In situ TEM characterization of electrical properties of semiconductor nanowires

Keywords
In Situ Biasing, Transmission Electron Microscopy, Semiconductor nanowires, Electrical breakdown, I – V measurements

Fields
Material Science

Abstract
In this work In Situ biasing TEM was used to analyze the electrical properties of InAs nanowires (NWs). With the increase in electrical current a breakdown of NW occurs close to the cathode side. Dynamical changes was monitored in real life with simultaneous I – V measurements.

Purpose
• Driving force: Potential application of InAs semiconductor NWs in high performance electronic devices
• Fabricate low ohmic contacts to the InAs NW
• Characterize electrical properties of InAs NWs excluding experimental artefacts
• Real time observation of the breakdown of the NW with simultaneous electrical characterization

Challenges
• Limitation of the electrical measurements making contact using scanning tunneling microscopy lead to:
  a. Wrong values for the I – V properties
  b. Strong heating of the NW
• High resolution imaging of the starting position of breakdown
Results

In current example, by means of in situ biasing TEM authors monitored a breakdown process of InAs NWs with simultaneous recording the I-V properties (Figure 1). From Figure 1 (d) – (k) it is clearly seen that the breakdown does not occur at the middle part of the NWs, which could be intuitively expected regarding the fact that due to two equal electrodes on both sides and Joule heating NW should be the hottest at the center. Instead, the breakdown occurs much closer to the cathode. Prior to the breakdown, the sphere-like particles appear close to the anode side, which grow in size and number (Figure 1 (j) – (k)). By means of EDX it was shown that these particles are reach in indium (Figure 2 (b)), while the broken area is arsenic reach (Figure 2 (c)). Therefore, it was proposed that the breakdown mechanism is based on electromigration of In leading NW breakage near the cathode side.

Authors showed that by using the MEMS based Nano-Chips for current experiment it became possible to avoid NWs strong heating induced by Joule heating as a result of high resistance contacts. Electrical measurements with simultaneous TEM imaging showed that with increasing the current, the breakdown of the NW occurs at the cathode side. Authors proposed an electromigration mechanism and Joule heating for the breakdown process.