Semiconductor nanowires have attracted much interest due to their outstanding properties as building blocks in nanoelectronic devices [1]. Among these, InAs nanowires with a smaller band gap and higher electron mobility exhibit particular potential for high-performance transistors, memory, interconnects, and sensors. Since a high stability of these nanowires (NW) is required, it is important to perform failure tests. There are some reports on in-situ TEM with electrical failure tests [e.g. 2-5] on the electrical properties as well as the failure tests of semiconductor nanowires, but these were done with an in-situ STM tip in a TEM holder. In this setup the electrical contact of the STM tip with NWs is realized by moving the STM tip to contact one side of the NWs. However, it is difficult to control the contact quality as well as the contact resistance between the NWs and STM tip. We have developed an alternative setup allowing the investigation of the electrical properties as well as breakdown of tapered InAs nanowires with Ohmic contacts using a homemade in-situ TEM biasing holder. Furthermore, by having more than two contacts on the nanowire we could also measure the contact resistance of the applied contacts (except for the most outer contacts), which showed that the contact were Ohmic. By measuring a number of segments of a tapered nanowire we determined that the electrical resistivity is constant (~10^-2Ω·cm) for nanowires with diameter larger than 120 nm and gradually increases for thinner sections. The electrical breakdown started in the position close to the cathode side, and starts with electromigration of In, followed by the sublimation of arsenic. The critical current density for breakdown was about 106 A/cm². The setup for electrical measurement is shown in Fig. 1(a). The electrodes deposited on silicon nitride membrane consist 5 nm Cr and 95 nm Au with a width of 500 nm and separated by 4 µm from each other. Then of 500 nm wide 5 µm long gaps were created by drilling holes on the membrane using a FIB. Next, a single tapered nanowire was transferred onto the electrodes by using an ex-situ nano-manipulator. Finally platinum was deposited on top of the joints between the nanowire and the electrodes with FIB to ensure a good contact quality. REFERENCES 1. S. W. Nam, et al, Science 336, 1561(2012) 2. T. Westover, et al, Nano Lett. 9, 257 (2009). 3. Z. Xu, D. Golberg, and Y. Bando, Nano Lett. 9, 2251 (2009). 4. K. Davami, et al, Chem. Phys. Chem. 13, 347 (2012) 5. J. Zhao, H.Y. Sun, S. Dai, Y. Wang, and J. Zhu, Nano Lett. 11, 4647 (2011). Acknowledgement: This work was supported by the ERC project 267922–NEMinTEM and the National Natural Science Foundation of China (Grant No. 61106084 and 61332003). C. Zhang and H. Wang are grateful for the support of China Scholarship Council.
Fig. 1: (a) Scheme of the in-situ chip. The tapered InAs nanowire is connected to five electrodes on a SiN membrane. Each of the electrodes is 500 nm wide and separated by 4µm. Slits are present on the SiN membrane, allowing TEM of the NWs suspended over these slits. (b) bright field TEM image of tapered InAs nanowires with Ohmic contacts.

Fig. 2: (a) HAADF image of one InAs nanowire after breakdown, particles were found close to the anode, while the breakdown happened in a position close to the cathode. (b)-(d) EDX maps of the nanowire at low magnification, which shows clearly the particles close to the anode are rich in indium and oxygen.