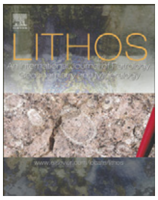
Lithos 113 (2009) 454–464

Contents lists available at ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos



Nanoinclusions in microdiamonds from Neogenic sands of the Ukraine (Samotkan' placer): A TEM study

Victor M. Kvasnytsya [a,*], Richard Wirth [b]

[a] Institute of Geochemistry, Mineralogy and Ore Formation, National Academy of Sciences of Ukraine, Palladin Avenue 34, 03680 Kyiv-142, Ukraine
[b] GeoForschungsZentrum Potsdam, Experimental Geochemistry and Mineral Physics, Telegrafenberg, 14473 Potsdam, Germany

ARTICLE INFO

Article history:
Received 8 October 2008
Accepted 17 May 2009
Available online 18 June 2009

Keywords:
Microdiamond
Mineral inclusions
Fluid inclusions
TEM
Ukrainian shield
Placer

ABSTRACT

Mineral and fluid inclusions in seven microdiamonds (ca. 0.2 mm in diameter) from the Neogene, Samotkan' placer of the Ukrainian shield were investigated by TEM. Various types of submicron- or nanometre-sized inclusions such as olivine and orthopyroxene, Fe,Sn oxide and assemblages of mineral multi-phases were observed.

In an octahedral microdiamond crystal numerous olivine and enstatite micro- and nanocrystals were observed. Their composition is close to that of other olivine and enstatite inclusions found in kimberlitic diamonds worldwide. An unusual feature of these minerals in the samples studied, however, is a relatively high NiO content: 0.50–0.80 wt.% in olivine ($Fo_{91.3–92.1}$) and 0.40–0.70 wt.% in enstatite ($Fo_{94.1–95.4}$). These peridotitic mineral associations represent the host (possibly lherzolitic mantle) in which the diamonds grew. The mean Mg# values of olivine and enstatite inclusions in Samotkan's microdiamond are, respectively, 91.43 and 94.83, which are closer to Mg#-values of these minerals in lherzolite, rather than in harzburgite assemblages (included in diamond). In addition, enstatite–clinoenstatite, K-richterite, graphite, and Fe,Sn oxide were also identified as nanoinclusions in Samotkan' diamond; the Fe,Sn oxides and magnetite were found in two microdiamonds of the transitional {111}+{110} form. The K-richterite and graphite have been attributed to epigenetic inclusions. The origin of Fe,Sn oxide is not clear.

Assemblages of multi-phase, minerals were observed in four microdiamonds of variable morphology: octahedron, transitional {111}+{110} form, cube and cube-coated diamond. These phases belong to fluid-bearing inclusions and are enclosed in cavities which, as a rule, are not filled completely by the solid phases. The remainder of the volume is occupied by a fluid that for the most part has been released during sample preparation. In the majority of cases the multi-phase assemblages consist of carbonate, mica, rutile, ilmenite, apatite and sylvite. Carbonates are the most abundant phases in the fluid inclusions; they are calcium-rich carbonates, frequently with admixtures of Fe, Mg and Sr. The mica inclusions are enriched in silicon, with Si varying from ca. 6.7 to 7.0 a.p.f.u. The multi-phase mineral assemblages present in Samotkan's microdiamond are similar to fluid-bearing, microinclusions found previously in other diamond types (e.g., fibrous diamonds, the fibrous coat of coated diamonds or the internal clouds of octahedral diamonds) from kimberlites of different provinces worldwide. They represent the carbonate-, alkali-, and chlorine-rich mantle fluid composition present during crystallisation of the Samotkan's microdiamond. Judging from the composition of the multi-phase assemblages it may be assumed that the Samotkan's microdiamond grew from a carbonatitic to a slightly silicic melt, rich in alkali and volatile components.

1. Introduction

Inclusions in diamonds provide information about the mantle environment in which they grew, the composition of the fluid from which they formed and *P*–*T* conditions responsible for diamond growth. One can distinguish between primary (proto- and syngenetic) and epigenetic mineral inclusions, and primary multi-phase or fluid inclusions.

Primary and epigenetic mineral inclusions in kimberlitic- and lamproitic-hosted diamond from almost all diamond-bearing provinces of the world have been the subject of extensive study. Most frequently, the primary mineral inclusions are silicates such as garnet, olivine, and pyroxene, oxides (e.g., chromites) and sulphides (Sobolev, 1974; Meyer, 1987; Harris, 1992). The size of these crystalline inclusions varies over a wide range; from tens of nanometers up to a millimeter. These can indicate both mantle paragenesis (peridotitic or eclogitic) and also *P*–*T* parameters of diamond crystallisation. For example, the primary mineral inclusions in so-called "super-deep" diamonds such as ferropericlase in association with Mg, Si-and Ca,Si-"perovskite", majoritic garnet, which have allowed estimates to be made of the depth of diamond crystallisation (lower mantle) (e.g., Harris et al., 1997; Davies et al., 1999; Stachel et al., 2000; Kaminsky

---

* Corresponding author.
E-mail address: kvasnytsya@ukr.net (V.M. Kvasnytsya).

0024-4937/$ – see front matter © 2009 Published by Elsevier B.V.
doi:10.1016/j.lithos.2009.05.019

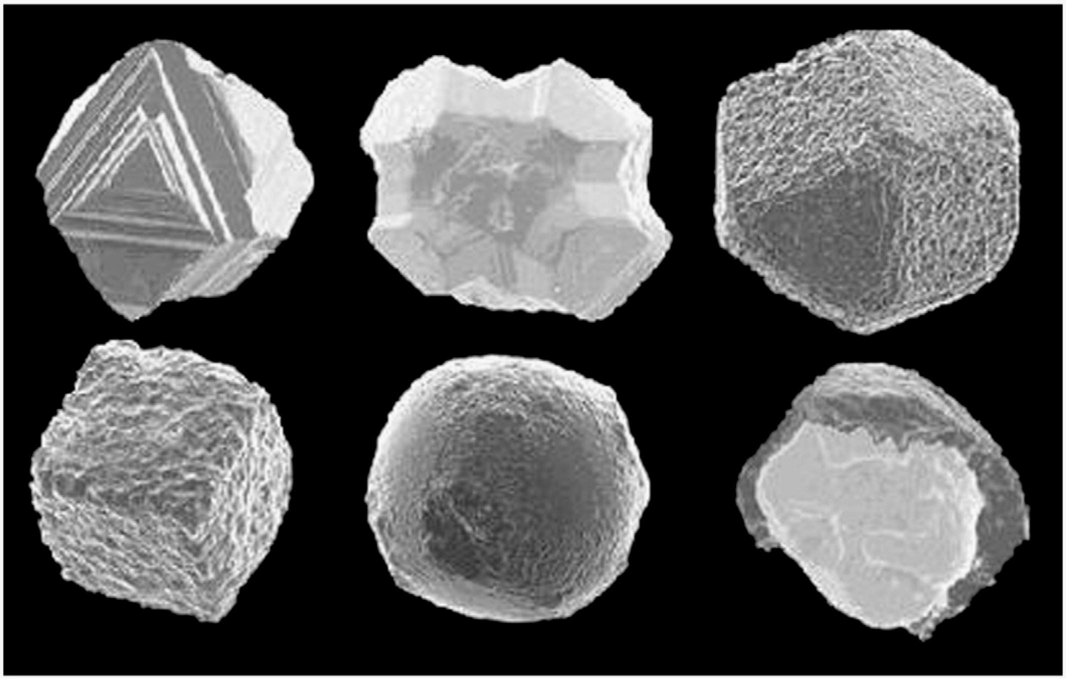


Fig. 1. Typical morphologies of microdiamond from the Samotkan' placer. Upper row, from left to right: octahedron, transitional {111}+{110} form, cube–octahedron; the lower row — cube, cuboid, coated diamond (octahedron–cube combination).

et al., 2000; Kaminsky et al., 2001; Brenker et al., 2002; Hayman et al., 2005).

In contrast, there are much less data available that pertains to fluid inclusions of kimberlitic or lamproitic diamonds. Such inclusions have been observed and described in fibrous diamonds (most frequently these are cubes), in the fibrous coat of coated diamonds, and in internal 'clouds' of octahedral diamonds, in kimberlites from different regions of the world (e.g., Navon et al., 1988, 2003; Guthrie et al., 1991; Navon, 1991; Schrauder and Navon 1994; Izraeli et al., 2001, 2004; Klein-BenDavid et al., 2003, 2007; Zedgenizov et al., 2004; Tomlinson et al., 2006; Logvinova et al., 2008). The fluid inclusions are assemblages of different multi-phase minerals (0.1–0.5 µm in size) which infill cavities within the diamond crystals, together with various fluid components. Among these are several important inclusion-types, such as 'carbonatitic', namely those rich in carbonate minerals and that contain Mg, Ca, Fe, K and Na, 'hydrous-silicic', that are rich in water, Si, Al and K, and 'hydrous-saline' species, rich in Cl, K and Na (e.g., Schrauder and Navon, 1994; Izraeli et al., 2001; Klein-BenDavid et al., 2004, 2006). Frequently, such multi-component systems are included in diamond as carbonate–silicate melts, usually in association with alkaline-chloride components. It is believed that diamond captures during growth supercritical fluids of the above mentioned compositions (silicate or carbonatite melt or hydrous-saline fluids), which, depending on its composition, crystallises upon cooling as 'multi-phases'. A variety of carbonate minerals, phlogopite–biotite, high Si mica, high-Mg silicate, kyanite, ilmenite, magnetite, K, Fe-sulphides, apatite, halides, and quartz constitute the bulk of minerals in such fluid-bearing inclusions.

Distinct from kimberlitic- or lamproitic diamonds (see above) are the fluid (nano)inclusions of metamorphic microdiamonds. Here the most abundant mineral phases within the fluid inclusions are oxide- and, to a lesser extent, silicate- and carbonate minerals (e.g.,Sobolev and Shatsky, 1990; De Corte et al., 1998; Dobrzhinetskaya et al., 2003, 2005, 2006; Hwang et al., 2005).

In this study we focus on nine microdiamonds from the Neogene Samontkan' placer of the Ukrainian Shield. The diamonds have an uncertain origin and their genesis, with respect to their micro- and nanoinclusion suite, has been investigated with the aid of transmission electron microscopy (TEM).

2. Geology and description of the Samotkan' microdiamonds

The Neogene, "Samotkan" titanium–zirconium placer deposit is located within the Pre-Dnipro block of the Ukrainian Shield. This is a typical granite–greenstone block, across which Archaean granitoid cupolas and greenstone belts are broadly developed; Proterozoic rocks and their derivatives, as well as Phanerozoic volcanic or magmatic

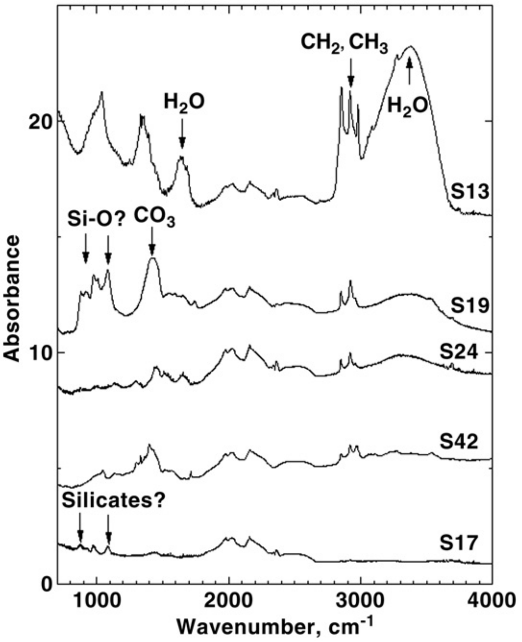


Fig. 2. Characteristic FTIR-spectra of five Samotkan' microdiamonds. Nitrogen-free diamonds were selected, showing absorption bands for water, carbonates and silicates.