Carbon nanomaterials as result of nanodiamonds annealing

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Abstract

Primary detonation nanodiamond (ND) particles have mainly of a close-to-spherical shape; however, particles of irregular shape (triangles, rods etc.) were also observed. The size of the nanodiamond particles is 2-20 nm with the size distribution maximum corresponding to 4–6 nm (about 90% of all particles). Primary ND particles were combined into agglomerates with size up to millimeters (Fig.1a). HRTEM showed that basic part of primary nanodiamond particles are single crystals, but essential portion of particles has different defects of crystalline structure: twins with {111} twinning plane, high-angle boundaries between fragments of nanoparticle etc. Some defects can exist only in nanosized objects. For example, configuration as five-pointed star from twins leads to change of crystal parameters from the tabular values for bulk crystals (Fig.1b).

ND annealing in vacuum or non-oxidized conditions leads to transformation into onion-like carbon nanoparticles [1]. Particles with defects of crystalline structure undergo transformation into carbon onions during annealing in vacuum at lower temperature than particles without structural defects. Investigation showed that basic part of nanodiamonds have diamond structure during annealing up to 950-1000 ^{o}C. Small part of nanodiamonds with size around 2 nm can transform into carbon onions at temperature 800 ^{o}C. After annealing of nanodiamond agglomerates at 1000-1300 ^{o}C, mixture of nanodiamonds and carbon onions is formed (Fig.1c). In temperature interval 1300-1500 ^{o}C, there is mixture of nanodiamonds with carbon onions, but with small volume fraction of nanodiamonds. Only carbon onions are present after annealing of nanodiamonds at 1500-1600 ^{o}C (Fig.2a). Mixture of carbon onions and graphenes is formed after annealing of nanodiamonds at 2000 ^{o}C (Fig.2a, b).

Transformation of primary nenodiamond particle is depended from its size and position in agglomerate. Small particles (2-4 nm) and particles from surface of agglomerates transform more easily than big nanodiamond particles (6-20 nm) and particles in center of agglomerates. Figure3 shows results of EELS from central and surface parts of agglomerate after annealing at 1000 ^{o}C. One can see that surface area contents more graphite-like materials (sp^2 bonding) than central area of agglomerate.

It is necessary to control temperature of treatment during development of nanodiamond content materials.

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References

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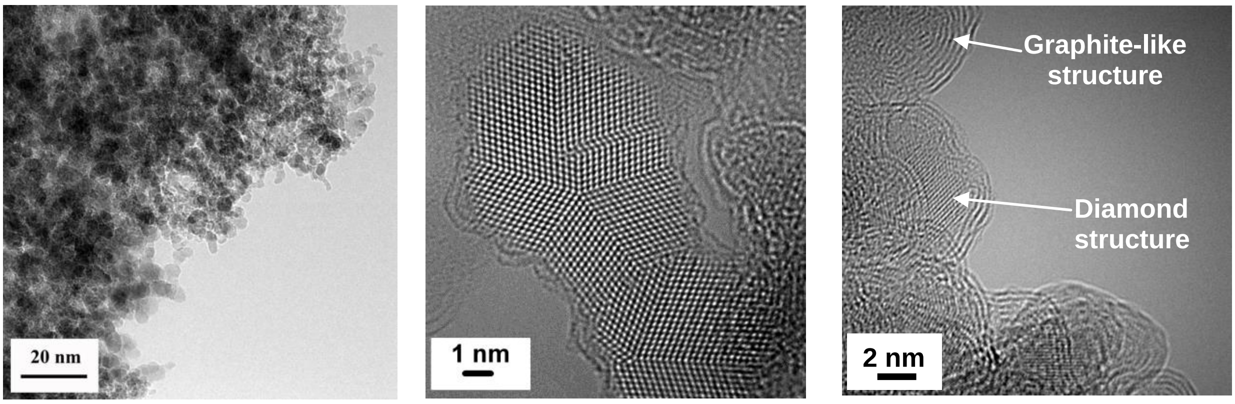
Figures



a b c

Figure 1. Initial nanodiamonds (a, b) and ND after annealing at 1000 ^{o}C (c)

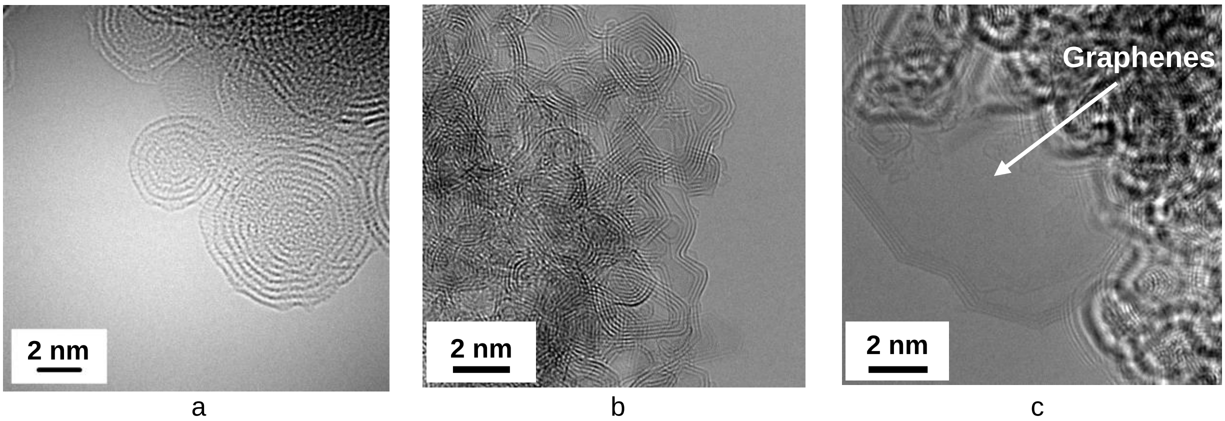


Figure 2. Nanodiamonds after annealing at 1500-2000 °C: carbon onions after annealing at 1500 °C (a); mixture of carbon onions and graphenes (b, c)

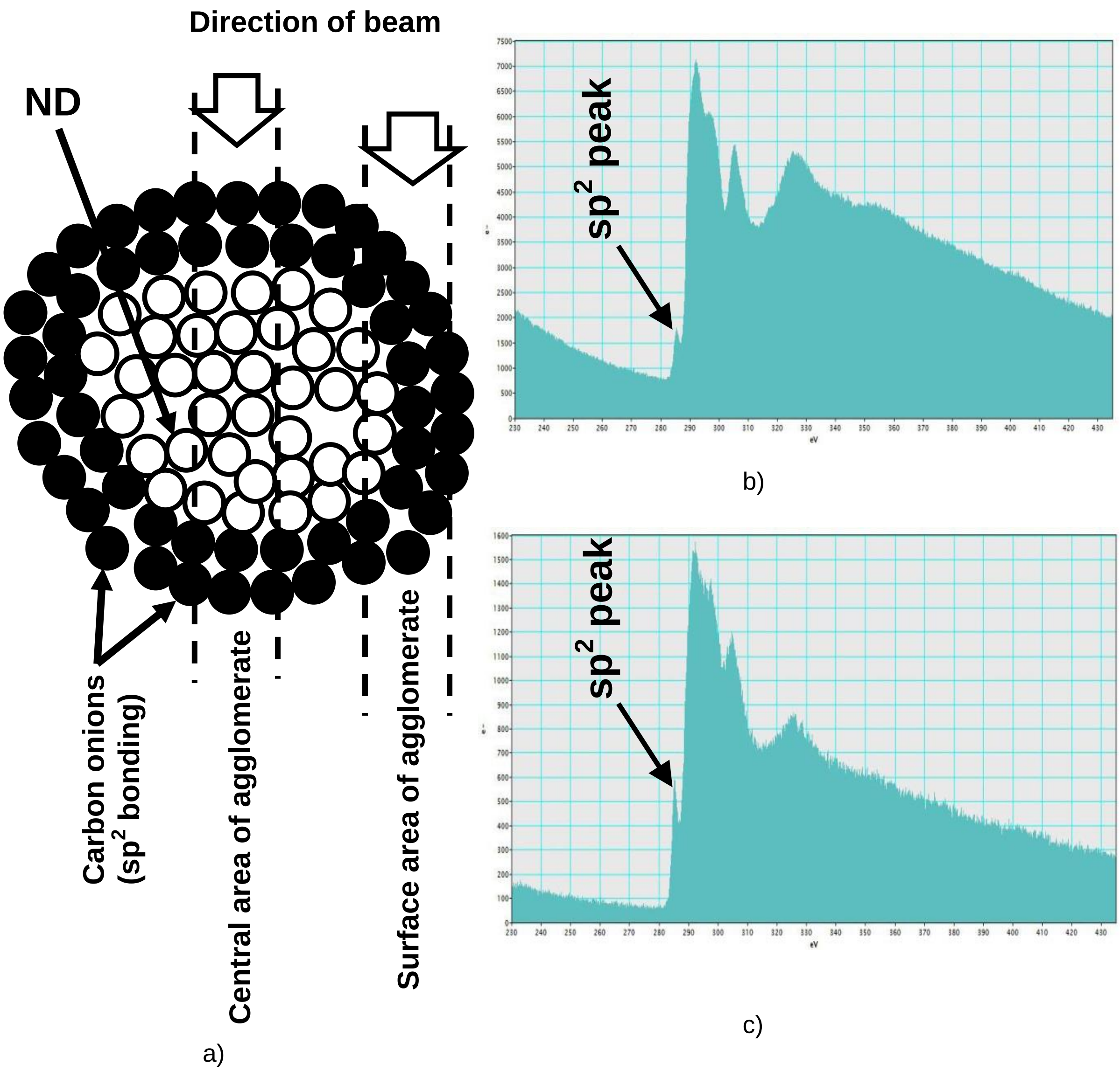


Figure 3. EELS results: a) scheme of agglomerate; b) EELS from central area of agglomerate; c) EELS from surface area of agglomerate.