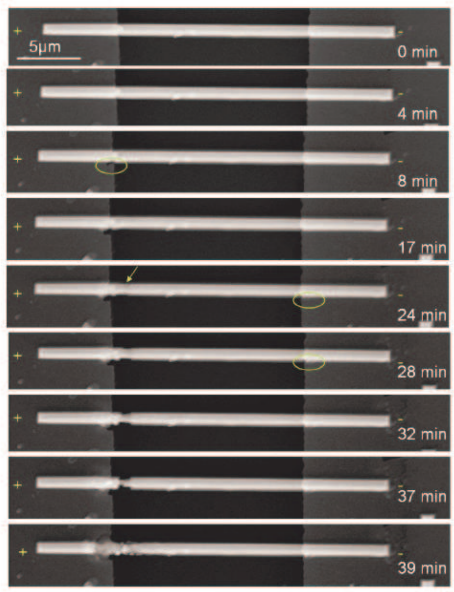
08-10 Electromigration and thermal measurements in single-crystalline silver nanowires: Four-wire resistance measurements on carbon nanotubes

C. Wirtz, N. M. Buckanie, S. Stiene, I. Rod, C. Hassel, J. Lindner, R. Meckenstock, F. –J. Meyer zu Heringdorf, G. Dumpich

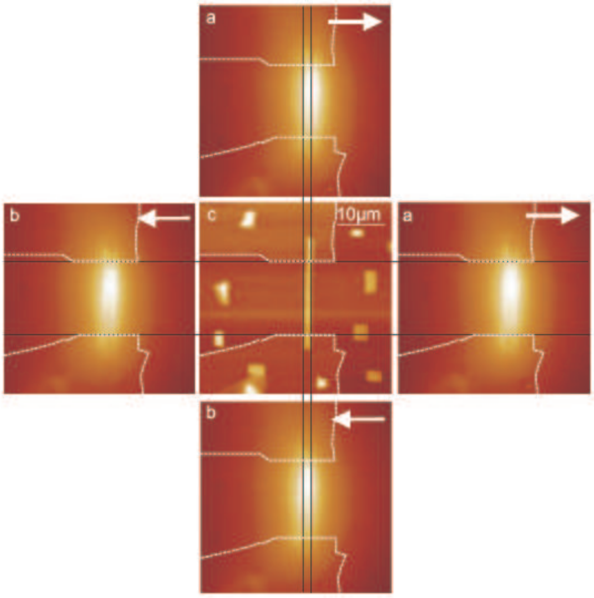
We have investigated the electromigration behaviour of nanostructured Ag interconnect lines. *In situ* scanning electron microscopy in conjunction with four-terminal resistance measurements was used to study electromigration in polycrystalline and self-organised single-crystalline Ag nanowires. Atomic force microscopy was employed for the topographical characterisation of the nanowires. We have prepared the polycrystalline Ag nanowires and contacted the single-crystalline Ag wires by means of electron beam lithography. The research effort was principally focused on the investigation of single-crystalline nanowires. Initially, the results of earlier results were confirmed, showing that the direct force and not the wind force is responsible for current-driven mass transport in single-crystalline Ag nanowires.



Series of SEM images showing a single-crystalline silver nanowire during the course of electrical current stressing at 4.1×10^{7} A/cm². Silver is depleted from the anode side of the wire and transported to the cathode terminal, where it is deposited in small hillocks. The overall conductivity of the wire deteriorates progressively with time, reflecting the reduced cross section at the anode side.

A new result in this context is that the direction of mass flow also follows the direct force in single-crystalline nanowires subjected to 90 MeV charged ion bombardment. The defects inflicted by irradiation obviously do not cause an increase of the wind force. Further experiments performed on single-crystalline wires covered by thin polycrystalline stripes confirm the assumption that mass flow takes place via surface diffusion.

For the first time, it could be shown that spatially resolved thermal imaging of current-carrying single-crystalline nanowires is possible by scanning thermal microscopy (SThM). These experiments showed that the contribution of thin polycrystalline silver layers to the overall thermal conductivity is small compared to the thermal conductivity of the substrate.



AFM and SThM images of a single-crystalline silver nanowire during current stressing. The central image (c) represents an AFM topography scan, while (a) and (b) (each shown twice as to allow for spatial correlation with the topographical data) represent the thermal images. The respective scan directions are indicated by an arrow in the upper right portion of the image.

Although it was found that the direct force and not the wind force is responsible for the electromigration behaviour of single-crystalline Ag nanowires in general, in one case failure of a singe-crystalline wire was apparently dominated by the wind force. It is believed that this observation was due to grain boundary diffusion. From August of 2008, the aforementioned EBL techniques have also been successfully used in application of electrical leads to carbon nanotubes obtained from the Dresden IFW, aiming at four-wire resistance measurements. Preparations to incorporate Focused Ion Beam and further nanomanipulation techniques into our research efforts are currently being made.