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EELS Study of Pure Amorphous Diamond

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Carbon allotropes have diverse properties depending on internal structure and bonding. Amorphous carbon has both sp^2 and sp^3 bonds and its properties are determined by sp^2/sp^3 ratio. The amorphous diamond-like carbon with high sp^3 fraction (up to 88%) has outstanding mechanical properties. Ion beam induced amorphisation in diamond results in formation of disordered carbon regions with variable sp^2/sp^3 ratios through transition of some broken sp^3 bonds into more stable sp^2 bonds with corresponding density reduction [1-4]. Depending on the annealing conditions the disordered carbon can be converted into polycrystalline [2-3] or highly oriented graphite (high pressure annealing) [5]. Recently, purely sp^3 tetrahedral amorphous carbon was obtained from glassy carbon using high pressure (50 GPa) laser annealing (1800 ^{o}K) [8]. In the present study new method of fabrication of pure amorphous diamond through ion implantation and thermal annealing has been demonstrated.

The channels of disordered carbons were fabricated into single crystal diamond at depth 1.8 µm by 1 MeV He^+ ion implantation through metal mask with apertures. The width of apertures was in range 25 – 200 nm. The implantation fluence was 2×10^{17} ions/cm^2. Samples were annealed in vacuum at 950 ^{o}C for 2 hours. The implanted regions were studied after ion implantation and after annealing using TEM and EELS.

The absence of diffraction contrast in TEM images of implanted channel as well as diffraction pattern (FIG. 1) confirms its amorphous structure. The carbon K-edge EELS spectrum (FIG. 2a) shows the prominent peak at 285 eV (π* peak) indicating the presence of sp^2 bonded carbon in implanted channel after ion implantation. TEM study of implanted diamond after thermal annealing showed no change in structure of channels – they remained amorphous. EELS study of carbon K-edge revealed the absence of peak at 285 eV (FIG. 2b). The disappearance of π* peak indicates the complete conversion to σ bonds and the formation of amorphous 100 % sp^3 bonded carbon or pure amorphous diamond. Plasmon energy in low loss spectra is a function of valence electron density and in amorphous channel was measured to be 32.6 eV (FIG. 3) corresponding to density 3.27 g/cm^3 which is lower than diamond (3.52 g/cm^3) but is consistent with a random distribution of sp^3 sites [7].

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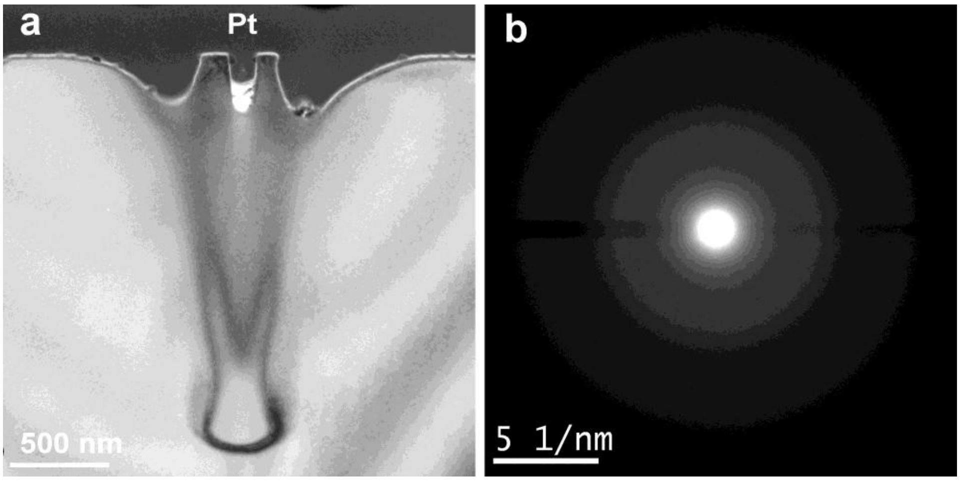

FIG.1. a) Bright field cross-sectional TEM image and b) corresponding diffraction pattern of disordered carbon channel in diamond after 1 MeV He^+ implantation.

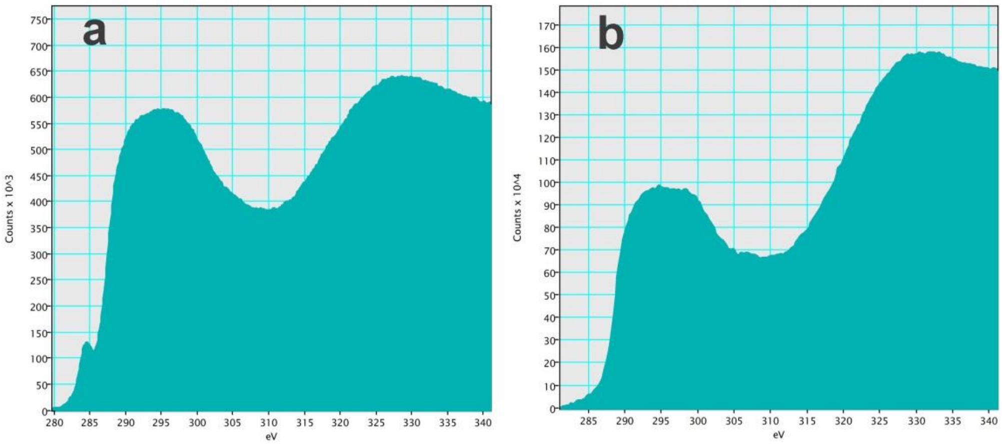

FIG.2. EELS spectra of carbon K-edge in implanted channel and bulk diamond after a) ion implantation and b) thermal annealing.

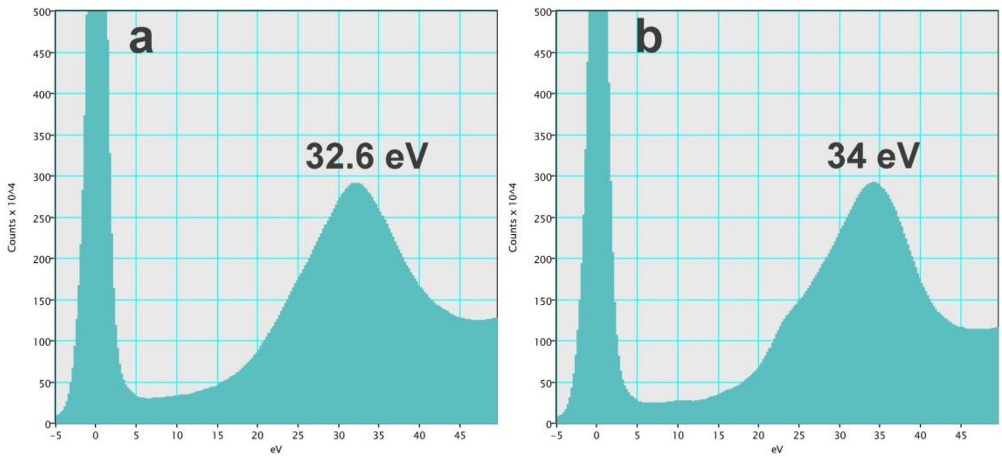

FIG.3.Low loss EELS spectra in a) amorphous diamond channel and b) bulk diamond.