Simultaneous Measurement of All Isotopes of Iron and Nickel in Cosmic Spherules

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Recent measurements of Ni isotopes in a pyroxene-rich chondrule from the Semarkona chondrite [1] and in Fe-rich bruennerite from the Orgueil meteoriite [2], made during searches for in situ decay of extinct ^{60}Fe, showed surprisingly large Ni mass fractionation effects. These measurements were made with the microbeam resonance ionization mass spectrometer CHILI [3], using laser ablation to desorb atoms from surfaces. In order to better understand the effects measured in extraterrestrial materials, we have begun analyzing Fe and Ni isotopes in samples known to have large mass fractionation effects.

Cosmic spherules collected from deep-sea sediments have been known since the Challenger expedition [4]. Spherules of magnetite and wüstite, sometimes with Fe-Ni metal cores, show mass fractionation effects in Fe, Ni, and O of up to several tens of ‰/u [5–7]. Ion microprobe analyses of Fe and Ni have unresolvable interferences (^{54}Cr-^{54}Fe; ^{58}Fe-^{58}Ni; ^{64}Ni-^{64}Zn), whereas CHILI can selectively ionize Fe or Ni, and thus, measure all isotopes of each element. Using laser ablation, Ni photoionization lasers can be delayed by 200 ns relative to Fe lasers to separate ^{58}Fe from ^{58}Ni with the time-of-flight mass spectrometer [3]. Atoms sputtered with a Ga primary ion beam have higher energy and do not spend as much time in the atom cloud, so a technique was developed to fire the Fe and Ni lasers separately on alternate primary ion shots. This reduces the useful yield by 50%, but cleanly separates the signals at mass 58 u. Fe is suppressed in the Ni scheme by 25,000×; Ni is suppressed in the Fe scheme by >2000×. Preliminary results on metallic cores of two cosmic spherules from deep-sea sediments show Ni mass fractionation effects of 0.9±0.8 and 6.7±0.7 ‰/u (1σ), but we expect oxide mantles and oxide-only spherules to show larger mass fractionation effects.

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