Off-axis electron holography of focused ion beam milled transistors

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Rau et al. (Phys. Rev. Lett. 82 (1999) 2014) recently used electron holography in the transmission electron microscope (TEM) to map the electrostatic potential in transistors that had been thinned using mechanical polishing and ion milling. n- and p-type regions were distinguished as bright and dark contrast in phase images, respectively. Here, holography is applied to transistors prepared using focused ion beam milling (FIB), which is widely used to prepare samples in the semiconductor industry.

**Bright field image of FIB-prepared sample A, B, C and D on NMOS (3.26nm gate), NMOS (0.5um gate), PMOS (0.32um gate) and PMOS (0.5um gate) transistors, respectively.**

Samples were prepared for TEM examination using FIB. Off-axis electron holograms were recorded at 300 kV in a Philips CM300 field emission gun (FEG) TEM and at 300 kV in a JEOl 3000F FEG TEM. Similar results were obtained using both microscopes.

**Histogram of PMOS transistor (D) in bright field image, 300kV, tip current voltage 160kV.**

An alternative solution is to perform the final milling from the substrate side. Milling from several directions also allows the very surface of the wafer to be removed, reducing the size of the overlap needed in the hologram between vacuum and the doped region.

**Bright field images of sample milled in several directions using FIB (final thinning from substrate side), with surface subsequently cleaned by low angle milling in a Gatan PIPS.**

**CONCLUSION:** Off-axis electron holography has been used to examine dopant contrast in transistors prepared for TEM examination using FIB. Artifacts associated with sample thickness variations and charging have been identified, and methods for removing them have been proposed. It should be noted that future work is still required to understand the physics that underlie electrostatic potentials measured in semiconductors in the TEM to the forms of the conductance and valence bands.