TOF-SIMS — A POWERFUL TOOL FOR THE ANALYSIS OF STARDUST. T. Stephan, Institut für Planetologie/ICEM, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (stephan@uni-muenster.de).

Introduction: During the last two and a half decades, the analysis of small samples has become more and more important in cosmochemistry. With the collection of interplanetary dust particles (IDPs) [1] and the isolation of presolar grains from primitive meteorites [2], the necessity for new techniques with high sensitivity and high lateral resolution has increased. For many years now, secondary ion mass spectrometry (SIMS) has played an important role in the analysis of such samples [3]. Two major trends in the development of new SIMS instruments emerged during the last years, NanoSIMS and TOF-SIMS. Both will be instrumental in the analysis of samples from the Stardust mission [4].

NanoSIMS: Improvements of the classical ion microprobe with double focusing magnetic mass spectrometers has led to the development of Cameca's NanoSIMS 50 [5–7]. This instrument is characterized by a high spatial resolution, ~50 nm with a cesium primary ion source, used for negative secondary ions, and ~200 nm with an oxygen ion source for the analysis of positive secondary ions. A multi-detection system allows the simultaneous measurement of up to six masses. High secondary ion yields at high mass resolution ideally meets the requirements for isotope analyses of sub-micrometer-sized samples.

TOF-SIMS: Another concept, time-of-flight (TOF-) SIMS, also reaches ~200 nm lateral resolution by using a fine-focused gallium liquid metal ion source. After its introduction into cosmochemistry in the early 1990s, this technique has grown to a powerful tool for the study of micrometer-sized samples [8]. The advantage of this instrument lies in its capability of simultaneously measuring **all** secondary ions with one polarity. Both polarities can be measured in two consecutive analyses. Secondary ions released during sputtering with the Ga-beam are separated in a drift tube according to their flight time after acceleration in an electric field. Due to the time-of-flight concept, secondary ions are generated in a short (typically ~1 ns) primary ion pulse. With 10 kHz repetition rate and 10–50 primary ions per shot, only monolayers of a sample are consumed even during an eight-hour measurement. Consequently count rates at a specific mass are relatively low and the capability of measuring isotopic ratios is limited by counting statistics.

Nevertheless, for presolar grains, where deviations from solar isotopic ratios are often tremendous, statistical errors of some percent are tolerable. It is noteworthy that with TOF-SIMS for the first time the isotopic heterogeneity within a single 2 µm-sized presolar silicon carbide grain was discovered [9].

The main advantage of TOF-SIMS is the parallel detection of the entire mass range that is in principle unlimited. This allows to measure major, minor, and trace elements, their isotopes, as well as molecular ions, all simultaneously in a single measurement. Simultaneous detection is a prerequisite to discover with SIMS possible correlations between different ion species from small samples, since SIMS is always destructive and samples may change under the ion beam. TOF-SIMS is ideally suited to discover unexpected properties of the investigated samples because no preselection of ion species to be analyzed is necessary.

Combination of different techniques: For a comprehensive study of small samples like IDPs a combination of different techniques is appropriate to yield a maximum of information on single grains and their components. While isotopic anomalies within such grains can easily be detected with NanoSIMS, TOF-SIMS allows a chemical and often mineralogical identification of the respective carrier phases [10–12]. With NanoSIMS alone, this would be impossible in case of very small samples due to sample destruction.

Outlook: Because of its characteristics, TOF-SIMS is a suitable technique for the analysis of samples from the Stardust mission. Grains from comet Wild 2 as well as contemporary interstellar dust are projected samples to be brought back in 2006. For both types of particles it is indispensable to use analytical methods that introduce the least possible bias and that allow subsequent analyses with other techniques. TOF-SIMS with its comprehensive analysis and the little sample destruction meets these requirements.

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