The use of massive cluster projectiles in SIMS has been shown to significantly enhance SI yields, specifically 100qkV Au400+4 delivered by the Pegase platform, which has shown to increase the yield of molecular ions by at least ten times.[1] To utilize this projectile for SIMS analysis several custom made instruments have been used at IPN-Orsay and Texas A&M University since 2003.[2,3] The results from the Pegase project[4] allow one to design new more ambitious instruments which take into account the results obtained in the MeV range (another increase of almost one hundred times).[5] At IPN-Orsay the Andromede project will be dedicated to surface analysis under vacuum and at ambient pressure for mass spectrometric analysis on native hydrated biological surfaces. The impact of nano-particles accelerated in the MeV range, by a Van de Graaff electrostatic accelerator from 1 to 4 MV, will serve as the primary ions for SIMS analysis.

For this project a new FIB column equipped with a LMIS, Liquid Metal Ion Source, termed NAPIS, NAno-Particle Ion Source, has been developed at Orsay Physics in collaboration with IPN-Orsay. The source is designed to produce a range of gold projectiles Auun+ (e.g. Au1+, Au3+, Au5+, and Au400+4) with beam intensities greater than 300pA (see figure 1). Initial tests show that the source is capable of producing more than 900pA of Au400+4 with 20qkeV impact energy. To separate the different projectiles produced from the source, a Wien filter (mass resolution of 20) is used. In a second step this source will deliver beams of synthesized nano-particles with definite sizes by using a nano-particle ionic liquid.

The goal of the Andromede Project at IPN-Orsay is to couple the NAPIS column to a 4MeV van de Graaff particle accelerator, and is currently in progress. The column is designed for direct injection of a parallel beam into the first stage of the accelerator, figure 2. The beam line is equipped with a ToF mass spectrometer and an Electron and positive Hydrogen Emission Microscope capable of locating ion impacts with sub-micrometer precision which was developed in collaboration with the E. A. Schweikert group.[6] The instrument is scheduled to be operational in fall of 2014. Before this date, the column will be used for the preparation of nano-structured surface samples for catalysis experiments and cationization effects to reduce the fragmentation and damaging of organic samples in static SIMS (Cluster project from Gabriel Lippmann Research Center).

The characterization and results from the NAPIS source and its integration into the Andromede Project will be presented. The Andromede Project is funded by the program for future investment: EQUIPEX, ANR-10-EQPX-23.
Figure 1: Mass spectrum of projectiles produced by the gold LMIS at 20qkV.

Figure 2: SIMION calculation for direct injection of a parallel beam at 20qkV into the first stage of the van de Graaff.

Motivation

Use of massive clusters in SIMS have shown to greatly enhance SI yields.

Irganox 1010

Molecular Ion Yield Enhanced by >1000X
High Impact Energy

Andromede Project

For impact energies at 4qMeV more than 50 molecular ions per impact are observed.
Iglex

Cluster MeV-SIMS & Material Science

Atomic MeV SIMS IBA Solid Irrad.

NEC 4 MV Van de Graaff Accelerator
Schematic of IPNO Column

Beam Direction

Wien Filter

Primary Ion Lens

Gold LMIS with Orsay Physics Cartridge

Mass Aperture
150µm

Distances in mm
Schematic of Cartridge

Suppressor +19 kV  Extraction +12.5 kV

Needle +20 kV  Beam Direction

Reservoir

Needle  Extraction
Gold Silicon LMIS Source

Beam Current (pA)

$\text{Au}^+$

$\text{Au}_2^+$

$\text{Au}_3^+$

$\text{Au}_3\text{Si}^{2+}$

$\text{Au}_4^+$

$\text{Au}_5^+$

$\text{Au}^{+2}$

$\text{Au}^{+2}$

$\text{AuSi}^+$

$m/z$

60 $\mu$A

40 $\mu$A

Au NP Region

Resolution = 26
Production of Gold Nano-Particle
Nano-Patterning Surfaces with Decelerating Lens

LMIS +20kV

Mass Aperture 150µm

Decelerating Lens +20kV

Sample +10kV

Beam Direction

Distances in mm
Nano-Patterning Surfaces with Decelerating Lens

Decelerating Lens

Distances in mm

Optical Image of Implantation

Ion Image of AuGe⁺

40keV Au₄₀₀ Implanted in Phenylalanine
Depth of Implantation ~10nm
NAPIS Column Injection into Accelerator

- Au LMIS
- Wien Filter
- Faraday Cup
- Decelerating Lens
- Faraday Cup
NAPIS

Injection into Accelerator

Beam Direction
Injection Into Accelerator

LMIS  Primary Ion Lenses

D=215μm,α=±0.8mrad

Wien Filter Aperture  Decelerating Lens

SIMION Calculation for injection into the accelerator via the NAPIS column
Spot Size of Beam

Total Beam

20 keV Au$_1^+$
Use of Additional Projectiles via ECR

Available Projectiles: \( \text{Ar}^{+1-7}, \text{SF}_5^+, \text{He}^+, \text{etc.} \)

Diagram showing the beam direction, gas inlet, and antenna connected to the accelerator.
NAPIS Column + ECR

Utilizing the ECR to increase the charge state of the emitted species from the gold LMIS
NAPIS Column + ECR
Conclusion

- $\text{Au}_{400}^+^4$ generated with greater than 900pA of beam current
- Injection of a parallel beam into the accelerator
- Nano-Patterning of Surfaces
- Coupling the ECR to generate $C_{60}$ and a series of gaseous PIs
- Injection of $\text{Au}_{400}^+^4$ into the ECR to increase the charge state
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