Natural silicon carbide from kimberlites: polytypes, trace elements, inclusions and speculations on its origin

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The origin of natural SiC (moissanite) found in carbonates, granitoids, kimberlites and other oxidised rocks is poorly understood, and it has often been assumed that the SiC is introduced during processing. However, in many cases contamination with synthetic SiC is implausible; it is clear that natural SiC (moissanite) does exist, but at present there is no consistent model for its formation. An extensive collection of moissanite grains from the Mir, Aikhal and Udachnaya kimberlite pipes, Yakutia, has been characterized in terms of structural perfection, defects, inclusions, and major- and trace-element chemistry and compared with synthetic SiC produced by various methods (Acheson, Lely).

Most natural SiC grains are 6H and 15R polytypes; some are 4H, 8H and 21R. No 3C grains were observed. Some grains (<10%) show extremely complex Raman spectra indicating strongly disordered structures, e.g., long-period polytypes. The shape of the LO band in the Raman spectra suggests the presence of significant amounts of non-compensated impurities. The spectra of some grains show vibrations related to OH groups or H in the SiC lattice. On average, the 15R grains are more enriched in impurities than the 6H grains. Cathodoluminescence maps and in-situ isotopic measurements indicate the existence of growth-related zoning on ~10-micron scale. Surprisingly, the density of dislocations and stacking faults is very low.

Our work has revealed considerable similarity between the geochemical properties (abundances of major and trace elements) of moissanites from geologically contrasting environments and stark differences with synthetic SiC. Trace-element chemistry provides a reliable method for distinguishing natural SiC from synthetics. Moissanite is virtually stoichiometric SiC with low O contents (0.1-0.3 wt%). Concentrations of some impurities (Al, B, Ti, V, Sc) are similar in natural and synthetic samples. However, the composition of natural SiC is much richer, due to the different degrees of perfection and amount/type of inclusions in natural and synthetic crystals. Inclusions are heterogeneously distributed in the host SiC and their size varies from few nanometers to hundreds of microns. They typically have rounded to negative-crystal shapes suggesting trapping of melt phases. Silicon is the most abundant inclusion phase. Less abundant are iron silicides ($FeSi_2$, $FeSi_3$) and not fully identified Si(C,O) phase(s) which could be silicon oxycarbide(s). Most chemical impurities are concentrated in the $FeSi_2$ and Si(C,O) phases. Trace-element patterns of $FeSi_2$ from different kimberlites are generally similar but also show locality-specific differences. The $FeSi_2$ is strongly enriched in LREE/HREE; extreme negative anomalies in Eu and Sm are consistent with highly reducing conditions. The overall pattern is similar to those of fibrous diamonds, suggesting formation from similar fluids. Textural and chemical features, the residual pressure on Si inclusions, and intergrowth with oxidation products (Si(C,O) phases and SiO_2) suggest that moissanite grew at high temperatures and elevated pressures and was subsequently partly oxidised, also at high T.