“Kamchatite” diamond aggregate from northern Kamchatka, Russia: New find of diamond formed by gas phase condensation or chemical vapor deposition—Discussion

Konstantin D. Litasov1,*, Tatyana B. Bekker2, and Hiroyuki Kagi3

1Institute for High Pressure Physics, Troitsk, Moscow, Russia
2Department of Geology and Geophysics, Novosibirsk State University, Novosibirsk, Russia
3Geochemical Research Center, University of Tokyo, Tokyo, Japan

Introduction

Kaminsky et al. (2019) described enigmatic polycrystalline diamond from the placers on Aynyn River at Kamchatka peninsula and named them “kamchatite.” The samples were picked up from the mineral separates in the alluvial deposits. They are up to 1 mm in size and have a rounded shape. Octahedral and irregular diamond crystallites (2–40 μm in size) occupy about 50 vol% of the aggregates. The matrix cementing the diamond crystals consists of Ca3(Si2O3)(CO3), tilleyite, SiC, Fe-Ni-Mn-Cr silicides, native silicon, graphite, calcite, and some amorphous material. Three types of composition of the amorphous materials can be recognized from transmission electron microscopy observations: tilleyite-like material, carbon, and SiO2. Another related finding of porous carbonado-like diamond was reported earlier for Avacha volcano (Gorshkov et al. 1995; Kaminsky et al. 2016). In this case, diamond crystallites have a size of 1–10 μm and contain minor interstitial materials represented by Mn-Ni-Si-Fe alloys, native Mn, WC, B4C, SiO2 (amorphous and tridymite); native Si and SiC. The authors suggested the natural origin of these diamonds during volcanic eruptions via a gas phase condensation with the possible participation of strongly reduced CH3H2 fluid during their formation (Kaminsky et al. 2019). The process can be similar to carbon vapor deposition (CVD) synthesis of diamonds. Recently we have found very strong evidence for the artificial origin of type Ib diamonds crystals (up to 0.7 mm in size) found in the volcanic rocks of Tolbachik volcano and peridotites and chromitites worldwide (Litasov et al. 2019b, 2019c; Pokhilenko et al. 2019). In Tolbachik, diamonds were found in the ash-like crusts and scabs on the solidified lava flow. They contain Mn-Ni metallic inclusions (with impurities of Fe, Cr, Ti, and Si), which generally resemble the chemical composition of the standard Mn30Ni50 catalyst for the diamond synthesis in Russia. Most diamonds from Tibet, Ural, Turkey, and Albania ophiolites contain metallic Ni-Mn-Co inclusions, which resembles standard Ni30Mn30Co3 catalyst for the diamond synthesis in China. Although there is an ongoing discussion on the subject (Yang et al. 2020; Litasov et al. 2020), our point of view remains unchanged and is supported by the mentioned similarities with the industrial catalysts.

Discussion

Diamond aggregate morphology and crystallite size

There is a possibility for the growth of natural nanocrystalline diamonds at relatively low P-T conditions or even at nearly atmospheric pressures (see Simakov 2018 for review). However, in this case, the size of diamond crystallites hardly exceeds 10 nm. In contrast, diamond crystallites in aggregates described by Kaminsky et al. (2019) have relatively large size up to 40 μm. This size of diamonds has never been observed in short-duration processes, such as the meteorite impact and very unlikely for natural CVD process because it requires very careful control of synthesis conditions.

Instead, the morphology of the aggregates is consistent with synthetic diamond-based materials for drilling tools. The closest analogs are polycrystalline diamond compacts (hereafter, PDC) (Lee et al. 1979; Hall 1986; Ringwood 1991) and carbonado-like diamond (Vereshchagin et al. 1969; Hall 1970), which are prepared by sintering of diamond powder at high P-T conditions (see below).

Mn-Ni silicide inclusions

Mn-Ni-Fe relations in silicides (Kaminsky et al. 2019) are close to elemental ratios in Tolbachik type Ib diamonds (Litasov et al. 2019c). They closely correspond to catalyst compositions for the growth of synthetic diamonds ranging from Mn30Ni30Fe10 to Mn30Ni50Fe40, although it may be deviated by metal melt fractionation during synthesis. For example, for diamond synthesized with the use of standard Mn-Ni catalysts, we can find a full range of metallic inclusions from pure Mn to pure Ni with, however, majority of compositions nearly correspond to that of catalyst (Litasov et al. 2019b). In Kaminsky et al. (2016), most of the metallic inclusions closely resemble Mn40Ni50 composition of PRGN-40 catalyst, which may have minor Fe and Si impurities (e.g., Shipilo et al. 2005). This is one of the important arguments in favor of the synthetic nature of the described diamond aggregates. The reason for the appearance of silicides instead of metallic Mn-Ni-Fe inclusions may be associated with the synthesis of PDC with the addition of Si as a bonding component.

Silicon and carbides

Interstitial microinclusions of Si and SiC are a common feature of diamond-SiC or diamond-SiC-Si PDCs. However, diamond aggregates from Kamchatka contain also WC and B4C (Kaminsky et al. 2016). The presence of these compounds is explained in some Soviet patents for PDC synthesis. During Si metal impregnation into the diamond aggregates an intermediate layer of different carbides, including WC and B4C, was used to increase the wear resistance of the diamond-bearing layer (e.g., Shulzenko et al. 1989). Then, a minor amount of materials from this layer can be observed in the resulting PDC.

* E-mail: litasov@hppi.troitsk.ru