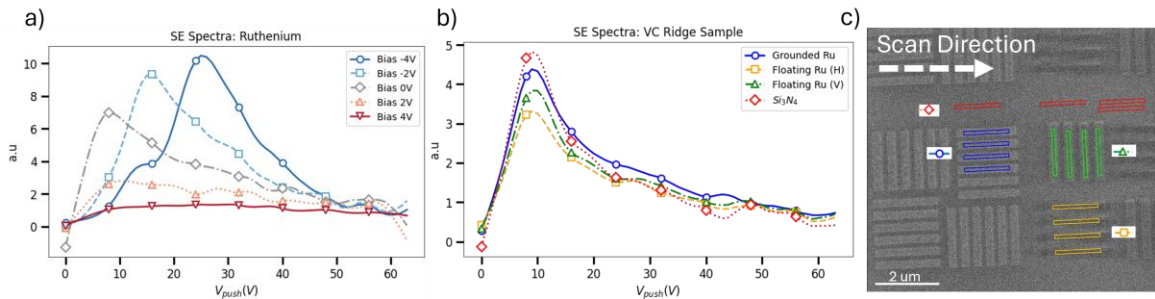


Figure 1: (a) SE Spectra from a Ru thin on an Al_2O_3 substrate under under positive and negative biasing. V_{push} is the deflection voltage used to vary the low pass SE energy threshold. (b) SE spectra from Ru contacts of varying charge states and Si_3N_4 on a semiconductor sample. (c) SEM Image of the semiconductor sample showing the bright grounded and dark floating contacts.

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References

- [1] Kazemian P, Mentink SA, Rodenburg C, Humphreys CJ. Ultramicroscopy 107 (2007)