

# Raman Spectroscopy for Quick Quality Analysis of Diamond Membranes



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## Introduction:

Very thin membranes of amorphous carbon, a micron or so thick, are used in high energy physics to strip electrons from fast moving ions to increase the charge state of the ion. In linear accelerators, these foils strip electrons from beams prior to insertion into cyclic accelerators. In proton rings, electrons are stripped from either hydrogen atoms or H<sup>-</sup> ions. In rare isotope beam rings, electrons are stripped from heavier atoms such as Ne, Xe, Kr, even U. Removing

the electrons changes the beam's charge state and distribution optimizing its overall energy level for insertion into the accelerator.

As the energy of these beams increases, lifetime of the carbon foils suffers. Downtime is expensive for these large, valuable facilities and radiation exposure to the maintenance workers must be minimized. Diamond, with its superior thermal conductivity, strong covalent bonding, lower vapor pressure and higher density is a reasonable candidate to replace amorphous carbon in this application. CVD processes can make diamond with varying concentrations of sp<sup>2</sup> vs. sp<sup>3</sup> bonded carbon. While early tests showed diamond's benefits in these stripper foil applications, it remained unclear whether the benefits came from the sp<sup>2</sup> or sp<sup>3</sup> bonded fraction.

Raman spectroscopy offers a way to quickly access the presence and relative amounts of sp<sup>2</sup> vs. sp<sup>3</sup> bonded carbon. Examining the peaks at 1332 cm<sup>-1</sup> and 1520 cm<sup>-1</sup> indicates the presence of diamond and graphite, respectively. Comparing the peak heights provides a measure of relative amounts.

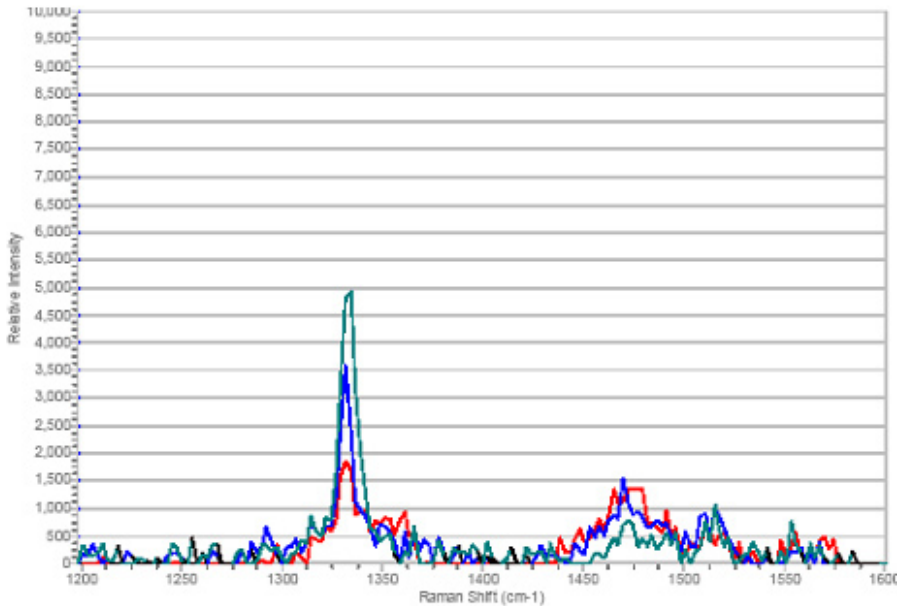
## Experiment & Results:

Stripper foil substrates were cut from standard silicon wafers using a numerically-controlled Nd:YAG laser. After nucleation, diamond films 1.5 μm thick were deposited on one side of the silicon. In order to vary the relative amounts of sp<sup>2</sup> vs. sp<sup>3</sup> bonded carbon, the ratio of methane to hydrogen was varied. After deposition, square centimeter windows were etched into the silicon leaving thin diamond membranes suspended on silicon frames as shown in Figure 1.

**Figure 1**



**Figure 2**



**Table 1**

CH4 Concentration	Raman Peak Ratio	Average Life (hrs.)
Green: 2.50%	9.9	74:55:30
Blue: 6.00%	3.6	2:56:45
Red: 13.30%	1.9	23:17:00

Raman spectroscopy was done on these membranes using a B&W Tek i-Raman® system with an excitation laser operating at 532 nm.

Peak heights were collected from the spectra and ratios of the peaks at 1332 cm<sup>-1</sup> and 1520 cm<sup>-1</sup> were calculated. The stripper foils were then tested in a beam line operating with Sn-117 ions.

Figure 2 shows an example of the Raman spectra that were obtained showing the characteristic peak at around 1332 cm<sup>-1</sup> indicating the presence of diamond

Table 1 summarizes the information obtained from the spectra and foil lifetime tests as a function of percent methane in the diamond deposition recipe.

## Conclusions:

CVD diamond stripper foils showed an improvement in lifetime vs. amorphous carbon foils in Sn-117 ion beams where the carbon foil lifetime averaged just above 8 hours. A quick Raman analysis of diamond foils proved effective in sorting foils made with high, medium or low concentrations of methane. The diamond foils made with the lowest concentration of methane (composed of the highest fraction of sp<sup>3</sup> bonded carbon) showed almost an order of magnitude longer lifetime in a high energy, heavy ion beam.