ISOTOPIC MICROANALYSIS OF RETURNED COMET NUCLEUS SAMPLES. Ernst Zinner, McDonnell Center for the Space Sciences and Department of Physics, Washington University, St. Louis, MO 63130 USA.

If isotopic measurements of interplanetary dust particles (IDPs) and primitive meteorites can serve as a guide to the isotopic analysis of returned comet nucleus material, an essential requirement will be the capability for microanalysis. The reason is that in both types of extraterrestrial samples large isotopic heterogeneities on a small spatial scale have become apparent once it was possible to measure isotopes in small samples. In the discovery of large isotopic anomalies the ion microprobe has played a significant role because of its high spatial resolution for isotopic ratio measurements. The largest isotopic anomalies in C, N, O, Mg, Si, Ca and Ti found to date were measured by ion microprobe mass spectrometry [1]. The most striking examples are D/H measurements in IDPs [2,3] and isotopic measurements of C, N and Si in SiC from the CM chondrites Murray and Murchison [4,5].

A number of IDPs shows large D excesses that are heterogeneous on a size scale of several μm. In one particular example, in the IDP Butterfly, a large D excess ($\delta D \geq 10000^0/_{00}$) was found to be concentrated in a region smaller than 1 μm [3]. In contrast to IDPs, unequilibrated ordinary chondrites that have large D excesses in bulk material do not show significant heterogeneities of the D/H ratio on a μm scale and to date no D rich hot spots have been found [6]. This might reflect the difference between more processed meteoritic and more pristine cometary material. Although it presently cannot be proven for any given IDP, many IDPs undoubtedly are of cometary origin. It has been argued that D enrichments in IDPs and meteorites are of interstellar cloud origin [cf. 7]. It is thus not unlikely that comets contain presolar material. Many links in this chain of reasoning are uncertain, it is certain, however, that the capability of isotopic microanalysis will be necessary to decide these questions.

Meteoritic SiC shows extreme isotopic anomalies in C, N, Si, Ne and Xe [4,5], with large isotopic heterogeneities for the first three elements in individual grains of a few μm in size [8]. Arguments for a presolar, circumstellar, origin of SiC grains are based on their isotopically anomalous composition and the fact that the chemical conditions (C/O < ratios) in the early solar system would not have allowed their formation. SiC has also been reported in IDPs [9]. No isotopic data have been obtained on these samples, but the ^{13}C excess measured in a fragment of the IDP could be due to the presence of SiC [9]. Again, based on the presence of SiC in meteorites and IDPs, it can be expected that such presolar grains will be found in comet nucleus samples. While the list of isotopic measurements in small extraterrestrial samples could be extended (cf. noble gases, O and Mg in IDPs) one should consider possible future developments that will bear on the isotopic analysis of returned comet nucleus material.

1. Extension of isotopic measurements in IDPs to other elements. Candidates are N but also Ca and Ti in refractory particles whose O isotopic compositions are proof of their extraterrestrial origin [10].
2. Development of methods to perform *in situ* isotopic measurements of volatile elements in ices. Isotopic information is expected to be not only contained in cometary mineralic matter but also in ices. While isotopic measurements of gases released by evaporation of ices will certainly play a role, it may be even more important to make *in situ* measurements. Slicing of ices for TEM studies is already within present technical

capabilities.

3. Better spatial resolution. Laser ablation of volatile coatings in a method that could achieve high depth resolution. High lateral resolution (*in situ* analysis of small grains) will probably be tied to sputtering by finely focussed ion beams (ion microprobe). A resolution of a few hundred Å can presently be achieved [12].
4. Increase in sensitivity. The number of atoms of a given species in a sample sets the ultimate limit for isotopic analysis, but in present mass spectrometers only a small fraction of these atoms are actually detected. Laser resonance ionization promises to selectively ionize nearly all atoms of a given element. The next step would be ion-resonant ionization of all elements in the sample and simultaneous detection of all their isotopes. Such developments will have to depend on advances in laser technology (UV lasers) and novel mass spectrometer concepts (e.g. Fourier transform mass spectrometry).
5. Exploration of non-destructive methods for isotopic analysis. There is a whole series of spectroscopic techniques (NMR, Raman) that, in principle, allow non-destructive isotopic measurements. Whether any of them are sensitive enough to become attractive for the analysis of microsamples remains to be seen.

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