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# Secondary Electron Yield at High Voltages up to 300 keV

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Secondary electrons (SE), emitted from bombardment of a matter with energetic particles such as electrons, ions, or protons, are conventionally defined as those with a kinetic energy of 50 eV or less. The parameter describing SE emission is called SE yield, δ, which defines as the number of SEs produced by each incident particle. The SE micrograph, which reveals the surface of materials, is the most widely used imaging mode for scanning electron microscopy (SEM). Recently, SE detectors have been installed on scanning transmission electron microscopes (STEM), as it augments the ability of imaging surface features to a bright-field or dark-field STEM image, which essentially reveal bulk information of a very thin specimen. The benefit of simultaneous imaging of surface (SE) and transmitted electrons (TE) at atomic-scale has been demonstrated in materials science research [1], such as learning the degradation mechanism of battery materials [2] and morphological evolution of catalysts during *in situ* heating [3].

What is the SE yield δ under high accelerating voltages, such as ranging from 60 to 300 keV in a STEM environment? This is a fundamental question that is yet to be answered. Knowing the SE yield is important to quantitative SE imaging analysis. To date, the majority of the SE yield data have been obtained in a conventional SEM environment at voltages up to 30 keV on bulk samples (which are too thick to emit transmitted electrons) [4-6]. Reimer and Drescher reported the only study of SE yield in a TEM up to 100 keV on thin Al and Au films [7].

We hereby carry out a systematic study of SE yield of selected thin film materials in a Hitachi HF-3300 TEM/STEM at accelerating voltages from 60 to 300 keV. We have selected TEM window chips (Norcada Inc., Edmonton, Canada) as our materials of interest, because this type of MEMS-based chips are flat, with uniform thickness, and widely used in the microscopy and microanalysis community. As shown in Figure 1, the 3mm-diameter chip is a 200-μm-thick silicon wafer with a 250x 250 μm$^2$ thin window at the center. The window materials are SiN, and gold and tungsten films deposited on the SiN layer with varied thickness (Table I). It covers medium to high atomic number (Z) materials with thickness ranging from 10 to 400 nm. We can also focus the beam on the 200-μm-thick silicon wafer, which enable us to measure SE yield of layered bulk composite.

The SE yield is evaluated from the equation, $\delta = (I_{scb} - I_{sc})/I_b$, whereas $I_{sc}$ is the specimen current, $I_{scb}$ is the 50 V-biased specimen current, and $I_b$ the incident beam current. Other than challenges such as high leakage current and surface contamination, measurement errors from possible high SE2 and SE3 emission from a STEM column with narrow beam path has to be taken into consideration. Nonetheless, we expect that this first study of SE yield up to 300 keV in STEM will open a new interesting topical area [8].

## References:

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[8] We thank the insightful discussions with Dr. Donovan Leonard and Dr. Martha McCartney.

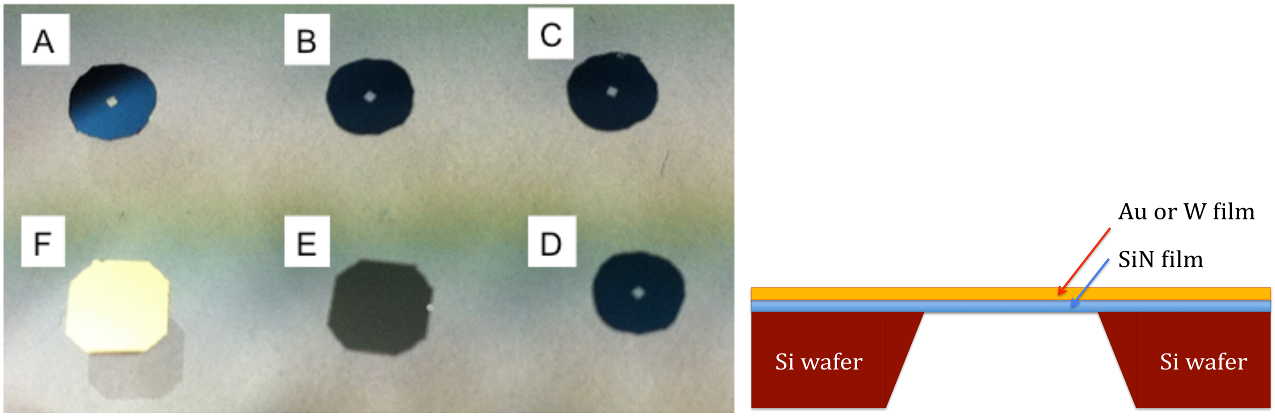

**Figure 1.** Norcada MEMS chips used for measuring SE yield. A-D: SiN window chips with varied thickness; E) tungsten coated SiN window; and F) gold-coated SiN window.

**Table I.** List of materials and thickness for the measurement of SE yield

| Materials | Thickness (nm) | | | | |
|---|---|---|---|---|---|
| SiN films | 10 | 30 | 50 | 100 | 200 |
| Au on SiN | 10 + 10 | 30 + 30 | 50 + 50 | 100 + 100 | 200 + 200 |
| W on SiN | | 30 + 30 | 50 + 50 | 100 + 100 | 200 + 200 |