



From electron-solid interactions to quantitative SEM metrology: testing the physics from yield to topography

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Quantitative scanning electron microscope (SEM) metrology depends on our ability to predict how electrons scatter, lose energy, generate secondary electrons, and ultimately produce detected signals. In model-based metrology, specimen dimensions are inferred by adjusting a simulated structure until its calculated SEM signal agrees with experiment. The accuracy of the result therefore depends not only on image quality or fitting precision, but on the validity of the underlying electron–solid interaction models.

I will describe a program to test these models at several levels using JMONSEL, a Monte Carlo simulator developed for quantitative SEM metrology. At the most fundamental level, a custom ultrahigh-vacuum spherical retarding-field analyzer measures secondary- and backscattered-electron yields and emission-energy distributions as functions of beam energy and incidence angle. Monte Carlo simulation of the analyzer itself is used to quantify instrumental effects such as grid interception, rescattering, and electron loss, allowing the measured quantities to be compared more directly with transport-model predictions.

A complementary experiment provides an end-to-end test of SEM dimensional metrology. Structures etched into thin single-crystal silicon membranes are measured at low landing energies typical of semiconductor CD-SEM operation, and their profiles are inferred by matching simulated and measured signals. The same structures are independently characterized in transmission at 300 keV, providing a reference profile against which the SEM result can be tested.

These experiments also motivate improvements to the underlying scattering physics. In particular, we are examining secondary-electron generation by replacing the low-energy, low-momentum-transfer portion of the conventional Penn dielectric-response model with energy-loss functions calculated from first-principles electronic-structure methods, including TDDFT and the Bethe–Salpeter equation.

Together, these efforts form a hierarchy of validation, from basic electron-emission observables to quantitative measurements of nanoscale topography. The broader question is whether models of low-energy electron generation and transport are sufficiently accurate for simulation to serve not only as an aid to interpretation, but as part of a quantitative measurement.

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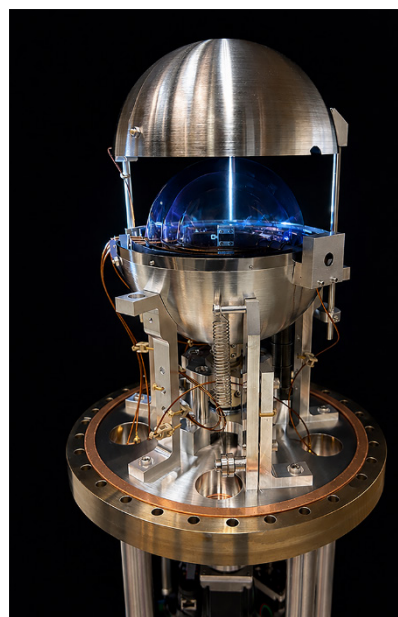


Figure 1. Custom spherical retarding-field analyzer for electron-emission yield measurements, mounted on its UHV flange

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