

Presolar diamonds from the Allende meteorite

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Until 1987, dust particles around stars had only been recognised by their appearance in stellar spectra, but the possibility of studying unprocessed stellar condensates from meteorites directly in the laboratory, have given important information not only about the Solar System formation, but also provided precise data for testing astrophysical stellar models.

Laboratory analyses of fine-grained diamond residues from primitive meteorites have shown that micro-diamonds are the most abundant form of presolar dust preserved in meteoritic samples (Lewis et al. 1987). The presolar diamonds carry isotopic anomalies which indicate a very complex formation history (Huss & Lewis 1994a, 1994b).

The presolar diamond content is very similar for all chondrite classes, around 500–1000 ppm of the matrix (Alexander et al. 1990; Huss 1990). Their median grain size is about 2 nm (Fraundorf et al. 1989), which means that each diamond contains a few thousand carbon atoms. Their size distribution is log-normal rather than power-law, reflecting growth rather than fragmentation and suggesting a short interstellar residence time (Lewis et al. 1989).

Various mechanisms have been proposed to account for the production of diamond grains in space, but the most likely scenario seems to be that they have condensed directly from stellar outflows (Lewis et al. 1987; Jørgensen 1988; Clayton 1989), the conditions in cool stellar outflows are remarkably similar to those employed in industry to produce diamonds by chemical vapour deposition (CVD).

Several groups of diamonds may exist with origin in different stellar types. In order to make it possible to identify the sites of formation observationally, I have extracted presolar diamonds from the Allende meteorite using the method described by Tang & Anders (1988). Once the diamonds were extracted they were studied using transmission electron microscopy and electron diffraction. Both presolar and CVD diamonds were examined, in order to gain a deeper insight into the structure of the two, as well as some possible presolar SiC grains (Andersen et al. 1995a). This work was carried out at the Technical University of Denmark in collaboration with J. Bohr and K. Glejbøl. To determine the optical properties in order to determine the monochromatic absorption coefficient in a form which is useful for stellar atmosphere calculations, I obtained spectra of both types of micro-diamonds in the infrared ($400\text{ cm}^{-1} - 4000\text{ cm}^{-1}$) and in the UV/visual ($12200\text{ cm}^{-1} - 52600\text{ cm}^{-1}$). The CVD diamonds were measured in order to get a more solid basis for the interpretation of the diamond spectrum. The spectra were obtained at the Institute of Chemistry (HCØ) at the University of Copenhagen in collaboration with F. Nicolaisen and P. G. Sørensen. These measurements have enabled me to calculate a self-consistent carbon star model atmosphere with the presolar diamonds included in the opacity and in the corresponding synthetic spectrum. The computed model is based on an improved version (Jørgensen et al. 1992) of the MARCS code (Gustafsson et al. 1975), which is used to calculate models of carbon star atmospheres and is used as the base for calculating synthetic stellar spectra. These calculations were done in collaboration with U. G. Jørgensen.

The calculated synthetic stellar spectra (Andersen et al. 1995b) have given the first opportunity to identify where the most prominent spectral features of diamonds are to be expected in carbon rich AGB star spectra. Neither of the features are observable from the Earth as they are all present in the infrared wavelength band, but with the ISO (Infrared Space Observatory) satellite, it should be possible to obtain full stellar spectra at these wavelengths, which means

that under the assumption that the extracted diamonds have the same optical properties they had when formed in the stellar atmosphere (and that micro-diamonds are formed in carbon stellar atmospheres) the absorption features will be observable.

At present I am calculating various stellar models under different assumptions and at the same time comparing the optical properties of presolar diamonds from various meteorites. These things are important to check in order to be certain that the optical properties of the diamonds are neither depending on which meteorite they are extracted from nor on which extraction procedure was used.

An observational identification of the stellar source of the presolar grains would lead to improved understanding of the upper layers of stellar atmospheres, of grain formation, of the mass loss process, and of the detailed chemical evolution of our Galaxy.

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