Nanoscale to Millimeter Scale Milling with a Focused Ion Beam Instrument.

Paul P. Tesch, Noel S. Smith, Noel P.Martin, and Doug Kinion

Oregon Physics LLC, 2704 SE 39th Loop Suite 109, Hillsboro, Oregon 97123, USA

A new focused ion beam (FIB) instrument capable of milling structures with dimensions from the nanoscale to millimeter scale has been developed. In this instrument, a radio frequency plasma ion source with an electrostatic matching lens has been integrated onto a commercially available two lens electrostatic FIB column to create a new FIB tool that can mill(or image) structures from less than 50 nanometers to over a millimeter in size. This ion beam instrument can be operated with a variety of gases and has been run with Xenon, Oxygen, and Helium.

The inductively coupled plasma ion source operating with Xenon has a measured brightness of B_r=1.3x10^4 Am^{-2}sr^{-1} , a virtual source size of d_v~13µm, and an angular intensity of I'~18mA/cm^2 with a 10kV extractor. With Oxygen the source brightness is B_r=4430 Am^{-2}sr^{-1}, the virtual source size is d_v~13µm, and the angular intensity at 10kV extractor is I'~9.2mA/cm^2. (1) The three lens optical column with it's large demagnification range (0.002-1) can balance the aberrations with the large virtual source size to produce an optimized beam for probe sizes from 30 nm to ~3 microns. This corresponds to a range of current of ~10 picoamperes to 2 microamperes.

This FIB instrument provides a milling rate that is well suited for creating patterned structures of a particular size from the nanoscale to nearly a millimeter. At 2 microamperes this tool has a volume removal rate without gas assisted etch of ~6000 µm^3/second and is capable of milling structure much larger than can practically be done with a conventional Ga LMIS FIB. Figure 1A shows a milled cross-section of a ~750µm diameter solder ball from a Ball Grid Array (BGA) that was milled in about six hours. With a conventional 50nA Ga FIB this would have taken ~ 100 days. Figure 1B shows an image of the under bump metallization layer taken with a 1nA Xenon beam. Applications for this FIB instrument include cross-sections for IC package failure analysis, prototyping of MEMS devices, Gallium free milling of nanoscale devices, high resolution oxygen beams for secondary ion mass spectrometry. Figure 2A and Figure 2B shows images taken at ~300pA with an Oxygen beam and resolution of ~80nm.

In this paper the performance of this new FIB instrument will be discussed and examples of milled structures at the nano-scale, the micro-scale, and the millimeter-scale with be presented.

[1] Smith et al., Proc. SIMSXVI Conf., Kanazawa, 2007

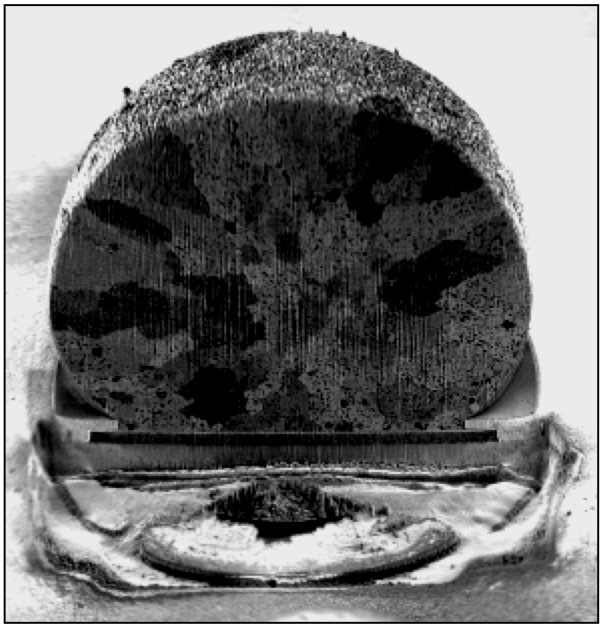

Figure 1A

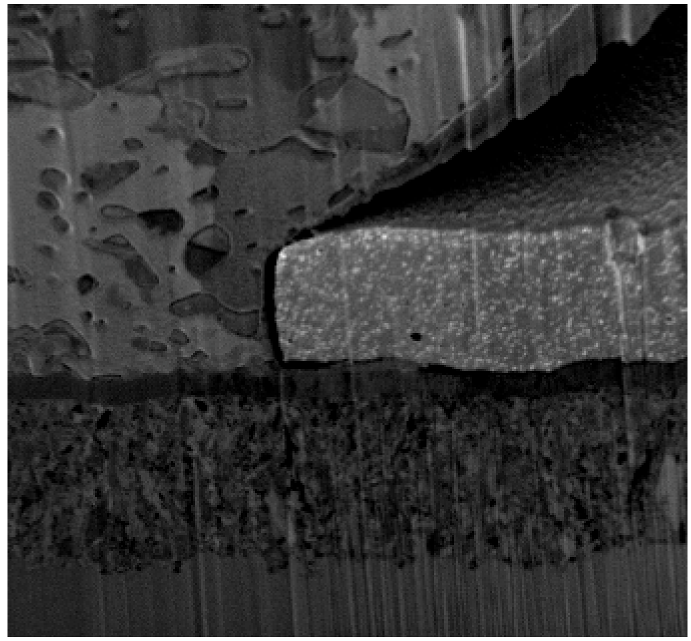

Figure 1B

Figure 1A shows a milled cross-section of a ~750μm diameter solder ball from a Ball Grid Array (BGA) that was milled in about six hours with a 1.7 microampere Xenon beam, Figure 1B shows an image of the under bump metallization layer taken with a 1nA Xenon beam.

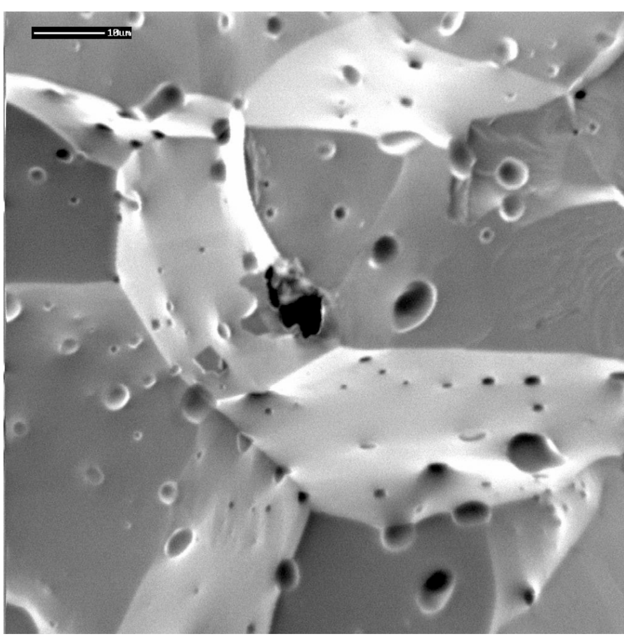

Figure 2A

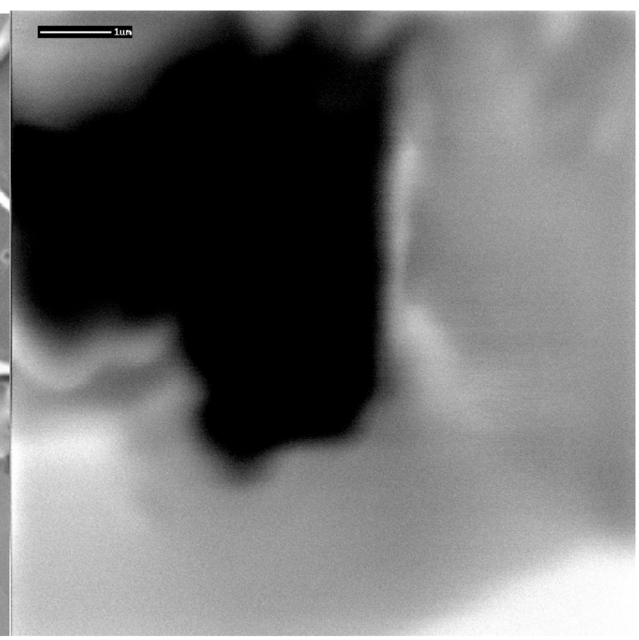

Figure 2B

Figure 2A and Figure 2B shows images taken at ~300pA with an Oxygen beam and beam probe size of ~80nm.