ElectroHydroDynamic emitters developments for improving Focused Ion Beam machines

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The patterning of samples using Focused Ion Beams (FIB) is very popular, widely used both for industrial[1] and emerging nanoscience prototyping applications[2,3]. This FIB technique allows 3D and direct patterning of target materials using a finely focused pencil of ions having speeds of several hundreds of km/seconds at impact with a penetration range of a few tens of nanometre. Thanks to this, local information and/or modifications can be obtained at the target surface. As far as the ion nature is concerned, apart that many elements can be used in FIB technology as pure elements or in the form of alloys, gallium (Ga^+ ions) is often preferred.

Traditionally for several decades FIB technology has been mainly based on gallium Liquid Metal Ion Sources (LMIS). LMIS are also known as electrohydrodynamically (EHD) driven ion emitters operating in a cone-jet mode. The very high brightness, long lifespan, small source size, and easy handling of this emitter remain its chief and most decisive advantages. On the other hand, some weaknesses are also well known that inhibit the resolution of EHD/LMIS-based FIBs. Therefore progress on ion sources operational characteristics still remains very desirable.
In this presentation we will first summarize our work aiming at understanding, optimizing and evaluating gallium LMIS “needle type” performances. In particular stable operation at lowest possible emission currents will be detailed. We will evaluate the gains in terms of patterning resolution and beam

selectivity[4].There is firm evidence that progresses can still be expected from this mature technology.

We will then review and detail the advantages of Liquid Metal Alloy Ion Sources (LMAIS) that represent a promising alternative to expand the already remarkable application field and potential of FIB machines in the field of nanosciences. Indeed selecting the best suited elements transported in a focused ion beam can open new nanofabrication routes. In this presentation we will explain that nearly half of the elements of the periodic table can already be made available to the FIB technology as a result of a continuous research effort in this area[5] and how, in our opinion, nanofabrication shall now take benefit of these capabilities.

Finally we will introduce our new addition to the arsenal of EHD driven devices: The Ionic Liquid Ion Sources (ILIS). ILIS are capable to produce ion beams through field-evaporation, also in the cone-jet mode, but from room temperature molten-salts[6]. The possibility of extracting both positive and negative ions at emission current several orders of magnitude below LMIS standards is already a very appealing perspective in terms of virtual source size and brightness. Then we will show that ILIS allows to access new ionic species thanks to the almost limitless chemical engineering latitude of molten salts. Moreover subsequent tuning can be achieved via selecting the tip polarity, the ion emission current and the ion landing energy. We will show the possibility to achieve a new kind of FIB patterning using a beam of chemically reactive ion radicals native in the transported beam. This represents a formidable perspective for FIB technology.

In conclusion we will summarize our vision on the future of FIB technology based on electrohydrodynamically (EHD) driven emitters operating in the cone-jet mode, both in terms of performances, versatility and on the science frontiers these might help to push.

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