Andromede project, from dream to reality.

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For a few years the collaboration between our groups explored the advantages of Nano-
Particle (NP) projectiles for the surface analysis. Our studies led to the Pegase project1,
found by NSF (Grant CHE-0750377) and installed in TAMU, which allows a 130 KV
acceleration of NPs delivered by a LMIS (Liquid Metal Ion Source). The results obtained
with this platform demonstrate the interest of this new probe for the biological and also nano-
structured surface analysis. The Pegase project allowed the design of a new more ambitious
instrument, taking into account the results obtained at higher energies in the MeV range2,
named ANDROMEDE which has won the national call for proposal EQUIPEX (Excellence
Equipment). This project is now being achieved. The goal is to create a new instrument for the
analysis by mass spectrometry of nano-fields and nano-objects present on a surface with a
spatial resolution around the µm. Molecular information (mass and structure) will be obtained
from the impact of a Nano-Particle accelerated in the MeV range by a Van de Graaff
electrostatic accelerator from 1 to 4 MV. The principal device of this new instrument is a
rising generation of ion sources NAPIS (Nano Particle Ion Source) installed in the
electrostatic accelerator terminal. The dedicated instrument will be a ToF mass spectrometer
with high mass resolution incorporating the localization of the NP impacts with micrometre
accuracy; this last point was developed in collaboration with the TAMU group from their
Electron Emission Microscope which is modified to obtain an image in positive mode from
the H⁺ emission (EPEM, Electron Proton Emission Microscope).

We shall recall the main results leading to the project. The Andromede project (ANR-10-
EQPX-23)3 enters its final step and will be described and the first results presented. The
commissioning of the Van de Graaff type accelerator made by NEC (National Electrostatics
Corporation, Middleton, Wisconsin USA) has been performed. A maximum voltage of 4160
MV was reached. The terminal voltage of 4 MV was left unattended without any problem
during 15 hours with a SF6 pressure of 6.5 bars. The accelerator is equipped with two
interchangeable ion sources. The ECR source Microgan™ is provided by Pantechnik. The
advantage of this source lies in the adjustment of the magnetic field which permits to produce
multicharged atomic ions like A⁸⁺ (with a minimum B configuration) or intact molecular ions
like fullerene C₆₀³⁺ (without minimum B). OrsayPhysics, partner of the Andromede project,
developed the ionic column NAPIS which provides beams of atomic ions, clusters and gold
nanoparticles constituted with a few hundred gold atoms.

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1 The Pegase project, a new solid surface probe: focussed massive cluster ion beams, S. Della-Negra, J. Arianer,
2 Massive Clusters: Secondary emission from qkeV to qMeV. New emission processes? New SIMS Probe? S.
3 http://ipnwww.in2p3.fr/-ANDROMEDE,384- This work has benefited from an “Equipement d’Excellence”
grant managed by the Agence Nationale de la Recherche (ANR-10-EQPX-23)
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For a few years the IPNO group explored the advantages of Heavy particles and MeV projectiles for surface analysis. These studies led to the use of Nanoparticles as a surface probe which is now developed by a collaboration between our group and the EA Schweikert’s group from TAMU. Speciality with the Pegase project, founded by NSF (Grant CHE-0750377) and installed in TAMU, which allows a 130 KV acceleration of NPs delivered by a LMIS (Liquid Metal Ion Source). The results obtained with this platform demonstrate the interest of this new probe for the biological and also nano-structured surface analysis. Results obtained at Orsay at higher energies in the MeV range, led to design a new more ambitious instrument named ANDROMEDe which is granted in the frame EQUIPEx (Excellence Equipment). This project is now being achieved.

First Experimental Results

The goal of the Andromede project is to create a new imaging mass spectrometry instrument capable of performing MeV SIMS, and MeV cluster SIMS, as well as another instrument to perform IBA techniques in one location. The two sources of primary ions chosen for the project will be placed in tandem in a NEC Pelletron® 4 MeV accelerator. An ECR will ionize species introduced through a gas inlet or evaporated/sublimated by an oven. It is possible to obtain multi-charged atomic ions as well as molecular ones as fullerenes. There is also a new LMIS named NAPIS (Nanoparticle Ion Source) capable of producing a range of metallic clusters (for gold: Au, Au, Au, Au, Au, Au, Au, Au, Au).

The design of this new imaging MeV cluster SIMS instrument will include a sample introduction interlock, a sample positioning stage, a high resolution mass spectrometer with electron and proton emission microscope.

The Van de Graaff accelerator built by the NEC Company has been commissioned. A maximum voltage of 4160 MV has been reached.

Pantechnik provided the ECR source Microgan™ with a 10 GHz RF generator of 100 W. The ECR source, with a minimum B configuration provides very intense beams reaching 100 µA for Cr and around 40 µA for argon A+. In the configuration “without minimum B”, the source delivers 50 µA of CO2+ for ten W. In this condition with the use of an oven, and Helium gas, tens of nano-amps of C60+ have been produced.

OrsayPhysics, provided the ionic column NAPIS. This column delivers gold atomic ions (50 nA), clusters (several nA) and nanoparticles composed of 100-1000 atoms (around the nA). The diameter of these quasi parallel beams injected into the accelerator is of the order of 500 microns.

The Andromede Project will be installed in a new facility of the University Paris Sud : IGLEX (it can be seen below). In this facility two EQUIPEx projects will be set in one place (Andromede and ThomX). This new multi-disciplinary facility will boost collaborations between physicists, chemists, biologists and medical researchers.

The Andromede Project is funded by the program for future investment: EQUIPEx, ANR-10-EQPX-23. M. Eller thanks the IPN for their financial support.

Conclusion

• With a “reasonable” energy of about 1-4 MeV per charge the massive projectiles induce emission rates of several tens to hundreds of ions per impact.
• The ion emission yields reach large values for bio molecules, for example the molecular ion yield is 30 % for lipid A (MW ~ 1300-1800 u).
• It is possible to obtain a Time of Flight spectrum with only one impact and thus corresponding to a surface of approximately 100 nm² and a volume of 10⁶ nm³.
• The very high electron and H+ emission yields permit to localize the impact in the sub-micrometric range with an emission microscope.

The availability of massive clusters at 150 keV with the Pegase project (Grant CHE-0750377) and the Andromede Project in the MeV range (ANR-10-EQPX-23) opens promising prospects for probing nano-domains.