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The Hyperion™ Ion Probe for Next Generation FIB, SIMS and Nano-Ion Implantation.

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A high performance ion source (Hyperion™) has been developed that significantly advances the capabilities of many ion beam techniques used by material scientists and engineers. Hyperion™ has been developed to provide focused beams as small as 10nm, beam currents up to several microamps and with a broad range of ion species that include He^+, O_2^+, Xe^+ and H_3^+. This paper summarizes a few applications that have been explored with this new system, along with some of the enhanced capabilities anticipated for surface engineering, sample preparation and surface analysis.

Hyperion™ is a high density, non-thermal plasma ion source that exhibits very high brightness, low energy spread and is able to operate reliably with a broad range of ion species [1,2]. This technology provides state-of-the-art performance in many areas of surface science and engineering that include FIB Milling, Nano Implantation and High Resolution Surface Analysis.

This new ion source provides a *useable* current that extends to many micro-amps with an energy normalized brightness of $>1x10^4$ $Am^{-2}sr^{-1}V^{-1}$ with xenon, $6.7x10^3$ $Am^{-2}sr^{-1}$ V^{-1} with helium, $4.5x10^3$ $Am^{-2}sr^{-1}V^{-1}$ with oxygen and $2.7x10^3$ $Acm^{-2}sr^{-1}$ with hydrogen. Unlike point ion sources (eg the liquid-metal ion source), the effective beam brightness at the target can be maintained from pico-Amps up to many micro-Amps. The combination of high brightness, low energy spread and very high angular intensity provides this broad range of operating currents. A comparison of the typical gallium FIB performance with the Hyperion™ FIB is shown in figure 1. Hyperion™ excels at beam currents >50nA, while still having the brightness to provide <25nm resolution for imaging at 30keV.

This system finds a broad array of applications, that includes large area cross-sectioning of next generation 3D IC technologies. In the coming years, critical interconnects and vertically stacked circuitry will often need to be excavated by deep FIB milling for failure analysis. Figure 2 shows a cross-section of a 'Through Silicon Via' (TSV), anticipated in the industry to replace external wire interconnects for these new high density devices. Once the fabrication process has been further developed for these 3D devices, over 10^5 TSV's are anticipated for some stacked die.

Applications such as prototyping MEMS and embedded circuit components have been demonstrated with this high current FIB. Figure 3 shows a micro-scale spiral RF antenna, often used on RF IC's, that has been fabricated here in <60 minutes. A 5µm thick layer of copper has been locally sputter deposited over a ~250x250µm area of silicon oxide with a 3µA Xe^+ beam hitting a copper target and creating a conformal deposit in ~25minutes. A bitmap has been uploaded to the FIB pattern generator, directing a 250nA, 25keV Xe^+ beam to mill away the excess copper. The deposited copper has a measured electrical conductivity that is within a factor of 3 of bulk copper, such that this 2.5nH (calculated) inductor would have a quality factor (Q) of ~20 at 5GHz, ignoring substrate losses and parasitic capacitive effects that can affect these parameters at higher frequencies.

Extrapolating from proven performance, our calculations show that a 30keV Hyperion™ ion probe, coupled with a biased sample stage can result in a system for up to 150keV nano-implantation with sub-10nm resolution. Figure 4 shows the anticipated performance of the source, coupled with an early generation FIB/Direct Write Implanter (MBI's NanoFab150), resulting in a system that could carry out patterned implantation of with a broad range of ion species and unprecedented precision.

In the field of surface analysis, tremendous advances are now being demonstrated with this new ion source. Historically, high sensitivity SIMS imaging has been limited to analysis with low resolution (>200nm) oxygen beams. Hyperion™ will be able to generate a 30keV oxygen beam to enable SIMS imaging at close to the theoretical resolution limit of 20nm. When operating with oxygen, this new source has a spectral brightness that is more than a factor of 30 higher than any other oxygen plasma source [3] used for surface analysis. This source also promises to make the requisite 150eV O_2^+ SIMS depth profiling of next generation Ultra-Shallow Junctions (USJ's) a viable technique for routine analysis, by reducing analysis times by as much as a factor of 20.

References

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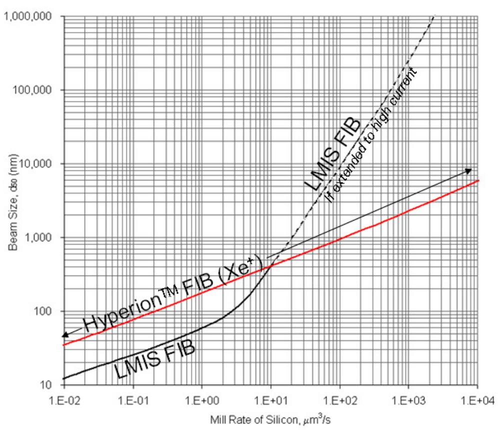

Fig.1. Comparison of Hyperion™ with LMIS FIB

Fig.2. Deep Cross-sectional analysis of Through Silicon Via.

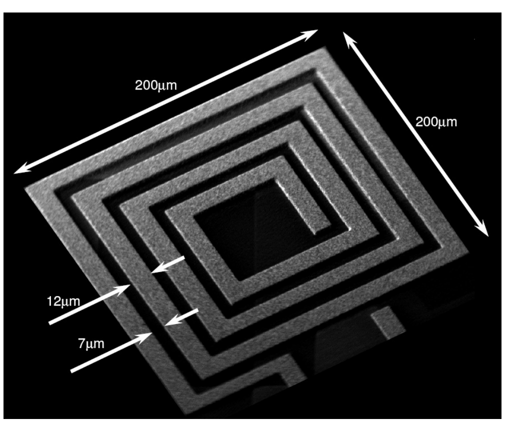

Fig.3. Prototyped copper-on-silicon oxide spiral antenna. 2.5nH inductance for wireless RF IC.

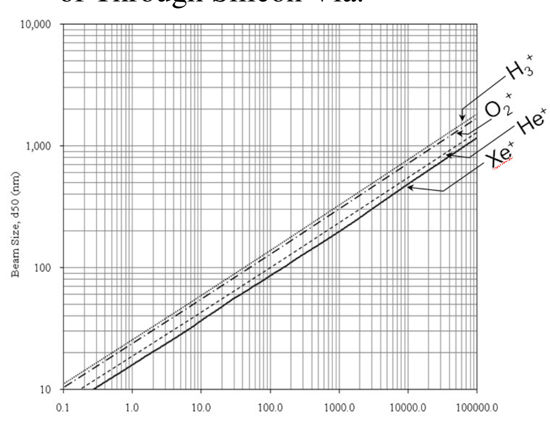

Fig.4. 100keV Nano-Implantation with Hyperion™ and a NanoFAB150 (MBI)

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