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Microanalysis of Nano-Crystalline Diamonds

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The properties of nanometer sized clusters of wide band gap materials are of current interest because of the possibility of engineering or tuning the band gap emission energy by changing the size of the nanostructured material. It has recently been demonstrated for the first time, that nano-crystalline diamond can be produced in a fused silica (amorphous silicon dioxide) substrate by MeV Carbon ion implantation followed by a suitable annealing procedure in a hydrogen-containing atmosphere. [1] Further it has been demonstrated that the size of the nano-crystalline diamond can be varied by changing the implantation dose. [2] Diamond has unique and useful properties including negative electron affinity, optical transparency, mechanical strength and the highest thermal conductivity of all known materials. Possible applications include low energy electron emitters for flat panel displays and high frequency photon emitters for opto-electronics.

Carbon has been introduced into the pure fused silica specimens using MeV ion implantation. The implanted specimens are subsequently annealed at atmospheric pressure for 3.6×10^3 s at 1100C in various ambients including oxygen, argon and forming gas containing hydrogen. For comparison, other pure fused silica specimens that have not been implanted have been subjected to the same annealing treatments.

Cathodoluminescence (CL) is the non-incandescent emission of light from a material, which has been irradiated with electrons. Cathodoluminescence microanalysis (spectroscopy and microscopy) in an electron microscope enables the detection of defects and dopants in materials with high sensitivity and high spatial (lateral and depth) resolution. Electron beam parameters, including beam energy, are varied to control the penetration depth of the incident electron beam, and hence the local volume of specimen probed. [3]

CL microanalysis of these specimens shows that at least one broad and two narrow, previously unreported low intensity emissions are observed from fused silicon dioxide implanted with 5×10^{16} C/cm^2 dose of 1 MeV Carbon ions following annealing (for 3.6×10^3 s at 1100C) in forming gas (4% Hydrogen in Argon). These emissions are observed at 2.78eV (FWHM ~0.08eV), ~3eV (FWHM ~0.25eV) and 3.17eV (FWHM ~0.1eV), as can be seen in Fig 1. The spectra have been corrected for total instrument response and fitted with the minimum number of Gaussian components using an iterative non-linear least squares algorithm. [4] These previously unreported emission components are not observed from any of the other implanted and/or annealed specimens regardless of their treatment procedure. The emission energies and peak widths of these emissions are not consistent with any known defects associated with the silicon dioxide host lattice. Depth resolved CL microanalysis has been used to confirm that these new emissions originate in the near surface region,

which is consistent with their association with the implanted nano-crystalline diamond layer. The possible origins of the previously unreported emissions will be presented.

As well as contributing to the understanding of the properties of nano-crystalline diamond, these results complement and are consistent with published data on the ion irradiation response of silicon dioxide. They also give insight into the fundamental processes associated with irradiation induced defect generation in silicon dioxide, a technologically important material that is often used in devices that operate in a radiation environment.

References

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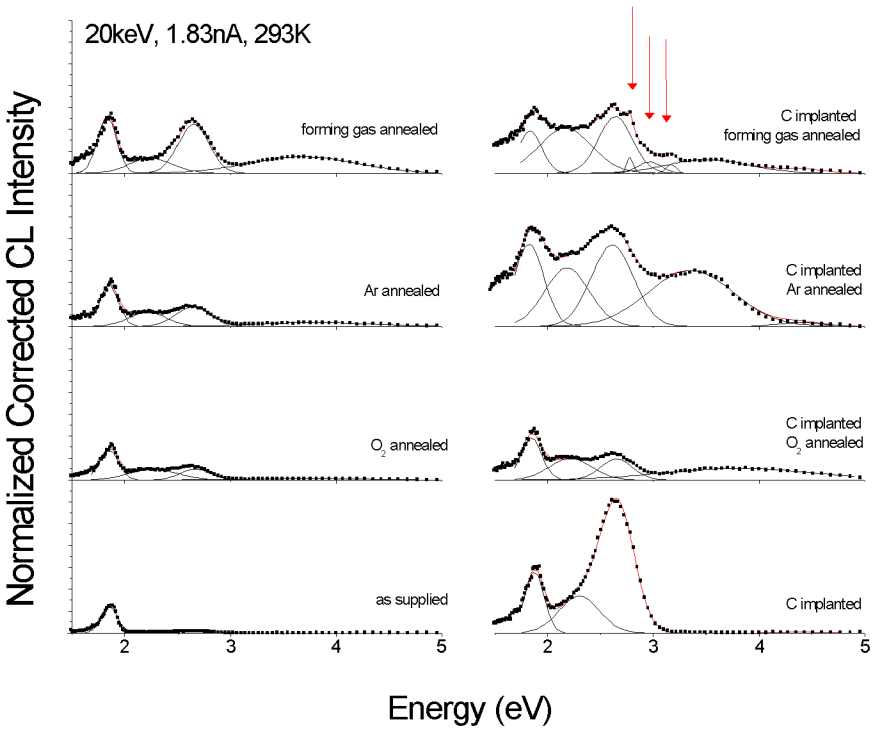

FIG. 1. A typical sample of the CL spectra corrected for total instrument response, from a series of implanted and annealed specimens. The previously unreported emission associated with the nano-crystalline diamond layer are indicated by arrows.

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