lightning

APPLICATION NOTE

In situ TEM characterization of electrical properties of semiconductor nanowires

TEM & Objective lens

FEI Titan ST

Holder / System

Lightning D9+

MEMS Device

Nano-Chip ST

Silicon nitride membrane with a 5 nm Cr layer for adhesion
Window: Through hole, size: 1.5 µm×5 µm
Electrodes: Gold, thickness: 95 nm, width: 1 µm, spacings: 4 µm

Sample

InAs NWs

Sample Preparation Technique

NW transferred to Nano-Chip ex situ nanomanipulatory FIB
Pt was deposited on the joint of the NW and the electrodes

In Situ environmental parameters

Voltage: up to ~1 V
Ramp rate: 1 mV/s
Temperature: 500 °C

TEM imaging parameters

Accelerating voltage: 300 kV

Analysis techniques

HAADF-STEM, EDX, HRTEM

Keywords

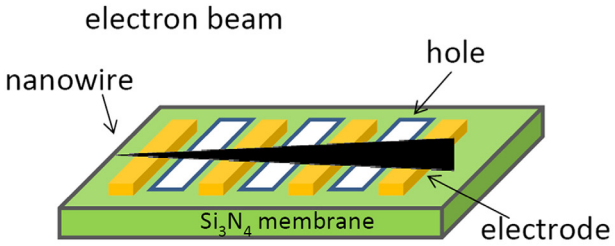
In Situ Biasing, Transmission Electron Microscopy, Semiconductor nanowires, Electrical breakdown, I – V measurements

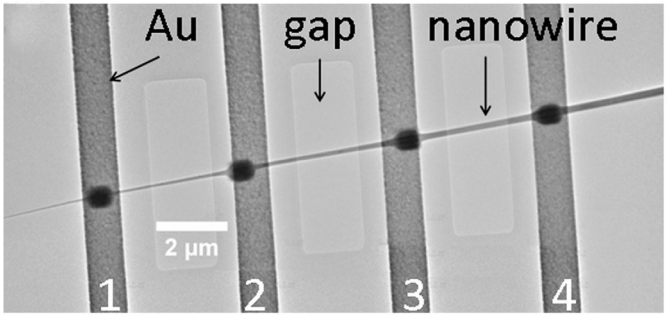
Fields

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.

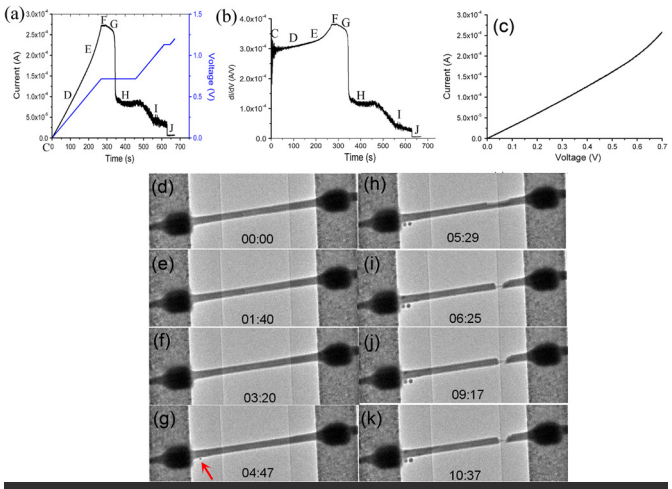


Figure 1. (a) – (c) I–V curves vs time of InAs NW during the whole process. (d) – (k) The corresponding TEM images at certain points depicted in (a) and (b).

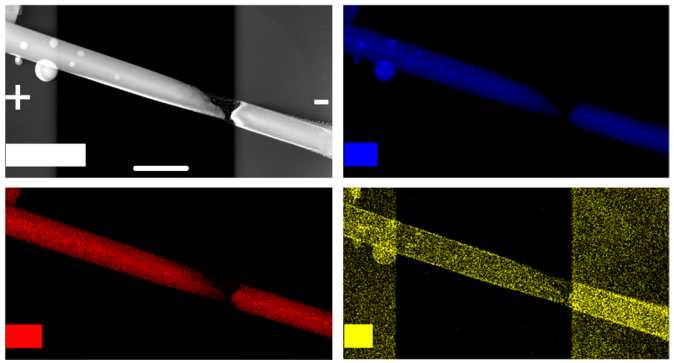
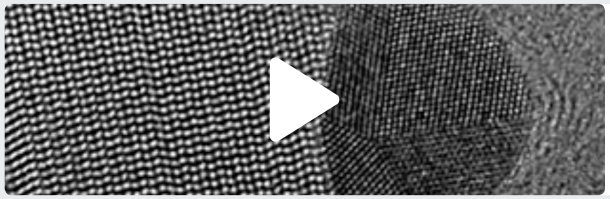


Figure 2. (a) HAADF image of the InAs NW after breakdown, indium particles observed close to the anode, while the breakdown happened close to the cathode. (b) – (d) EDX maps of the InAs NW.

Zhang, Chao, et al. “In situ electrical characterization of tapered InAs nanowires in a transmission electron microscope with ohmic contacts.” Nanotechnology 26.15, 15570 (2015)



For more applications, please visit:

www.DENSsolutions.com/applications/

DENS solutions