Experimental study of the interaction of ions with metallic nano-particles with sizes up to 10 nm

Arkadiusz Mika* [1], Rudy Delaunay, Alicja Domaracka*, Patrick Rousseau*, Lamri Adoui and Bernd A. Huber*

* Normandie Univ, ENSICAEN, UNICAEN, CEA, CNRS, CIMAP, 14000 Caen, France

Synopsis: Progress in the development of a new experimental setup, capable to perform collisions between highly charged ions and metal nanoparticles (NPs), is reported. For the first time such collisions of ions with "free" sub-10nm Ag nanoparticles have been performed showing the significance of sputtering phenomena.

Metal nanoparticles are objects which have been studied because of their unique size-related physico-chemical properties and their potential to impact modern applications in electronics, medicine and energy resources. Recently, these systems attracted much interest in the context of future nanoparticle-enhanced hadrontherapy, where metallic nanoparticle-based drugs are planned to be used as radiosensitizing agents. However, there are not many experimental studies concerning the interaction of slow/fast ions with large nanoparticles (10 nm), especially for the case of metallic clusters, although theoretical approaches do exist [1,2].

This work contributes to the clarification of the mechanisms induced by radiation at the molecular scale. It is a crucial step for the development of the so-called "nanodosimetry" and its further incorporation into medical treatment plans [3].

The experimental set-up COLIMACON DUO built in the ARIBE/Ganil facility in Caen with the final aim to study the interaction of ions and free metallic nanoparticles in the gas-phase is presented. This unique set-up is equipped with a magnetron based cluster source, capable to deliver intense molecular beams of metallic nanoparticles with a wide size distribution (~1 to 10 nm). A preparation and a deposition chamber allow to prepare and characterize the nanoparticles. Projectile ions are formed in an ECR ion source in charge states between 2 and 25 at an acceleration voltage of 15 kV. After the collision the positively charged products are analyzed with respect to their mass/charge ratio by time-of-flight spectrometry. Different mechanisms like electron capture, evaporation and sputtering will be discussed. Fig.1 shows the region of small-sized Ag clusters produced after collisions of 255 keV Xe^{17+} projectiles with silver clusters of ~8 nm in diameter. The spectrum, which is dominated by small fragments, is mainly due to sputtering processes. These are characteristic for irradiation of bulk surfaces. Shell closing effects for clusters having n=3, 9 and 21 atoms are observed (n=2, 8, 20 for neutrals) indicating their higher stability.

Considering the radiosensitizing efficiency of metal nanoparticles in cells, the passage of the ion deposits a significant amount of energy within the particle, leading to evaporation/sputtering and the production of a large number of atoms, small clusters and surrounding molecules. This can contribute to thermo-mechanical damage as well as to the spread out of metal in a nanoparticle-loaded cell. Furthermore, it may explain the observed radiosensitation by increasing the effects of toxicity.

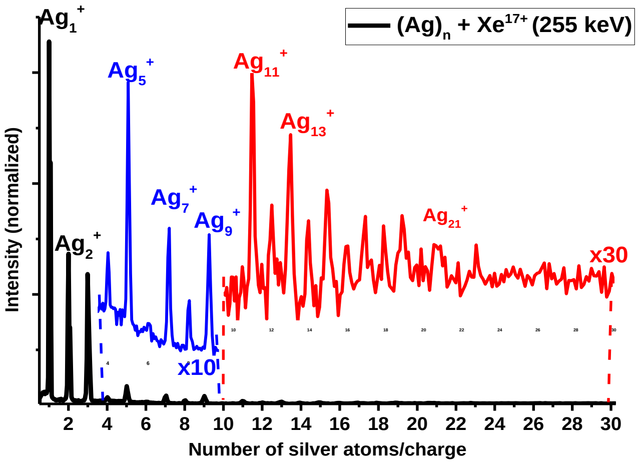

Figure 1. Low mass range of the spectrum produced in collisions between highly charged 255keV Xe^{17+} ions and $(Ag)_n$ particles with diameters between 2 and 10 nm.

References

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[1] E-mail: mika@ganil.fr , arkadiusz.p.mika@gmail.com