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Metamorphism of Cosmic Dust: Processing from Circumstellar Outflows to the Cometary Regolith

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Nucleation is a non-equilibrium process: the products of this process are seldom the most thermodynamically stable condensates but are instead those which form fastest. It should therefore not be surprising that grains formed in a circumstellar outflow will undergo some degree of metamorphism if they are annealed or are exposed to a chemically active reagent. Metamorphism of refractory particles continues in the interstellar medium (ISM) where the driving forces are sputtering by cosmic ray particles, annealing by high energy photons and grain destruction in supernova generated shocks. Studies of the depletion of the elements from the gas phase of the interstellar medium tell us that if grain destruction occurs with high efficiency in the ISM, then there must be some mechanism by which grains can be formed in the ISM. Various workers have shown that refractory mantles could form on refractory cores by radiation processing of organic ices. A similar process may operate to produce refractory inorganic mantles on grain cores which survived the supernova shocks. Most grains in a cloud which collapses to form a star will be destroyed; many of the surviving grains will be severely processed. Grains in the outermost regions of the nebula may survive relatively unchanged by thermal processing or hydration. It is these grains which we hope to find in comets. However, only those grains encased in ice at low temperature can be considered pristine since a considerable degree of hydrous alteration might occur in a cometary regolith if the comet enters the inner solar system.

Some discussion of the physical, chemical and isotopic properties of a refractory grain at each stage of its life cycle will be attempted based on the limited laboratory data available to date. Suggestions will be made concerning the types of experimental data which are needed in order to better understand the processing history of cosmic dust.

MICROANALYTICAL CHARACTERIZATION OF BIOGENIC COMPONENTS OF INTERPLANETARY DUST;* Filippo Radicati di Brozolo, G. P. Meeker and Ronald H. Fleming, CHARLES EVANS & ASSOCIATES, Redwood City, CA

The elemental, isotopic, textural, and molecular analysis of interplanetary dust particles (IDP) presents a unique opportunity for the study of the origin of prebiological organic molecules in the early solar system and perhaps even in the interstellar medium.[1] Programs are now under way to obtain pristine IDP from low earth orbits and from comet rendez-vous missions. The analysis of these pristine materials will require a new level of sophistication in sample handling, preparation and analysis. We report the early results of our study in the development of new microanalytical characterization techniques for the study of biogenic components in pristine interplanetary dust.

We have developed a procedure to embed small particles in a non-organic medium for the preparation of microtome cross sections. The particles are gold coated, embedded in indium and heated to form an indium-gold alloy. Cross sections of a small Murchison meteorite matrix particle have been obtained which show the particle to be totally surrounded by $AuIn_2$. This technique was developed using class 100 clean room conditions and can be applied without modification to IDP.

A secondary ion mass spectrometry (SIMS) study of IDP has also been successful. We have developed the ability to produce quantitative isotope ratio images of cross sections of IDP. We have demonstrated the technique by measuring inhomogeneous deuterium excesses in IDP with a lateral resolution of ~2 μm. The deuterium anomalies detected with this technique provide clear evidence for the extraterrestrial origin of the IDP particles analyzed.[2] The particles are preserved for further study by other analytical techniques such as TEM and laser ion mass spectrometry.

We have performed a systematic study of laser desorption and ionization for the analysis of selected model organic species and fragments of the Murchison meteorite using both single and double laser configurations of the Cambridge Mass Spectrometry LIMA 2A instrument. We have identified appropriate instrumental conditions (including several substrate materials) for the laser desorption/ionization analysis of organic species in extraterrestrial materials.

REFERENCES

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2. K. D. McKeegan, R. M. Walker, and E. Zinner, Geochim. Cosmochim. Acta, 49, 1971 (1985).

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