Fabrication of Suspended Nano-crystalline Diamond Foils for Stripping Electrons from a High Power Hydride Beam

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Thin nano-crystalline diamond foils are critical to the production of neutrons at the Spallation Neutron Source (SNS). These diamond foils are required to strip electrons from an accelerated hydride ion beam, converting it to a high-energy proton beam which is intensified and directed to a liquid mercury target causing neutron spallation. Planned power upgrades and a proposed Second Target Station at SNS have necessitated improvements to the diamond foils in order to withstand increased beam power. Here we describe progress on the scaling and characterization of a diamond foil fabrication process aimed at the production of more reliable and robust suspended foils, comprised of diamond films with reduced numbers of defects and better film uniformity.

Nano-crystalline diamond foils were deposited onto photo-lithographically patterned and reactive ion etched silicon substrates. The corrugated topography of the silicon surface, and subsequently deposited diamond films, helps to mitigate curling of the suspended films after release. Deposition was carried out in an argon rich plasma with methane and hydrogen via microwave plasma-assisted chemical vapor deposition (MPCVD). The foils were released by removing the underlying silicon substrates in an acid etch leaving 17mm x 30 mm x ~1 µm diamond foils supported on one side by the remaining 15 mm silicon handle. Film uniformity has improved tenfold due to a more powerful microwave generator that allows uniform films to be deposited across a larger area. Improvements in silicon patterning have also been achieved. Because patterning is now performed inside a cleanroom, defects, characterized as visible holes and tears in the suspended foils, have decreased substantially. Deep Reactive Ion Etching techniques have replaced wafer dicing to expose coupon sidewalls before diamond film deposition. The etched sidewalls provide a far smoother surface for diamond deposition, and significantly reduce tears at the edge of the foil 'box top'.

Raman spectroscopy and scanning electron microscopy suggest that the more uniform films grown at higher power retain the composition and crystallinity of previously used diamond films. These new diamond foils have been employed at the SNS with beam power up to 1.2 MW, and they have performed successfully. The latest foil operated at 1.0 MW for 32 days and 14 days at 1.2 MW, with a stripping efficiency that started at 98.3% and did not change noticeably during use.

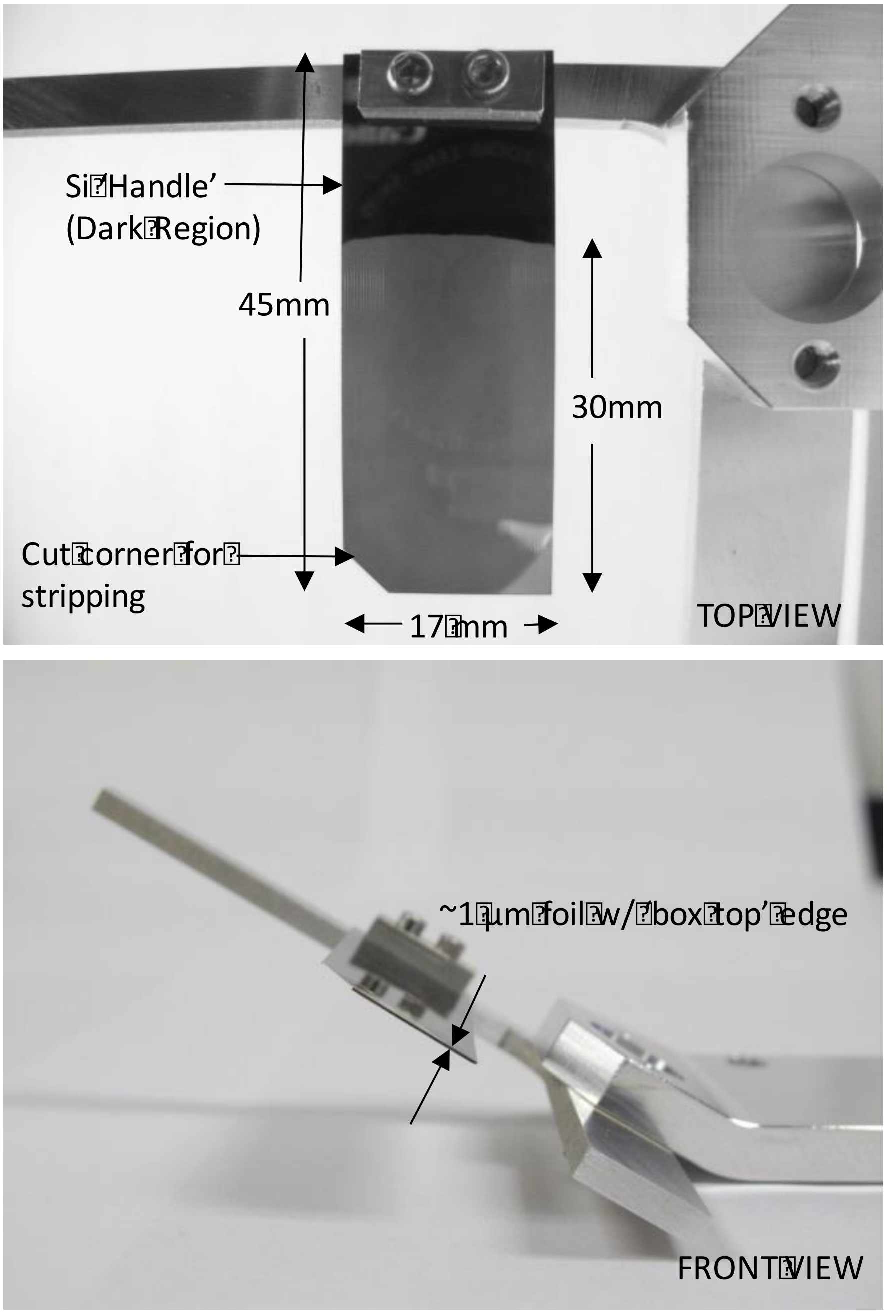

Figure 1: A free standing "released" diamond foil is shown from a top view (top) and front view (bottom). Films are designed to operate under extreme environments and are optimized to exhibit minimal vibration and deformation during use.