NASA/CR-97-
NASA-TM-112991

FINAL REPORT
NAG9-684

INTRODUCTION

This grant was awarded as part of an extended study of materials that had been exposed on the Long Duration Exposure Facility (LDEF). Originally scheduled for less than a year in orbit, the spacecraft actually remained in space for 69 months providing an unprecedented opportunity to study the meteoroid and orbital debris complex in near-earth orbit.

In addition, the LDEF materials were useful for testing technical concepts that needed to be validated for the Cosmic Dust Collector Facility (CDCF) – a large instrument that was under study for inclusion on the upcoming Space Station. As it turned out, CDCF, which was approved at one point as an external payload, was ultimately canceled due to the scaling back of the Space Station capabilities. However, the study of cosmic dust is still a field of great interest for NASA, being the crucial part of at least one experiment that is still being considered for a Discovery mission. The optimum analysis of hypervelocity impacts is thus a continuing NASA concern.

Two experiments, AO187-1 (F. Hörz, PI) and AO187-2 (E. Zinner, PI) were explicitly designed to measure the flux and composition of dust particles impacting LDEF. The former consisted of flat targets of Au and Al while the second comprised a set of 237 "capture cells" using Ge target plates covered by thin (2.5 μm) metallized plastic foils.

The spacecraft maintained a constant orientation with respect to its velocity vector thereby defining leading and trailing edges that faced respectively into and away from the direction of motion. Both AO187-1 and AO187-2 had detectors on both the leading and trailing edges of LDEF. It was expected that interplanetary dust particles would dominate impacts on the trailing edge while the leading edge would be exposed to both cosmic dust and particles of orbital man-made debris.

In AO187-1, the compositions of the impactors was determined by SEM-EDS techniques; in AO187-2 a sensitive surface analysis technique – SIMS – was used to determine both elemental and (some) isotopic compositions. In the initial analysis of AO187-2 [1,2], it was found that SIMS was more sensitive for the analysis of thin impact debris layers than SEM-EDS. The present grant was made to determine if SIMS analysis could also be applied to impacts recorded in the Au surfaces of AO187-1. Success would extend the analysis of AO187-1 and would also contribute important technical information for the design of future cosmic dust space missions.

The results obtained with this grant are incorporated in the attached paper presented at the Third LDEF Symposium [3] and are briefly summarized here. In addition, we comment on the potential implications of this work for future research.

DEVELOPMENT OF TECHNIQUES FOR SIMS ANALYSIS OF IMPACTS ON GOLD TARGETS

Although SIMS is more sensitive than SEM-EDS for surface deposits (and for multi-element measurements in general), it requires a flat surface to give meaningful results. Since the LDEF impacts produced deep craters with raised lips in the soft Au targets, it was not immediately clear if SIMS could be used. However, prior to the grant we had demonstrated a crater flattening technique that gave great promise. Basically, the Au substrate in the vicinity of an impact was pushed up from the back side of the target foil against a clean flat quartz plate. This resulted in a flattened area containing impact material that could then be studied by SIMS.

EXPERIMENTAL RESULTS

The results of the initial SEM-EDS analysis of AO187-1 by Hörz and co-workers were published in a special catalog [4]. Data were given for 199 impacts in a Au target from the trailing edge of LDEF. Sixty of these were classified as "natural," 5 of which were further classified as "chondritic," and 27 – a surprisingly large number – were classified as "man-made" (mostly Al-rich particles). However fully 112 impacts, or over half the total, gave no detectable SEM-EDS signals and could thus not be classified. These results differed from those found in SIMS analysis of trailing edge cells in AO187-2 where 75% of "extended impacts" were natural and no event clearly attributable to a man-made debris particle was found.

Fifteen Au samples containing impacts that had previously been studied by SEM-EDS were sent to us by F. Hörz to test the applicability of SIMS analysis. Eleven of the impactors had been identified as "natural," one as "man-made," and three were "unknown" having given insufficient signals for identification. Seven of these impacts were successfully "flattened" and studied by SIMS. The identification of the one impact that had been classified "man-made" by SEM-EDS was confirmed. One of two "unknowns" studied by us gave a large Al signal and could be confidently re-classified as "man-made." Of the four that had been classified as "natural," we confirmed the assignments for two but not for the two others which we found to be ambiguous.

It is clear that the SIMS analysis of flattened craters gives complementary information that is unattainable by SEM-EDS methods alone. We not only obtained signals when none were found by the x-ray method alone, we also obtained a wealth of new elemental data. This is shown clearly in Figs. 7 and 8 of Reference 3, where we use SIMS data to compare element abundances in the impactors with those previously measured in interplanetary dust particles for a total of *twenty-four different elements*..

As also shown in detail in Reference 3, we were able to obtain the first high precision isotopic measurements of natural LDEF impactors using SIMS analysis of two of the flattened Au impacts.

COMMENTS ON POSSIBLE FUTURE WORK

Funding for the continued analysis of LDEF materials was cut off before all of the first order scientific information had been extracted. It is clear to us that it would be important to examine as many of the Au impacts as possible using the techniques that we demonstrated in this initial study. It would also be highly desirable to extend the techniques to other materials such as the flat Al plates that covered much of the LDEF surface. As it stands now, the flux of man-made particles that can reach the protected trailing edge surfaces is quite uncertain. None were found by us in AO187-2 but their presence in AO187-1 targets is confirmed by the work described here.

It is also important to preserve the LDEF materials so that they may be studied by future investigators using even more sophisticated analytic measurements. The impacts recorded in A0187-2 and AO187-1 that have already been partially studied by existing SIMS techniques *represent an extremely important scientific resource for future work.* In particular, some of these impacts may make it possible to measure the isotopic composition of cometary material. Dust particles from long-period comets encounter the earth with very high velocities and are thus preferentially destroyed relative to slower, asteroidal particles during atmospheric entry. Cometary particles may thus be grossly underrepresented in the stratospheric micrometeoroid collections. In contrast, LDEF impacts are produced by particles with the full range of velocities. Because of their potential scientific importance, continued care should be taken to store the relevant surfaces under clean conditions so they may be properly analyzed by future, improved analytical instruments.

REFERENCES

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