Geochemistry of Diamonds

with Large-Geometry SIMS

Elemental and isotopic signature of diamonds

Natural diamonds crystallize only at high pressures and temperatures, conditions that occur in the upper mantle, at depths exceeding ~150 km and temperatures above 950°C. Nitrogen being the main chemical impurity in diamonds, with concentrations ranging from 0 to 5000 ppm, N-isotopes are a key geochemical tool due to the striking differences of $\delta^{15}N$ between external reservoirs and the mantle. The study of diamonds and their impurities not only provides important insights into the conditions prevailing in the very deep mantle, but also helps us to understand the evolution of our planet.

Large-Geometry Secondary Ion Mass Spectrometry (LG-SIMS) is the technique of choice for in situ characterization of diamond crystals and their inclusions. It provides fine-scale isotopic and elemental data that yields information about the crystallization history of individual diamonds and the evolution of fluids during crystal growth. In the present examples, stable isotope and chemical analysis of diamond were performed at a microscopic scale for investigating intracrystalline variations in C- and N-isotope ratios and N-abundances.

Providing essential data on N isotope fractionation

In spite of major advances, the remaining questions about diamond formation remain profound and complex. For instance, significant gaps exist in our understating of the magnitude of N-isotope fractionation between diamond and its parental fluid. In a recent study shown in Figure 1, detailed isotopic (C- and N-isotope) and chemical (N-abundance) data collected by multi-collector LG-SIMS provided fundamental information on isotopic fractionation factors that are critical to data modelling.

Measuring low signal intensities with high precision

In Figure 2, the nitrogen content [N] and isotopic composition $\delta^{15}N$ were measured in a LG-SIMS ion microprobe equipped with low noise Faraday Cup (FC) detectors. Because the N content varies significantly in diamonds, the corresponding signal count rate ($^{12}C^{14}N^-$) can vary by orders of magnitude. Such a range of signal intensities is appropriate for measurement on a FC detector with a low noise 10^{12} Ω resistor preamplifier board (~ 5 x 10^7 c/s down to ~ 10^5 c/s range). This detector offers high precision with no need for gain monitoring.-

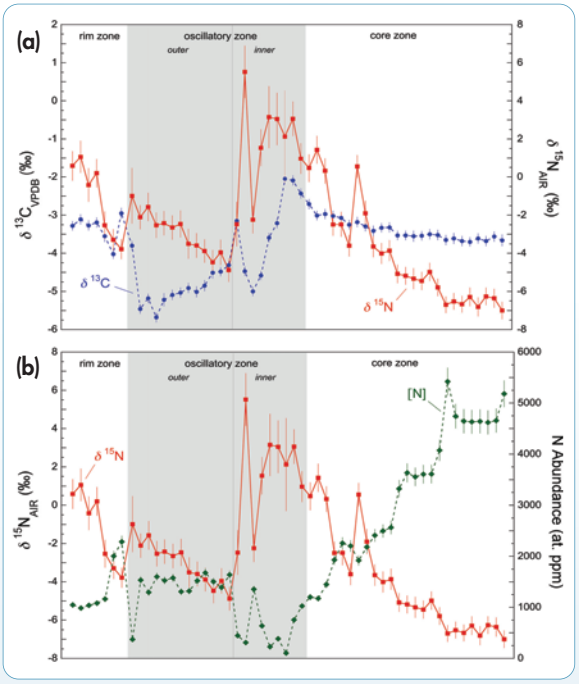


Figure 1: C- and N-isotope, and N-abundance profiles across the four growth phases of a complexly-zoned, eclogitic diamond (JDE-25). (a) profiles for $\delta^{13}C$ and $\delta^{15}N$. (b) profiles for $\delta^{15}N$ and [N]. Data collected on IMS 1280 at CCIM, Univ. of Alberta (Canada). From D.C. Petts et al., Chemical Geology 410, 188 (2015).

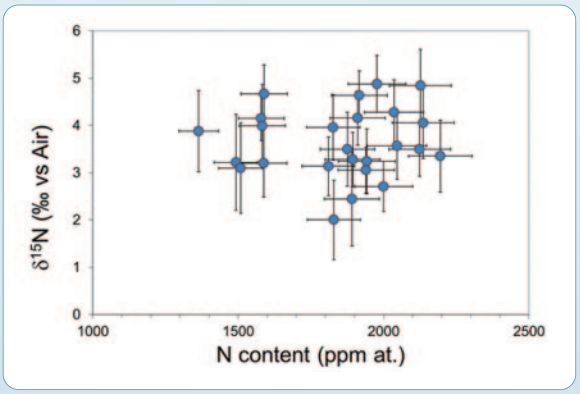
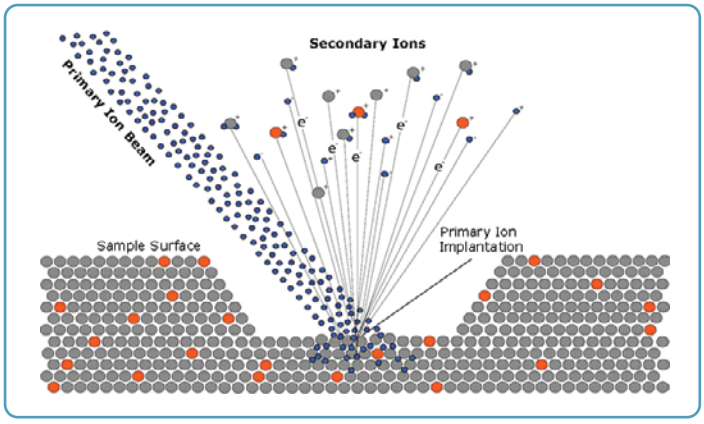


Figure 2: N-isotope and N-abundance preliminary data obtained on six plates of natural diamonds (total of 25 spots) using a dynamic multi-collection recipe: $^{12}C^{13}C^-$ and $^{12}C^{14}N^-$ were measured in parallel mode on FC 10^{11} Ω and FC 10^{12} Ω detectors respectively, then $^{12}C^{15}N^-$ was measured on an Electron Multiplier. High mass resolution conditions (~ 9,200) were used to separate $^{12}C^{14}N^-$ from $^{13}C_2^-$. An external reproducibility (1SD) of 230 ppm for [N] and 0.74‰ for $\delta^{15}N$ was obtained Data collected on IMS 1280-HR at CRPG Nancy (France). Courtesy of E. Thomassot, CRPG Nancy..

The Technique Behind



Dynamic SIMS

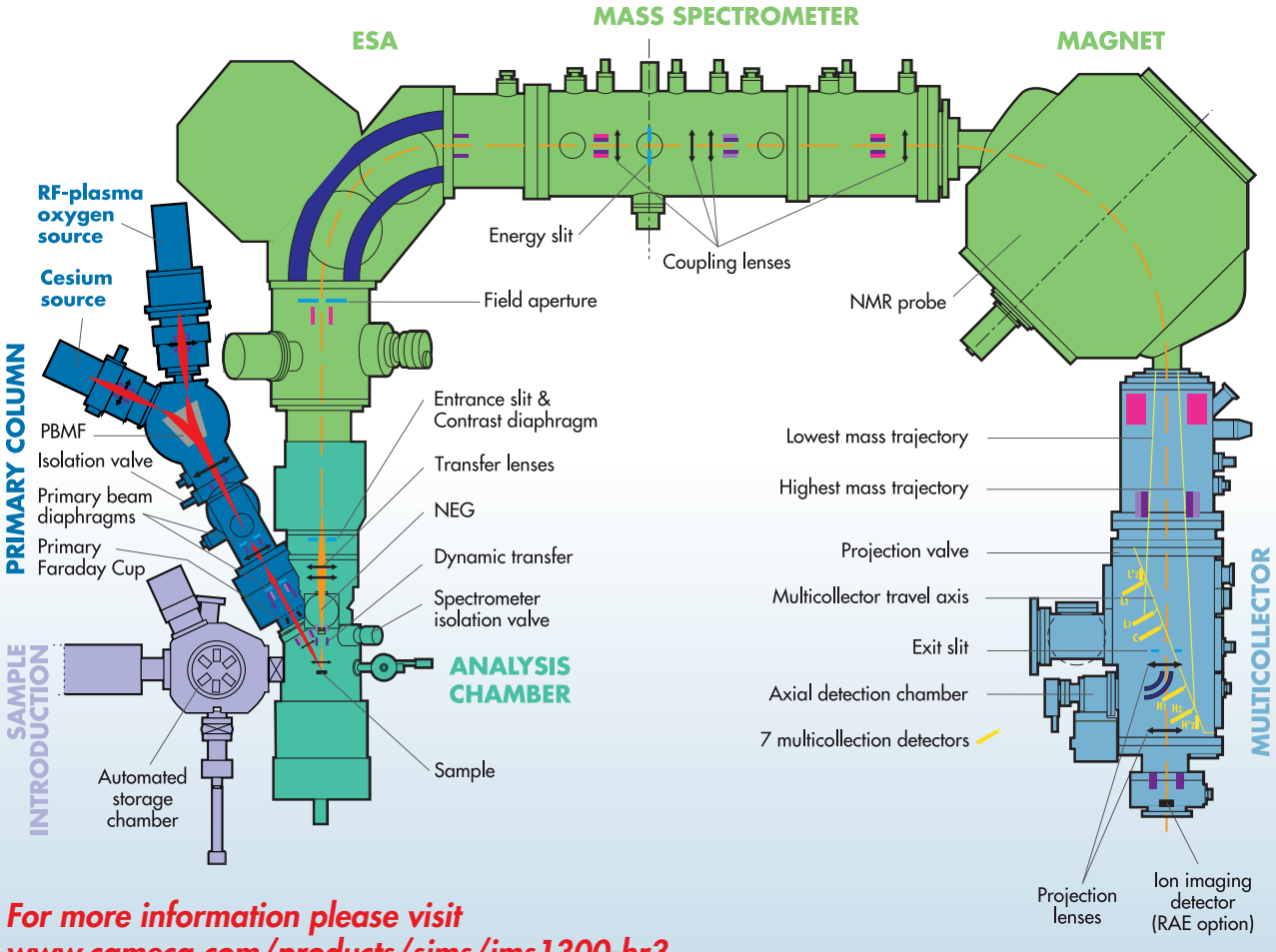
When a solid sample is sputtered by primary ions of few keV energy, a fraction of the particles emitted from the target is ionized. Secondary Ion Mass Spectrometry consists of analyzing these secondary ions with a mass spectrometer.

The SIMS technique is "destructive" by its nature (sputtering of material). It can be applied to any type of flat, solid material that can be kept under vacuum.

In dynamic SIMS, bulk composition and in-depth distribution of trace elements are investigated with a depth resolution ranging from sub-nm to tens of nm. SIMS is recognized as the most sensitive elemental and isotopic surface analysis technique.

CAMECA IMS 1300-HR³

The latest generation multicollection Large-Geometry SIMS is equipped with a high-brightness RF-plasma oxygen ion source in addition to the cesium microbeam source. It also includes an automated storage chamber for analysis of multiple mounts in chained mode.



For more information please visit
www.cameca.com/products/sims/ims1300-hr3

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