An investigation of nanodiamond and carbon onion structures by UNR-TEM methods

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Transformation processes in a isolated diamond nanoparticles under vacuum annealing were studied by combination of UHR-TEM method and nanodiffraction. Initially, part of diamonds were combined in agglomerates, consist of several blocks, others – were monocrystalline. It should be noted the latter predominated in initial detonation synthesis diamond particles. Still, a significant part of particles contained various defects of crystalline structure: twins with {111} twining plane; large-angle boundaries both with various twins and in between blocks, etc. Only the reflexes corresponded to one crystalline zone existed on the nanodiffraction patterns of the monocrystalline initial particles. After the annealing at 1000°C, three types of nanoparticles were observed on the surface of agglomerates: (1) diamond nanoparticles shaped similar to the initial state; (2) totally transformed onion-like carbon nanoparticles (carbon onions); and (3) unidentified owing to a poor contrast nanoparticles. It should be noted that on the surface of nanodiamond particles after small annealing many investigators observed layers often called as graphite-like. However, nanodiffraction patterns of such particles show that these layers should be assigned to the amorphous state, because reflexes corresponding to the crystalline phase do not appear. The nanodiffraction pattern of carbon onion consists of broadened rings, corresponded to graphite. No individual reflexes, which implies the complete transformation of the nanoparticles, were observed. Nanodiffraction patterns of unidentified nanoparticles were represented by many individual reflexes that fill with some density the diffraction rings corresponding to diamond. This fact allows to suggest that the monocrystalline structure breaks down into numerous fragments of extremely small size. That is why the crystal lattice does not resolve and the shape of the nanoparticle resembles an amorphous state. In the literature, such a state is often called "amorphous diamond". In the transformation process, this state might be intermediate. In further transformation, the amount of amorphous diamond fraction goes down, while a graphite-like component increases. Thus, the diamond structure undergo the transformed into a graphite-like. The process is violent, and it is extremely difficult to observe nanoparticles simultaneously containing the graphite-like and diamond structures. Still, on large-size nanoparticles it is sometimes possible to register the residual part of the diamond constituent.