The nature and distribution of defects created by low energy (<200 keV) variable temperature electron irradiation and annealing in CVD diamond

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Individual and ensembles of defects in diamond, such as the negatively charged nitrogen-vacancy (NV^-) centre, have the potential to form the building blocks for numerous technologies, including quantum computers, sensors, and network.[1,2] The production of these defects, with optimised properties, is an important research area. The formation pathways for many defects remain yet to be fully understood, and for the precise positioning of single NV^- centres it is important to know how far vacancies diffuse. Electron irradiation of diamond at energies above approx. 145 keV creates interstitials and vacancies and both these intrinsic defects assist the diffusion of carbon atoms and impurities through the crystal lattice.[3,4] Irradiation at high temperatures and annealing treatments can be used to investigate this diffusion, the mechanisms through which vacancies and interstitials are lost, and defect formation.[5,6]

A Transmission Electron Microscope (TEM) provides a high level of control over electron irradiation parameters; electron energy (irradiation damage depth), electron dose, irradiation area, and sample temperature.[7,8] In this work we present variable temperature electron irradiation studies of high purity electronic grade CVD diamond between 90 K and 1273 K using a TEM. An electron energy of 200 keV has been used, with doses ranging from 10^{14} to 10^{21} e^-/cm^2. Characterisation of the defects created and their distribution has been carried out using confocal photoluminescence measurements at liquid nitrogen temperatures, including studying their diffusion and interactions in subsequent annealing studies.

The studies reported here focus primarily on the neutral vacancy, a defect believed to be a neutral di-vacancy defect, and NV^0/NV^- defects. The defects created using the TEM are compared to an annealing study carried out on a bulk electron irradiated sample, where absorption spectroscopy has been used to quantify defect concentrations. Migration of the vacancy and interstitial have been modelled and a comparison between experimental and simulated data is presented.

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