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Sensitivity Analysis of Simulated Backscattered Electron Emission against Electron Dosage of Buried Semiconductor Features

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Existing attempts to develop performance of semiconductor devices entails size reduction along with cutting-edge non-planar architecture. In the fabrication of these devices, the demand for greater precision measurement of the end dimensions of contact holes and deep trenches has risen. Furthermore, each layer's overlay alignment precision has similarly become very significant. Alternatively, SEM overlay is at present under discussion for use in in-device overlay since overlay measurements from dedicated kerf structures often do not match performance in-circuit, enhanced resolution demanding use cases, in addition to a reference metrology. Primary application spaces are measurement of features from multiple mask levels on the same surface and buried features [1].

Modern CD-SEMs are adept at measuring overlay for cases where all features are on the surface. Though, to measure overlay of buried features, high voltage SEM (HV-SEM) is needed. Gate-to-fin and BEOL overlay are important use cases for this technique. A JMONSEL [2] simulation exercise was performed for these two cases using 10 nm line/space gratings of 5 lines of graduated increase in depth of burial (10 – 50 nm). In an effort to probe the backscattered electron behavior of buried features, the backscattered electron data profile is considered as an image stack to further explore sensitivity dependency vs. energy loss. The backscattered electron image stacks were binned in energy loss intervals of 10 – 50 eV. These simulation results were used to calculate the sensitivity measurements of buried features versus electron dosage for an array of electron beam voltages as previously reported [3].

Next, to emulate real image data the electron emission statistics need to be modulated by dose-dependent shot noise and instrumental artifacts i.e., additive white Gaussian noise (AWGN). Since signal data is aggregated on top of background noise, additive white noise is considered in percentage increase of the noise term under the square root in the sensitivity formula (Figure 2). In the formula, η_{ref} is the backscatter yield of the background material in question, C is the contrast between this material and the background, and $(I_B*\tau)/e$ is the electron dosage (where I_B = beam current, τ = dwell time, and e = elementary charge). The resultant imaging data stream is then assessed so as to understand the noise tolerance of the buried feature signature. Results indicate that there may be optimal energy loss windows along with imaging electron dosages for the detection of buried features for a given material set(s) use case.

References:

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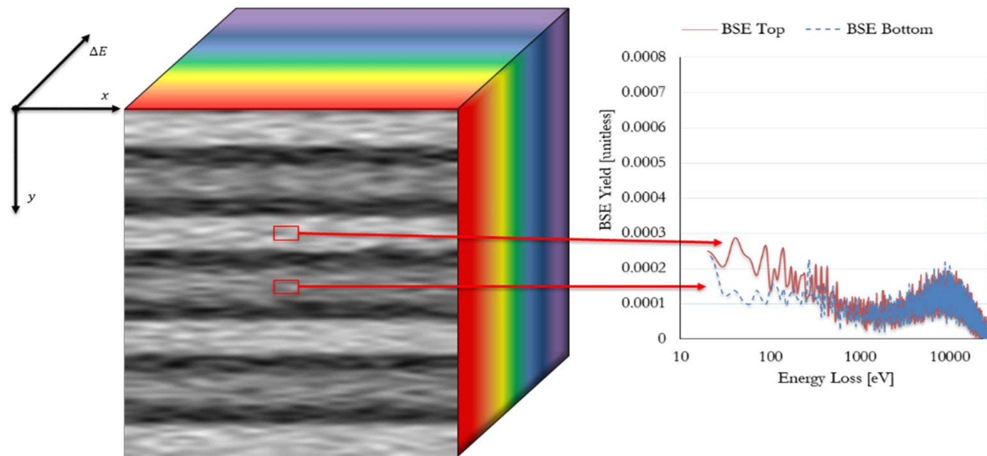

Figure 1. Example simulated energy loss stack profile of buried Cu gratings filled with SiO_2 under SiO_2 overlayer.

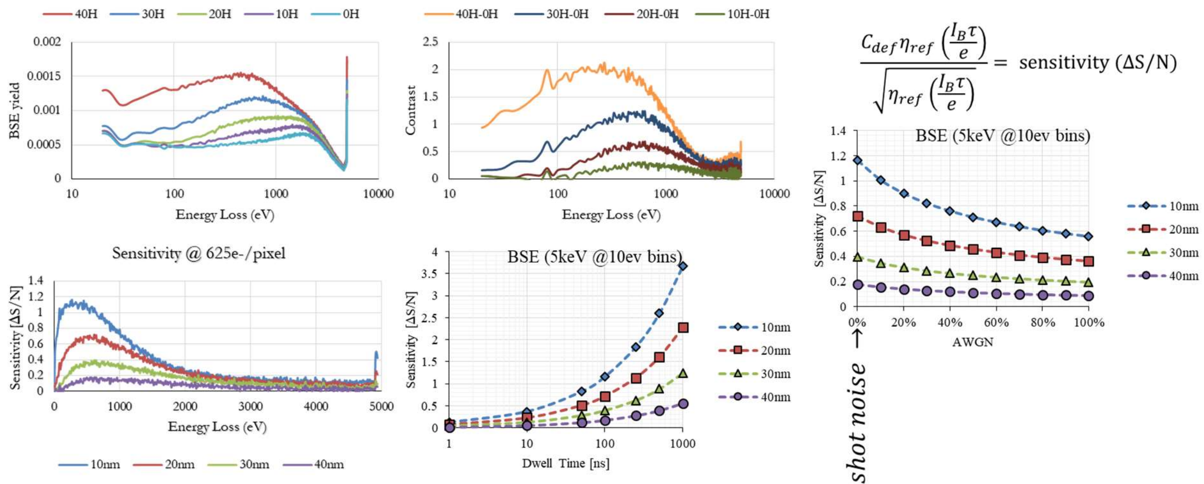

Figure 2. Left: After shot noise modulation – graphs of backscattered yield vs. energy loss, contrast vs. energy loss, sensitivity vs. energy loss, and sensitivity (using highest contrast value) vs. dwell time (in nanoseconds at 1 nA) for buried Cu/SiO_2 grating under SiO_2 overlayer under 5 keV landing energy. Right: Sensitivity vs. AWGN noise (for 100 ns dwell time sensitivity results).

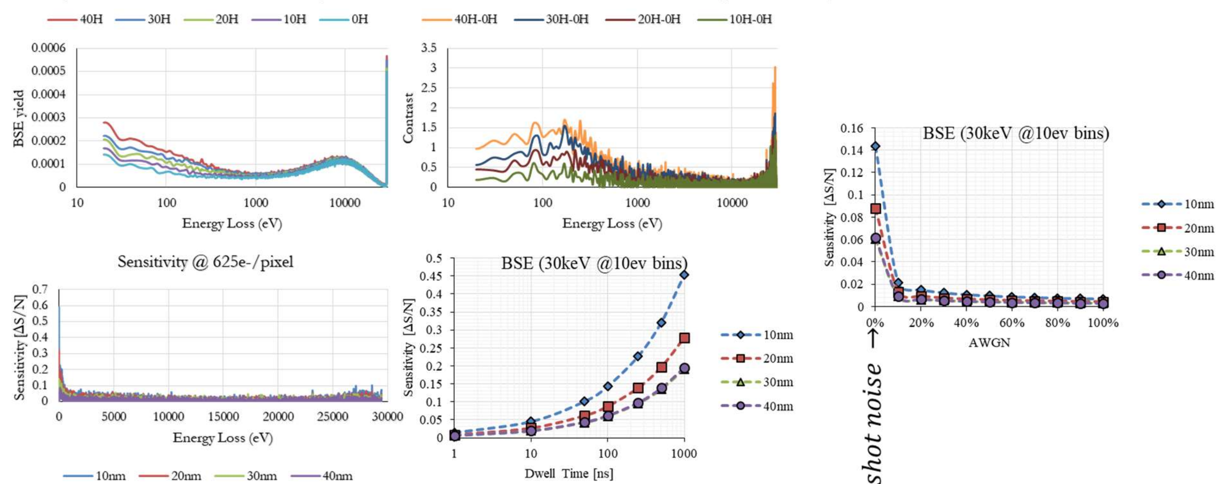

Figure 3. Graphs for buried Cu/SiO_2 grating under SiO_2 overlayer under 30 keV landing energy.

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