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A spectroscopic and carbon-isotope study of mixed-habit diamonds: Impurity characteristics and growth environment

Daniel Howell,[1,*] William L. Griffin,[1] Sandra Piazolo,[1] Jana M. Say,[2] Richard A. Stern,[3] Thomas Stachel,[3] Lutz Nasdala,[4] James R. Rabeau,[2] Norman J. Pearson,[1] and Suzanne Y. O'Reilly[1]

[1]ARC Center of Excellence for Core to Crust Fluid Systems (CCFS) and GEMOC, Department of Earth & Planetary Science, Macquarie University, New South Wales 2109, Australia

[2]ARC Center of Excellence for Engineered Quantum Systems (EQUS), Department of Physics and Astronomy, Macquarie University, New South Wales 2109, Australia

[3]Canadian Center for Isotopic Microanalysis, Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta T6G 2E3, Canada

[4]Institut für Mineralogie und Kristallographie, Universität Wien, Althanstrasse 14, 1090 Vienna, Austria

Abstract

Mixed-habit diamonds have experienced periods of growth where they were bounded by two surface forms at the same time. Such diamonds are relatively rare and therefore under-investigated. Under certain physical and chemical conditions, smooth octahedral faces grow concurrently with rough, hummocky cuboid faces. However, the specific conditions that cause this type of growth are unknown. Here we present a large array of spectroscopic data in an attempt to investigate the impurity and carbon-isotope characteristics, as well as growth conditions, of 13 large (>6 mm diameter) plates cut from mixed-habit diamonds. The diamonds all generally have high nitrogen concentrations (>1400 ppm), with the octahedral sectors enriched by 127–143% compared to their contemporary cuboid sectors. Levels of nitrogen aggregation are generally low (2–23% IaB) with no significant difference between sectors. IR-active hydrogen features are predominantly found in the cuboid sectors with only very small bands in the octahedral sectors. Platelet characteristics are variable; only one sample shows a large B′ band intensity in the octahedral sector, with no platelets occurring in the cuboid sector. Other samples either show a small B′ band in both sectors, or just in the cuboid sector, or none at all. These data support a model that shows the concentration-adjusted aggregation rate of nitrogen to be the same in both sectors, whereas the subsequent platelet development is reduced in the cuboid sectors. This is because the interstitial carbon atoms have interacted with *disk-crack-like* defects only found in cuboid sectors, which in turn reduces their chances of aggregating to form platelets. These *disk-crack-like* defects are also thought to be the most likely site for the IR-active hydrogen features and they maybe intrinsic to cuboid growth in mixed-habit diamonds. When they are graphitized, as they are in all of the diamonds in this study, this may reflect a heating event prior to volcanic exhumation. Spectroscopic analysis of the green cathodoluminescence exhibited by all of the diamonds shows nickel centers to be present in only the cuboid sectors. Carbon isotope data, obtained by secondary ion mass spectrometry, show very little variation in seven of the diamonds. The total range of 217 analyses is –7.94 to –9.61 (±0.15)‰, and the largest variation in a single stone is 0.98‰. No fractionation in carbon isotopes is seen between octahedral and cuboid sectors at the same growth horizon. These data suggest that the source fluid chemistry, as well as pressure, temperature, and oxygen fugacity were very stable over time, allowing such large volumes of mixed-habit growth to occur. The high concentration of impurities, namely nitrogen and hydrogen, is probably the critical factor required to cause mixed-habit growth. The impurity and isotopic data fall in line with previous modeling based on diamond growth from reduced carbonates with the loss of a ^{13}C-enriched CO_2 component.

Keywords: Mixed-habit diamonds, FTIR mapping, nitrogen concentration and aggregation states, carbon isotopes, nickel defects