

CHONDRULE-LIKE MATERIAL IN WILD 2: A NEW INSIGHT FROM IMPACT EXPERIMENTS OF CHONDRULE FRAGMENTS ON STARDUST ANALOGUE AL FOIL. M. Van Ginneken¹ and P. J. Wozniakiewicz¹, ¹Centre for Astrophysics and Planetary Science, School of Physical Sciences, University of Kent, United Kingdom (m.van-ginneken@kent.ac.uk; p.j.wozniakiewicz@kent.ac.uk)

Introduction: NASA's Stardust mission was the first mission to bring back to Earth material from a celestial body, i.e. the Jupiter Family Comet (JFC) 81P/Wild 2 (hereafter Wild 2) [1]. Cometary dust was captured via impact into a collector that was deployed during a fly-by through the coma of Wild 2 at a relative speed of 6 km s⁻¹. The collector consisted of silica aerogel secured into a metal frame by aluminum 1100 foil (hereafter Al foil). A major result of the mission was the discovery that, contrary to expectations, Wild 2 was not predominantly composed of presolar grains and low temperature outer solar nebula material, but rather high temperature (>>1000 °C) material typical of primitive meteorites [1 - 3]. This suggests that the rocky part of Wild 2 is mostly made of high-temperature components that formed in the inner solar system before being transported outward to the comet-forming region. Most of the surviving supra- μ m particles studied exhibit high-temperature chondritic material, including Calcium-Aluminum Inclusions (CAIs) and chondrule fragments [4 - 13].

The iron content of silicates in chondrules is commonly used to determine the redox conditions in their environment of formation, and is represented as Mg# (mol% MgO/[MgO+FeO]) [14]. Wild 2 chondrule fragments exhibit an Mg# covering the whole range of values observed in primitive chondrites (i.e., petrologic type 2 or 3 carbonaceous and unequilibrated ordinary chondrites; e.g., [15]). A positive correlation between Mg# in olivine and $\Delta^{17}\text{O}$ values suggest an affinity of Wild 2 chondrule fragments with CR2 chondrites [16, 17]. However, Wild 2 particles exhibit mostly Fe-rich type II compositions (Mg# >10), whereas ~99% of chondrules in CR chondrites are type I [15, 18]. This would indicate that Wild 2 chondrules formed in an environment more oxidizing than chondrules of CR2 chondrites and may originate from a multitude of chondritic reservoirs. However, the number of chondrule fragments extracted from aerogel and analyzed so far is limited, preventing a clear comparison to the whole population of chondrules in Wild 2.

An interesting alternative to the study of particles from the aerogel is the study of microscopic crater resulting from the impact of Wild 2 dust on Al foil. Experiments using a Light Gas Gun (LGG) at the University of Kent, U.K., to simulate Stardust craters by impacting silicates minerals on Al foil at normal incident and 6.1 km s⁻¹ velocity, have shown that the

shape of craters depends mainly on the physical properties of the impactor [19]. Solid grains or dense consolidated aggregates similar to chondrule fragments will result in bowl-shaped craters, the depth of which depending on the density of the material, whereas loose aggregates of submicron particles result in complex features. Simulation of Stardust impacts using silicate grains have shown that about 50% of silicate dominated impactors are retained as residue, which can be analysed and provide precious chemical information [20].

Studies of residues in a small ($\phi < 10 \mu\text{m}$) or large ($\phi > 10 \mu\text{m}$) craters on Stardust foil have shown that these can give information on the bulk chemistry of the original particle, which is a critical parameter to identify the impacting material [21]. For instance, ferromagnesian compositions typical of chondrules can be recognized with confidence with EDX surveys. In some instances, presence of relict crystals have been interpreted as unmelted crystalline material rather than recrystallization products after total melting of the impactor [22]. Relict minerals can further constrain the nature of the original particle, assuming the minor element chemistry has not been severely affected. Furthermore, experimental works simulating the impact of a wide range of mineral samples at Stardust capture speed have shown that residues of anhydrous minerals can be confidently identified using conventional analytical techniques [23 - 25]. However, experimental works using poly-mineral samples are lacking. Both the study of the morphology and residues of such craters would provide a means to identify craters resulting from the impact of chondrule fragments. Being able to efficiently identify such craters and characterize the pre-impact chondrule mineralogy and chemistry may allow for future statistical studies and, as a result, to draw a comprehensive picture of the chondrule population in Wild 2.

Here we will present preliminary data of a study of craters and residues resulting from the impact of fragments of different types of chondrules on Stardust analogue foils. We aim to determine whether the different chondrules produce craters and residues that may be distinguished from one another by chemical or morphological differences.

Method: Impact experiments were carried out at the Light Gas Gun facility at the University of Kent, U.K. Chondrules several hundreds of micrometres in size were extracted from the chondrites Allende (CV3), Karoonda (CK3), Chainpur (LL3) and NWA 801

(CR2). One chondrule of each meteorite was randomly selected and used for the experiments. After extraction, chondrules were fragmented in roughly two equal parts. One part was embedded in epoxy resin and characterized by SEM-EDX, determining their main textural, mineralogical and chemical properties. The other part was used in impact experiments, being crushed for further fragmentation to produce particles tens of micrometers to sub micrometer sizes, to simulate the grain-size of Wild 2 particles. Impact experiments were carried out at approximately 6 km s^{-1} . Al foil analogue targets were $4 \times 4 \text{ cm}$ in size. Resulting craters were investigated using a Hitachi S-4700 field-emission scanning electron microscope coupled with a Bruker XFlash annular EDX detector, allowing for precise chemical maps of residues lining the craters (Fig. 1).

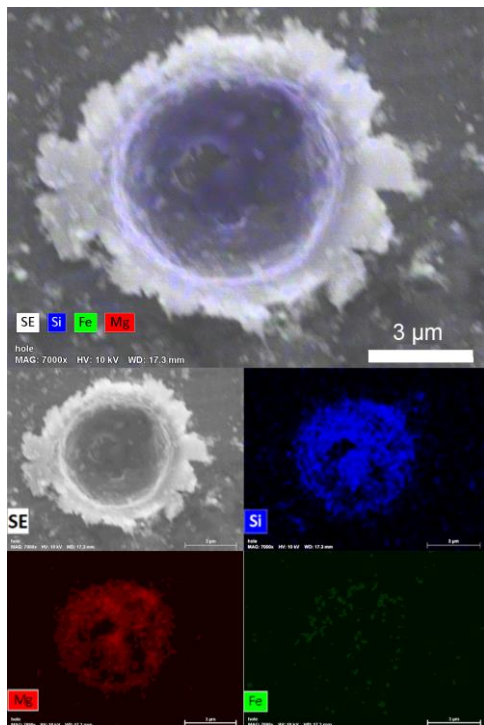


Fig. 1. Chemical map of a crater showing residue of chondrule material from chondrite Allende (CV3), along with individual Si, Mg and Fe maps.

Results: Impact experiments resulted in thousands of microscopic impact craters on each target. Crater size ranges from submicrometer to several tens of micrometers in diameter. The vast majority of craters are bowl-shaped and exhibit residues that contain apparent fragments of the impactor (Fig. 1). About 50 craters $\sim 1 \text{ µm}$ to $\sim 30 \text{ µm}$ were selected in each sample for chemical mapping. Obvious EDS peaks for Si and Mg are observed in most of the residues observed, along with detectable amount of Fe. Two occurrences of S-

rich residues were observed in craters from Karoonda and Allende, whereas two occurrences of Ca-rich residues are observed for Chainpur and NWA 801.

Discussion and conclusion: Preliminary observations show that impacts are consistent with previous observations that chondrule material prominently produces bowl-shaped craters, further constraining craters of interest on Stardust foil. The chemistry of the residues is mostly akin to Fe-poor silicate-like (i.e. Si, Mg-rich, with detectable Fe), consistent with type I POP chondrules that are prominently common in carbonaceous chondrites. Moderately refractory elements Mg and Fe are depleted in most residues, whereas refractory Ca is increased, consistent with high temperatures during impact.

Additional work will aim to fully characterize the residues. Future work also include analysis and comparison against craters and residues produced by synthetic aggregates simulating CP IDP-like impactors.

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