Conductive bridging RAM (CBRAM) is an emerging nonvolatile memory concept and alternative to RRAM, PCM or MRAM, offering lower energy consumption, higher speed and better 3D implementation opportunities. Despite research efforts, there are still two major obstacles to be overcome: the cycle-to-cycle and device-to-device variability. One cannot tackle these problems without examining the functioning of such device structures at the atomic level. TEM observation of the conductive bridge, also referred to as filament, is challenging due to localization problems and FIB preparation influences. One can avoid these issues by direct electrical contacting the electron transparent TEM lamellae. This requires the ability to create a stable electrical contact on a < 100 nm thin TEM lamella without destroying it.

In this work we prepared TEM lamellae from a blanket layer stack containing a 5 nm Al₂O₃ electrolyte and created a top contact by depositing Pt using the FIB beam. As bottom contact the TEM Cu grid was used. To lower the contact resistance, a 100nm thick platinum layer is sputtered over the specimen prior to the final thinning process. After thinning, the lamellae are cut into several cells allowing multiple filament creation within one lamella (fig. 2). In order to contact these small areas we rely on a so-called nanoprobing setup implemented in a SEM. The setup is based on four independent probes with fine mechanical control as they are piezo-driven, providing sub-nm precision for landing on the TEM lamellae contacts. Basically the probe-contact area can now be used to impose the required I-V cycling of the dielectricum. However one does observe that the contacting resistance dominates the entire system such that the resistance drop from a filament bridging the Al₂O₃ layer cannot be observed. To overcome this problem the quality of the contact resistance is improved by replacing the commercially available tungsten probes which have a thin oxide on their surface causing the high resistance, with conductive diamond tips. These probe are in-house fabricated, oxide free and gave a good electrical contact with substantially decreased tip wear (fig. 1). The IV’s obtained with these nanoprobes, show a gradual SET process, with a resistance change from the high to low resistance state of 100 X (fig. 3). It is shown that the cells on these lamellae can be reset to their original high resistance state at least 5 times. In order to elucidate the material changes related to the SET/Reset process, TEM/STEM and chemical EDS analysis are performed in a Tecnai and Titan microscopes, on the structures before/after the switching (fig. 4).

Acknowledgement: Felix Seidel acknowledges the Institute for Promotion of Innovation by Science and Technology in Flanders (IWT) for his Ph.D. fellowship.
Fig. 1: Figure 1: SEM image during the nanoprobing with diamond tips. Probe P1 functions as bottom electrode contact on the Pt coated Cu grid and P2 as top electrode on the ion Pt. Inset: stack scheme, FIB-cut and Pt backcontact. Red line indicates position of expected filament.

Fig. 2: Figure 2: STEM image of the sample before switching. FIB cuts reach into silicon and divide the specimen into cells, which can be tested independently. Inset: HR-TEM of switching layers. If a positive bias is applied on the Cu, Cu\(^{+}\) ions bridge through the Al\(_2\)O\(_3\) layer towards the Si.

Fig. 3: Figure 3: IV cycling on a single cell of the stack on the thinned lamella allows to set and reset the device several times.

Fig. 4: Figure 4: EDX map showing the distribution of elements.