Raman spectroscopic study of garnet inclusions in diamonds from the mantle transition zone

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ABSTRACT

Raman spectra of syngenetic majoritic garnets were obtained from the Brazilian Sao-Luiz diamond suite. These garnets have a low majoritic content (<50%). Spectra were collected from (1) inclusions embedded in the diamonds and (2) inclusions extracted from the diamonds. From the latter, a clear relationship exists between the Raman spectra and the chemical analysis. All the majoritic garnets (Si > 3) have a characteristic signature in the frequency region of the SiO6-SiO4 stretching vibrations. This vibration gives a broad peak between 800 and 900 cm−1 just before an intense band (900–930 cm−1) classically assigned to Si-O stretching vibrations of the SiO4 tetrahedra in all known garnets. This broad band is also present in non-majoritic garnets (Si = 3) that result from the transformation, within the diamonds, of majoritic garnets into low-pressure garnet + pyroxene intergrowths. We show that the presence of significant TiO2 content in these normal garnets leads to Raman spectra mimicking those of majoritic garnets. The occurrence of a broad shoulder between 800 and 900 cm−1 as well as broad bands near 960 and 1030 cm−1 in the Raman spectra are no longer diagnostic features indicative of a majoritic garnet when the TiO2 content of the garnets is high (>1 wt%) as is the case for the Sao Luiz diamonds. The full width at half maximum (FWHM) of the strong Raman mode near 910 cm−1 is the only reliable signature that discriminates Si = 3 from Si > 3 garnets. The frequency of the diamond Raman mode used as an in-situ piezometer shows that the actual pressure of the garnet inclusions is between 0.5 and 0.8 GPa.

INTRODUCTION

Mineral inclusions in diamonds provide unique samples from the Earth’s mantle. The discovery of majoritic garnets and pyroxenes, which have been transformed from the perovskite structure during ascent, shows that diamonds and their inclusions provide the deepest known samples of the Earth’s mantle (Moore and Gurney 1985; Harte and Harris 1994; Harte et al. 1999; Joswig et al. 1999). These findings have confirmed the occurrence in the mantle of minerals previously only synthesized in high-pressure experiments (Ringwood and Major 1971) or observed in shocked meteorites (Smith and Mason 1970).

The characterization of these rare samples is an experimental challenge and it is of prime importance to use non-destructive techniques to characterize the mineral inclusions while they are still embedded in their diamond hosts. Such in-situ measurements not only provide information on the state of stress of the inclusion (Izraeli et al. 1999), but also, because of good spatial resolution of micro-Raman spectroscopy, is well suited to the non-destructive identification of small inclusions in diamonds.

This paper focuses on inclusions in diamonds from Sao Luiz (Brazil). These diamonds contain a suite of very rare inclusions that formed both in the mantle transition zone (depths of at least 350 km) and in the lower mantle (at depths greater than 660 km; Gasparik and Hutchinson 2000). From this suite of inclusions, we report Raman spectra of transition zone garnets that were either extracted from these diamonds and chemically analysed, or collected from the inclusions while still embedded within their diamond host. These spectra are then compared to those collected from: (1) majoritic garnets produced in high-pressure experiments; (2) typical eclogitic garnets; (3) garnets formed from the breakdown of majorite within specific rocks; and (4) majoritic garnets occurring in heavily shocked meteorites. We show that the presence of Ti can lead to an ambiguous determination of majorites from Raman spectra.

EXPERIMENTAL METHODS

Raman spectra were recorded in back-scattering geometry with a Raman microspectrometer (model XY, Dilor Company) equipped with a CCD detector. The laser beam (488 or