FULLERENE-DIAMOND TRANSFORMATION UNDER IRRADIATION WITH CHARGED PARTICLES (REVIEW)

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For the first time nanodiamonds were obtained at the Max Planck Institute (Stuttgart, Germany) in 1997. Dr Banhart and his group investigated transformation of fullerenes into diamond under electron beam irradiation in the electron microscope (electron beam energy is 1.25 MeV). Next experiment in MPI (Stuttgart) hows that much larger amounts of diamond can be obtained if uses ions from linac instead of electrons as irradiating particles. A fullerene sample was irradiated with 3 MeV Ne^+ from the pelletron accelerator. Under the ion irradiation, the temperature of a sample reached 1000-1400K. The maximum range of 3 MeV Ne^+ ions in a sample is about 2 μm.

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Linear accelerators are very important instruments for experimental investigations in modern physics. Here we consider obtaining the nanodiamonds under electron or ion irradiation of fullerenes [1-4] using linear accelerators. For the first time nanodiamonds were obtained at the Max Planck Institute (MPI) in Stuttgart (Germany) [5]. Dr Banhart and his group investigated transformation of fullerenes into diamond under electron beam irradiation in the electron microscope (electron beam energy is 1.25 MeV) [5-8]. The fullerenes-electron beam interaction has three consecutive stages. At the first stage fullerenes and nanotubes [9-11] transform into onion-like fullerenes [12-13] at sample temperatures above 600K. Onion-like fullerenes ("onions") consist of an arrangement of closed, concentrically nested graphitic shells. The "onion" diameters can reach some tens nanometers. `The distance between graphitic shells is 0.34 nm. At the second stage, the distance between the graphitic shells decreasing from 0.34 nm to 0.22 nm towards the center means that the onions are in a state of high self-compression. At last, at the third stage under electron irradiation at temperatures above 900K the cores of compressed carbon onions transform into diamond. Once nucleated, these diamond crystals grow under continuing irradiation until almost the whole onions have transformed into diamond. Theory of graphite-diamond transformation [14] predicts that after nucleation the growth process takes place at low pressure. The largest diamonds produced in the electron microscope were about 100 nm in size. The total amount of diamond which can be produced during the irradiation period in the electron microscope is extremely small because the sample areas have to be irradiated with an intense focused electron beam of only a few microns in diameter. Next experiment in MPI (Stuttgart) [15] shows that much larger amounts of diamond can be obtained if ions from the linac is used instead of electrons as irradiating particles. The fullerene sample was irradiated with 3 MeV Ne^+ at a current density of 60 $\mu A/cm^2$ from the pelletron accelerator. Diameter of a sample is 3 mm. Under ion irradiation, the temperature of a sample reached 1000-1400 K. The maximum range of 3 MeV Ne^+ ions in a sample is about 2 μm. Using standard thermodynamics, M. Zaiser and F. Banhart have derived a non-equilibrium phase diagram [14] that gives the regions of stability for graphite and diamond as a function of the irradiation intensity and temperature. Next step for more amounts of nanodiamonds is scaling increasing of the output energy and average current of a beam in a heavy ion linear accelerator. This year Florian Banhart used an electron beam to link (or to weld) two hollow carbon nanotubes [16] for creation of ultra-miniaturized electronic circuits in future.

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