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# Novel Ion Species: An Exploratory Study of an Unknown Application Space

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The Center for Advanced Materials Characterization in Oregon (CAMCOR) housed at the University of Oregon campus is thrilled to have acquired the Hydra, a new plasma FIB with the ability to switch between four different ion species: xenon, oxygen, nitrogen and argon. This is a unique tool of which there are only a few in the world, with CAMCOR being one of the earliest adopters and the only open-access facility in North America to offer external users beam time and services on the new platform.

For the past several years, commercially available plasma FIB systems have only been available with Xenon sources, and the primary applications have focused mainly on large-scale milling of silicon-based devices. Because of the novelty of the Hydra's ability to mill and deposit with multiple ion species, the application space is not fully understood or explored. Many questions are being generated regarding what ion beam chemistry is optimal for milling specific material types. Additionally, it has been observed that using variable ion beam species can affect deposition rates and artifacts while using in situ gas injection systems such as platinum, carbon, and tungsten.

To begin addressing these variables, CAMCOR entered a collaborative study with Thermo Fisher Scientific to characterize the mill-rate and texturing artifacts associated with using different ion species at varying accelerating voltages, on many sample types. An automation script was written to stream-line and standardize the procedure of preparing substrate surfaces, milling boxes, and measuring the oblation rate. Materials to be tested with varying beam chemistries and energies include Si, InGaAs, LR White, Ti and Diamond.

As preparation for milling and measuring, the automation script tilts the stage to a large negative tilt and uses a high beam current to clear away oxides and other debris in a process known as "spin mill". Then, after tilting to 52˚ and prompting the user to select the desired ion species, an array of rectangles are milled with depth increasing along one axis and energy along the other. The volume that has been removed is measured using a line milled down the center of the box as a measurement tool.

The results so far have been quite exciting. The Oxygen beam is proving to be an excellent milling source for making curtain-free cuts on carbon-based structures such as diamond and biological tissue. Varying the accelerating voltage of each ion beam specie has shown to affect both deposition, etch rates and textures of materials in our study.

While we have learned many things observing near-surface artifacts in our study, we are also starting to explore implantation artifacts via depth profiling studies with ToF-SIMS and XPS. For example, the oxygen and nitrogen sources show a clear peak in mill-rate at 5kV. We believe this is because 5kV is the energy at which implantation begins to occur faster than milling, resulting in the creation of SiN and SiO, harder materials to mill than Silicon alone.

To gain an understating of what compounds are created and at what depths, milled surfaces were analyzed with ToF-SIMS and XPS. So far, we have confirmed that SiN is formed at a depth corresponding to the energy with a ratio of ~1nm/kV.

We can think of a few possible applications for the selective hardening phenomena due to implantation: site-specific doping, etch masks, and anti-corrosive properties to name some examples.

In this talk, we will share the results of our study to-date as well as interesting ideas, applications, and results we have discovered while using non-Gallium ion species.

References

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