Investigation of the Secondary Emission Characteristics of CVD Diamond Films for Electron Amplification

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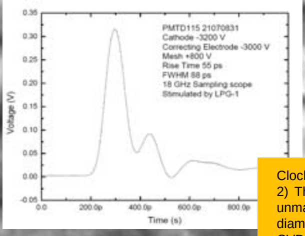
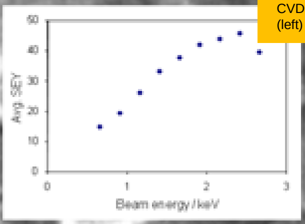
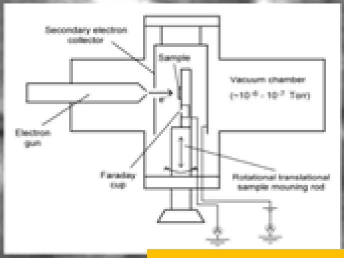
CVD Diamond dynode advantages

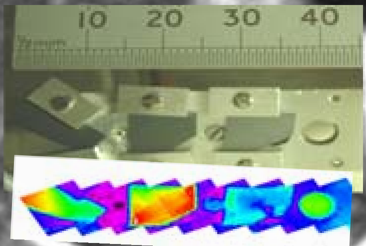
- Negative electron affinity - high secondary electron yield (SEY)
- Narrow electron energy distribution and low dynode no. (high SEY) – excellent time resolution
- High SEY gives good gain statistic – low noise
- Wide band-gap – low noise or high temperature
- Robust, stable SEY – easy to regenerate
- Easy to produce – chemical vapour deposition
- Boron doped – conductive
- Easily patterned and structured



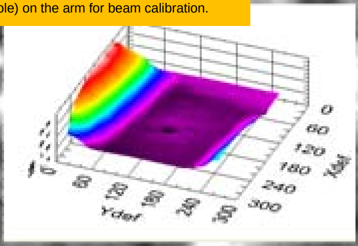


Clockwise from bottom left: 1) SEY of hydrogen terminated CVD diamond. 2) The temporal signal from a Photek single diamond dynode device, with unmatched rise time for a PMT. SEM micrographs of 3) a 2-dimensional diamond fibre matting made by coating a W wire mesh, and 4) inkjet-seeded CVD growth to form the word "diamond" on mirror p-silicon - scale bars are (left) 1 mm, (right) 100 µm. [Bristol CVD Diamond group]





Clockwise from bottom left: 1) A labelled photograph, and 2) a schematic of the experimental apparatus. 3) A composite showing a photograph of the arm with diamond samples together with the corresponding SEY x,y scan. 4) An SEY scan of the Faraday cup (black hole) on the arm for beam calibration.

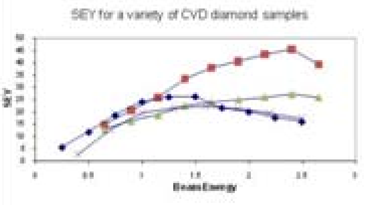


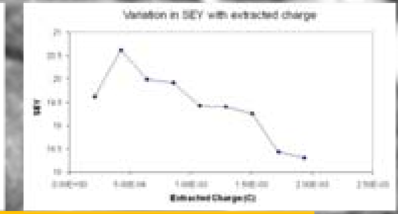
Experimental setup

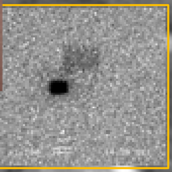
- Stainless steel vacuum system ~ 10^{-7} mbar
- Oil-free "Maglev" turbo plus scroll pump
- Organic contamination minimized
- Rotation and translation of Diamond target
- Surrounding secondary electron collector
- Variable biases on target and collector
- Current measurement – Keithley 6515 Electrometer
- LabView automation:
    - Pulsed E-beam (0.1 sec up)
    - Synchronized current measurements
    - Beam scanning for SEY 2D imaging

Experimental results

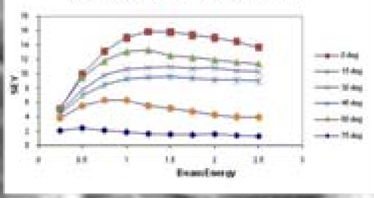
- Initial results showed lower than expected SEY (≤ 12 up to 2.5 keV) which degraded quickly
- Electron beam deposition (EBD) is a factor – contamination reduces SEY
- It's effect was reduced by:
    - Moving to an oil-free vacuum system
    - Reducing the beam current
    - Minimizing the electron beam time
- The effects of hydrogen desorption are similar
- So far we haven't identified which dominates
- Modifications drastically improved results
- Measurements with a variety of diamond material
- Best SEY measured so far:
    - 45 at 2.4 keV
    - Hydrogen terminated NEA surface
    - Boron doped CVD diamond
- Measurements of SEY with E-beam incident angle give unexpected results (SEY at 0° is highest)







Clockwise from bottom left: 1) SEM micrograph of a CVD diamond surface showing "ageing ", dark regions are previously imaged areas. 2) Before (top) and after (bottom) photos of the Faraday cup on the target arm after prolonged E-beam illumination showing EBD. 3) A plot showing SEY versus E-beam energy for a number of tested samples. 4) Typical degradation in the SEY with extracted charge. 5) Variation of SEY with E-beam angle of incidence (an unexpected result awaiting investigation)



Conclusions

- We have measured SEY for a variety of CVD diamond materials
- The cause of SEY degradation (EBD or hydrogen desorption) is yet to be established
- Diamond shows promise as a dynode material for high performance PMTs

Background image: an SEM micrograph of a polycrystalline diamond surface manufactured by chemical vapour deposition on a silicon substrate. The typical crystal size is ~1 micron.

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