*33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.**30I**, O-5.007 (2006)*

# The Search for Interstellar Dust in Laboratory Plasmas

E. Kovacevic[1], I. Stefanovic[1], J. Berndt[1], C. Jäger[2], H. Mutschke[2], Y.J. Pendleton[4], H.W. Becker[3], C. Godde[1] and J. Winter[1]

[1]*Institute of Experimental Physics II, Ruhr University Bochum, Germany*

[2]*Astrophysical Institute and University Observatory, F.Schiller-Universität Jena, Germany*

[3]*Institute of Experimental Physics III, Ruhr University Bochum, Germany*

[4]*NASA Ames Research Center, Moffet Field, California, USA*

## Introduction

Carbonaceous compounds are a significant component of interstellar (IS) dust and the composition and structure of such materials is therefore of key importance for astrophysics (see for review Pendleton 2004). We presented previously (Kovacevic et al 2005) a plasma polymerized carbonaceous material produced in RF discharge under low pressure, using $C_2H_2$ as a precursor component. The IR spectra (4 µm-15 µm) of the resulting spheroidal carbonaceous nanoparticles reveal a strong aliphatic band (3.4 µm feature), weak OH and carbonyl bands, and traces of aromatic compounds, all characteristics identified with dust in the diffuse interstellar medium of our galaxy (data in Kovacevic et al. 2005, dust analog review in Pendleton & Allamandola 2002). In the previous work, we presented mostly the analysis of IR spectra of particles. However, there are some additional important astronomically observed phenomena correlated with dust particles, e.g. the UV extinction bump at 217.5 nm, the extended red emission at 500-1000 nm, electron emission from the particle surfaces, importance of fractal surface of the particles for the surface reactions, elemental abundances of the materials, etc.

Our plasma driven polymerization process has similarities to stellar outflow conditions and provides a convenient way to make carbonaceous IS analogs. Even more, such low temperature plasmas provide an excellent trap for the particles ("plasma matrix isolation"), enabling investigations on the above mentioned phenomena, as well as manipulation of the particles, e.g. with atomic hydrogen, or UV irradiation.

In this paper we present extinction measurements in the VIS/UV and infrared range on carbonaceous dust particles. The strongest feature in the interstellar extinction curve in the UV range is the bump at 217.5 nm. It is characterized by a stable position, and a band width that changes according to the interstellar environment (Fitzpatrick and Masa 1988). All recent results point strongly toward a carbonaceous carrier for the UV bump (Menella et al.1998) and among those hydrogenated amorphous carbon (HAC) seems to be the most favoured (Schneiter et al. 1998). The band occurs, anyway, in correlation with famous infrared absorption feature at 3,4 µm, identified as carbonaceous tracer. More than 30 years after the discovery of the UV extinction band (Stecher1965), its physical origin remains one of the most challenging astrophysical problems. Laboratory obtained data are of enormous importance for the understanding of the interstellar extinction curve and could provide information about the amount of carbon locked in interstellar medium.

## Experimental set-up and results

The experimental set-up for the absorption (extinction) spectroscopy is shown on figure 1. As the radiation source for UV/VIS measurements we used a deuterium lamp, which was, as the spectrograph, enclosed in vacuum atmosphere (equipment from Astrophysical Institute and University Observatory, Jena, Germany, described in detail in Schnaiter et al. 1996). Absorption measurements in infrared region have been also obtained in-situ, by means of Fourier Transformed Infrared Spectroscopy (standard Bruker 55 device).

Experiments have been carried out in RF, capacitively coupled plasmas with weakly ionized carrier gases (acetylene as precursor, diluted in Ar, He, Xe or N, precursor:carrier gas=8:0.5 sccm). The gas pressure was 0,1 mbar, and the input power about 15W. We present here the results obtained by polymerization from acetylene in argon and in helium atmospheres. As shown on figure 2a), there are some visible differences in IR spectra if we compare particles with same size grown in helium/acetylene and argon/acetylene mixtures.

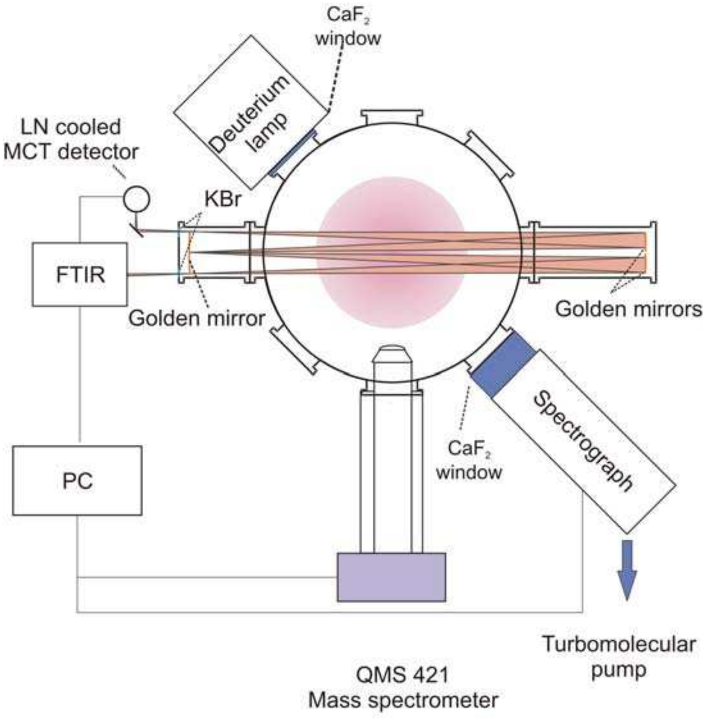

Figure 1 Experimental set-up

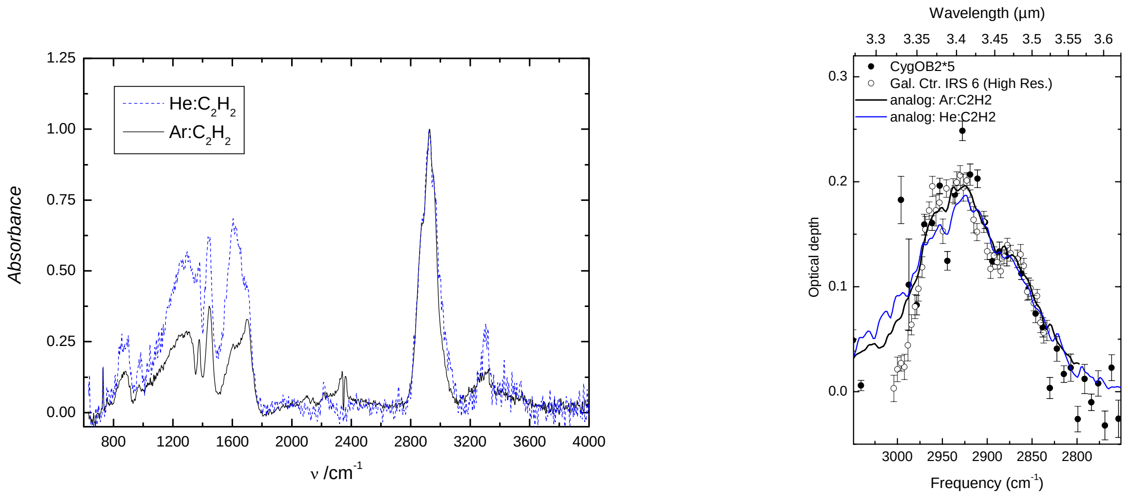

*Figure 2: a) IR spectra of the dust particles, radii 150 nm (blue obtained in He:$C_2H_2$ mixture, black in Ar:$C_2H_2$ mixture); b)comparison of the IR spectra (3.4µm feature): solid lines- data obtained from the laboratory particles, cycles - astronomical observational data.*

In both cases typical CH stretching features at 2940 cm$^{-1}$ and correlated CH deformation bands at 1450 and 1375 cm$^{-1}$ are present. The important deference between the features occurs in the spectral region below 1800 cm$^{-1}$, in the region 1550 – 1600 cm$^{-1}$. It was shown (Ferrari 2003) that in the region below 1800 cm$^{-1}$ CC skeleton modes play a significant role in the IR spectra of hydrogenated carbon material. The thesis was proven with H-D substitution experiments (Ferrari 2003), revealing clearly a CC skeletal region between 1300 – 1400 cm$^{-1}$ and 1550 – 1600 cm$^{-1}$. In the case of the particles grown with argon as carrier gas we can observe the peak at 1600 cm$^{-1}$, arising as a shoulder on the low frequency tail of the carbonyl feature. This relatively sharp peak must be ascribed to C=C double bond stretching vibrations (Kobayashi et al. 1974, Bounouh et al. 1995, Ferrari et al. 2003, Sokrates 1980), probably of aromatic origin (skeleton modes).

In the case of helium as the carrier gas, this peak is dominant, broad and well defined, it is overblending carbonyl (now visible only as shoulder on 1600 cm$^{-1}$). From the width of this feature it is possible to conclude that the C=C bonds are found here in many different configurations, both alkene and aromatic, and that these configurations are probably distorted (Bounouh et al. 1995, Sokrates 1980). In the case of the particles grown in Ar matrix, this peak is clearly weaker. The presence of the peak in this range is characteristic for C=C double bonds only, and is an indication that there is a fraction of sp$^2$ C atoms bonded not to H, but only to other C atoms (Stefanovic et al 2005). Differences between those two similar materials, both matching the observational IR spectra (figure 2b), can be shown also by means of transmission electron microscopy and through slight differences in H/C ratio.

In this way we obtained two carbonaceous materials, both being adequate candidates in the IR region, but with slight differences in $sp^2$ content, both with satisfying H/C ratio (Furton et al. 1999). The results of in-situ UV/VIS spectroscopy (extinction) obtained for relatively big particles (>100nm) are shown on the figure 3, in comparison with some of interstellar extinction curves taken from Mennella et al 1998. The first results do not show the bump as narrow as the average bump in the astronomical observations, but the tendency is there. The further work should be concentrated on the measurements of the small particles (<50nm).

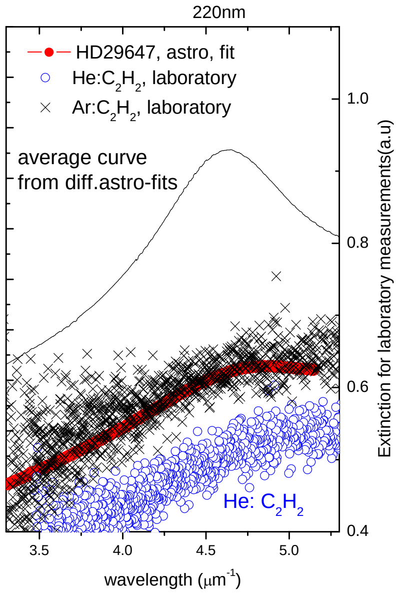

*Figure 3: Extinction curve in the UV/VIS region. Comparison between laboratory and astronomical data (fitted astro-data: Mennella et al. 1998)*

The UV features contain also the information on the size and optical properties of the material and can be therefore, besides astrophysical applications, used as independent *in-situ* particle diagnostic for dusty plasmas.

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