Ultrafast nano-fabrication using Xe-plasma FIB-SEM and its Cu milling applications using the Rocking-stage

S. Sharang, A. Benkouider, T. Hrnčíř, J. V. Oboňa, J. Jiruše
TESCAN ORSAY HOLDING, a.s. Libušina tř. 21, 623 00 Brno, Czech Republic
abdelmalek.benkouider@tescan.cz

E. Principe
TESCAN USA, Warrendale, PA 15086, United States

Conventional Ga FIB has a reasonable resolution (typically up to 2.5 nm). However, these instruments present some limitations, including Ga ion implantation and contamination, and slow sputtering rate. New liquid metal alloy ion sources (LMAIS) have been developed to overcome these limits[1]. However, none of the proposed LMAIS sources is suitable for rapid milling because they can only deliver probe current up to few tens of nA. Contrary, emerging Xe plasma FIB systems promise faster removal rates[2,3].

Homogenous copper FIB milling arises from the need to perform various circuit edit operations below the dielectric layer following the copper layer. If the layer beneath the dielectric is affected by inhomogeneous milling, it can lead to short-circuit and eventual device breakdown. Failure analysis on an integrated circuit was performed using rocking stage with 6-axes piezo movement capabilities together with the novel approach of the combined Xe-plasma ion source FIB and SEM system (XEIA). The new Xe plasma FIB offers sputtering speed up to 50 times faster than the most powerful Ga FIBs. Compared to conventional Ga ion sources, the Xe plasma ion source reduces dramatically the time for cross-sectioning from tens of hours or even days to a matter of hours[4,5].

Site-specific milling of copper with different milling strategies were tested to optimize time and homogeneity of the milling across the target surface and to overcome the channeling effect posed by polycrystalline copper. Only during the last few nanometers of copper layer the water vapor is used to protect the dielectric layer. The complete removal of copper was followed with XeF_2 assisted milling of the dielectric layer to observe the unharmed circuitry. Channeling effect was reduced by regulating the sputtering rates across different grains keeping the underlying dielectric layer safe. Ultra-high-resolution scanning electron microscopy (UHR-SEM) imaging was used for constant monitoring of the removed material to help modulate the process for highest throughput in the least possible amount of time[6].

---

[1] A. Benkouider et al, Thin Solid Films 543 (2013) 69-73
[2] T. Hrnčíř et al, 38th ISTFA Proceedings (2012) 26
[3] J. Jiruše et al, Microsc. and Microanal. 21 (2015) 1995
[4] A. Delobbe et al, Microsc. and Microanal. 20 (2014) 298
[5] T. Hrnčíř et al, 40th ISTFA Proceedings (2014) 136
[6] The authors would like to acknowledge that this work is performed within the European Commission Initial Training Network, STEEP (Grant no. 316560).

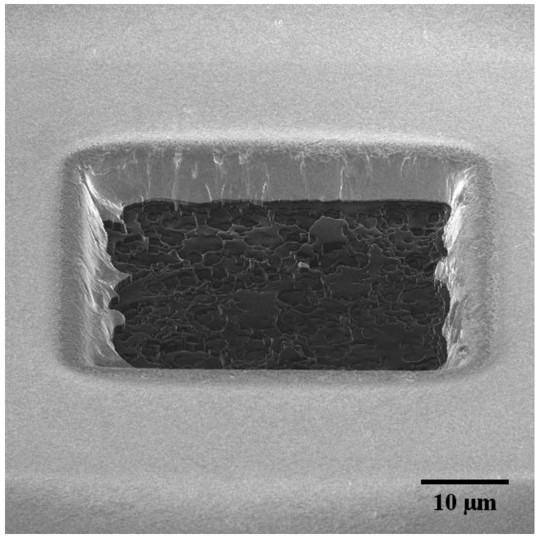

Figure 1: SEM image of uniform delayered Cu sample area using Xe FIB milling and the rocking-stage.

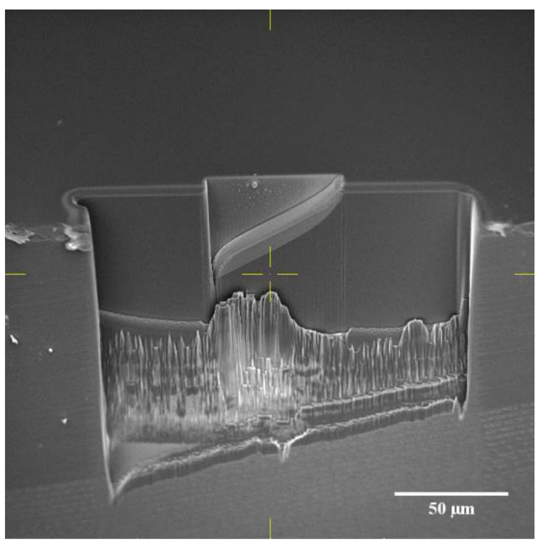

Figure 2: Cross section of through silicon pre-patterned area. A trench of 170 x *20* x *50 μm^3 in size was removed in only 20 minutes with Xe FIB rough milling.*