E-beam Nano-machining for Circuit Edit: an Invasiveness Study

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As integrated circuit down-scaling brings minimum dimension features well below 100nm, Circuit Edit (CE), which has relied historically on liquid metal ion source (LMIS)-based Focused Ion Beam (FIB) micromachining, is rapidly losing image resolution and machining acuity. E-beam nano-machining may become the next technology of choice for CE, given its finer machining acuity, superior resolution, and material etch selectivity. However, CE requires etching near MOS transistors, so device irradiation invasiveness must be characterized for a workable range of acceleration energies, doses, and keep-away distances for e-beam based CE.

We investigated the invasiveness of e-beam irradiation on ring oscillators in 65nm integrated circuits, tracked as percent change in oscillator frequencies resulting from the irradiation. Device preparation consisted of back side thinning by mechanical polish, local laser chemical etching to 10μm Si, and finally, FIB gas-assisted etching, leaving 200 – 1600nm remaining Si.

At an acceleration energy of 30keV, through approximately 1μm Si thickness, a lowest detectable invasiveness (causing >0.5% frequency shift) was attributed to a 0.01nC/μm^2 dose, while total transistor failure occurs for doses exceeding 1nC/μm^2. For 5nC/μm^2 irradiation dose through 1μm Si, the lowest detectable invasiveness was observed at an acceleration energy of 10keV.

E-beam nano-machining is typically performed at low acceleration energies, conveniently lowering electron flux at the devices. Using a 1keV beam at 200nm Si thickness and 400nm horizontal distance to devices, at potentially “lethal” doses, we observed no frequency shifts.

The results herein delineate the regimes of invasiveness-free e-beam-based CE, and demonstrate the absence of e-beam irradiation invasiveness at low acceleration voltage in typical CE scenarios.