Broad Ion Beam Grid Cutting with Gatan PECS for 3D Scanning Electron Microscopy and Microanalysis of Integrated Circuits and Layered Structures

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Special microscopic technologies are necessary to characterize the sample in all three dimensions. Ion beam sputtering is a versatile tool for various purposes. Depending on the ion beam operation conditions and parameters selected tasks can be solved, e.g. cleaning, smoothing, thinning, selective etching, sputter coating and ion beam cutting. Ion beam slope cutting (IBSC) [1] can reveal the internal microstructure by a representative cut through the sample along selected surface lines. The cut area is free of deformations and smooth also in very inhomogeneous materials concerning composition, hardness, porosity etc. By IBSC 10000 times larger analysing areas can be produced compared with the focused ion beam (FIB) technology.

A modification of IBSC leads to the ion beam grid cutting technology. This technology has been introduced with laboratory equipment [2]. Here its application and further development is carried out with the available ion beam apparatus Gatan Precision Etching Coating System (PECS). The principle is drawn in FIG.1. A parallel beam of inert gas ions is directed onto the sample through a shielding grid and removes material in selected regions with a resulting network of bars. By SEM four families of perpendicular ion beam cuts can be observed to analyse the three-dimensional microstructure (FIG. 1b). In a modified version oblique incident ions according to FIG. 2 are used to generate only three families of cuts suitable for observation - however, some of them are inclined to the initial surface for better resolution of the layered structures and observable with really perpendicular incident electrons in the SEM or other analytical tools. The cut areas in this technology can be processed additionally by the same ion beam for other tasks as e.g. selective etching of the internal microstructure or polishing with rocking or rotation of the sample. By this additional ion beam processing steps often only one selected group of areas, e.g. the inclined family, can be prepared. The same apparatus allows sputter deposition of insulating samples.

With these techniques mainly IC microstructures and layered systems will be investigated as demonstrated in the following applications. FIG. 3 shows an IC structure with the Mo mesh for grid cutting. The cutting lines along the surface can be adjusted with the optical microscope. FIG. 4 shows the IC surface strongly inclined in the SEM with the bar network on 100 mm^2 chip area produced with 9 keV Ar ions. A single bar with cutting through tungsten plugs and conducting metal bands is seen in FIG. 5. By selective etching with the same ion beam at nearly normal incidence onto the cut area the internal grain structure of the tungsten plugs will be visible (FIG. 6). On this way buried structures over extended areas of many square millimetres can be revealed and the entire 3D microsystem can be investigated by SEM and other micro-analytical tools.

References

[1] W. Hauffe, Production of Microstructures by Beam Sputtering, Chapter 6 in *Sputtering by Particle Bombardment III* (Eds. R.Behrisch and K.Wittmaack), Springer Ser. Topics in Applied Physics, Vol. 64 (Springer-Verlag Heidelberg New York 1991) p. 305

[2] W. Hauffe, Proc. 12th European Congr. Electr. Microscopy (EUREM 2000) Brno/Czech Republic, September 2000, Vol. II, p. 571

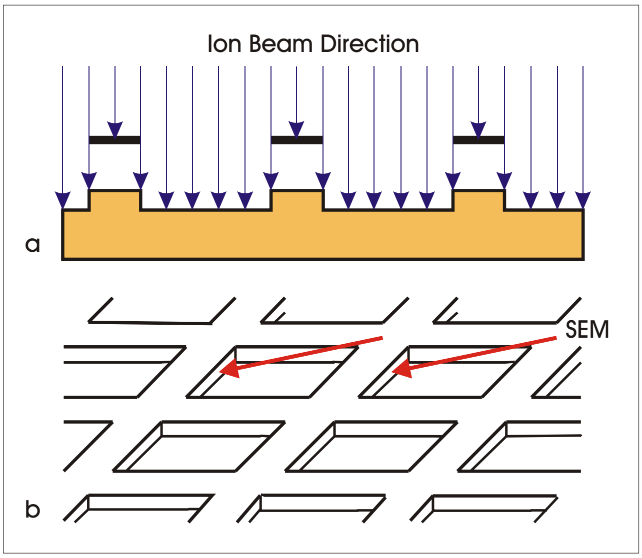

FIG. 1. Principle of ion beam grid cutting (IBGC)
a) Sputtering in selected regions through a shielding grid up to the required depth
b) Observation of the cut areas by SEM

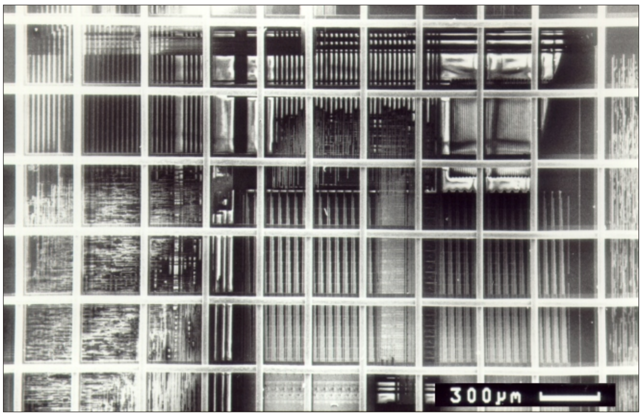

FIG. 3. Integrated circuit with a Mo mesh for ion beam grid cutting

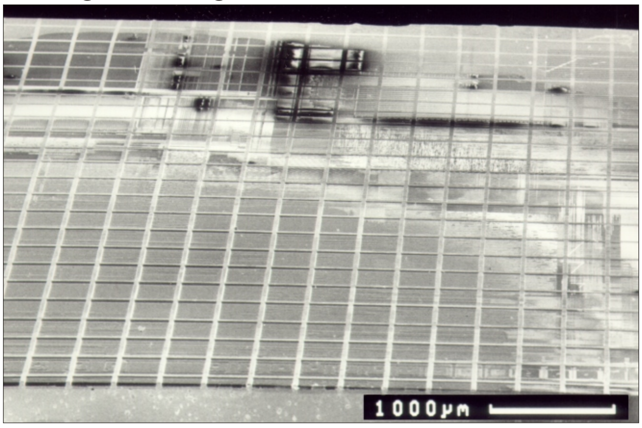

FIG. 4. IC surface with the system of cut bars covering a ship area with dimensions of one square centimetre

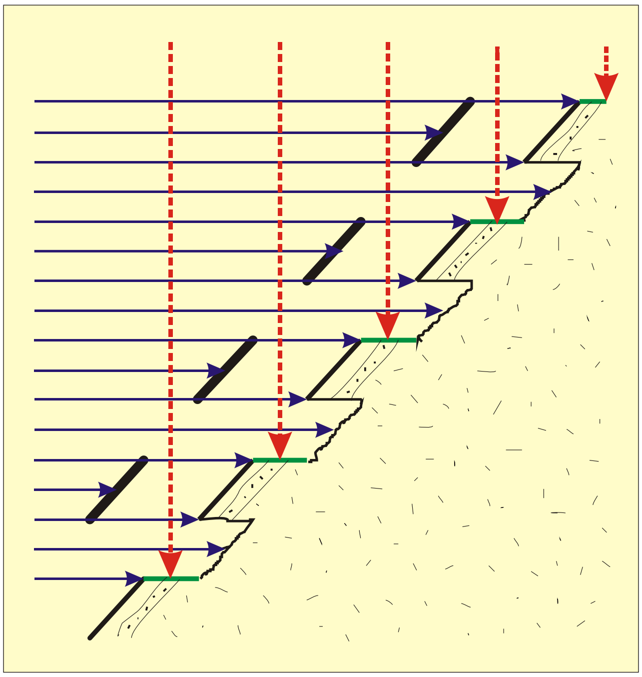

FIG. 2. Modification of ion beam grid cutting for oblique incident ions producing inclined cutting areas through a layer sytem (⟶ ion beam for cutting; ⟶ electron beam of the SEM)

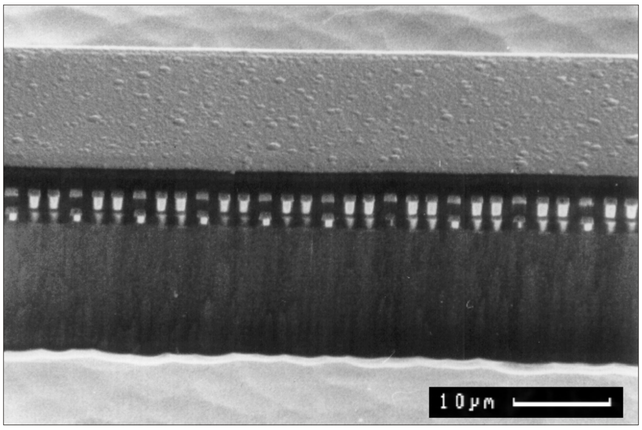

FIG. 5. Single bar of the bar network on the IC surface with cut regions through tungsten plug structures and conducting metal bands

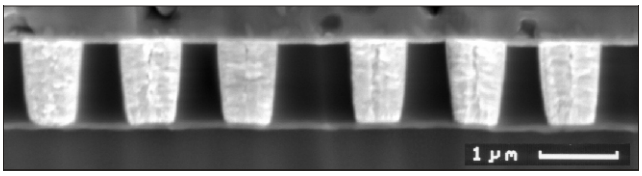

FIG. 6. Detail of the perpendicular cut through tungsten plugs after selective ion etching of the internal grain structure