

ダイヤモンドの起源を顕微赤外分光分析と希ガス質量分析で探る Comprehensive studies to reveal the origin of diamonds using micro-FT-IR spectroscopy and noble gas mass spectrometry

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Chemical and isotopic compositions of volatile species in diamonds have a potential to constrain the origin of the host diamonds. Among them, noble gas isotopes can provide unique insights because they show different values between the more primordial plume source, which is possibly stored in the deep mantle, and the depleted MORB source in the convecting mantle. On the other hand, noble gases must be extracted by crushing or heating the samples, resulting in complete destruction of the sample which makes further investigation using other analytical methods impossible. Here we present comprehensive studies on various types of diamonds using non-destructive micro-spectroscopic methods and following noble gas isotope analysis to extract as much information as possible from a single diamond crystal.

Cubic diamonds from the Udachnaya kimberlite pipe, Siberia with abundant micro-inclusions [1] were investigated to clarify their origin and genetic relation to the host kimberlite. According to the distribution of inclusions traced by carbonates observable with FT-IR mapping, the samples were cut into several pieces and noble gases in each of them were extracted using in vacuo stepwise heating or crushing. The crush-released He exhibited $^3\text{He}/^4\text{He}$ of 4-7 R_A , indicating that the inclusion-hosted He has similar $^3\text{He}/^4\text{He}$ to that of the host kimberlite magma (6 R_A , [2]). A correlation between CO_3^{2-} and ^3He contents suggests that mantle-derived noble gases are trapped in the carbonate-rich inclusions. In contrast, predominant release of radiogenic ^4He by the heating indicates that diamond-lattice-hosted He is dominated by radiogenic ^4He produced in situ from trace amounts of U and Th after the diamond formation. The crush-released inclusion-hosted Ne isotope ratios obtained by the crushing several diamond stones together, which exhibits similar volatile compositions each other based on FT-IR investigation, showed a striking similarity to that of the host kimberlite magma, indicating they have the common origin. Since their source He-Ne isotopes are explainable by a mixing between a plume-like and a radiogenic/nucleogenic components [2], the diamond-forming fluids and incipient carbonatitic fluids/melts of the kimberlite magma may originate from SCLM peridotite previously metasomatized by a plume, or HIMU plume involving recycled material.

The primary source of alluvial diamonds from a placer deposit in the northeastern Siberian Platform has not been well constrained (e.g., [3]). Because secondary minerals might have formed in abundant cracks in the diamonds, micro FT-IR analysis was applied before and after each heating step of noble gas extraction up to 1100 deg. C, to trace possible decomposition of secondary minerals. Subsequently the samples were crushed in vacuum to extract noble gases from inclusions enclosed in the host diamond. Neither change in FT-IR spectra nor noble gas release was significantly observed during the heating, indicating negligible contribution of secondary noble gases adsorbed and/or trapped in the cracks. While carbonate-rich diamonds showed He and Ne isotope ratios similar to MORB, significant radiogenic/nucleogenic contribution were observed in carbonate-poor samples, suggesting that the latter formed in a subducted slab. Although crustal noble gases in polycrystalline diamonds have been reported (e.g., [4]), it has not been well clarified whether such noble gases are hosted by the diamonds or secondary minerals. Our observation using FT-IR spectroscopy and noble gas mass spectrometry revealed that the crustal noble gas feature is intrinsic to some of the Siberian alluvial diamonds and that the origin of unknown source diamonds can be constrained by their primary noble gas signatures.

[1] Zedgenizov et al. (2004) Mineral. Mag. 68, 61. [2] Sumino et al. (2006) GRL 33, L16318. [3] Ragozin et al. (2009) Dokl. Earth Sci., 425A, 436. [4] Honda et al. (2004) Chem. Geol. 203, 347.

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