Microscale D/H and C/H imaging of meteorites and IDPs – Calibration of ion microprobe data with terrestrial analogues and meteoritic residues

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Chondrites and interplanetary dust particles (IDPs) show large C contents and inhomogeneously distributed, strongly elevated D/H ratios compared to Earth and the solar system. The anomalies are mainly carried by organic matter that was formed in the interstellar medium and subsequently altered by parent body processing (Alexander et al., 1998). The carriers of the isotope anomalies have not unequivocally been identified, but µm-scale isotopic and elemental imaging by ion microprobe provides useful information. For example, quantitative D/H, C/H and $^{15}N/^{14}N$ imaging has been used to identify at least three distinct types of carbonaceous material in IDPs (Aléon et al., 2001, 2003). In general, the highest D/H ratios are associated with C, but high D/H ratios have also been observed in some C-poor regions of IDPs (Mukhopadhyay and Nittler, 2003). Precise C/H ratios are hence essential to distinguish the phases and ultimately identify the carriers of the various D/H signatures in IDPs. However, element ratios are difficult to determine with ion microprobes due to matrix effects depending on secondary yields.

We have begun a systematic examination of the isotope and element fractionation of our Cameca 6f imaging system (Nittler and Messenger, 1998). Various well-characterized extraterrestrial and terrestrial organic samples with a large range of C/H and D/H ratios such as coals, aromatic and aliphatic hydrocarbons, hydrated minerals and organic residues of primitive meteorites will allow us to precisely establish calibration ratios for C/H and D/H, to assess possible matrix effects and to determine realistic uncertainties. Furthermore, imaging data for µm-sized matrix particles from a range of meteorite types will be presented in order to enlarge the database for both weathered and relatively unaltered primitive chondrites allowing for a comparison with IDPs and returned STARDUST samples.

References

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TOF-SIMS – A tool for sub-micrometer analysis in geo- and cosmochemistry

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Introduction

The analysis of micrometer and even sub-micrometer-sized samples has become more and more important in geo- and cosmochemistry. Typical examples are individual interplanetary dust particles (IDPs), ~10 µm in size, that often consist of hundreds of smaller grains. Some of these phases are isotopically highly anomalous, presolar grains embedded in isotopically normal, solar matter. These grains provide us with information about stellar and interstellar processes that formed the building blocks of our solar system.

TOF-SIMS

Time-of-flight secondary ion mass spectrometry (TOF-SIMS) is one of the techniques that are ideally suited for these tiny, complex samples (Stephan, 2001). With TOF-SIMS major, minor, and trace elements, their isotopes, and molecules can be measured at a lateral resolution of ~200 nm.

The main advantage of TOF-SIMS compared to double-focusing ion microprobes is its detection of all secondary ions with one, selectable polarity in a single experiment. This is due to the time-of-flight principle where even the heaviest molecular ion eventually reaches the detector. Therefore, hydrogen, *e.g.*, can be measured simultaneously not only with all elements that form ions with the respective polarity but also with the heaviest bio-molecules. Further major differences to other SIMS instruments are little sample consumption (typically only a few atomic monolayers are sputtered during a measurement) and high transmission (20–80 %, depending on the ion species). However, count rates for individual ion species are rather low and statistical errors are often limiting the measurement accuracy, especially for isotope analysis.

Conclusion

Whenever high lateral resolution is required, and pre-selection of ion species to be measured has to be avoided, especially for samples with unknown composition, TOF-SIMS is an extremely valuable tool that can provide a huge range of information with a minimum of sample destruction.

Reference

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