Growth of high-quality large diamond crystals under high pressure and high temperature

Sumiya H., Toda N.
Electronics & Materials R&D Laboratories, Sumitomo Electric Industries, Ltd.: 1-1-1, Koyakita, Itami, Hyogo, 664-0016, Japan

The temperature gradient growth method under HP/HT is an excellent technique to grow high-quality large diamond crystals. In 1985, we developed a mass-production process based on the temperature-gradient method which enabled the commercialization of type Ib diamond (containing dispersed nitrogen impurities) of about 1-2 ct. Later, in 1990, we made it possible to produce larger crystals weighing 9 ct (12 mm across). However, it had been impossible for a long time to produce high purity type IIa diamond (free from chemical impurities) commercially because of the crucial problem of inclusions. To avoid inclusions in growing type IIa diamond crystals, growth rates had to be kept very slow (1mg/hr or less).

During the past decade, we developed the following method to reduce the impurities and to remove inclusions in synthetic diamond crystal [1]. The concentration of chemical impurities in synthetic diamond crystal (N, B, Ni) can be reduced to levels lower than 0.1 ppm by adding an element from group IVa to the solvent, using a high-purity carbon source, and employing an Fe-Co solvent. Also, the incorporation of an element of group Ib into the solvent permits a substantial decrease of inclusions in the diamond crystals and, consequently, high-quality type IIa diamond crystals of 1-2 ct with few inclusions can be obtained even at a growth rate as high as 2-3 mg/hr. Recently we have successfully grown large high-quality type IIa diamond crystals up to 8 ct (10 mm across) at a high rate of 6-7 mg/hr owing to a more suitable selection of the solvent metal and reoptimization of the growth conditions [2].

These synthetic type IIa diamonds show no absorptions due to impurities in wide-ranging wavelengths. The diamonds have fewer crystal defects, less internal strain than natural diamonds or synthetic type Ib diamonds [3]. The crystalline quality is found to be further improved by using a strain-free, low-defect seed crystal [3]. The high-purity and high-crystalline-quality improve the mechanical and thermal properties of the diamond [4, 5]. These salient characteristics of the synthetic type IIa diamond permit application to a considerably wide range of industrial and scientific uses [6]. The most distinctive application of the high-quality large diamond is as a monochromator crystal for a synchrotron X-ray radiation beam. The high crystalline quality and the excellent thermal properties make it possible to be used in monochromators of high power synchrotron radiation beams.

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References

[1] H. Sumiya, S. Satoh, Diamond Rel. Mater. **5**, 1359, (1996)
[2] H. Sumiya, N. Toda, S. Satoh, J. Crystal Growth, **237-239**, 1281 (2002)
[3] H. Sumiya, N. Toda, Y. Nishibayashi, S. Satoh, J. Crystal Growth **178**, 485 (1997)
[4] H. Sumiya, N. Toda, S. Satoh, Diamond Rel. Mater. **6**, 1841, (1997)
[5] Y. Yamamoto, T. Imai, K. Tanabe, T. Tsuno, Y. Kumazawa, N. Fujimori, Diamond Rel. Mater., **6**, 1057 (1997)
[6] H. Sumiya, S. Satoh, S. Yazu, Rev. High Pressure Sci. Technol. **7**, 960, (1998)