Recovery After Mishap—
Salvaging Genesis Solar Wind Sample Science

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The collectors returned by the Genesis mission contain solar wind atoms that can be analyzed in sophisticated laboratory instruments to measure, very precisely, the composition of the sun. Since the sun contains more than 99% of the mass in the solar system, knowing its elemental and isotopic composition is a good average measure of the composition of the solar nebula at the time when the planets were forming. Scientists already have rocks from the moon, Mars, and the asteroids and dust particles from comets. Genesis' solar data allow new insights into tracing the chemical evolution of diverse planetary samples, most of which came from a common starting material—the solar nebula. Separate collections were made of high-speed solar wind, coronal mass ejection solar wind, and interstream low-speed solar wind. Information from these different solar regimes adds to the understanding of solar physics (figure 1).

Genesis solar wind collectors are highly polished surfaces into which solar wind nuclei are implanted, typically 40 to 100 nanometers below the surface (figures 2 and 3).

The advantages of returning samples to the laboratory are many. State-of-the-art instrumentation can be used for analysis to very high precision, different techniques can

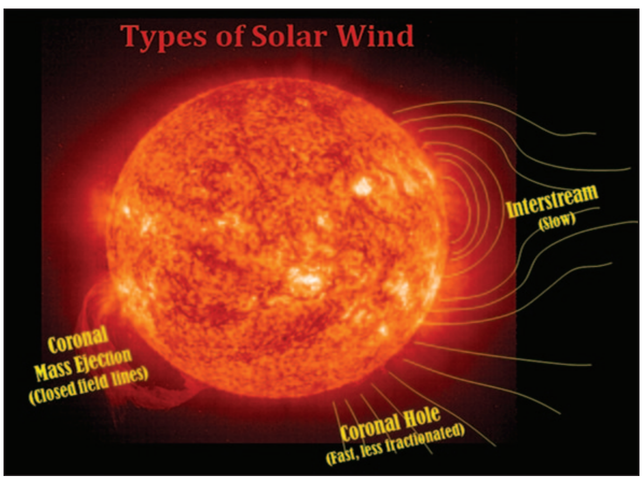

Fig. 1. *Genesis mission collected separately three regimes of the solar wind: interstream slow solar wind, coronal hole high-speed solar wind, and coronal mass ejection solar wind.*

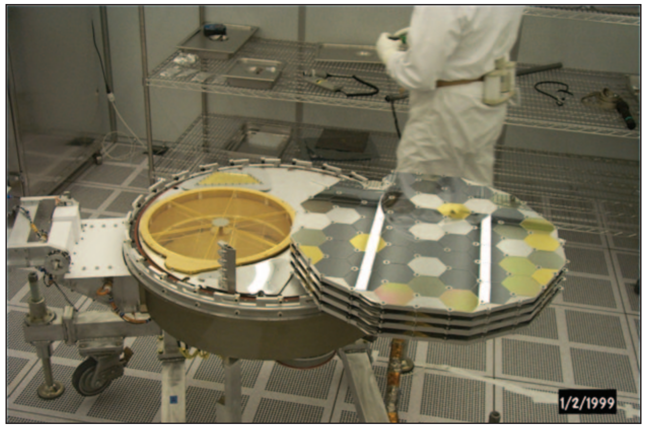

Fig. 2. *Hexagonal polished collectors of pure materials accumulated solar wind from three regimes over a 28-month period at the Earth-Sun L1 location.*

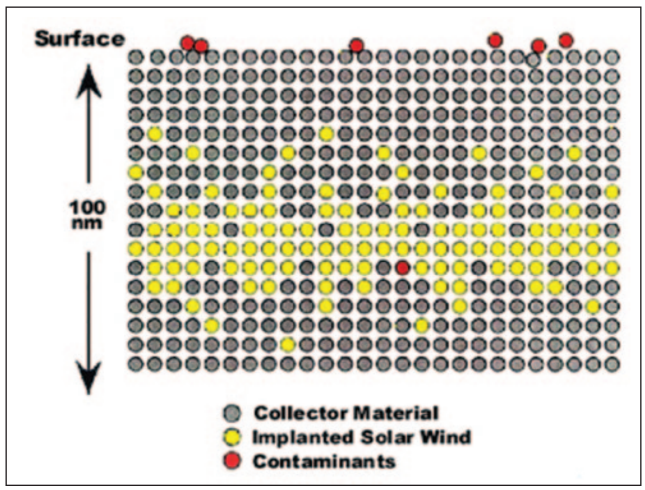

Fig. 3. *Solar wind nuclei are implanted just below the surface of the polished collectors.*

be used to verify the same measurement, multiple teams can confirm or dispute the results, and evolving science questions can be addressed through new types of analyses. To this list of advantages of returned samples, add one more: recovery from mishaps is greatly enhanced.

The Genesis mission was launched in August 2001, collected solar wind at the Earth-Sun L1 location for

28 months, and returned to Earth in September 2004. The parachute did not deploy, and the return capsule hit the ground at an estimated 300 kilometers per hour, which resulted in the collector canister breaking open and exposing the collectors to the environment. Many of the collectors were fragmented and contaminated with particulate debris and a molecular film.

Early Design Choices Proved Useful During Recovery

Because the analytical goals were challenging, the solar collectors were comprised of very pure, very clean materials, and assembled under International Organization for Standardization Class 4 conditions. Fifteen distinct materials were used for collectors, allowing overlap in analysis for specific elements on a variety of materials. Some materials survived the hard landing better than others. Sapphire-based collectors survived in larger pieces. Diamond surfaces were more resistant to scratching.

A variety of collector cleaning processes were tested to remove the contaminant particles and molecular film after return. Some collector materials proved more easily cleaned than others. Thus, the variety of collector materials not only provided an analytical redundancy, but also more options for cleaning the surface without disturbing the solar wind.

Flight-like collector reference materials were preserved. These specimens proved crucial as “blanks” for subtracting background components of measured parameters. These reference materials were also used in development of cleaning processes.

The thickness of the hexagonal solar collectors was unique for each solar wind regime: 700 micrometers (µm) for bulk solar wind, 650 µm for coronal mass ejection, 600 µm for high speed, and 550 µm for low speed. Since collectors were dislodged and fragmented on the hard landing, collector thickness is the only direct way to determine solar wind regime.

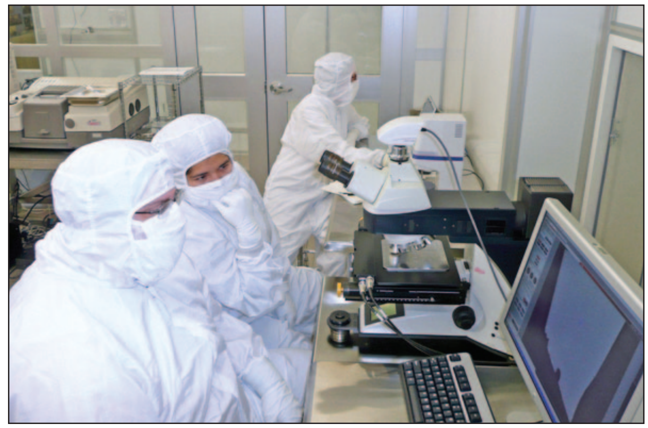

Fig. 4. *Recovered collector fragments are imaged and measured for the online catalog.*

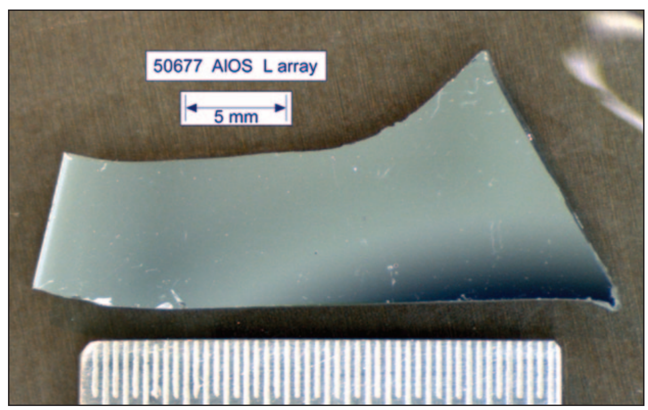

Fig. 5. *An example from the online catalog is this aluminum-on-sapphire sample.*

Characterization of Collector Fragments

Collector fragments can be easily identified by optical observation, except for silicon. The two types of silicon are crystals grown by different methods. They are distinguished by use of Fourier transform infrared spectroscopy to observe a carbon-oxygen bond, present only in silicon crystals grown by one method. A catalog of the collector fragments is available on the internet. The catalog contains an image, the material, the dimensions and

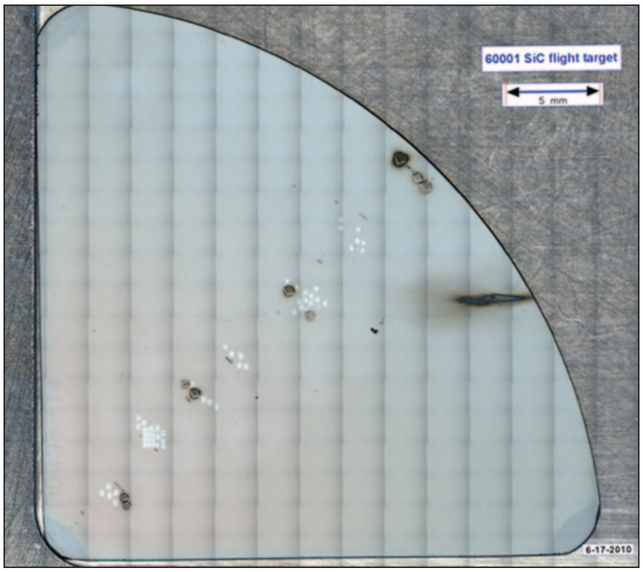

Fig. 6. *This mosaic image of a Genesis silicon carbide collector shows the effects of ion beam analyses by two science groups.*

area, the solar wind regime, and a qualitative assessment of surface condition (figures 4 and 5). Cataloging is an ongoing process with 1600 samples displayed as of 2011.

Cleaning of Collectors Fragments

Megasonically energized ultrapure water (UPW), which was successfully used to clean the payload prior to launch, was adapted to remove particulate contamination from solar wind collectors. The continuous flow process produces water of 18 megohm/centimeter resistivity (ionic concentrations in the low parts per trillion). A megasonic cleaning head was mounted to a single wafer spin processor to apply UPW cleaning to small, irregular collector fragments. In this configuration, a small collector fragment held by a vacuum chuck is spun up to 3000 rpm. Megasonically energized UPW is applied for 30 seconds to 15 minutes, depending on material. Extra spin time effectively dries the collector fragment. Particles greater than 5 µm are efficiently removed, leaving no solvent residue.

A commercial ultraviolet (UV) lamp device creates a UV ozone-cleaning atmosphere, which effectively removes the 5 nm film found on some collector fragments. Typical UV exposure times are 30 minutes.

Cleaning performed at Johnson Space Center (JSC) Genesis curation facility is first-order cleaning. Members of the science team have developed second-round cleaning with strong acids, such as hydrofluoric and aqua regia. JSC curation assists with documentation and logistics for this iterative process with the science community.

Science Results

Important science results are emerging from analysis of the Genesis solar wind samples. The science community is doing this challenging work on the 400 Genesis solar wind samples allocated for research purposes. Investigators have the capability to choose a measurement site on a given collector sample to avoid damaged areas and to make multiple analyses. Figure 6 shows a silicon carbide collector, which has been analyzed for two different elements by two different research groups. The number one and two science goals of determining the solar oxygen isotope and nitrogen isotope compositions have been published.