Fe ISOTOPIC COMPOSITION OF PRESOLAR SiC GRAINS.

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Introduction: Iron is mainly produced during explosive nucleosynthesis and is the seed for the s-process during the evolution of stars. Due to low concentration of Fe in presolar silicon carbide grains and interference on ^{58}Fe (from ^{58}Ni), it has been difficult to measure Fe isotopes and to date only a few presolar SiC grains have been analysed [1, 2, 3]. Here we report Fe isotopic compositions (^{54}Fe, ^{56}Fe and ^{57}Fe) of thirty one mainstream and twenty supernova grains (type-X) from the Murchison meteorite.

Experimental: Two gold mounts with ~1400 SiC grains from the Murchison KJG separate [4] were analyzed in the ims-3f ion probe to look for X grains (excess in ^{28}Si/^{30}Si) by low mass resolution isotopic imaging. The NanoSIMS was used to further confirm candidates as X grains by their characteristic C, N and Si isotopic compositions [5]. Fe isotopic measurements were made subsequently in combined mode (peak jumping and multicollection) using an O^- primary beam. Two different series of Fe measurements were made; the first series did not include ^{59}Co.

Expectations: Asymptotic gaint branch (AGB) stars, the parent stars of mainstream grains, do not produce Fe but the intial Fe is modified by the s-process. ^{54}Fe, which is a p-process isotope, is s-processed to ^{56}Fe, which in turn contributes to ^{57}Fe and ^{58}Fe [6]. Grains forming around AGB stars (≤3 $M_\odot$ and solar metallicity) are expected to have excesses in ^{57}Fe (~50-140‰) and ^{58}Fe (400-1000‰) [6]. Unfortunately, it is impossible to resolve ^{58}Ni from ^{58}Fe using any ion probe. Hence, in the present work we are considering only ^{54}Fe/^{56}Fe and ^{57}Fe/^{56}Fe ratios.

The main source of Fe are supernova explosions and production in Type II supernovae takes place in the inner core region. Understanding the incorporation of Fe isotopes into SiC grains might give a basic idea about the compositions of different SN zones. Though supernova grains are expected to have varying Fe isotopic composition depending on which SN zones contributed to a given grain, one still expects to see high enrichments in ^{57}Fe and ^{58}Fe, mainly in the region where a n-burst takes place.

Results: Supernova grains have a number of subgrains as seen from the variation in secondary ion signals from some isotopes during NanoSIMS analysis. Apart from Cr-rich subgrains, we found large numbers of Fe-Ni-Co-rich subgrains in several X grains.

δ^{54}Fe values for mainstream grains are close to solar within the errors (Fig. 1). In contrast, δ^{57}Fe varies from –297 to +130 ‰. Four grains have negative δ^{57}Fe, the others lie close to the solar value. 9 X grains out of 20 show clear enrichment in ^{57}Fe (190 to 890 ‰) and 3 of them show depletions (-380 to -220 ‰).

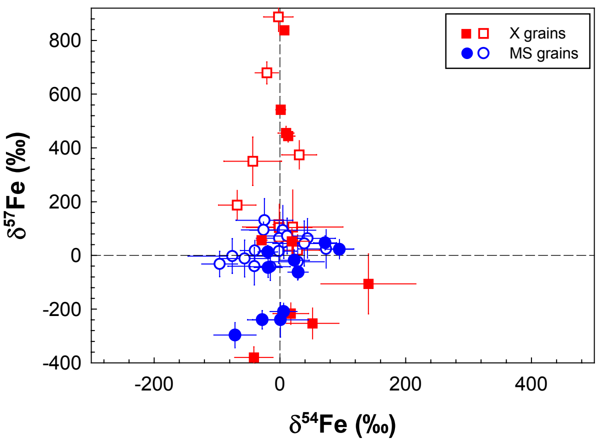

Figure 1. Three-isotope plot for the Fe isotopic compositions of presolar SiC grains from Murchison. Filled symbols are for grains with mesurement conditions which included ^{59}Co. Errors shown are 1 sigma.

Discussion: ^{57}Fe enrichments predicted from model calculations for mainstream grains cannot be detected in the present work, probably due to large errors.

Supernova grains receive contributions from various SN zones. To deconvolve the measured compositions into contributions from each zone is a difficult puzzle. There are many possibilities to explain the anomalies obtained in the present study.

Out of 8 different SN zones, the Ni-zone contributes the most Fe. As discussed by [7], this innermost zone has enhanced ^{54}Fe with respect to ^{57}Fe and ^{58}Fe (Fig. 2), which, however, is not seen in any of the X grains measured. Although mixing of this zone with other zones can result in a huge range of Fe isotopic compositions that can be incorporated into SiC grains, it is difficult to obtain solar ^{54}Fe/^{56}Fe while having enrichments in ^{57}Fe.

Anomalies in trace elements such as Mo and Zr have been explained with the n-burst model. The n-burst region is predicted to have δ^{54}Fe~ -860‰ and δ^{57}Fe ~ 5100‰ (for a 25 $M_\odot$ supernova) [9]. Mixing of this region with the outer SN zones might be a way to explain the results obtained on some of the X grains.

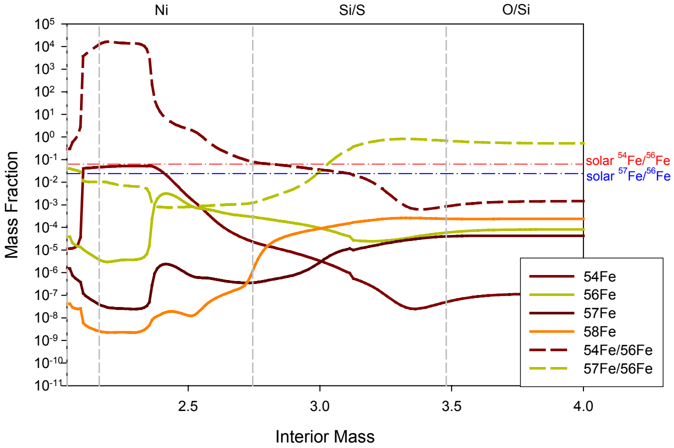

Figure 2. Spaghetti plot of Fe isotopes in the inner zones of a 25 M⊙ supernova [8].

Ion implantation calculations [6] can reproduce the experimental results very closely. For example, a grain with 100 ppm Fe according to [6] has δ^{57}Fe/^{56}Fe ~ 1500 ‰, δ^{54}Fe/^{56}Fe ~ 0 (or slightly negative).

However, only 40-100 nm close to the surface have been implanted with ions (velocity 500km/s) [6] and, moreover, the NanoSIMS analysis does not show any decrease of the anomaly with time for any of the

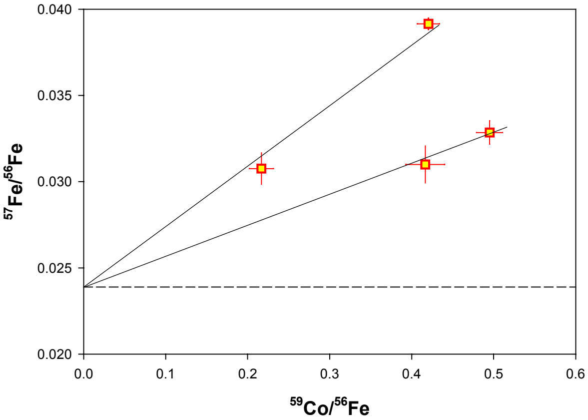

Figure 3. ^{57}Fe/^{56}Fe vs. ^{59}Co/^{56}Fe ratios in SiC X grains. The dashed line indicates solar ^{57}Fe/^{56}Fe.

A fourth possibility, which seems most likely, is the incorporation of the radioisotope ^{57}Co into the forming SiC grains. ^{57}Co decays to ^{57}Fe with a half life of 272 days. This possibility looks promising for two reasons: (1) The half life is similar to that of ^{49}V (330 days) and *in situ* decay of ^{49}V in SiC has been proven by [8]. (2) All 9 X grains with excesses in ^{57}Fe have Fe-Ni-Co- rich subgrains. However, it is very difficult to determine if the ^{57}Fe excess is correlated with subgrains due to their small size (~ 200 nm or smaller).

Definitive evidence of live ^{57}Co incorporation in SiC grains would be a positive correlation of ^{57}Fe/^{56}Fe with ^{59}Co/^{56}Fe. 11 X grains were measured for ^{59}Co in the second measurement series along with Fe isotopes, and 4 out of 11 show enrichments in ^{57}Fe. Figure 3 shows two limiting "isochrons" for these 4 X grains.

^{57}Fe enrichments could result from a combination of s-process enhancement and from the decay of ^{57}Co. In figure 3, it is difficult to distinguish between the two. If the ^{57}Fe excess is radiogenic, two limiting inferred ^{57}Co/^{59}Co ratios are 0.036 and 0.018

Figure 4 shows the variation in ^{57}Co/^{59}Co expected for different zones of a 25 M⊙ supernova immediately after the explosion [9]. As can be seen, a single correlation line cannot be expected for X grains forming at different intervals and receiving different SN mix. Moreover, the analyzed X grains could originate from different supernovae.

More X grains need to be measured in order to confirm a correlation between ^{57}Fe/^{56}Fe and ^{59}Co/^{56}Fe and the *in situ* decay of the radioisotope ^{57}Co.

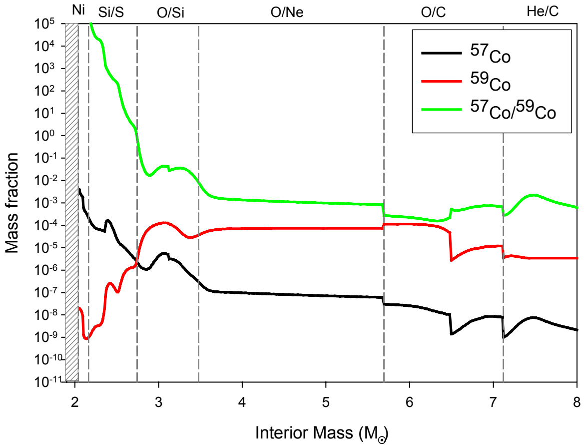

Figure 4. Variations in the abundace of cobalt isotopes immediately after the explosion of a 25 M⊙ supernova.

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