Thin Films and Coatings

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In-situ inspection of nanogap structures fabrication by electromigration.

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The fabrication of nanogaps has generated much interest for applications in molecular electronics, plasmonics, single molecule analysis and detection. A nanogap consists of a pair of metal electrodes separated by a nanoscopic space. A number of methods for fabricating nano-gap electrodes has been demonstrated, such as mechanical break junction, electrochemical deposition, electromigration and Focused Ion Beam (FIB). Electromigration induced break junction was established as an effective technique for nanogap fabrication between 1 and 30 nm in width, due to its reliability, reproducibility and high throughput capability [1]. This process is driven by the mass transport generated by the migration of ions in metals (e.g. in a metal wire), due to the momentum transfer between conducting electrons and diffusing metal atoms. The accumulation of ions at the anode and the void generation at the cathode can result in nanogap formation.Various models were developed to describe the electromigration process [2], they however use the information on the final shape and dimension of the gap as input parameters, and do not consider the behavior of the structure that is forming during the process. This work focuses on the in-situ monitoring by Scanning Electron Microscopy (SEM) of the electromigration process during the formation of nanogaps. This procedure leads to an improved understanding of the mechanism of the process and the behavior of the metal wire during the electromigration. Figure 1a shows a chip containing 8 micro-wires, which are designed to perform the fabrication of 8 nanogaps. The electromigration process is controlled by a custom-made electronic board [3]. While the voltage increases, the current is continuously measured. The values of the current and the resistance over time are used to take control decisions on the voltage applied. If the rate of electromigration is too fast, the voltage is reduced in order to slow down the wire deepening and avoid thermal run away and melting. This process is repeated until eventually the wire breaks into two parts, which are separated by a nanogap. The electromigration process was performed and inspected in a Zeiss AURIGA CrossBeam FIB/FESEM Workstation electron microscope. Kleindiek micromanipulators with tungsten tips were used to contact the sample with the electronic board [Figure 1b]. During the process, it was observed that initially the wire is thinning and holes are created at the grain boundaries that are present in the metal structure. The expected behavior is that nanogaps are normally created at this location, however, it was also observed that some of the openings slightly re-close after some time. The narrowest point of the gap remains at this location. Figure 2 shows the created nanogap at a magnification of 350 kX. The nanogap is visualized as a narrow break perpendicular to the wire longitudinal axis, approximately 5 nm in width in this case. The proposed results can be used for the validation of existing models.

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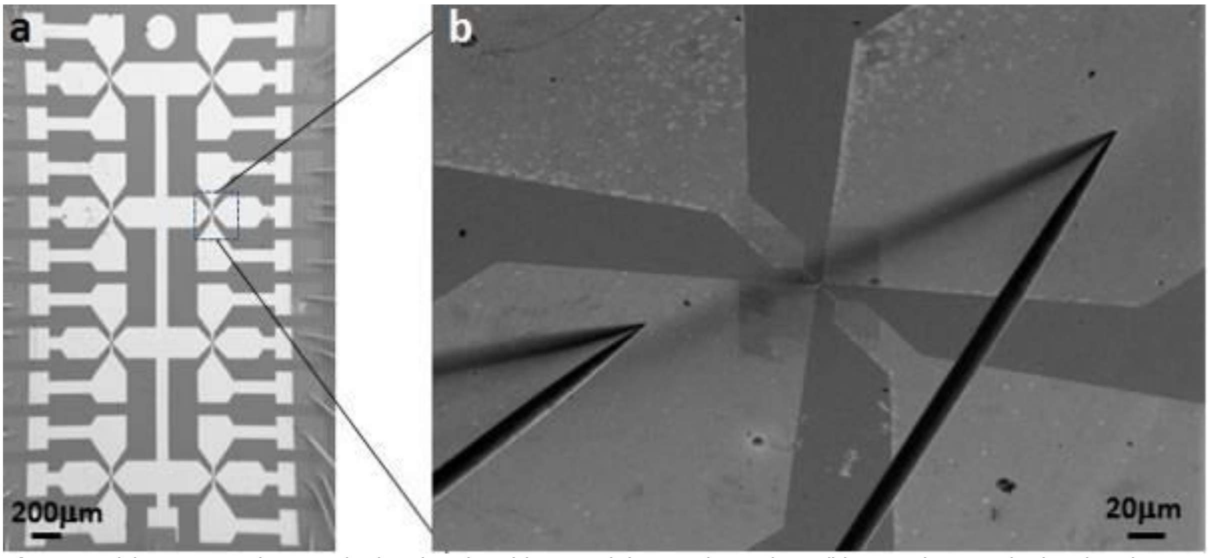

Figure 1. (a) FESEM micrograph showing the chip containing 8 micro-wires, (b) FIB micrograph showing the tungsten tips placed on the pads for electromigration.

Figure 2. FESEM micrograph showing the nanogap.