Diamond formation through intermediate sp2 carbon from fluid in dolomite marble during the Kokchetav UHP metamorphism

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Graphitic carbon inclusions were discovered inside microdiamond grains in dolomite marble from the Kokchetav Massif. The discovered inclusions are sp2 carbon species and are probably relics of an intermediate metastable phase for diamond formation from H2O-rich fluid during UHP metamorphism; on our previous studies on diamond and graphite, these carbon species are not metamorphic graphite relics, not graphite changed from diamond, and not graphite crystallized from H2O-rich fluid at later stage.

We examined over 5,000 diamond grains in 40 thin sections of dolomite marbles under a transmission optical microscope. Five sp2 carbon inclusions have been discovered in five diamond grains. These host diamond grains are 4-15 µm in diameter. These graphitic carbon inclusions are black under a microscope and their sizes are 1-5 µm across.

The microdiamond in dolomite marble has been classified into S-type, T-type, and R-type grains on the basis of the morphologies [1], Raman spectra [1], cathodoluminescence spectra [2], and carbon isotopic compositions [3]. R-type and the core of S-type formed at 1st stage, and T-type and the rim of S-type crystallized at 2nd stage from H2O-rich fluid. All sp2 carbon inclusions were found only in the rim of S-type (one grain) and T-type (four grains).

Using multilayered 2D Raman mappings at different focal depths with solid-state laser (487.9 nm), Ar+ laser (514.5 nm), and He-Ne laser (632.8 nm), the Raman spectra of the examined graphitic carbon inclusions show a peak at ca. 1580 cm−1 (assigned to G-band caused by sp2 bond of carbon), and these sp2 carbon inclusions are completely included inside the host diamond grains. The G-bands of peak position with FWHM for the sp2 carbon inclusions are as follows: (the rim of S-type) 1572.0 cm−1 with 17.8 cm−1, 1581.3 cm−1 with 17.7 cm−1, and 1576.5 cm−1 with 16.5 cm−1; (T-type) 1574.9-1584.0 cm−1 with 18.0-28.3 cm−1, 1580.3-1587.1 cm−1 with 17.3-41.9 cm−1, and 1581.5-1584.2 cm−1 with 17.7-31.0 cm−1. The relative peak intensities of G-band to the host diamond band (ca. 1332 cm−1) are less than 10 %, and the strongest G-band peaks were detected at the center of the host diamond grains. The spectra of the inclusions often show disordered graphite bands; D1-band (ca. 1360 cm−1) and D2-band (ca. 1620 cm−1), but these bands are usually weak rather than G-band.

The discovered sp2 carbon inclusions were formed at the 2nd stage of the diamond formation, and could be relics of an intermediate metastable phase precipitated from H2O-rich fluid and followed by the transformation to diamond. This interpretation is consistent with the previous studies of diamond synthesis using C-O-H fluid at diamond stability fields (e.g. [4]).

References

Keywords: microdiamond, sp2 carbon inclusion, diamond formation, intermediate metastable phase, H2O-rich fluid, Kokchetav UHP metamorphism