Synthesis of large diamond crystals for solid-state electronics and diamond electrodes

Nikolay Novikov, Tamara Nachalna, Sergey Ivakhnenko, Oleg Zanevsky, Victor Malogolovets, Gennadiy Podzyrey and Ludmila Romanko

V.Bakul Institute for Superhard Materials of the National Academy of Science of Ukraine
2 Avtozavodskaya Str., Kiev
Kiev 04074
Ukraine

We have studied the synthesis of large (about 7 mm) semiconducting diamond single crystals with predetermined properties to be used as electrodes and working elements of various devices of solid state electronics that operate under extreme conditions.

Diamonds were seed-grown in a toroid-type high-pressure apparatus by the temperature gradient method. An iron-aluminum alloy was used as a solvent for carbon. In each run, the temperature was measured with a Pt-30%Rh/Pt-6%Rh thermocouple accurate to $\pm$ 2 K. The accuracy of the pressure measurements was $\pm$ 0.1 GPa. The growth of diamond single crystals was initiated by the octahedron or cube faces of the seed with an edge of 0.5-0.8 mm. The highest value of the axial temperature gradient was 20 K/mm and the values of the radial temperature gradient did not exceed 0.3 K/mm. Diamond single crystals were boron-doped by the addition of hexagonal boron nitride to the growth medium. The growth cell design allowed one to produce 5–5.5 carats of diamond in one growth cycle.

Based on the results of the comprehensive studies of the grown crystals using EPR, IR spectroscopy, cathodoluminescence, SEM and electrophysical measurements, we have established a link between the synthesis parameters and the crystal electrical and thermal conductivity, morphological peculiarities, the amount of majority electrically active impurities and their distribution over the bulk of the crystals. This has allowed us to synthesize crystals with the high thermal conductivity ranging from 1600 to 2000 W/m.K and the resistivity from 10 to 107 Wcm, the concentration of uncompensated acceptors being from 2x1017 to 1.5x1018 cm-3 as well as to define the best conditions for the synthesis of large semiconducting diamond crystals having a uniform distribution of the boron impurity over the individual growth pyramids. The crystal fragments that correspond to the <100> and <111> growth pyramids are characterized by the higher uniformity of physical properties and can be efficiently used both in electronic devices that operate under the extreme conditions and as diamond electrodes.

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