Characterization of Laser Ablation Spots on Silicon and Gallium Arsenide Surfaces by FIB, SEM and TEM

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An ablation laser used to mark the surface of a material can allow site-specific sample preparation to carry over from optical microscopy to electron or focused ion beam microscopy where buried structures, visible optically, are not otherwise observable beyond the sample surface. This work investigates the extent of damage induced by making an ablation laser spot on various semiconductor samples including depth of the ablation hole and extent of amorphization of neighboring material.

A coumarin dye laser (Micropoint® by Photonics-Instruments) was focused through the optics of an Olympus BX-10 optical microscope with a 20X final objective lens to ablate a spot on the surface of silicon and gallium arsenide wafers. Optical power density delivered to the sample surface depends on the focusing optics, health of the coumarin dye cell, and the controllable neutral density filter positioned between the laser and focusing optics through which the laser beam passes. In these experiments, the minimum power required to create an ablation spot on silicon and gallium arsenide surfaces was similar (additional spots were made at higher power settings).

An FEI Strata-400 dual-beam FIB-SEM was used to characterize and prepare ablation spots using 10 keV SEM imaging and 30 keV Ga⁺ for cutting cross-sections for depth analysis. A JEOL 3100F TEM was used for high resolution imaging in STEM mode with ADF and HAADF detectors.

Images A and B in Figure 1 correspond with the ablation spot made on the GaAs surface. Image A shows the top-down view of the spot and Image B shows the cross-section that was made through FIB milling. Images C and D in Figure 1 correspond with the ablation spot made on the Si surface. The ablation spot on the gallium arsenide surface appeared to have a broader splattered pattern than on the silicon surface where the ablated spot appeared to be more contained. However, the depth of damage of the ablation spot on the silicon surface is significantly larger than the depth of damage on the gallium arsenide surface.

Figure 2 contains images that correspond to STEM analysis using the JEOL 3100F TEM with the ADF detector. Image A shows the extent of damage into the GaAs surface is 20 nm. Image B shows the extent of damage into the Si surface which is 8.5 nm.

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Figure 1: (A) Top-down SEM image of an ablation spot made on GaAs surface at 10kx. (B) FIB cross-section imaged by SEM for same ablation spot shown in A at 10kx. Depth of ablation spot is 275 nm. (C) Top-down SEM image of an ablation spot made on Si surface at 10kx. (D) FIB cross-section imaged by SEM for same ablation spot shown in C at 10kx. Depth of ablation spot is 525 nm.

Figure 2: (A) TEM image of GaAs cross-section with ADF detector at 250kx. (B) TEM image of Si cross-section with ADF detector at 250kx.