Organic Matter in Space
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Ion irradiation effects on sooting flames by-products

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Abstract. Carbonaceous extraterrestrial matter is observed in a wide variety of astrophysical environments. Spectroscopic signatures reveal a large variety of chemical structure illustrating the rich carbon chemistry that occurs in space. In order to produce laboratory analogues of the carbonaceous cosmic dust, a new chemical reactor has been built in the Laboratoire de Photophysique Moléculaire. It is a low pressure flat burner providing flames of premixed hydrocarbon/oxygen gas mixtures, closely following the model system used by the combustion community. In such a device the flame is a one-dimensional chemical reactor offering a broad range of combustion conditions and sampling which allows production of many and various by-products. In the present work, we have studied the effect of ion irradiation (200-400 keV), at the Laboratorio di Astrofisica Sperimentale in Catania, on several samples, ranging from strongly aromatic to strongly aliphatic materials. Infrared and Raman spectra were monitored to follow the evolution of the films under study, and characterize the irradiation process-induced modifications.

Keywords. Astrochemistry, methods: laboratory, ISM: dust, cosmic rays

1. Introduction

Carbonaceous extraterrestrial matter is observed in several astrophysical environments. Spectroscopic signatures observed by telescopes and satellites reveal a large variety of chemical structures, illustrating the rich carbon chemistry that occurs in space.

At the Laboratoire de Photophysique Moléculaire a new chemical reactor allows us to produce cosmic dust analogues (Cao *et al.* 2007). The chosen reactor is a low pressure flat burner providing sooting premixed flame (hydrocarbon / oxygen gas mixtures), a model system for the combustion community. The flame offers a broad range of combustion conditions and sampling, to synthesize a large variety of soot under controlled properties, ranging from hydrogenated amorphous carbon to strongly aromatic material.

It is known that irradiation processes play a important role in space in the life-cycle of carbonaceous dust. Consequently, in this work, we study the effects of ion irradiation (H^+, He^+, and Ar^{++}, energy of 200-400 keV), at the Laboratorio di Astrofisica Sperimentale in Catania, on several soot films, ranging from strongly aromatic to strongly aliphatic materials. The explored fluence range is $10^{14} - 10^{16}$ ions cm^{-2}.

Samples are monitored using infrared and Raman spectroscopy, to characterize the process before, during, and after irradiation. The experimental approach and setup are similar to the ones used previously in the Catania laboratory to characterize amorphization experiments of carbon-rich materials (Baratta *et al.* 2004, Brunetto *et al.* 2004).

2. Results

In Figure 1 we display two examples of Raman spectra of a soot sample (mix of aromatic and aliphatic structures) irradiated with 400 keV Ar^{++} ions and 200 keV He^{+} ions.

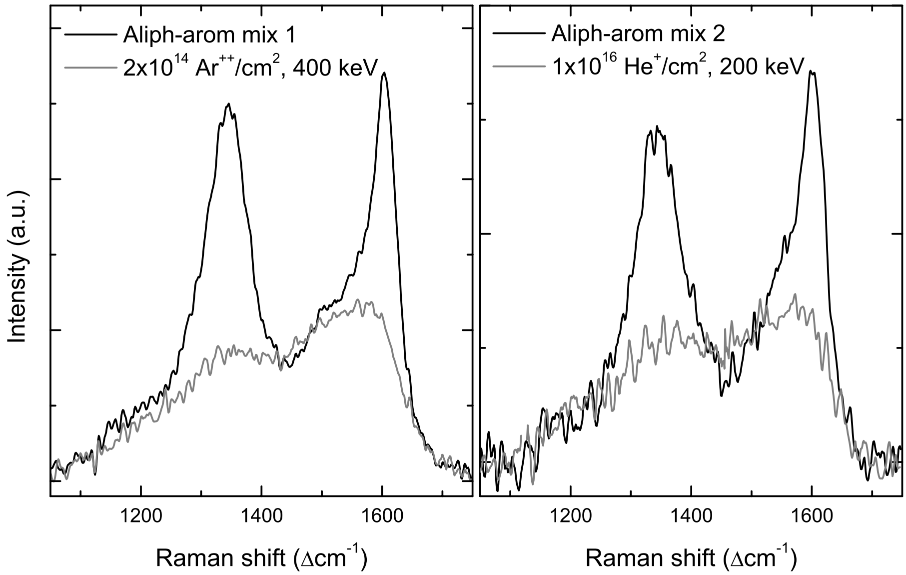

Figure 1. Raman spectra of soot sample (mix of aromatic and aliphatic structures) irradiated with 400 keV Ar^{++} ions (left) and 200 keV He^{+} ions (right).

We measure the variations of relative peak sizes, positions, and widths of the so-called D (disorder) and G (graphitic) lines. These reflect the degree of disorder of the material (broader lines corresponding to more disordered materials). At the given energy, we observe an amorphization effect due to Ar irradiation ∼50 times more efficient than He.

We compare our results with those obtained in the analysis of extraterrestrial organic matter (Sandford *et al.* 2006) and other irradiation experiments of carbonaceous materials of astrophysical relevance (Baratta *et al.* 2004). We find that Raman spectroscopy confirms previous amorphization experiments on carbonaceous materials, closely following the evolutionary path of meteorites, interplanetary dust particles, and cometary grains collected by the Stardust mission.

IR spectroscopy shows the destruction of aromatic bonds (when present) partly converted to aliphatic C-H bonds, which are in turn destroyed at higher dose. The combined technique of soot production and modification by ion irradiation, enriches the possibilities to synthesize cosmic dust laboratory analogues with tailored properties. Astrophysical implications of the studied irradiation processes for the lifecycle of carbonaceous dust are under investigation.

References

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