LABORATORY MEASUREMENTS ON THE INFRARED FEATURES OF INTERSTELLAR SILICATE GRAINS

W. Krätschmer
Max-Planck-Institut für Kernphysik
Postfach 10 39 80
6900 Heidelberg - 1 (FRG)

ABSTRACT

Thin layers of an amorphous silicate coating were obtained by ion sputtering of crystalline olivine on KBr substrates. The dielectric functions of the coating were determined from reflection and transmission measurements in the wavelength range between 5 and 25 μ. The small particle extinction of the amorphous silicate shows a strong feature at 9.7 μ and a weaker one at 17.5 μ. In wavelength position both absorption bands agree with astronomically observed features.

INTRODUCTION

The broad and featureless absorption and emission at about 10 μ wavelength observed in many astronomical objects as been ascribed to silicate dust grains (see e.g. Ney 1977). Laboratory measurements have been carried out to specify the nature of this silicate in more detail. Amorphous silicates, produced by condensation of vaporized olivine and by high dose radiation damage of crystalline olivine (Stephens and Russell 1979, Krätschmer and Huffman 1979), as well as hydrated silicates e.g. from carbonaceous chondrites (Zaikowsky and Knacke 1975) show a 10 μ feature similar to the astronomical observations. Unfortunately, not very many data are available on the dielectric functions of astrophysically interesting silicates. Together with the size and shape distribution of the dust grains, the dielectric functions of the grain material completely determine the extinction, scattering and absorption of the dust.

In this work, we present the optical constants of an amorphous olivine-like silicate which was produced by ion sputtering of crystalline olivine.

EXPERIMENTAL PROCEDURES

Magnesium rich crystals of olivine were bombarded with 20 keV Argon ions and the material sputtered from the surface was caught on KBr substrates. The thickness of the fairly uniform coatings ranged from

I. Halliday and B. A. McIntosh (eds.), Solid Particles in the Solar System, 351–354.

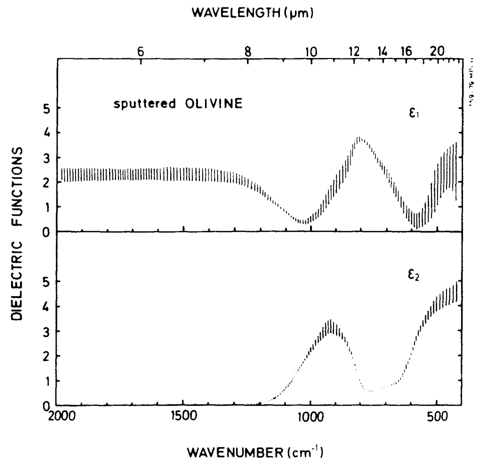

Figure 1: The dielectric functions of the amorphous silicate coatings obtained by ion sputtering of crystalline olivine.

0.5-1.5 μ depending on sputtering conditions and time. The accurate thickness measurement was performed interferometrically. A Beckman IR 11/12 spectrophotometer has been used to measure the transmission of the coated substrate between 5 and 25 μ wavelength. The reflectivity of the coatings at nearly normal incidence was determined using the same instrument equipped with a reflectance attachment. From transmission and reflectivity (accuracy ±0.5%) the dielectric functions of the coating were calculated.

RESULTS AND DISCUSSION

Figure 1 shows the dielectric functions of the amorphous silicate. The dashed area results from the ± 0.5% uncertainty of the reflectivity and transmission data. As compared to the dielectric functions of crystalline olivine (Brunel and Vierne, 1974), this amorphous silicate shows a considerable decrease in the peak ε_2 values, a loss of sharp structures, shifts in the band centers and considerable increases in the band widths. With regard to the optical constants of radiation damaged olivine (Krätschmer and Huffman, 1979), this silicate shows an even lower ε_2 peak and a complete loss of residual features in the 10 μ domain. It is therefore believed that the sputtered silicate is in a state of disorder which exceeds the degree of disorder produced by high dose radiation damage.

The resulting small particle extinction normalized per unit volume of the solid has been calculated from the dielectric functions and is shown in Fig. 2. Spherical Rayleigh particles were assumed and scattering has been neglected. Two absorption features result at about 9.7 and 17.5 μ which also show up at the same wavelength positions in the experimentally determined extinction of amorphous olivine dust grains

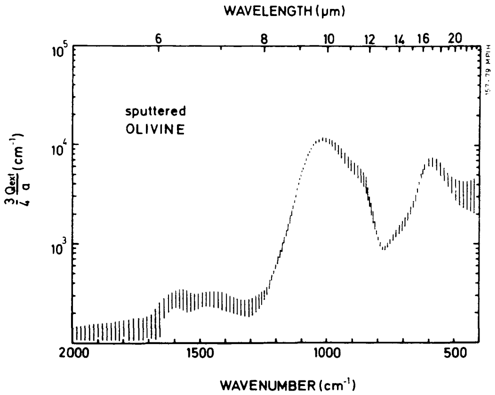

Figure 2: The calculated absorption coefficient of spherical Rayleigh particles consisting of the amorphous silicate.

(Krätschmer and Huffman, 1979).

The position of the main feature at 9.7 μ compares favourably with astronomical data and the peak at 17.5 μ may correspond to a weak feature observed in many astronomical sources shortward of 20 μ (see e.g. Forrest et al. 1978). The spectrum of the amorphous silicate produced, therefore seems to resemble to a good approximation that of interstellar grains.

The width of the calculated 9.7 μ feature (FWHM≈2.0 μ) is smaller than most of the astronomical data suggest. This discrepancy may indicate particle size and shape effects or chemical differences within the interstellar grain populations (see e.g. Day and Donn, 1978). All these effects would tend to increase the width as compared to the calculated absorption profile. A more serious discrepancy seems to exist in the ratio of the 17.5 μ compared to the 9.7 μ absorption, which according to most astronomical observations appears to be smaller than in the case of the considered amorphous silicate. However, as has been pointed out (see e.g. Forrest and Soifer 1974) because of radiation transfer effects it seems to be rather difficult to evaluate the astronomical data and to derive band shapes and strengths at these long wavelengths.

It should be emphasized that in this study we have attempted to produce a material similar to the interstellar silicates, rather than to stimulate the formation of interstellar grains or to suggest a formation mechanism.

The main conclusion of this work is that grains of amorphous silicates of olivine-like composition show optical features rather similar to those which interstellar grains produce at 9.7 and 18 μ.

https://doi.org/10.1017/S0074180900067048 Published online by Cambridge University Press

REFERENCES

Brunel, R. and Vierne, R.: 1974, Bull. Franc. Miner. Cryst., 93, pp. 328-337.
Day, K.L. and Donn, B.: 1978, Astrophys. J., 222, pp. L45-48.
Forrest, W.J. and Soifer, B.T.: 1976, ibid, 208, pp. L129-132.
Forrest, W.J. et al.: 1978, ibid, 219, pp. 114-120.
Huffman, D.R.: 1977, Adv. Phys., 26, pp. 129-230.
Krätschmer, W. and Huffman, D.R.: 1979, Astrophys. Space Sci., 61, pp. 195-203.
Ney, E.-P.: 1977, Science, 195, pp. 541-546.
Stephens, J.R. and Russell, R.W.: 1979, Astrophys. J., 228, pp. 780-786.
Zaikowsky, A. and Knacke, R.F.: 1975, Astrophys. Space Sci., 37, pp. 3-9.

DISCUSSION

Hawkes: Do you have any comment on the argument advanced by Wickramasinghe, Hoyle and coworkers that there was excellent agreement between the infrared absorption spectrum of cellulose and the astronomical observations, and their resulting hypothesis that cellulose is a primary constituent of interstellar grains?
Krätschmer: This hypothesis encounters some severe difficulties. For example, according to this theory one would expect absorption at about 3μ, 10μ, and 20μ to show up simultaneously. Astronomical observations suggest, however, that there is no correlation between the 3μ feature on the one hand and the two features at 10μ and 20μ on the other.

Staude: According to our results, (Röser and Staude: 1978 Astron. Astrophys. 67, p. 381) the dominance of large particles should prevent the absorption features being seen in the zodiacal light. The situation is different in comets because of the steeper particle size spectrum.
Krätschmer: I agree. But this now provides the possibility of checking whether cometary and interstellar dust are actually similar in their infrared absorption features.