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Zr AND Mo ISOTOPIC CONSTRAINTS ON THE ORIGINS OF UNUSUAL TYPES OF PRESOLAR SiC GRAINS*

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DISCLAIMER

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Introduction: Although most presolar silicon carbide grains form in asymptotic giant branch red giant stars (the so-called mainstream grains) or supernovae (the X-grains), there are a number of other minor types of grains whose origin is less clear. The dominant mechanisms of heavy element nucleosynthesis, the *s*-process and *r*-process, are thought to occur mainly in AGB stars and supernovae, respectively [1], and the isotopic patterns in heavy elements in presolar grains can be used to constrain their origins. We have previously reported that mainstream SiC grains have strong enrichments in the *s*-process isotopes of Sr, Zr and Mo [2–5] and that X-grains have an unusual Mo isotopic composition that differs from *s*- and *r*-process expectations [6,7]. We report here the first measurements of Zr and Mo isotopes in several grains of other rare types that were found in the same mount as the mainstream and X-grains reported previously.

Experimental methods: Approximately 1400 grains of Murchison SiC grain size separate KJG [8] were dispersed onto a soft gold mount. A search for X-grains was made by ion imaging [9] with the Washington University ion microprobe. In addition to the X-grains, three B-grains, one Z-grain and a unique ^{29}Si, ^{30}Si-rich grain were identified [10]. The isotopic compositions of Si, C and N were measured by ion microprobe in these grains (Table 1). The isotopic compositions of Zr and Mo in a number of grains were measured by laser ablation laser resonant ionization mass spectrometry using the CHARISMA instrument at Argonne National Laboratory. The analytical methods were similar to those used previously [3].

Table 1. C, N and Si isotopes in unusual SiC grains in CHRL108.

Grain	Type	^{12}C/^{13}C	^{14}N/^{15}N	δ^{29}Si	δ^{30}Si
61-2	B	4.4±0.0	308±20	156±6	100±11
289-1	B	3.5±0.0	423±58	−9±11	4±14
342-1	B	9.0±0.1	1364±175	62±11	23±12
170-1	Z	76.2±1.6	2431±426	-125±13	363±20
146-1	unique	844±34	213±21	2678±21	3287±43

B-grains: We measured Mo isotopes in three B-grains and Zr in two of them (Fig. 1). All three B-grains have Mo isotopic compositions near normal, but the two Zr patterns show large ^{96}Zr excesses. In a study of B-grains reported at this conference, Amari et al. [11] pointed out that J stars, a likely source of the grains, do not have excesses in *s*-process elements in their stellar envelopes. The lack of an *s*-process Mo signature is consistent with this origin, but the Zr signature is puzzling. The origin of ^{96}Zr-enriched isotopic patterns is not clear. ^{96}Zr excesses are to be expected from the *r*-process, but they can also be produced in the *s*-process if the neutron density is high enough to drive through the *s*-process branch at ^{95}Zr ($T_{1/2}$ = 65 d). In addition, our parallel studies on Zr and Mo isotopes in X-grains [6,7,12] have shown unusual Mo isotopic patterns that are not due to the *s*- or *r*-processes and are accompanied by ^{96}Zr excesses. These X-grain Mo and Zr patterns most likely result from the neutron burst that occurs as a result of a Type II supernovae explosion. It is clear, however, that the B-grains do not have a normal s-process Zr isotopic signature, which is characterized by ^{96}Zr depletions [2].

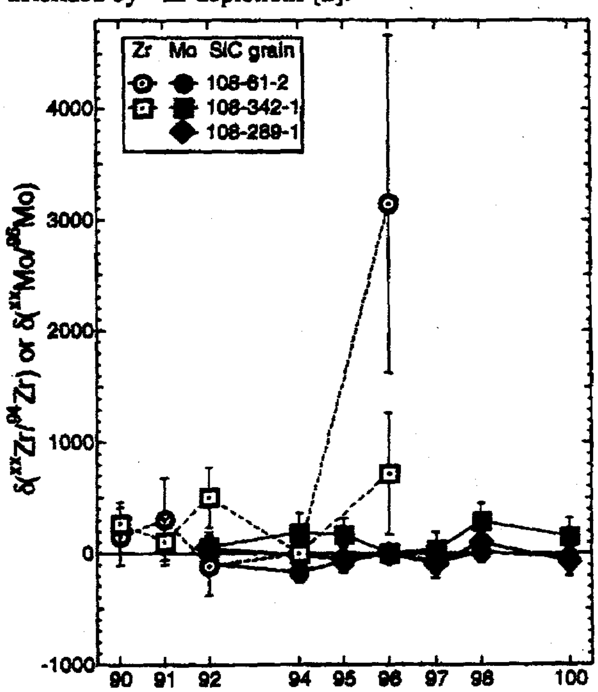

Fig. 1. Zr and Mo isotopes in Type B presolar SiC grains. Uncertainties are ±2σ.

Z-grain: We identified one Type Z grain during our search of the CHRL108 mount and have analyzed it for Mo isotopes. Type Z grains have large excesses of $^{30}Si/^{28}Si$, but not $^{29}Si/^{28}Si$, relative to the solar system and Hoppe et al. [13] have suggested that these grains formed in low-mass, low-metallicity AGB stars that experienced strong cool-bottom burning. Such stars are expected to have an *s*-process signature in their envelopes and the Mo isotopic composition of our single Z-grain (Fig. 2) is consistent with this idea. The Z-grain has Mo isotope pattern that looks very much like those mainstream grains with a large *s*-process component. In mainstream grains, $\delta^{92}Mo$, $\delta^{94}Mo$ and $\delta^{100}Mo$ are all the same, whereas in the Z-grain, $\delta^{100}Mo$ is somewhat lower than $\delta^{92}Mo$ and $\delta^{92}Mo$. This suggests that the grain may have come from a star with a different ratio of *r*- to *p*-process isotopes.

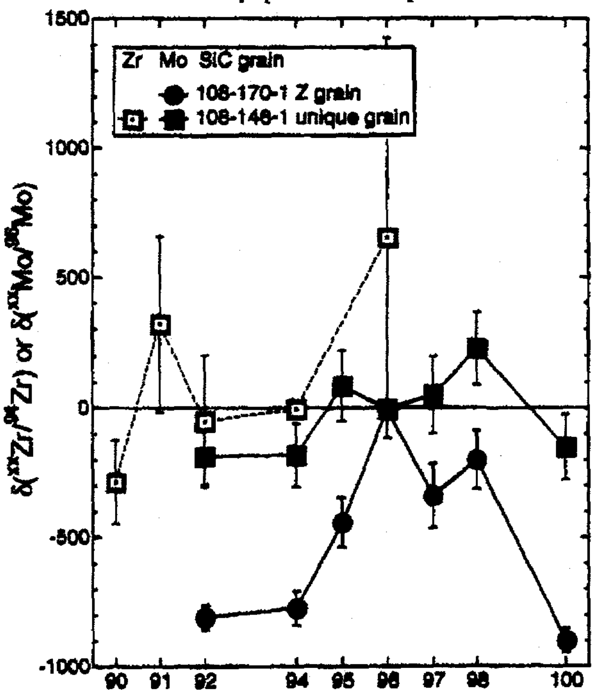

Fig. 2. Zr and Mo isotopes in a Type Z and a unique presolar SiC grain. Uncertainties are ±2σ.

Unique grain: During our search of the CHRL108 mount, one grain of a type not seen before was found [10]. This grain had spectacular $^{29}Si/^{28}Si$ and $^{30}Si/^{28}Si$ ratio, 3.7 and 4.3 times solar, and isotopically light $^{12}C/^{13}C$ and slightly heavy $^{14}N/^{15}N$ ratios (Table 1). An origin in a Type II supernova or a Wolf-Rayet star was suggested [10]. The count rates for Zr and Mo in this grain were quite low, so for many isotopes ratios are solar within error. The only significant anomalies found were depletions in $^{90}Zr/^{94}Zr$, $^{92}Mo/^{96}Mo$, $^{94}Mo/^{96}Mo$ and $^{100}Mo/^{96}Mo$ and an enrichment in $^{98}Mo/^{96}Mo$. The Mo isotopic pattern bears some resemblance to an s-process pattern in that it has negative $\delta^{92}Mo$, $\delta^{94}Mo$ and $\delta^{100}Mo$, but differs in that $\delta^{95}Mo$, $\delta^{97}Mo$ and $\delta^{98}Mo$ are normal or slightly positive. The fact that the Zr and Mo isotopic patterns of the unique grain do not match those seen in X-grains suggests that the unique grain may not have a supernova origin. A Wolf-Rayet star was suggested as a source for the grain, because neutron capture in these stars can produce large enrichments in ^{29}Si and ^{30}Si. In fact this process is so effective that mixing with isotopically more normal material, perhaps in a binary system, was invoked to explain the silicon isotopic composition of the grain [10]. The lack of a significant neutron capture signature in the Zr and Mo isotopic patterns is therefore curious, unless the levels of Zr and Mo from the isotopically normal companion overwhelm the anomalies produced in the Wolf-Rayet star.

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