Molecular growth induced by heavy ion collisions

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Synopsis The formation of large covalent species is observed after the collision of 3 keV Ar^+ with loosely bound carbonaceous clusters. The low-energy projectile strongly and promptly (fs) interacts with molecular nuclei. The formed reactive species and the kick-out atoms interact with neighbouring molecules leading to molecular growth before the cluster dissociation (ps). Experimental results are well reproduced by classical molecular dynamics.

In space, large carbonaceous molecules such as fullerenes [1] or polycyclic aromatic hydrocarbons, PAHs [2] have been observed or are expected to be present. Their energetic processing by ionising radiation (photons, electrons, ions) plays a role in their destruction but also in their formation, e.g. by shrinkage of larger carbonaceous matter to form fullerene [3].

A peculiarity of ion collisions is that the energy is deposited on the molecular electronic cloud (electronic excitation) and, as the projectile is massive, on the molecules nuclei, the so-called nuclear energy loss which occurs in Rutherford-like collisions. The latter is higher for heavier ions and it is maximum in low velocity collisions ($v < 0.1$ a.u.) [4], typical of shock in space.

We have recently observed a rich molecular growth inside of clusters of pyrene, a polycyclic aromatic hydrocarbon, after collisions with low-energy ions [5]. The dependence with the projectile indicates that nuclear energy loss plays a central role in the growth mechanism which is further confirmed by the good agreement with classical molecular dynamics. Thus the following scenario has been established. In penetrating trajectory, near central collisions occur between the projectile and molecular nuclei and molecular fragments could be promptly kicked out on the fs timescale. Thus, reactive species are produced which could form covalent bond with neighbouring molecules before the cluster dissociation (ps timescale).

Here, we will present results on the formation of covalent carbon nanoparticles inside of C_{60} fullerene clusters induced by the collision with Ar^+ at an energy of 3 keV, i.e. in the velocity range where the nuclear energy loss is maximum. The production of covalently bound species is stated from the observation of multiply charged systems with size much smaller that the appearance size of multiply charged weakly bound van der Waals clusters. A further confirmation is the good agreement with simulation results. Due to the energy deposition localised on molecular nuclei, the formed species are less excited that in laser-induced coalescence process [6], thereby the ion-induced molecular growth is more efficient and leads to larger molecular system.

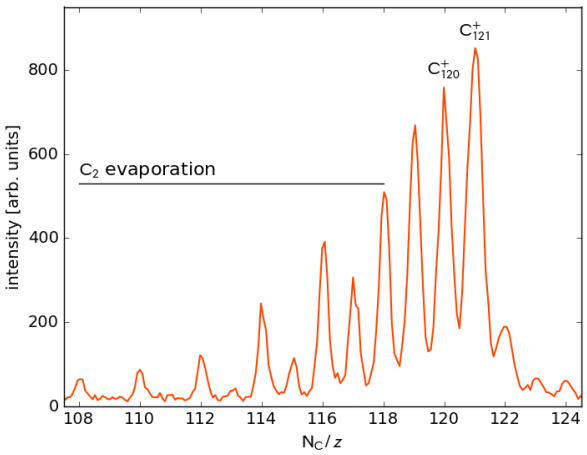

Figure 1. Mass spectrum in the mass range of two C_{60} molecules after the interaction of 3 keV Ar^+ projectiles with a distribution of $[C_{60}]_k$ clusters.

References

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