Type of presentation: Oral

IT-7-O-3113 In-situ biasing and switching of electronic devices into a TEM.

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In order to understand the physics of new materials that are currently being developed for use in electronic memories it is now necessary to perform in situ switching inside a Transmission Electron Microscope (TEM).
In this talk we will present our approach towards the development of a robust integrated characterization system that enables in-situ biasing and/or switching of electronic devices inside a TEM. As microscope time is valuable, the basic idea is to be able to electrically test a device before and then after specimen preparation outside of a TEM such that the electrical properties are understood before in situ operation in the TEM. The goal is to correlate the electrical properties to modifications in the crystalline structure and composition measured using HAADF STEM and EELS and the dopant/vacancy distribution measured by electron holography [1]. For this task we have been using a dedicated specimen holder featuring six static electrical contacts and a piezo-actuated movable probe tip which can act as a local electrical lead.
Figure 1 shows a TEM image of the movable tip used to switch a $SrTiO_3$ resistive memory [2-3] that has been prepared using focused ion beam milling. The TEM image shows that the probe has introduced stress into the membrane. The poor electrical contact can also cause local heating and can even cause the specimens to explode. Despite these problems, the external electrostatic potential applied to the probe can cause a reversible switching of the active layer between high and low-resistive states, however the experiment is difficult, stressful and time consuming.
Our approach is to use fixed contacts on both simple and complicated devices. An example is provided in Figure 2 which shows a resistive memory cell [4]. A thick slice of the wafer has been sawn and then a Xenon-Ion FIB has been used to remove a large volume of material to provide a site specific region of interest. This region is then thinned to electron transparency using a conventional Ga FIB. Metal deposition in the FIB has been used to rewire the electrical contacts inside the device such that the switching can be performing by wire bonding the top contacts.
In this presentation we will present the two different approaches of switching memory devices in situ in the TEM and compare the advantages of each.

References:
[1]Nature Materials, 8, 271 (2009)
[2]Nature Materials, 5, 312 (2006)
[3]Advanced Materials, 21, 2632 (2009)
[4]Nature Materials,6, 824 (2007)

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Fig. 1: In-situ biasing using a probe manipulated by a piezo-electric motor. A thin TEM lamella prepared using conventional FIB specimen preparation techniques is mounted onto a TEM grid. The movable metallic probe (a) approaches and makes contact (b)to the top of the specimen.

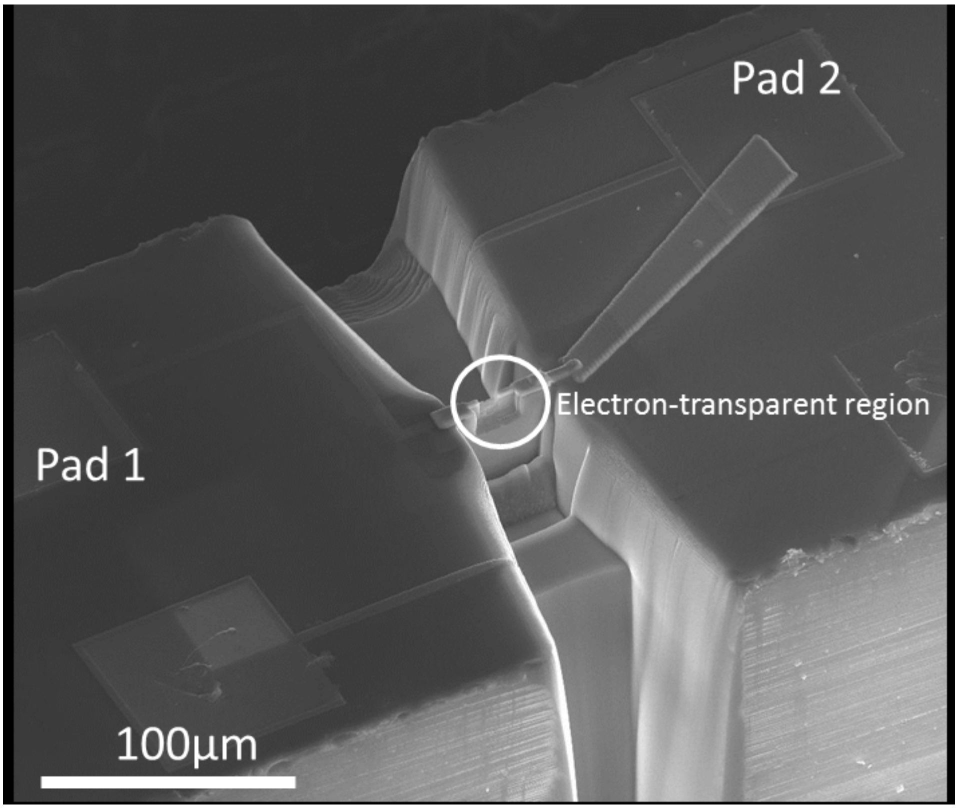

Fig. 2: Memory cell prepared using Plasma FIB Xenon milling. The milling rate of the Xe-Fib enables us to remove large quantities of material. The electron transparent region containing the memory cell is patterned starting from a “bulky” slab. The two bonding pads can be hard-wired and used in the TEM to allow for in-situ switching of the device.