Measurement of laboratory-produced argon diffusion and solubility in glasses and minerals using UV laser ablation microprobe

S.P. Kelley *Dept of Earth Sciences, Open University, UK*
M.R. Carroll *Dept of Geology, University of Bristol, UK*
R.A. Brooker
D.S. Draper *School of Earth Sciences, Macquarie University, Australia*

Introduction

Noble gas extraction by laser ablation microprobe using an ultra-violet laser (UVLAMP) is opening new areas of study in noble gas geochemistry. This new technique affords the opportunity to analyse not only 'opaque' minerals *in-situ* in rock slices (those accessible to infra-red and visible laser techniques) but all important silicate minerals. Studies of natural samples have utilized the technique to compare argon components in minerals such as biotite/quartz (Kelley *et al.*, 1994) and phengite/biotite/k-feldspar/quartz (Arnaud and Kelley 1994) 'in-situ'. Unfortunately, the paucity of laboratory-derived solubility and diffusivity data restricts interpretation of such mineral systems. However, this new technique can also be used to determine noble gas concentrations and diffusion profiles in thermally treated minerals and glasses with a spatial resolution of better than 3μm. Early results demonstrate the potential of this technique to produce laboratory determined solubility and diffusivity data for a comprehensive range of minerals.

Techniques

Argon extraction using a quadrupled Nd-YAG laser ($\lambda = 266$nm), requires ablation times of up to 20 minutes to extract sufficient argon for measurement in an MAP 215-50 noble gas mass spectrometer. The power density during 10ns pulses focused to a 10m laser spot is extremely high ($\sim 3 \times 10^{10}$ W cm^{-2}) and the light is typically absorbed in the top few microns of the sample. The average rate at which energy is dumped into the sample during analysis is typically 0.01–0.1W (1–10mJ/pulse at 10Hz), over two orders of magnitude smaller than typical powers delivered by CW visible and IR lasers, leading to insignificant heating outside the laser pit even after long irradiance. This opens the doors to new sample extraction procedures, including beam raster which can achieve a much higher spatial resolution than current techniques. Beam raster was achieved in the present system by moving the sample chamber on a programmable XY stage.

The only major artefact noted during the analysis was a surface effect which resulted in anomalously high concentrations in the first/surface analysis. The effect is thought to be caused by introduction of argon into cracks and defects induced in the top micron of the sample during the polishing procedure.

Preliminary results

Controlled laboratory heating of gem quality iron rich (up to 1.5% FeO) K-feldspar and synthetic basalt glasses in 1–2 kbar argon pressure have yielded argon concentration gradients up to 70μm deep, which have been imaged with a resolution of as little as 2.5μm by the UVLAMP using a beam raster technique. Argon diffusion rates in the K-feldspar, from Madagascar, are around an order of magnitude slower than previously derived diffusion rate for K-feldspar (Foland 1974).

Argon diffusivity in a synthetic basalt glass was measured over a range of temperatures from 400°C to 700°C. No higher temperature runs were performed in order to avoid problems with devitrification. Results compared well with experiments on argon diffusivity from 1300 to 1450°C, performed at 10 to 13 kbar which were analysed using an electron microprobe (cf. Carroll and Stolper 1991).

References

Arnaud, N.O. and Kelley, S.P. (1994) *Contrib. Mineral. Petrol.*, submitted.

Carroll, M. R. and Stolper, E.M. (1991) *Geochim. Cosmochim. Acta*, **55**, 211–25.

Foland, K.A. (1974) *Geochim. Cosmochim. Acta*, **38**, 151–66.

Kelley, S.P., Arnaud, N.O. and Turner, S.P. (1994) *Geochim. Cosmochim. Acta*, (in press).