Non-gallium Focused Ion Beam Nanofabrication of III-V Materials

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The application space of Focused Ion Beam (FIB) systems is ever expanding. Although these research tools have been in use for decades, they are still used in new and innovate ways for the purposes of nanofabrication and rapid prototyping.[1] The continued evolution of the FIB instrument has diverged from gallium being the traditional Liquid Metal Ion Source (LMIS), into a new process space where alloy sources (LMAIS) are able to provide a much wider capability and applications.[2-4] In this report, we will discuss the application of non-gallium FIB processing of Ga-group V compound semiconductor materials, and milling strategies.

Gallium arsenide (GaAs) is the most widely used compound semiconductor material. The direct processing of Ga-group V (GaAs, GaN, GaP) materials with a Ga ion beam results in dense droplets formed in the milled areas.[5] Strategies to reduce this effect include the use of cryostages and in-situ gas assisted etching. We have found that by changing the ion type, one can avoid droplet formation completely on these materials, figure 1.

The sputtering rate of these materials is increased substantially when milling with Au$^+$ ions, as compared to Ga$^+$ ions. From empirical data, we observe nearly a 2x increase in the milling rate of GaAs when Au$^+$ ions are used under identical conditions and doses compared to Ga$^+$ ions. From ion beam simulations, one should expect approximately a 17% increase in the sputtering rate when selecting the heavier Au+ ion, but rather we observe an 86% milling rate increase, while still maintaining droplet-free formations.

To further enhance the milling rate, we have performed experiments with varying the beam step size, dwell time, and milling strategy, all while keeping the total dose constant. We have obtained a further 88% increase in milling rate of these materials.

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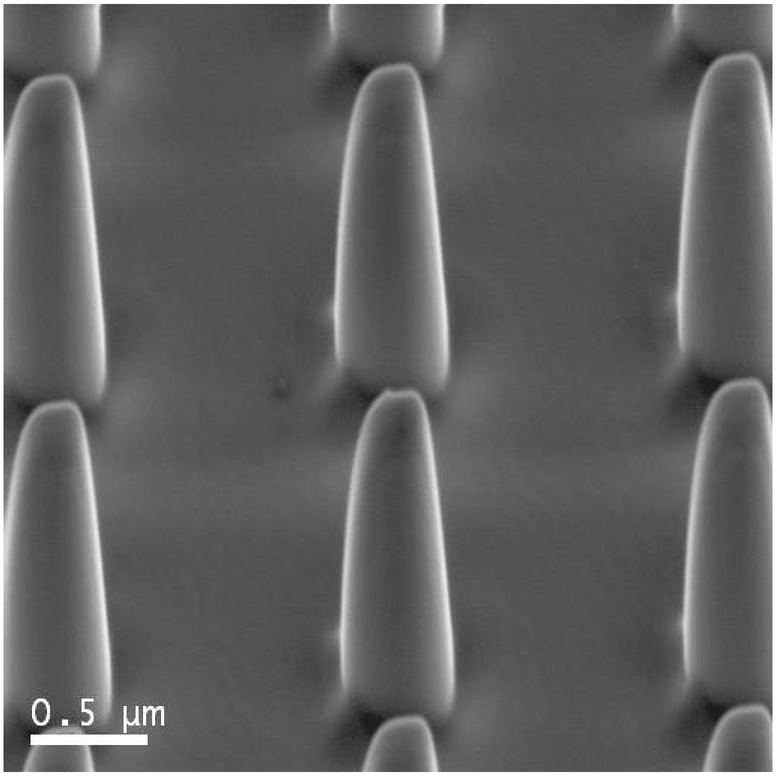

Figure 1. Pillar array milled into GaAs with a fluence of 30,000 μC/cm^2 Au+ ions at 30kV. No evidence of Ga droplet formation is visible. Image magnification is 80kx, sample tilted to 60° for imaging.