customer report

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WITec
focus innovations

Carnegie Institution Washington, Geophysical Laboratory
The Sky's the Limit – Analyzing Extraterrestrial Materials

Carnegie Institution of Washington
Geophysical Laboratory

Customer Profile

The Geophysical Laboratory of the Carnegie Institution of Washington is a private, nonprofit organization engaged in basic research and advanced education in the earth sciences. The Carnegie Institution of Washington was founded in 1902 by Andrew Carnegie "to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind". Since its inception in 1905, the Geophysical Laboratory has been one of the world's foremost laboratories in the science of petrology, and has remained at the forefront of high-pressure, high-temperature research and the investigation of extraterrestrial materials.

Initial Situation

Specializing in the analysis of precious extraterrestrial material, such as interstellar dust particles (IDPs) or meteorites, the Geophysical Laboratory often deals with very small sample volumes that must be investigated nondestructively. Even cometary particles collected from the comet Wild 2 by the NASA Stardust spacecraft during a close flyby will be analyzed after its return to earth in January 2006. Analysis of this celestial dust promises to yield novel clues to the evolution of our Solar System, the formation of our Sun, the planets and possibly even life itself. Therefore it is important to produce the best optical, chemical and physical analysis of that material with the widest possible variety of techniques. This is particularly challenging as these particles are often small (1–100 µm in diameter) and heterogeneous on sub-µm scales. It is important, though difficult, to resolve chemical and morphological heterogeneity of these particles on a micrometer scale. Hence, extremely sensitive analytical techniques with high spectral and/or spatial resolution are desirable for these studies.

Instrumentation

For this purpose, a non-destructive analytical microscopy system (WITec alpha SNOM upgraded with confocal Raman capabilities) has been integrated into the existing laboratory infrastructure. This system combines confocal transmission and reflection microscopy, scanning near-field optical microscopy, atomic force microscopy, confocal Raman spectroscopy and fluorescence microscopy. It can provide 3D information on sample structure and composition and allows direct measurements of small particles, using very little laser energy. Raman spectroscopy is an ideal tool for initial high-resolution optical and chemical characterization, from which mineralogical and structural information can be obtained, and the presence of organic substances can be determined.

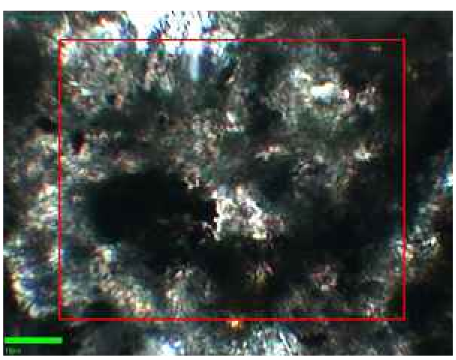
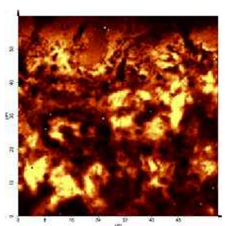


Fig. 1: Transmitted light image of chondrule from an Antarctic CV meteorite in a petrographic thin section. The chondrule rim is at the upper edge of the image and the red box outlines the Raman scan boundaries. Scale bar is 10 micrometers.



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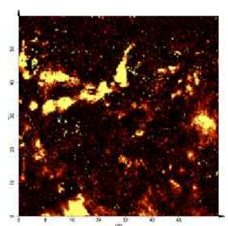

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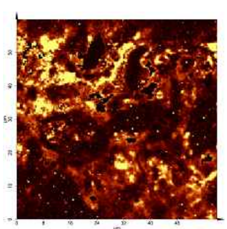

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Fig. 2 - 4: Images of olivine (Top left), pyroxene (top right), and carbon (bottom left) within the scan. Associations between silicates and carbon may provide a new understanding of chondrule formation mechanisms in the early Solar system.

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Typical Results

1. Chondrules (Fig. 1 - 4)
Chondrules are small silicate globules found in many meteorites that are some of the earliest solids to condense out of the solar nebula, even predating the formation of asteroids and planets. They are relics of processes that were at work in the earliest days of our solar system and can give us an understanding of not only planetary formation processes, but also the character of planets found around other stars. The WITec instrument is used here to analyze the silicate and carbon phase petrography of chondrules with high spatial and spectral resolution in work designed to furhter understanding of the formation mechanisms of chondrules.

2. Interplanetary dust particles (Fig. 5 - 7)
Interplanetary dust particles are small, fragile particles of extraterrestrial material that constantly fall to the Earth and are collected by high-flying aircraft equipped with oil-coated collector plates. Raman imaging provides mineral phase identification and crystalline structure measurements that can then be coupled with elemental and isotopic information from other techniques for a comprehensive characterization of these particles. Collecting both Stokes and anti-Stokes spectra concurrently allows the monitoring of the sample temperature to prevent damaging these small, fragile samples. This and other Raman techniques developed for IDPs will be applied to the cometary particles that will be returned by the STARDUST robotic probe.

Achieved Improvements

Since using the WITec high-resolution microscopy system, the Geophysical Laboratory has been able to chemically and structurally image samples nondestructively before the samples undergo additional analysis that often requires intrusive and/or destructive sample preparation. The obtained information on the inner chemical and mineralogical composition of extraterrestrial particles may be a key to a better understanding of the formation of our solar system.

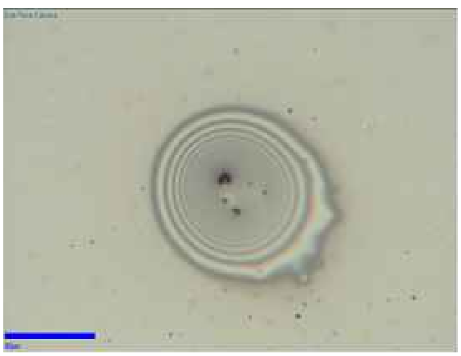

Fig. 5: Reflected light microscopy image of a cluster of IDPs in oil. Scale bar is 80 micrometers.

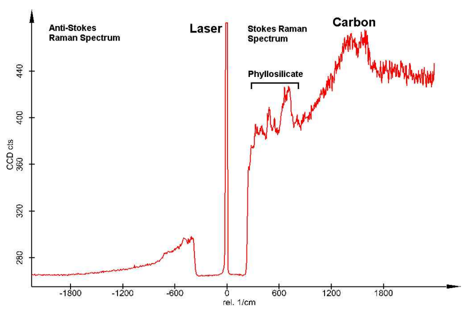

Fig. 6: Combined Stokes/anti-Stokes spectrum for monitoring particle temperature showing carbon and phyllosilicate phases in an IDP in the image to the left.

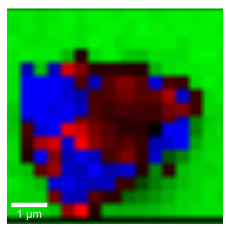

Fig. 7: RGB image of IDP – red is carbon, blue is phyllosilicate, and green is the glass substrate.

Fig. 1: Dr. Marc Fries, Research Associate, Carnegie Institution, Geophysical Laboratory

"The ability to non-destructively image the distribution of the mineralogical phases in an extraterrestrial particle reveals formerly unseen aspects in the formation of these prehistoric rocks."
Dr. Marc Fries, Research Associate, Carnegie Institution, Geophysical Laboratory