TRANSMISSION ELECTRON MICROSCOPY OF NON-ETCHED PRESOLAR SILICON CARBIDE.
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Introduction: Our solar system formed from nuclei produced in earlier generations of stars. Mixing in the proto-solar nebula isotopically homogenized most of this material, but some grains, called presolar grains, retain their original isotopic composition. The isotopic properties of presolar SiC grains indicate that most of the grains formed in the outflows of carbon-rich Asymptotic Giant Branch (AGB) stars [1,2]. The microstructure of these presolar grains reflects the conditions of the dust formation and subsequent alteration. Early microstructural studies of SiC grains obtained by acid dissolution from meteorites show that most isotopically anomalous SiC grains have the face-centered cubic β-SiC structure [3-6]. However, Daulton *et al.* [7] have shown that a small fraction of sub-micron presolar SiC grains are of the hexagonal 2H polytype (α-SiC). Although the harsh chemical treatments of these grains does not alter their crystal structure, significant alteration of the surface morphology of the grains due to the acid treatments has been observed [8]. In addition, the acid treatments may preferentially remove cracked or fissured grains, and possible sub-grains, such as graphite. By studying SiC grains isolated by physical separation and found *in situ*, we attempt to obtain a more complete analysis of presolar SiC microstructures, including the surface morphology, in order to address the formation and processing history of the grains. In our prior work, we reported on one *in situ* SiC grain (hereafter CBIS1) [9]. Here we present results from two additional grains, one *in situ*, and one prepared as a physical separate.

Experimental: The *in situ* grain (hereafter CBIS2) was identified in a polished section of the CM2 meteorite Cold Bokkeveld by x-ray mapping with a JEOL JXA-8900 electron microprobe, following the process outlined in [9]. The physical separate grain (hereafter MPS1) was prepared by crushing and ultrasonicating a piece of Murchison, then dispersing the residue on a graphite planchette, where the grain was identified as SiC by x-ray mapping [8]. In order to preserve the grains for TEM analysis, they were not subjected to isotopic analysis in the ion probe and we thus do not have unambiguous proof of their presolar origins. However, the TEM results discussed below are consistent with previous observations of isotopically anomalous SiC grains. Furthermore, SiC grinding powders, which could present a source of contamination, were not used in preparing either the Cold Bokkeveld or Murchison samples. We prepared ultra-thin sections of the grains for TEM using a focused ion beam workstation (FIB) lift-out technique adapted to *in situ* [9] and free-standing grains [10]. TEM studies were carried out using a JEOL 2010F equipped with a NORAN Vantage EDS system.

Results and Discussion: The morphologies of the two grains (Figs. 1 and 2) are different from each other, and that of the previously reported *in situ* grain CBIS1 [9]. The physical separate MPS1 is round, with an average diameter of 0.9 μm (Fig. 1). Concentric layering of dark and light bands at the edge of the grain indicate a rim structure with compositionally segregated layers. The rim is a finely-grained nanocrystalline or amorphous silicate phase, ranging in thickness from 15 to 50 nm. The diagonal lines running from bottom left to top right are characteristic of stacking faults commonly seen in β-SiC. Unfortunately, the sample support film failed and the section was lost before the crystal structure could be confirmed by diffraction.

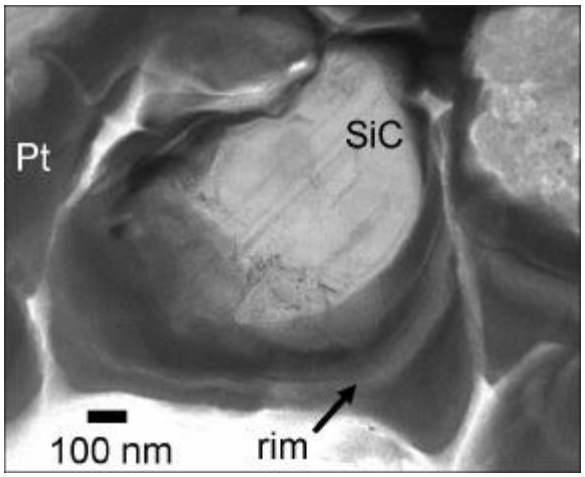

Figure 1. Transmission electron micrograph of a presolar SiC grain from a Murchison physical separate. The Pt is due to the FIB preparation.

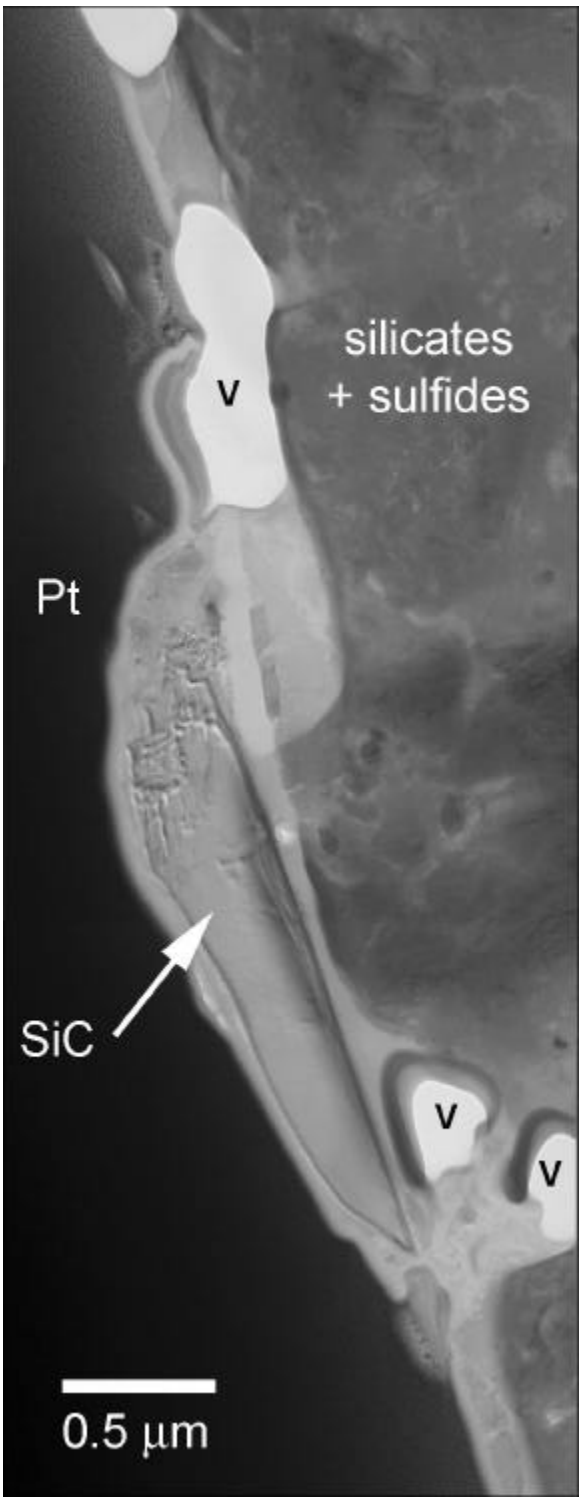

Figure 2. Transmission electron micrograph of an *in situ* SiC grain from Cold Bokkeveld. The top surface of the meteorite section is on the left. The label Pt refers to the protective platinum coating deposited in the FIB; V indicates voids. The dark edges at the boundary of the SiC grain are function of focusing conditions, and not indicative of a rim.

The morphology of CBIS2 (Fig. 2) is flake-like, with dimensions of 2 μm by 300 nm. The crystal structure of the grain was confirmed by electron diffraction to be cubic β-SiC. The bulk of the grain appears to be free of defects, such as stacking faults, except for the top end, which appears to be fractured. The grain is surrounded by fine-grained (< 10 nm) nanocrystalline or amorphous silicates. Because the composition of the surrounding materials varies as function of position around the SiC, and there is no layering, we believe this material is not a pre-accretionary rim, but rather matrix material of the host meteorite.

In comparison with CBIS1, both of these grains appear more well-ordered, with fewer defects, and no sub-grains. The lack of graphite sub-grains confirms that the previously reported graphite sub-grains in CBIS1 were not an artifact of the FIB sample preparation. The rim on MPS1 is consistent with prior SEM observations suggesting a thin silicate rim on some physical separate grains [8]. It also provides a possible protective mechanism for the survival of the grain during exposure to hot nebular gases in the proto-solar environment, as discussed by [11]. Further work to determine the distribution of SiC morphologies of non-acid exposed grains, and to correlate these morphologies with isotope data is planned.

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