Analysis of light lithophile elements (Li, Be, B) by laser ablation ICP-MS: Comparison between magnetic sector and quadrupole ICP-MS

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ABSTRACT

We report techniques for in-situ abundance measurements of the light-lithophile elements (LLE; Li, Be, and B) in silicate glasses by laser-ablation inductively coupled mass spectrometry (LA-ICP-MS), and compare the analytical performance of a sector field and quadrupole mass analyzer for these measurements. LA-ICP-MS is shown to be an effective means of determining LLE abundances at spatial scales between 25 and 100 μm. Detection limits depend on instrumental sensitivity and ablation rate, but can be in the low- to sub-ng/g range. Measured ion yields for ⁷Li, ⁹Be, and ¹¹B ion, normalized to ⁴³Ca as an internal standard, remain largely constant during ablation, although ¹¹B shows a relative increase once the ablation crater aspect ratio exceeds ~1. Surficial contamination, particularly of B, can be removed rapidly via a short pre-ablation (~20 pulses) immediately prior to analysis. The sector field ICP-MS provided considerable improvements in analytical performance over the quadrupole mass analyzer, although longer magnet settling times result in greater duty cycle losses. Calculated detection limits for a given set of ablation conditions are 20–90 times lower, and useful yields (the ratio of atoms ablated to counts detected) are 20–75 times greater for the sector field instrument. Analysis of reference glasses shows that LA-ICP-MS provides accurate measurements of Li, Be, and B contents in silicate glasses over a range of compositions (komatiite to rhyolite). LA-ICP-MS also offers similar accuracy and precision and marked improvements in sample throughput compared to secondary ion mass spectrometry (SIMS) analysis of LLE abundances, although SIMS has higher useful yield and thus provides better spatial resolution.

Keywords: Light-lithophile elements (Li, Be, B), laser ablation ICP-MS, SIMS, geochemical reference standards

INTRODUCTION

The light-lithophile elements—Li, Be, and B (LLE)—provide important information about a broad range of geological and geochemical processes (e.g., Chaussidon and Libourel 1993; Domanik et al. 1993; Ottolini et al. 1993, 2004; Chaussidon and Jambon 1994; Chaussidon and Koeberl 1995; Hervig 1996; Lee-man and Sisson 1996; Ryan et al. 1996; Brenan et al. 1998; Kent et al. 1999a, 1999b; Seitz and Woodland 2000; Kent and Rossman 2002; Berlo et al. 2004; Marschall and Ludwig 2004, Scambelluri et al. 2004; Tiepolo et al. 2005, and many others). The LLE represent both a range in volatility, solubility in aqueous fluids, and incompatibility during melting and crystal fractionation, and thus are particularly useful tracers for a range of terrestrial and extraterrestrial magmatic and hydrothermal environments.

In many terrestrial and extraterrestrial materials, the LLE are present in relatively low abundances—typically in the low μg/g to ng/g range—and thus, sensitive analytical techniques are required to determine their concentrations with appropriate precision and accuracy. In addition, it has proven advantageous in many cases to procure information at small spatial scales (10–100 μm) using microbeam-based analytical techniques—predominantly secondary ion mass spectrometry (SIMS) (e.g., Chaussidon and Libourel 1993; Domanik et al. 1993; Ottolini et al. 1993, 2004; Chaussidon and Jambon 1994; Chaussidon and Koeberl 1995; Hervig 1996; Brenan et al. 1998; Kent et al. 1999a, 1999b; Seitz and Woodland 2000; Kent and Rossman 2002; Marschall and Ludwig 2004). Analysis at these small scales allows investigation of LLE in restricted sample domains, such as within individual minerals or melt and mineral inclusions, as well as investigation of variations in LLE concentrations relating to mineral growth, solid-state diffusion, and other processes. Microanalysis also can be used to avoid areas of alteration, which is useful for studies of samples such as meteorites and submarine glasses where small regions of glass or minerals may remain unaltered and where inclusion of altered areas would significantly bias the composition of bulk samples. SIMS techniques are capable of determining LLE contents down to the ng/g concentration range (e.g., Kent and Rossman 2002; Marschall and Ludwig 2004; Ottolini et al. 2004) but also require relatively long analysis times (>10 min) and careful attention to reducing surface contamination—particularly for B (e.g., Shaw et al. 1988; Marschall and Ludwig 2004).

Herein, we report results from laser-ablation ICP-MS (LA-ICP-MS) analysis of Li, Be, and B concentrations in silicate glasses. We discuss analytical protocols and other issues of note regarding measurement of LLE in silicate glasses, and present a comparison between a sector field and a quadrupole...