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ARIBE: A LOW ENERGY ION BEAM FACILITY IN CAEN

V. BERNIGAUD, O. KAMALOU, A. ŁAWICKI, M. CAPRON, R. MAISONNY,
B. MANIL, L. MAUNOURY, J. RANGAMA, P. ROUSSEAU,
J.-Y. CHESNEL, L. ADOUI and B. A. HUBER

Centre de recherche sur les ions, les matériaux et la photonique (CIMAP) – CEA - CNRS - ENSICaen - Université de Caen – Boulevard Henri Becquerel BP5133 F-14070 Caen cedex 05 France
E–mail: prousseau@ganil.fr

Abstract. Beams of low-energy ions are specific tools for interdisciplinary research allowing for preparing and studying the properties of complex systems like (bio)molecules, clusters and surfaces. In particular highly charged ions can induce strong electronic excitations as they are carriers of a large amount of potential energy up to the high keV range. But also other types of ion beams, like size-selected cluster beams or beams of biomolecular species, are useful for preparing and structuring surfaces or performing collision experiments. The ARIBE facility, located in Caen, which is part of the distributed European Facility LEIF, delivers such types of beams. In the present contribution recent technical developments and typical results are discussed.

1. INTRODUCTION

The ARIBE installation, located in Caen, is part of the Distributed European Low Energy Ion beam Facility (LEIF). Other access-giving partners are H-EBIT from the MPIK in Heidelberg, the ZERNIKE-LEIF installation from KVI in Groningen, the ELISA infrastructure at the University of Aarhus, and the QU-LEIF installation at Queen's University in Belfast. These installations are devoted to study the interaction of low energy ion beams with matter. The ARIBE facility distributes different kinds of low-energy ion beam. A well-established high intensity low energy ion beamline delivers a beam of multiply charged ions (MCI) in high charge states produced by an electron cyclotron resonance (ECR) ion source. To study very low energy interactions involving multiply charged ion, a beam line has been installed which decelerates ions down to kinetic energies of a few eV (typically 5 eV) per charge. Very recently a size-selected cluster ion beamline and an electrospray ion source coupled with a quadrupole mass filter allowing for the production of beams of complex systems have been developed. These latter beamlines are mobile and can be coupled and crossed with the beamlines of multiply charged ions. Thus, the study of stability and fragmentation of complex systems, charged during the interaction with MCI, becomes feasible. As part of the ITS LEIF Integrated Infrastructure Initiative and of the GANIL pluridisciplinary facility, external users are encouraged to apply for beam

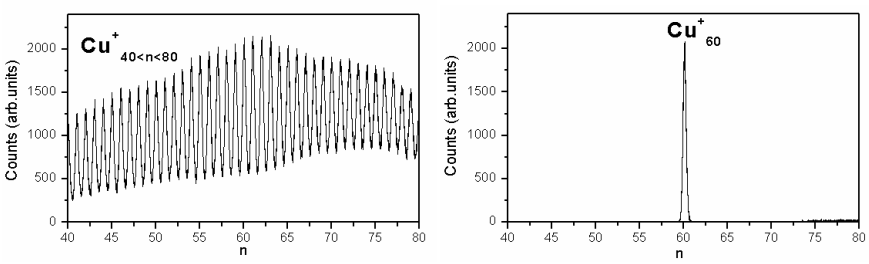

Figure 1: Mass spectra of copper clusters without mass selection (left) and of a size-selected cluster beam of Cu_{60}^{+} by using time-of- flight mass selection (right).

time and to send in scientific proposals. In order to apply for beam time at one of the five infrastructures one might contact the website: `http://www.its- leif.org`, where more information on the modalities and where the application forms are given.

2. BEAMLINES

There are seven high intensity beamlines supplied by a Supershypie ECR ion source which is able to produce multiply charged ions (A^{q+}) in high charge states with high intensity. Typical beam intensities of eμA are reached for Xe ions in charge states q up to 30+. The kinetic energy of the multiply charged ions can be varied between 3 $q$keV and 25 $q$keV. Among the seven beamlines available, two are entirely magnetic; one of them is equipped with a complete installation to study the fragmentation of clusters induced by multiply charged ions. This instrument has been widely used to study the interaction of multiply charged ions with fullerenes, fullerenes clusters (Manil et al. 2003), and biomolecules (Schlathölter et al. 2006). After a switching magnet, five more beamlines with electrostatic optics are available. Each of the seven beamlines is equiped with diagnostics tools, steerers, and movable apertures.

The very low energy beamline is connected to a Caprice ECR ion source which is able to provide multiply charged ions in high charge state (up to Xe^{30+}). There is a diagnostic chamber to characterize the ion beam and to prepare its shape before entering the decelerating lens system. This ion optical system serves to slow down the ions and to focus them at an image plan, which can be moved in a range of 20 cm. It is possible to decelerate the beam starting from 20 keV/q down to a few eV/q with a size of about 3 mm (Lebius et al. 2003).

The beamline of size-selected cluster ions has been recently developed at the CIMAP laboratory (Kamalou et al. 2008). A magnetron discharge sputters a metallic or semiconducting target and sputtered particles are then aggregated in a liquid nitrogen-cooled condensation zone. A heat bath situated after the cluster source allows controlling the temperature of the clusters, i.e. the cluster internal energy. An octupole ion guide helps to transport cluster ions to the mass filter. Mass selection is obtained by using a Wiley-McLaren time- of-flight mass spectrometer. Pulsed ion beams of size-selected clusters $A_n^{+,-}$ are available with sizes varying from several atoms up to $n = 10000$ with a typical kinetic energy of 3 keV. In order to separate neutral clusters from charged ones, the cluster ions are 90°- deflected by a quadrupolar electrostatic

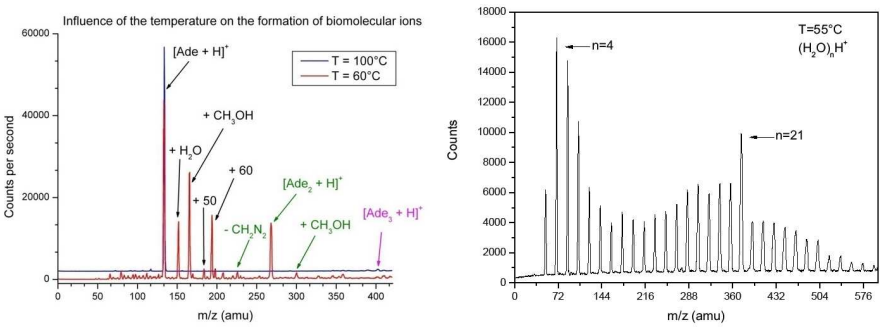

Figure 2: Mass spectrum of protonated adenine (left) and of water clusters (right) obtained with the electrospray ion source.

deviator. A typical mass spectrum obtained with copper clusters is shown in the left part of figure 1. We observed separated peaks of Cu_n^+ cluster ions for $40 \leq n \leq 80$. On the right part of figure 1, a mass-selected Cu_{60}^+ cluster beam is obtained by using mass filtering by time-of-flight.

With the increasing interest for biomolecular studies and the need to produce biomolecules in the gas phase, which are too fragile to be evaporated by using an oven device, the electrospray ion source (Fenn et al. 1989) appears to be most appropriate to obtain large biomolecules in the gas phase. We have recently built an electrospray ion source at the ARIBE facility in collaboration with the Aarhus group. This source is coupled to a quadrupole mass filter in order to produce a beam of mass-selected biomolecular ions. First mass spectra have been obtained in spring 2008. A typical mass spectrum of the protonated adenine ($[AdeH]^+$) is displayed on figure 2. Furthermore, we have been able to produce water clusters ($[(H_2O)_nH]^+$) by using a corona discharge instead of the spray technique, as shown in the right part of fig. 2.

3. RECENT RESULTS

As an example, we will discuss in the following two type of experiments. The first one concerns the deposition of mass-selected clusters on a substrate. Deposition experiments of mass-selected copper clusters with a deposition energy of about 0.7 eV/atom have been performed on highly oriented pyrolytic graphite (HOPG) and on SiO_2 substrates. Pictures obtained with an Atomic Force Microscopy (AFM), shown below (figure 3), indicate that copper clusters are evidently mobile on the HOPG surface and that they finally stick only along cleavage steps, dislocation lines or other surface defects. When deposited on a SiO_2 substrate, copper clusters do not move, they stay at their landing position.

A second example concerns the fragmentation of FeTPPCl molecules. Figure 4 shows a typical mass spectrum of FeTPPCl when ionised in collisions with O^{3+} ions at 30 keV. The singly charged intact molecule is found to be the most abundant in contrast to experiments with electrons (Feil et al. 2006). The intact molecule is observed in charge states up to $q = 3$. However, with increasing charge state the loss of the Cl atom becomes more and more important. Figure 4 shows that in addition to the loss of the Cl atom also the loss of 1 or 2 phenyl groups (peaks labelled a

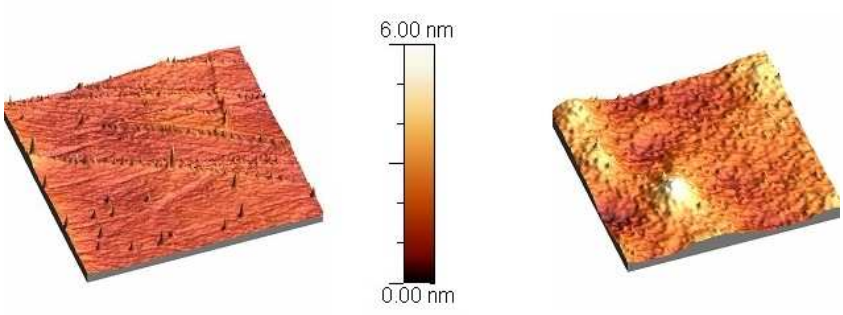

Figure 3: 3D AFM pictures of positive Cu clusters deposited on a HOPG surface (left side) and on a SiO_2 surface (right side).

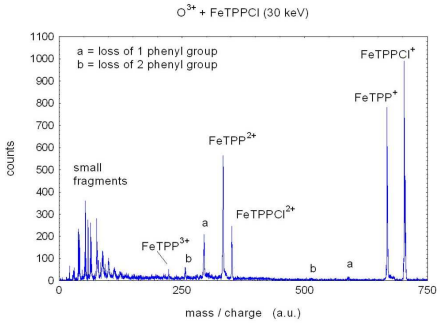

Figure 4: Typical fragmentation spectrum obtained in 30 keV-collisions of O^{3+} ions with FeTPPCl molecules. The peaks characterised by a and b correspond to the loss of 1 and 2 phenyl groups in addition to the Cl-atom, respectively.

and b) becomes increasingly important with the charge state of the ionised molecule. Finally, small fragments are observed which are due to a more complete break-up of the multi-ionised molecule.

The presented results have been obtained at the ARIBE facility, a part of the distributed infrastructure LEIF; the support by the ITS LEIF Project 026015 is gratefully acknowledged.

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