INVESTIGATING MICROMETEORITE MATERIAL RETENTION ON GENESIS MO-PT FOILS.
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Introduction: In 2001, NASA's Genesis mission set out to collect the solar wind (SW) by exposing ultra-pure collectors to the SW for ~2.4 years and return it to Earth for elemental and isotopic analysis [1]. One of the goals of the mission was to analyze the flux of radionuclides (^{10}Be, ^{26}Al, ^{53}Mn) in the SW by exposing ~8000 cm^2 of a Mo-coated Pt foil (~48 µm thick) to the SW in efforts to quantify convective processes in the heliosphere. The abundances of ^{10}Be and ^{26}Al in the SW are quite uncertain, but analyses of excess ^{10}Be in surficial lunar soils [2] suggest the fluence of SW radionuclides is on the order of a few 100 atoms/cm^2.

Prior to the launch of Genesis, we expected that micrometeorite (MM) impacts may pose a problem for the SW radionuclide analysis. Using a terrestrial MM accretion rate [3], we calculated the total MM fluence across the entire Mo-Pt foils could be up to ~150 µg, or ~19 ng/cm^2. The concentrations of radionuclides in MM vary from 10^9 to 10^{10} at/g for ^{10}Be and 10^{10} to 10^{11} at/g for ^{26}Al, as shown in previous studies on cosmic spherules from Antarctic ice and deep sea sediments [4]. In the worst-case scenario, the contributions of cosmogenic radionuclides from MM impacts are comparable to or exceed those in the SW. Therefore, removal of MM contamination prior to dissolution of the Mo layer may be required in order to measure the concentration of SW derived radionuclides in the Mo-Pt foils. Due to the crash of the Genesis Sample Return Capsule upon return to Earth, the Mo-Pt foils were heavily damaged and contaminated with Utah dirt and spacecraft materials. Since Utah dirt contains high concentrations of ^{10}Be and ^{36}Cl, removing this contaminant became the first priority, while the search for MM contamination took a backseat. Now that promising cleaning methods have been developed to remove this dirt contamination [5], the search for MM became our next priority.

Our work sought to constrain how much MM contamination is on the foils to determine whether this would pose a threat to the SW radionuclide analysis. In order to address this concern, we identified MM craters on a large area of the Mo-Pt foils and measured the crater diameters to determine the MM flux and size-frequency distribution (SFD). We then searched for MM material in or near these craters to determine how much MM material was actually deposited onto the foil.

Methods: Prior to searching for MM's, the circular center foil #50053 was cut into 16 pieces of up to 20 x 20 cm to fit in the custom-built chamber of the Tescan Vega 3 SEM at UC Berkeley's Space Sciences Lab. These foils were carefully stretched out [5] and scanned in the BSE mode with a resolution of ~4 µm/pixel, yielding ~200,000 BSE images of 2x2 mm each.

Crater Identification: During the past ~5 years, many of these BSE images were visually checked for MM impacts. In the first round, hundreds of features were flagged as potential craters. These features ranged in size from 20-120 µm. Craters were separated into 2 categories: highly probable impact craters and potential craters. Highly probable craters were larger features that exhibited clear evidence of a hypervelocity impact, even at low-resolution (bright rim of Pt substrate, nearly circular cavity, Fig. 1a). Generally, crater diameters that were equal to or exceeded 80 µm automatically fell into this category, because this was the approximate threshold at which impacts physically punched through the Pt-backing and left a clear cavity. Craters with diameters of 40-80 µm were often easy to identify, as they showed a clear depression in the Pt substrate, as well as a raised rim. Some of the smaller craters (<40 µm) were more difficult to identify, as other features appeared to have the characteristics of a hypervelocity impact, but upon higher resolution SEM imaging (Fig. 1b) or a quick EDS analysis turned out to be a circular artifact or dirt/spacecraft contamination. Crater diameters reported in this work represent the average of two perpendicular measurements from rim to rim.

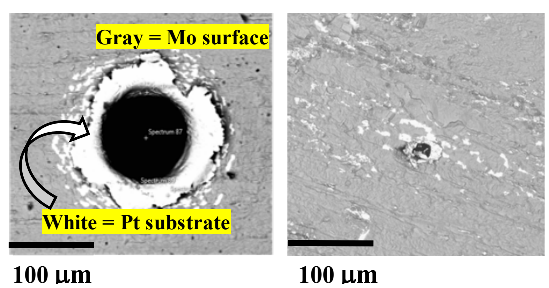

Fig. 1a (left) and 1b (right): Features that were flagged as potential micrometeorite impacts during crater identification step. Upon further imaging, 1b was characterized as contamination.

Crater punch-outs: We physically removed the most compelling features from the foils using a 1-3 mm punch-out tool. Once a feature was punched out, it was mounted onto carbon tape for SEM-EDS analysis. This work focused on foil #50053,0302 (~256 cm^2) where we punched out 14 features, of which 6 were confirmed as MM craters.

Automated Particle Analysis: To identify and measure the chemical composition of low-Z (i.e., Z<28) contaminants on the foil punchouts, we used Oxford Instruments Aztec Particle Analysis software [6]. The smallest particle the software could identify is ~2 µm. To distinguish chondritic particles from other contaminants, we used a Si content of 10-40 wt%, a Mg/Si ratio of ~1 and a Fe/Si ratio of >0.3.

Spot analysis. Since the automated particle analysis routine has difficulties identifying particles inside the crater, we also took 2-5 point spectra from each of the highly probable craters in this project (both inside the crater walls and around the rim) to search for chondritic material that may have been missed by Aztec.

Results and discussion. To date, we have searched a total area of ~3750 cm^2 (~50% of the entire Mo-Pt foil). Of the hundreds of features that were initially tagged as potential craters, only 22 were confirmed to be MM impact craters. Based on the diameter of these 22 craters, we first determined their SFD (Figure 2).

The SFD of MM craters on the Mo-Pt foils shows that the flux of small MM is 15x lower than on the long duration exposure facility (LDEF) [4]. Although LDEF was placed in a low-Earth orbit, studies on Genesis Aluminium foils suggest gravitational focusing should not significantly affect the SFD we observe on the Mo-Pt foils [7]. Based on the LDEF data, we also expected to find ~10 craters >250 µm, and at least 2-3 in the 500 µm range, but have not found any craters >120 µm so far. Based on the lower MM flux, we only expect 1 or 2 craters >200 µm on the remaining foil. This implies that the total flux of MM material that impacted the Mo-Pt foil is much lower than we expected. Based on the ratio of crater diameter/particle diameter of 4 for MM impacts [8], and a density of 2.5 g/cm^3 for chondritic MM [4], we estimate that a total of only ~150 ng of MM material has impacted the foils that we searched so far. This is a factor of ~400x less than we initially expected based on LDEF.

Both searches (by automated particle analysis and by selective spot analysis) for MM material near the 6 confirmed and the 8 rejected MM craters on foil 50053,0302 did not yield any particles with chondritic composition. Since the minimum particle size analyzed by Aztec is ~2 µm, corresponding to a mass of 5-10 pg for chondritic material, we conclude that for each MM impact <10 pg of MM material was deposited onto the foils. This corresponds to <6% of the impactor mass that produced the smallest crater (20 µm) to <0.03% of the impactor that produced the largest crater (120 µm). This percentage is much lower than the surviving mass that was found inside craters on the Stardust Aluminum foils that were produced by impacts of Wild2 cometary materials [9]. The absence of any significant MM material on the Genesis foils is an encouraging result for the planned SW radionuclide analysis.

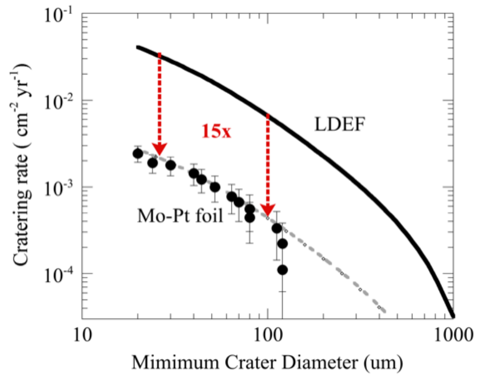

Fig. 2: Cratering rate on the Mo-Pt foils. Dashed curve represents fit through data from this work; rate is ~15x lower than on LDEF (solid curve) [4]

Conclusions: Based on an extensive search of MM impact craters on ~3750 cm^2 of the Mo-Pt foil, we conclude that the SFD of small craters on the Genesis foils is shifted to a 15x lower flux than the SFD on LDEF, and we did not find any of the expected impact craters larger than 120 µm. In addition, no significant MM material was detected inside or near any of the MM craters. These two observations imply that MM contamination on the Genesis foils presents little to no threat for the SW radionuclide analyses. We will continue to search the remaining foil area to verify that no larger MM impacts are present.

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