DUST-BUSTER ISOTOPE TOF-MS FOR STARDUST

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Academia Sinica (AS) and Argonne National Lab (ANL) have entered into a collaboration to develop a high sensitivity time-of-flight mass spectrometer (TOF MS). It aims to measure as many isotope ratios as possible over a wide mass range in individual grains collected by the STARDUST spacecraft during its fly-by of comet Wild-2. A new MS called DUST-BUSTER is being built at AS based on the new TOF MS design developed at ANL. An instrument of similar design, named SPIRIT, is already in operation at ANL. A 157 nm (=7.9 eV photon) F_2 laser with 1 mJ/pulse energy running at 100 Hz was used as the source of photons. It photoionizes secondary neutral atoms sputtered from the grain surface by a primary Ar^+ ion beam. This high sensitivity TOF MS has a transmission of >95% resulting in high useful yields (>12% demonstrated for Mo). Here we report preliminary results for measuring the isotope ratios of several major elements (e.g. Ti and Ca) in refractory minerals such as sphene ($CaTiSiO_5$).

To test the precision of analog data collection (i.e. the integration of detector current over time-of-flight), we used a 1 µA primary ion beam (100 µm across). This is suitable for large signals because the integrated charge is proportional to the total number of ions. The short term (same day) reproducibility for Ti 46, 47, and 50 relative to 48 were within 1% (1). The deviations from absolute ratios as measured at AS by thermal ionization mass spectrometry (TIMS) were less than 10 %.

The second experiment tested the ion counting method by reducing the Ar beam to < 1 nA and < 10µm in width. Data acquisition using counting works best when analyzing low intensity signals from small particles. It improves the signal-to-noise ratio since ions can be separated from analog noise by discrimination. In counting mode, we accumulated spectra consisted of 5120 averages with the most intense signal being <0.1 count per average. Typical reproducibility was 5-10% (1) with hydride remaining a major interference. Pre-cleaning the target surface before data acquisition reduces hydride formation and increases photo-ion yield.

A major difficulty in analyzing comet dust is that individual isotopically unique grains are so small that often only one analysis per grain is possible. With the high sensitivity of laser post-ionization TOF MS simultaneous precise measurements on all species that are photoionized are possible. For instance, TiO photo-ions were more abundant than Ti photo-ions when using 157 nm UV. Therefore if Ti and TiO (even TiO2) all yield the same isotope effects then the measurements are more likely to be correct since interferences in different mass ranges should cause different artifacts in general. Similarly, some Ca isotope ratios may be measured from both Ca and CaO.

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