Composition determination of Fe mineral inclusions in diamond by confocal µ-XANES

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Introduction

Due to the depth and the extreme physical conditions (temperature, high pressure) direct studies of the deep Earth are in practice impossible. Indirect methods based on high-pressure techniques and seismic waves are therefore mostly applied to study the conditions at the deep Earth. Natural diamonds, however, provide a more direct way. During the growth of a natural diamond, fluids, minerals or rock fragments can be trapped inside it. These inclusions are then shielded from the environment during the transport of the diamond towards the Earth surface preserving their original capture composition. In this way, these inclusions provide the most direct way possible to derive the composition of the deep Earth [1-2].

The majority of natural diamonds are formed in the lithospheric upper mantle (< 200km depth). Only a few sources, e.g. Juina (Brazil) and Kankan (Guinea) provide diamonds from superdeep sub-lithospheric mantle regions of the deep Earth which originate at depths of several hundreds of km.

Identification of the main mineral phases present in the inclusion can be obtained with micro-XANES of the lower atomic number minor/major elements of the inclusions. Due to the high scattering power of the diamond host, fluorescence µXANES in a confocal detection scheme is required in order to improve signal-to-scatter background ratios.

In the example below, a diamond from Soa Luiz (Brazil) was studied with confocal µXANES at the Fe K edge in fluorescence detection mode.

Experimental

The Fe K confocal µ-XANES spectra were recorded at beamline L of the DORIS III storage ring in fluorescence mode using a Si(111) monochromator. The fluorescence radiation was recorded with a Vortex-EX SDD detector (SII, 50 mm^2, 350 µm crystal thickness, measured energy resolution 177 eV at Fe Kα). The monochromatic beam was focused by a polycapillary lens (XOS inc., NY, USA) resulting in a beam size of about 25 µm (FWHM) at the Fe *K* edge. The confocal detection was achieved with a second polycapillary half-lens (XOS inc.) placed in front of the energy dispersive detector. The µXRF spectra were recorded with an excitation energy of 7200 eV. The measured FWHM acceptance was about 22 µm for Fe Kα radiation. The vertical FWHM of the confocal ellipsoidal detection volume was 16 µm.

In order to access the inclusions within the diamond with the confocal set-up and to reduce matrix absorption, a window was polished in the diamond very close to the inclusion location (in the order 100 µm or less). The diamond was then mounted with the polished surface oriented vertically and placed under an angle of 45° with respect to the incoming µ-beam and the detector axis.

Results

The elemental maps of a horizontal confocal µXRF plane through one of the inclusions in this diamond is given in Figure 1, together with the µXRRF sum spectrum of the 2D scan. The main element is Fe, the heaviest element detectable with the used setup. The confocal µXANES spectra recorded at two positions separated by 45 µm in height in this inclusion are also shown in Figure 1. These spectra show very good agreement with enstatite, a pyroxene mineral.

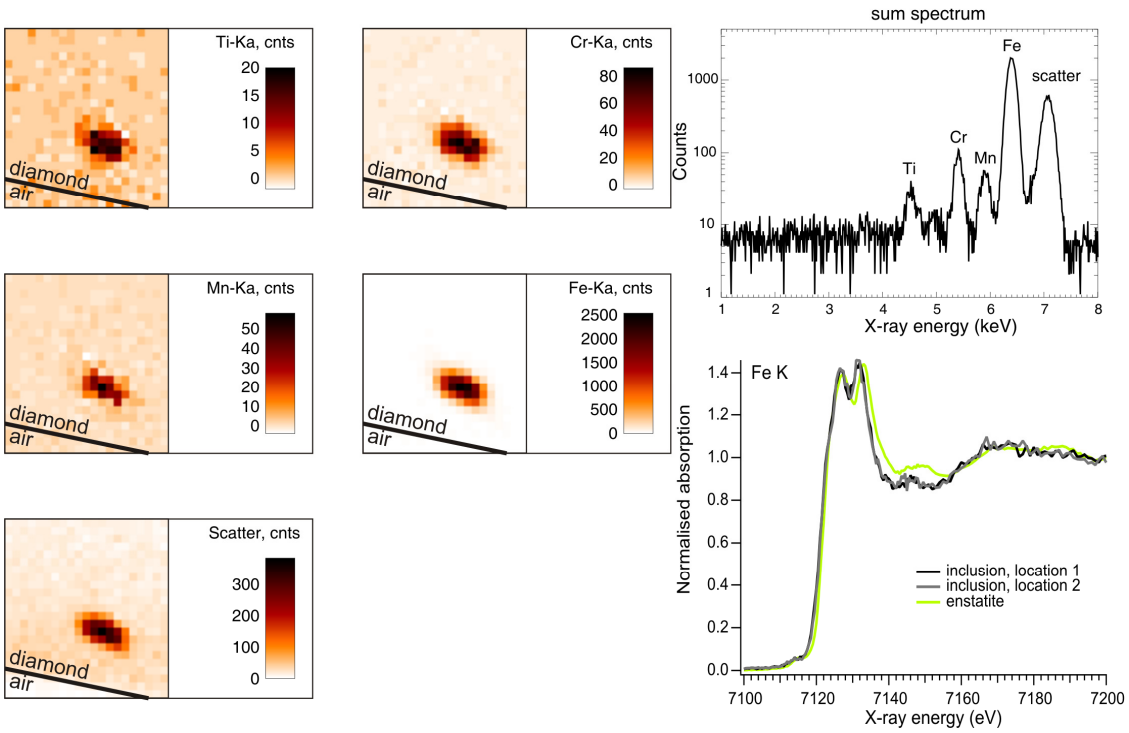

Figure 1: Confocal µXRF elemental distributions for Ti, Cr, Mn, Fe and the scatter peak from a horizontal cross-section through the inclusion. Map dimensions: 21×10 µm × 21×10 µm, 2 s RT, 7200 eV.

Conclusions

Confocal Fe K µ-XANES allows the in-situ identification of Fe containing mineral inclusions within diamonds of ultra-deep origin.

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