High purity diamond single crystals and their possible applications in hi-tech areas

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During the past decade, the technologies of perfect diamond single crystals, including semiconductor ones, have been developing rapidly. However, despite the 50ct and above success rate in the single crystal growth processes, the prospects of diamond single crystals application in modern electronics and other high-tech areas remain undiscovered. There are the following main methods for obtaining diamond crystals: growth at high pressures and temperatures (HPHT) and gas-phase synthesis (CVD). Both methods have a number of advantages and disadvantages. In HPHT processes, it is possible to obtain structurally perfect crystals, but the diamond size is limited by the dimensions of the high-pressure cell. In the case of CVD, the growth volume can be much larger, and it is easier to apply doping in the synthesis of semiconductor crystals, but still, it is not yet possible to produce dislocation-free diamonds.

Currently, there are several main hi-tech directions where we can anticipate successful use of diamonds.This is primarily passive electronics: diamond heat sinks. This is associated with a sharp decrease in the cost of the diamond itself, an increase in its size and in its thermal conductivity.On the other hand, we can now establish some new directions that have emerged on the basis of the successes in the perfect diamond single crystals synthesis:

- X-ray optics, including the creation of X-ray lasers on free electrons
- Extreme electronics, Schottky diodes and a β-decay diamond battery; sensors of nuclear radiation, high-temperature sensors
- acoustoelectronics, including resonators with a frequency of up to 40GHz
- quantum crystals, quantum computers, controlled formation of NV and other centers in diamond
- single-crystal diamond tools, including those combined with laser radiation, as well as for application in micro- and nanoscale

The research carried out at FSBI TISNCM in these and other fields showed high potential for the use of perfect diamonds. Thus, in 2012 a free-electron X-ray laser using diamond optics was launched in the US for the first time in the world; later beam dividers, high-resolution spectrometers, focusing lenses and other devices were created thereupon.In 2017, a β-decay diamond battery was tested, and an output power of 50μWt/cm^3 was obtained.In 2014, p-type diamond single crystals were synthesized, and their crystallization and electronic structures were studied showing that their physical properties are due to the formation of B-C layers.These and a number of other experimental results open up new horizons for using high-purity diamond single crystals, including semiconductor crystals, in the hi-tech industry comprising electronics, nuclear and medical equipment.

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