Metrology for 3D Devices: Plasma-FIB for High-throughput Sectioning of Large Dimensions

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ABSTRACT

Milling speeds with a gallium focused ion beam (FIB) are often much too slow for many sample preparation and surface engineering applications. For example, cross-sectioning stacked-die semiconductor devices and prototyping micro-mechanical structures are growing applications that require milling rates that far exceed those provided by the gallium FIB.

The high brightness of the gallium liquid metal ion source (LMIS) can be fully exploited to form beam diameters of nominally 5-50nm with beam currents of 1pA-1nA. However, above 10nA the LMIS-FIB spot size tends to increase rapidly as a function of current, with the geometric aberrations of the condenser lens becoming dominant. A 100nA gallium LMIS-FIB can only be focused into a nominal spot size of 5-10um, with the column aberrations causing the beam brightness at the target to be attenuated by a factor of 10^3, compared to the source brightness. In this high current regime, an ion source not only requires high brightness, but also a high enough angular intensity to prevent condenser lens aberrations from influencing the final beam diameter.

Here we review a focused ion beam that employs an inductively coupled plasma (ICP) ion source (Hyperion™). This ICP-FIB is able to focus a 2000nA, 30keV xenon beam into a 3um spot and provide an imaging resolution of <20nm with 1pA. The same ion source is also readily operated as a high brightness source of oxygen, hydrogen and any inert ions.

The ICP ion source operates by transferring energy to plasma electrons via a radio frequency induction field, creating a plasma state without a cathodic electrode. This method of plasma creation can create high plasma densities ($>1x10^{13}$ ion cm^{-3}), coupled with very low mean thermal ion energies (<0.05eV), providing the conditions required for energy normalized beam brightness values that exceed $1x10^4$ $Am^{-2}sr^{-1}V^{-1}$ and an angular intensity of several mA/sr. This high brightness can be attained with long lifetimes (>>2000 hours), stable beam current (<±0.5% drift per 30 minutes), an axial energy spread for the extracted ion beam of 5-6eV and for a broad array of ion species.

The Hyperion™ ion source is already capable of generating smaller probe diameters than the liquid metal ion source (LMIS) FIB at beam currents in excess of 20nA, and the future for this technology promises to be even brighter. This paper discusses the principles of the ICP-FIB and presents an array data from that exemplifies the capability for creating large area cross-sections of next generation 3D semiconductor devices.

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