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 physical 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 ^oK) [6]. We report TEM and EELS studies of purely amorphous diamond fabricated by a new method using a combination of ion implantation and thermal annealing.

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 ^oC for 2 hours.

TEM image and diffraction pattern (Fig.1) revealed the amorphous structure of the channel created by implantation. The carbon K-edge in 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].

References

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