SIMULATION IN LABORATORY OF SOLID GRAINS PRESENT IN SPACE

L. COLANGELI[(1)], E. BUSSOLETTI[(2,3)] & V. MENNELLA[(3)]

(1) *Dipartimento Ingegneria Industriale, Università di Cassino, via Zamosch 43, 03043 Cassino, Italy*
(2) *Istituto Universitario Navale, via Acton 38, 80133 Napoli, Italy*
(3) *Osservatorio Astronomico di Capodimonte, via Moiariello 16, 80131 Napoli, Italy.*

ABSTRACT. Laboratory data on cosmic dust analogue materials are compared with recent results obtained by means of spectroscopy and mass spectrometry on cometary dust, meteorites and interplanetary dust. Their actual chemical and physical properties can be further clarified, as well as possible links with interstellar dust.

1. Introduction

Recent observations of cometary dust, meteorites and interplanetary dust particles (IDPs) have shown that the identification of their nature can allow to obtain important hints about the composition and the evolution of cosmic dust. In particular, the correct interpretation of spectroscopic and mass spectrometry results is essential to clarify some open questions. We recall here some relevant points:

1) PUMA 1/2 and PIA experiments have detected: a) silicate grains with elemental abundance close to that of carbonaceous chondrites; b) "CHON" particles containing mainly light elements; c) mixed particles characterized by the presence of both light and heavy elements (Jessberger et al. 1988);

2) spectrophotometry of several comets have evidenced a broad 9.7 μm band associated with amorphous and/or hydrated silicates. Comets Halley and Bradfield show also a sharp peak at 11.3 μm, which is presently attributed to the additional presence of crystalline olivine (Hanner et al. 1990);

3) comets Halley, Wilson and Bradfield show a structured emission feature around 3.4 μm, similar to that observed towards the galactic center source IRS7, which seems to indicate some link between interstellar dust and cometary material. This band is representative of a class of CH_n (n = 1,2,3) resonances which should show additional signatures between 3 and 13 μm. However, as shown by Chyba and Sagan (1987) and by Colangeli et al. (1990), these other *fingerprints* could not be observed in Halley's spectra, recorded when the comet was at a solar distance of about 1 AU, due to the blanketing effect produced by the continuum emission;

4) several laboratory analyses on meteorites have shown the presence of diamond structures, SiC and amorphous carbon. Very recently Cronin and Pizzarello (1990) have analyzed the aliphatic content of Murchison meteorite (CM2) eliminating carefully most of the possible terrestrial contaminants. In contrast with previous

A.C. Levasseur-Regourd and H. Hasegawa (eds.), Origin and Evolution of Interplanetary Dust, 91–94.

results, the absorption spectrum does not show evidence of the presence of long chains of n-alkyl groups and olefinic structures. Intense features appear at 3.4 - 3.6 μm and at 7.2 μm (methyl and methylene signatures) and around 6 μm (C=O resonances). Though rare, SiC is observed as small grains in meteorites in two allotropic forms: type 1 (d = 0.06 - 0.2 μm) and type 2 (d = 0.1 - 1 μm), with occasional particles with diameter up to 12 μm (Anders et al. 1989);

5) IR spectra of IDPs present dominant silicate features at 10 and 20 μm. Although their extraterrestrial origin is not confirmed, some carbonaceous features have also been identified around 3.38 μm (methyl stretch), 3.4 μm (methylene feature) and 3.5 μm (CH_2 and CH_3 symmetric stretching). Raman spectroscopy of single IDPs shows the presence of two bands at 1350 and 1600 cm^{-1} typical of disordered carbonaceous materials. The bands relative intensity indicates that graphitic platelets not larger than 25 Å should be present in the grains (Allamandola et al. 1987).

2. Laboratory Analogue Materials

Since 1980 our group has produced, characterized morphologically and measured the optical properties from VUV to FIR of several materials able to simulate cosmic solid particles such as amorphous carbon, SiC, PAHs, and silicates. Details on the subject are reported in Bussoletti et al. (1987).

2.1. SPECTRAL PROPERTIES OF CARBONACEOUS GRAINS

Hydrogenated amorphous carbon (HAC) grains with average radius of $\simeq$ 40 Å show in IR a class of absorption bands which match, in wavelength position, some of the so-called *unidentified infrared bands* observed in space. The IR spectrum of HAC grains closely resembles that reported for *uncontamined* Murchison meteorite by Cronin and Pizzarello (1990); in addition, most bands detected in absorption fall at the same wavelength. Furthermore, HAC grains show a 3.4 μm band very similar in profile to that observed, in absorption, towards the source GC-IRS7 and, in emission, from comet Halley. Colangeli et al. (1990) have shown that the fit of the cometary feature by HAC grains optical properties is rather satisfactory and it is consistent with carbon abundance constraints imposed by PUMA 1/2 and PIA observations. Therefore, it exists the possibility that cometary solid material may be similar to HAC grains. It is interesting to note that (see section 1) both diamond particles in meteorites and some IDPs show features in the 3.4 - 3.5 μm range, but not around 3.3 μm. This evidence can be diagnostic of the materials short-scale structure. In fact, features at 3.39, 3.42, and 3.51 μm are typical of -CH_2 and -CH_3 radicals bound to a diamond-like (sp^3) carbon structure. On the contrary, sp^2-CH_n (n=1,2,3) resonances in graphitic-like structures fall mainly at shorter λ. The same behavior is observed for HAC grains produced in laboratory. Here the presence of diamond-like bonds in an overall amorphous structure is confirmed by the *optical gap* evidenced by extinction data in the far-UV (Colangeli et al. 1990).

Other interesting similarities between IDPs and amorphous carbon grains arise from the comparison of Raman spectra. As for many IDPs, Raman spectroscopy on amorphous carbon grains evidences typical features at 1350 and 1600 cm^{-1} (Fonti et al. 1990). Both these features are Raman active modes in randomly oriented structural units which constitute the grains. According to Allamandola et al. (1987), these features show a striking similarity to interstellar IR emission spectrum towards the Orion nebula. In conclusion, HAC grains contain, on a short-scale, both graphitic and diamond bonds. The similarities with observations of cometary material, meteorites and IDPs indicate that these particles resemble

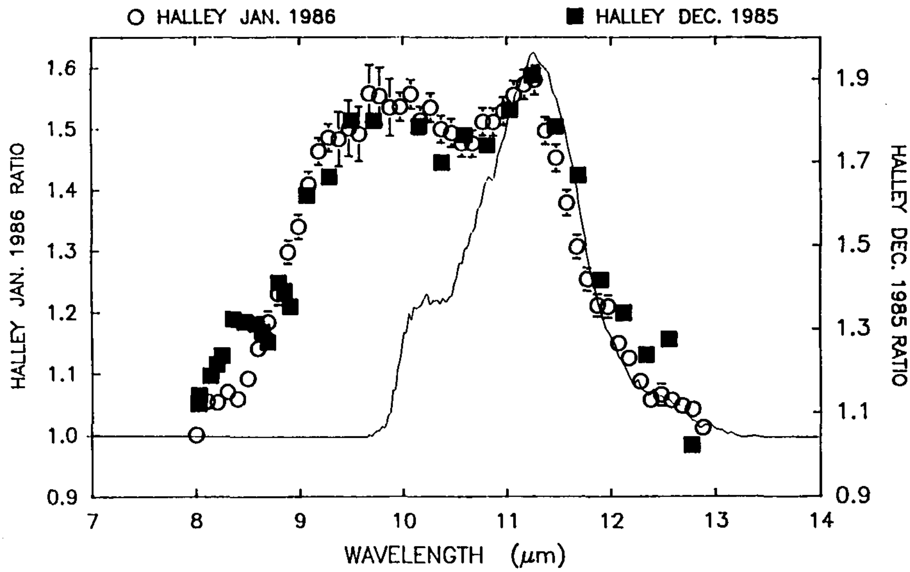

Figure 1: Fit of the cometary band at 11.3μm by means of the optical properties of SiC grains.

HAC grains to some extent.

2.2. SIMULATION OF THE 11.3 μm EMISSION BAND IN COMETS.

As already mentioned in section 1, the 11.3 μm emission band from comets Halley and Bradfield suggests the presence of crystalline silicatic grains in addition to the amorphous and/or hydrated component. To check this possibility, Blanco et al. (this book) have produced in the laboratory and analyzed spectroscopically various forms of crystalline and amorphous synthetic and natural silicates. The fit of the cometary features at 9.7 and 11.3 μm appears satisfactory. Nevertheless, IR spectral laboratory mesurements on various kinds of SiC grains (Borghesi et al. 1985) show a strong 11.3 μm band. We have to recall that silicon carbide solid grains are expected to form mainly in the atmosphere of carbon rich cool stars ($C/O > 1$). The presence of SiC particles has been confirmed by several astronomical observations, as a definite 11.3 μm band has been seen towards a wide variety of sources. Frenklach et al. (1989) have shown that carbon and silicon carbide could occur in core-mantle structures since their formation in cool stars atmospheres. Therefore, if cometary material is, to some extent, representative of the *primordial* composition of the pre-solar nebula we cannot exclude *a priori* the presence of SiC in comets. In support to this idea comes the detection of small amounts of *exotic* SiC in meteorites (section 1). On this ground we have simulated the emission spectrum of P/Halley at around 11.3 μm with the optical properties of α-SiC grains produced in the laboratory. As shown in Fig. 1, the fit of the peak and the long wavelength-side of the band profile appears rather good. Of course, at shorter wavelengths the contribution from silicates is needed to get a complete simulation of the observations. However, we note that only a few percent ($< 10\%$), by mass, of SiC is required to account for the observed intensity. Therefore, on a qualitative basis, we have to include SiC grains as a possible candidate to cometary grains. This suggestion needs further investigation in order to define abundance constraints on this class of particles. If the detection of SiC grains in comets is confirmed, we will have a further evidence of the relation existing between comets, interplanetary and interstellar dust.

3. Acknowledgements

This work has been supported under contracts by CNR, ASI and MPI.

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