A system for massive, rapid material removal for device analysis in monolithic 3D integrated circuits

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With the increasing prevalence of advanced 3D integration of heterogeneous electronic components into a complex system-in-package device, new challenges for device fabrication and analysis arise. In particular, stacked device spatial organization makes it difficult to access components deep within a structure using conventional chemical jet or mechanical techniques. A focused ion beam (FIB) milling system has been used to perform mm^3-scale package material removal in order to access components of a monolithic 3D integrated circuit. By using a Xe inductively coupled plasma (ICP) source instead of a conventional Ga liquid metal ion source (LMIS), epoxy packaging was removed at a rate exceeding 4×10^4 μm^3/sec. The same system was also used to perform bulk silicon removal at rates exceeding 3×10^3 μm^3/sec. These rates outperform what is achievable with a conventional LMIS FIB by three and two orders of magnitude, respectively. The use of gas chemistry local to the mill site and other process improvements will be discussed. The ICP source emission has an energy spread of 3.6 eV under normal operating conditions which makes it also suitable for nanometer-scale probe formation when used with an appropriate focusing column. The reduced brightness and virtual source size of the ICP source will be discussed.

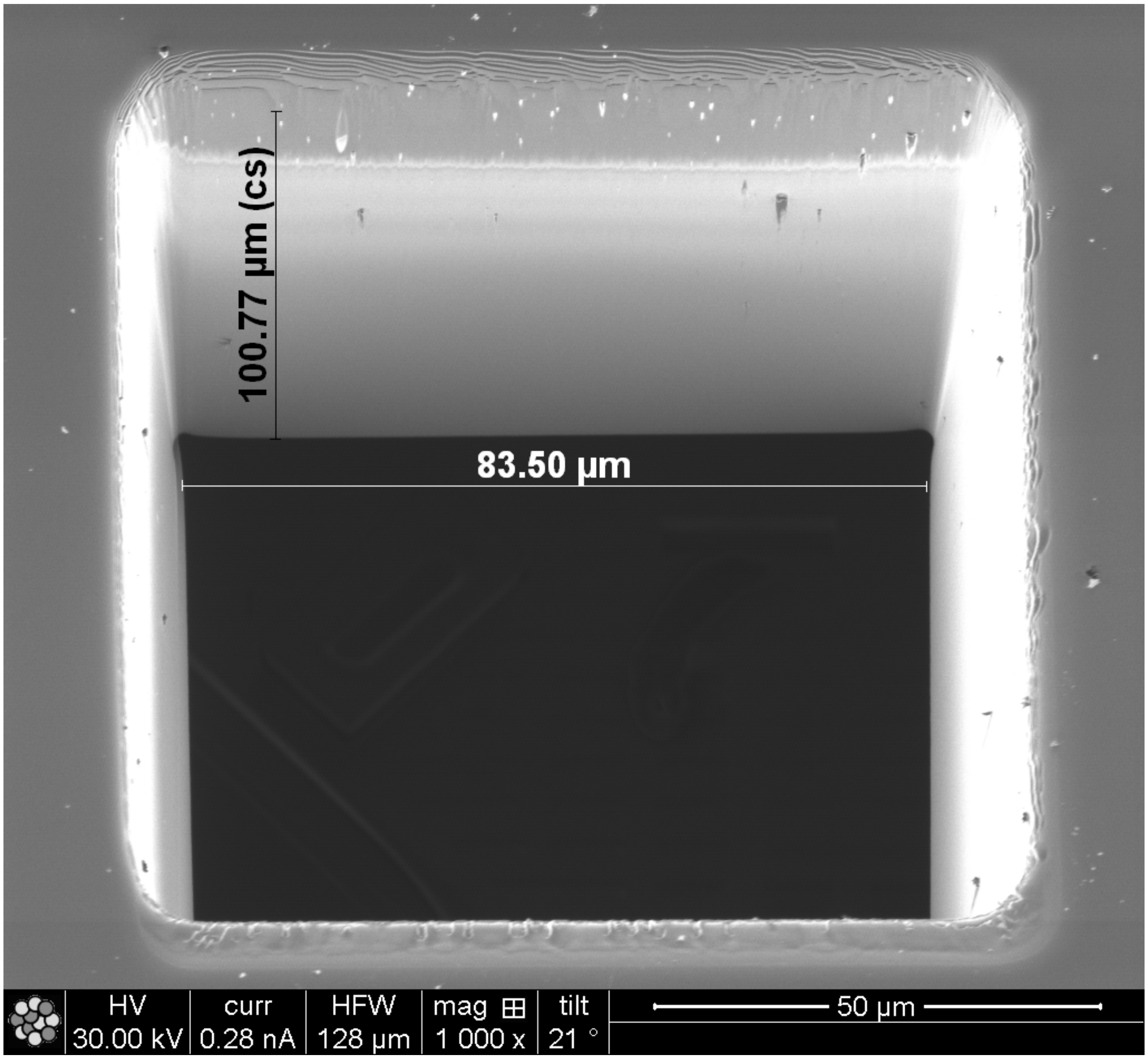

Fig I: Gallium LMIS FIB micrograph of an access hole milled though a layer of silicon, revealing an enclosed MEMS device just barely visible in the shadows. The 7.1×10^5 μm^3 of silicon was removed with a 1.5 µA xenon beam whose landing energy was 30 keV in less than four minutes, giving a material removal rate approaching 3.0×10^3 μm^3/sec.