

Predicting SEM Charging Artefacts in Semiconductor Structures Using a Dynamic Charge Balance Model

G.T.B. Coemans^a, J.P. Hoogenboom^a, C.W. Hagen^a, T.F. Fliervoet^{a,b}

^a *Delft University of Technology, Delft, The Netherlands;*

^b *ASML Research, Eindhoven, The Netherlands*

Low landing energy scanning electron microscopy (SEM) is widely used in semiconductor inspection due to its high surface sensitivity, reduced sample damage and ability to reveal electrical contrast. However, under these conditions samples often charge positively [1], producing image artefacts, particularly in structures containing insulating materials and electrically floating conductors. These artefacts can significantly complicate image interpretation and contour extraction, while their appearance strongly depends on imaging parameters such as dwell time, line dose and detector settings.

In this work we introduce a Dynamic Charge Balance Model (DCBM) that predicts the formation and evolution of charging artefacts in semiconductor structures whose local geometry can be approximated as a capacitive system. The model describes the interplay between primary electron irradiation, secondary-electron emission, charge accumulation and discharge, resulting in a time-dependent prediction of local surface potential and image contrast. Unlike conventional equilibrium-based descriptions of charging, the DCBM explicitly captures transient charging phenomena occurring during SEM raster scanning.

The model is evaluated using test structures containing floating ruthenium features (300 nm) embedded in insulating material. Experimental observations reveal characteristic bright and dark charging trails whose extent depends strongly on line dose but is largely independent of total accumulated dose. The DCBM reproduces these trends and correctly predicts the evolution of the observed contrast across a wide range of scan conditions.

Furthermore, the model predicts that sufficiently high line doses suppress the charging transitions responsible for contrast gradients and shadow artefacts, a prediction that is confirmed experimentally.

These results demonstrate that the formation and evolution of charging artefacts in low-energy SEM can be predicted using a physically motivated Dynamic Charge Balance Model. Beyond explaining observed image contrast, the framework enables predictive optimization of SEM scan conditions and provides a foundation for evaluating future charge-mitigation strategies in charging-sensitive semiconductor structures.

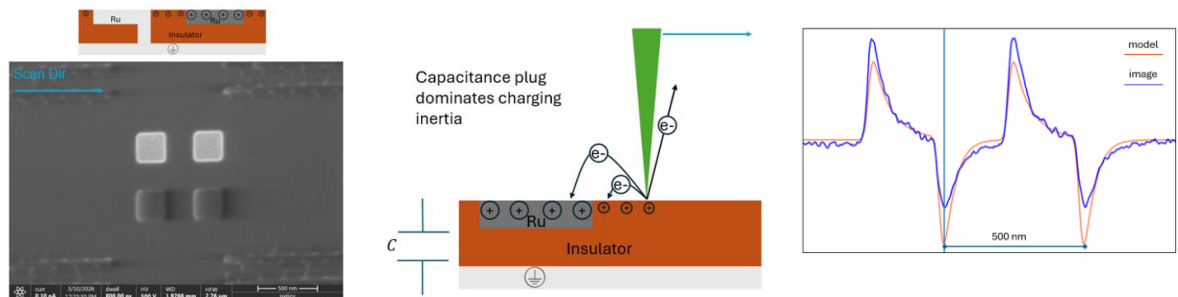


Figure 1. (a) Charging artefacts observed in a semiconductor test structure during low-energy SEM imaging. Floating Ru plugs appear dark due to positive charging, while grounded plugs remain bright. Contrast gradients and shadows between features are likewise charging-induced. (b) Capacitive representation of the floating plug in the model sample used in the Dynamic Charge Balance Model. (c) Experimental and simulated image profiles demonstrating agreement between model and experiment for floating Ru plugs at a dwell time of 1600 ns.

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References

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* Corresponding author: G.T.B.Coemans@tudelft.nl