MONASH University
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In situ (S)TEM studies using MEMS based devices at Delft University of Technology

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Science Lecture Theatre S9, Building 25

Abstract

In situ electron microscopy is a very powerful characterisation tool for a thorough understanding of processes occurring at the nanoscale under dynamic conditions. Using a combination of MEMS based devices and special TEM holders, we show the real time changes in a specimen under various dynamic conditions (i.e. heating, cooling, gas injection, current passage).

The first part of the presentation will be about electromigration – a process in which a metallic contact line is thinned by passing a current through it, whereby the gradual displacement of atoms ultimately leads to the destruction of the line. Electromigration is studied in nanobridges of polycrystalline Au, Ni, Pt, Pd, Pd–Pt fabricated using clean room facilities[1]. Electromigration in Pd–Pt alloy is quite different from the pure elements. In alloy bridges the destruction of the outer shape of the bridge is minimized which led to the observation of reversed electromigration[2]. This reversal of material transport upon a change of the electric field direction could be the basis of interesting applications such as a memristor.

In the second part of the presentation, some results from *in situ* heating and environmental TEM studies using a MEMS based environmental cell, called the nanoreactor, will be presented. The nanoreactor consists of two silicon chips facing each other with thin electron-transparent silicon nitride membranes. One half of the nanoreactor (bottom half) is embedded with a Pt coil for resistive heating[3]. Using one half of the nanoreactor, we have demonstrated the three-dimensional compositional and structural evolution during heat treatment at 100–250°C in a FIB specimen of an aluminium alloy, revealing in unparalleled detail where and how precipitates nucleate, grow or dissolve[4]. On closing the nanoreactor with the other half, we have shown that it is also possible to carry out gas-liquid-material interactions.

These studies using MEMS based devices show the TEM no longer serves as a mere characterization tool but also as a laboratory to carry out many interesting *in situ* experiments.

1. Rudneva, M.; Zandbergen, H. In situ Electrical measurements in Transmission Electron Microscopy. In Casimir PhD series, 2013.
2. Kozlova, T.; Rudneva, M.; Zandbergen, H. W. *Nanotechnology* **2013,** 24, (50).
3. Creemer, J. F.; Helveg, S.; Hoveling, G. H.; Ullmann, S.; Molenbroek, A. M.; Sarro, P. M.; Zandbergen, H. W. *Ultramicroscopy* **2008,** 108, (9), 993-998.
4. Malladi, S. K.; Xu, Q.; van Huis, M. A.; Tichelaar, F. D.; Batenburg, J.; Yücelen, E.; Dubiel, B.; Czyrska-Filemonowicz, A.; Zandbergen, H. W. *Nano letters* **2013**.

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