

Application of the SIMS technique to analysis of Ni-in-garnet and its value in diamond exploration

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Reason for the investigation

The Ni content of garnets is widely used in assessing prospects during diamond exploration. Garnet-bearing xenoliths or single garnet grains from kimberlite concentrate and stream sediment samples may be assigned a temperature of formation based on their Ni/Mg content, and such temperature estimates constrain depths of origin relevant to diamond formation.



The abundances of Ni in mantle xenoliths and kimberlitic garnets are generally too low to allow reasonably accurate analysis by EMPA (electron microprobe). PIXE (proton probe) analysis has been shown to be useful for Ni in garnet (Griffin et al., 1989; Ryan et al., 1996), but the Secondary Ion Mass Spectrometry (SIMS) technique offers a fast, accurate and precise alternative. Therefore, this project was aimed at establishing a straightforward and rapid technique for Ni analysis in garnets by SIMS and builds upon earlier unpublished work by McDade in 2000-01.

Since the application of the Ni geothermometer strictly depends upon knowledge of co-existing olivine compositions as well as those of garnet, the ion probe work placed emphasis on analysis of samples also containing olivine (although Ni in olivine is usually determined by electron microprobe) so that reliable temperature estimates could be calculated for the analysed samples.

Results

SIMS analyses for Ni were carried out on garnets in a wide variety of peridotitic garnet samples for which ICP-OES data were already available. Because of overlaps with other ions in the mass spectrum Ni analyses were performed using a high mass resolution technique (3000 M/ΔM) with zero energy offset.

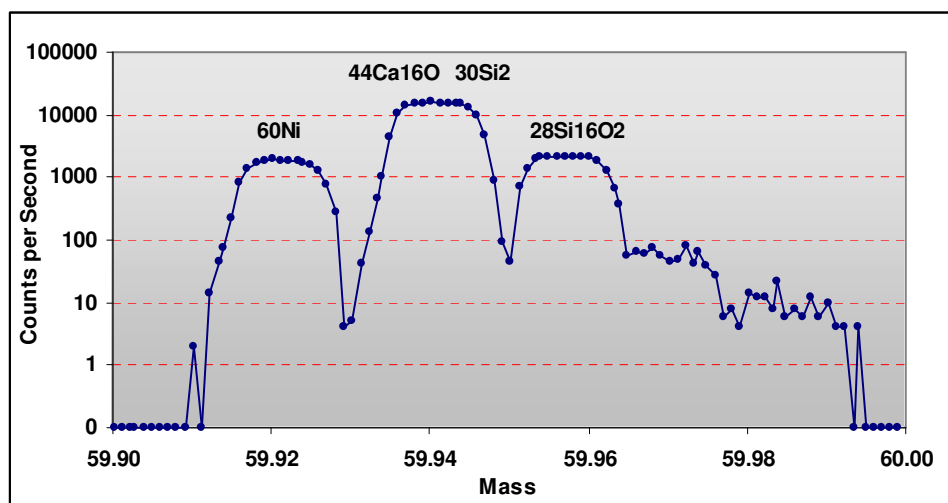


Fig 1. High Mass Resolution scan across ^{60}Ni in garnet

In developing this technique the Ni/Fe ratio was found to be the most suitable for several reasons: (i) Fe is present in sufficiently high concentrations to be accurately measured by electron microprobe and

hence is independently quantifiable; (ii) the chosen isotopes are present in sufficiently low concentrations as not to overload the detector; (iii) ^{57}Fe can be analysed under the analytical constraints (3000 M/ Δ M) required for accurate Ni determination; (iv) minimum movement of the magnetic field was required when switching between the ^{60}Ni to ^{57}Fe ; (v) Ni/Fe ratio was found to be independent of the variations in major element garnet chemistry.

The measurements were made in 20 cycles where ^{47}Ti and ^{57}Fe counts were collected for 2 s, ^{60}Ni counts were collected for 5 s. These procedures gave reliable results with counting statistics producing an average 1 s.d. precision of ± 2 ppm (equivalent to $\pm 10.1^\circ\text{C}$ using $T_{\text{Ni-Ryan}}$) which is smaller than the symbol size on Fig. 2. They also have a reasonably short analysis times (~ 6 mins/analysis). Repeated analyses of > 6 analyses per standard produced an average standard deviation of 1.3 ppm across the standards. Application of the technique to the wide range of compositions studied showed no observable matrix effects.

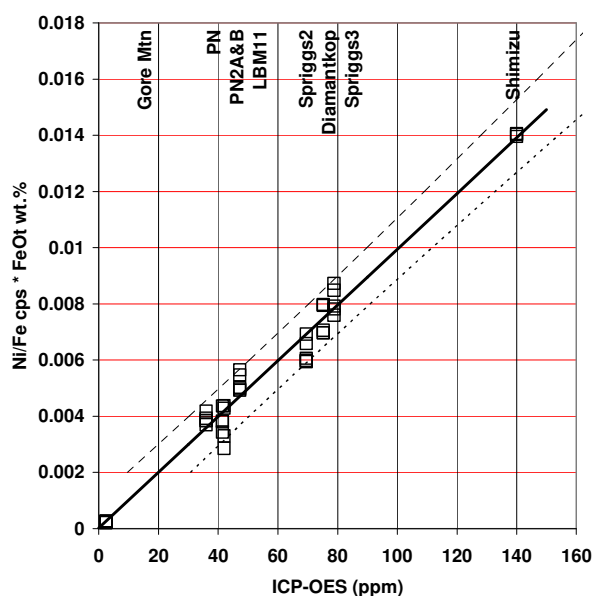


Fig 2. Ni/Fe * FeO ratio vs Ni concentration by ICP for 8 standards.

Discussion

A useful high mass resolution SIMS technique has been established for accurate determination of Ni concentration in garnet. This technique has high potential for application to multiple garnet analyses in diamond exploration projects. It is quick (~ 6 mins/analysis), with an average precision of ± 2.0 ppm, and is independent of bulk composition effects for the normal range of peridotitic garnet compositions. Compared to the use of the PIXE (proton microprobe) technique, it is believed that SIMS technique proposed has higher precision for the same analysis time.

The value of the technique in yielding Ni geothermometer estimates has been tested by application to a well categorised xenolith suite from the Jagersfontein kimberlite (Burgess, 1997), and to texturally well equilibrated samples from Matsoku (McDade et al. in prep.). In addition the technique is being applied to samples from the Newlands and Bobbejaan kimberlites in conjunction with other trace element analyses carried out in 2004-5 (Ivanic et al., this report).

References

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