TOF–SIMS ANALYSIS OF INTERSTELLAR SiC GRAINS; **T. Stephan** and **E. K. Jessberger,** MPI für Kernphysik, Postfach 103980, D–69029 Heidelberg, Germany.

Introduction. Ten interstellar SiC grains from the Murchison CM2 meteorite that were previously investigated at Washington University [1] have been analyzed using **T**ime–**O**f–**F**light **S**econdary–**I**on–**M**ass–**S**pectrometry (TOF–SIMS). During the last years we have demonstrated the potential of this technique for the analysis of small samples like interplanetary dust particles or micrometeorites [2–7]. Simultaneous detection of all secondary ions (positive or negative) at high transmission of the spectrometer (20–80 %) and sufficient mass resolution ($m/\Delta m \leq 6000$ at 50 % peakheight) for separation of most molecular interferences from elemental peaks at high lateral resolution (beam diameter: $\sim 0.2\ \mu m$) allow to obtain extensive information on individual SiC grains without completely destroying the sample. During a typical TOF–SIMS analysis only a few monolayers are consumed whereas conventional SIMS techniques, mainly with double focussing mass spectrometers (DF–SIMS), are more destructive and small samples like typical SiC grains are easily sputtered away. Therefore, TOF–SIMS seems to be ideally suited for the analysis of these grains with a typical size of a few microns. Nevertheless, TOF-SIMS suffers from some of the same problems like all SIMS techniques, *e.g.*, with quantification. Most attempts to measure isotopic ratios yielded unsatisfactory results so far because in many cases the required precision (typically in the order of permill) could not be achieved due to low count rates and therefore high statistical errors and/or due to non–sufficient mass resolution for a complete separation of interferences from hydrates (*e.g.*, $^{12}C^{1}H$ from ^{13}C).

Isotope analysis. Interstellar grains are well known for their huge variations in isotopic ratios, the only evidence for their interstellar origin [8], *e.g.*, the $^{12}C/^{13}C$–ratio in SiC grains varies over more than three orders of magnitude. Therefore, the required precision for isotopic measurements is relatively low. For the analysis of carbon isotopes, the major problem in TOF–SIMS is the separation of $^{12}C^{1}H$ from ^{13}C. The mass difference is 4.5 mamu which requires a mass resolution of $m/\Delta m = 2900$. Typically this can be achieved at 50 % peak height but in case of mass 13 amu the $^{12}C^{1}H$ peak is much more intensive than ^{13}C, in the range of the ^{12}C peak (CI: $^{12}C/^{13}C$=89.9 [9]). An increase of the mass resolution in TOF–SIMS in this mass range can only be achieved by reducing the primary pulse length, which yields to decreasing primary ion intensities and therefore lower count rates, or by increasing beam diameters, both not suitable for the analysis of small SiC grains with typically low secondary ion yields. Therefore, we developed a mathematical peak separation method which uses the shape of the ^{12}C mass peak to separate $^{12}C^{1}H$ from ^{13}C. With this technique we were able to calculate $^{12}C/^{13}C$ ratios for five SiC grains. The results are shown in Fig. 1. As long as the sample is enriched in ^{13}C, isotopic ratios for carbon can be determined and are within error limits identical to the results obtained by Amari and Zinner [1]. With TOF–SIMS isotopic analyses for several other elements than C were possible. Here again the precision was limited by the counting statistic and typical errors for isotope ratios are 0.4–50 %. Within these errors Li, B, S, and Cl showed no deviations from CI isotopic ratios [9]. For Mg and Si the exact determination of isotopic ratios is complicated by the occurrence of hydrates, mainly $^{24}Mg^{1}H^{+}$ and $^{28}Si^{1}H^{+}$.

Element abundances. Due to the parallel detection of all secondary ions with one polarity element ratios for several major, minor, and trace elements were obtained during our TOF–SIMS analysis. The results for positive as well as negative secondary ions are comprised in Fig. 2. Since all samples were previously analyzed with DF–SIMS using O^{-} primary ions all samples showed an intensive O^{-} peak leading to meaningless O/Si ratios. This also complicates the calculation of relative abundances for other elements because secondary ion yields are strongly dependent on the sample matrix, especially on the oxygen content. Nevertheless, all analyzed SiC grains showed strong depletions in Mg and Fe normalized to Si and CI as well as smaller depletions in B, S, K, Ca, Cr, and Mn. Li, Ti, and V are enriched. Among these elements we observed reasonably good correlations between Li, Na, Mg, K, Ca, Cr, Mn, and to a lesser extend, Al and Fe. Ti and V showed a good correlation as reported from similar SiC grains [10]. For B, C, O, F, S, and Cl no correlation was obvious.

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Conclusions. We have demonstrated the abilities of TOF–SIMS for the analysis of interstellar SiC grains. The main advantage compared to classical ion microprobe techniques is the low sample destruction. During our measurements only a few monolayers were consumed and there is still enough material for subsequent analyses with other techniques. With TOF-SIMS we measured C isotopes with sufficient accuracy at least for samples which are enriched in ^{13}C. Besides this, the determination of several major, minor, and trace elements was possible.

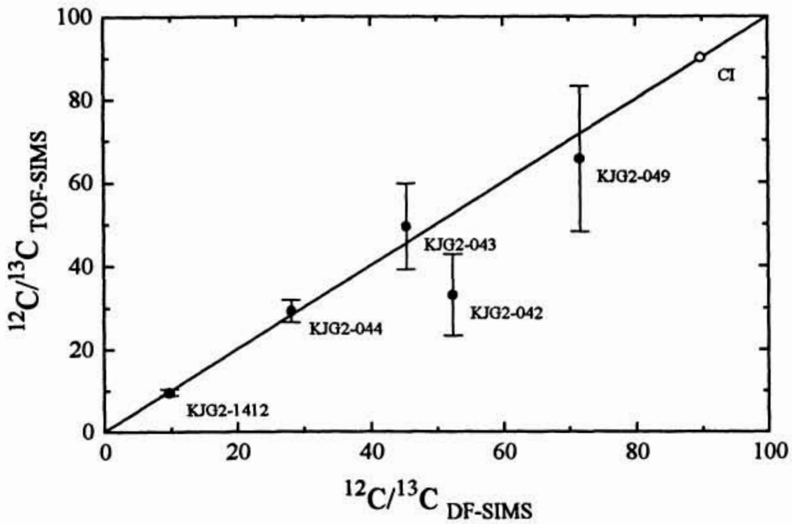

Fig. 1: Comparison of $^{12}C/^{13}C$ ratios determined by DF–SIMS [1] and TOF–SIMS.

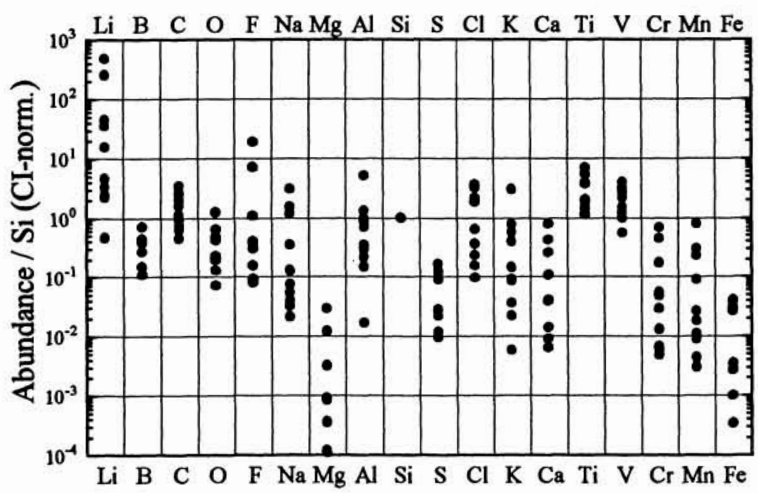

Fig. 2: Element ratios normalized to Si and CI chondrites of ten individual SiC grains measured by TOF–SIMS. C, O, F, S, and Cl were measured as negative secondary ions whereas all other element ratios were obtained from positive secondary ion spectra.

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