In-situ Monitoring of Electron Beam Induced Deposition by Atomic Force Microscopy in a Scanning Electron Microscope

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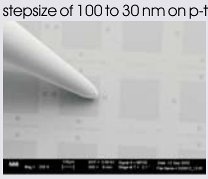
Introduction

Scanning Electron Microscopes (SEM) are widely used for analytics in the micro- and nanometer range. For further specific inspection an Atomic Force Microscope (AFM) is useful provided that positioning of sample and tip can be obtained quickly. A new type of AFM is proposed, whose compact and guidable setup allows the tip to be positioned inside and under observation of a SEM. Thus information on lateral dimensions and material from the SEM inspection could be completed by precise topography and friction measurements in-situ.
Electron Beam Induced Deposition (EBID) of tungstenhexacarbonyle has been carried out. Thus we are able to investigate the application of various techniques to analytics,

Electron Beam Induced Depositon

Tungstenhexacarbonyle $W(CO)_6$ shows a vapour pressure of 2 Torr @ 35 °C and serves as precursor for deposition of tungsten with carbon content (EDX). The external reservoir was heated to 35 °C but a dosing valve was used to keep the global chamber pressure in the range $6\ 10^{-6}$ to $3\ 10^{-5}$ mbar at a base pressure below $2\ 10^{-6}$ mbar. Deposition has been performed at electron energies of 1 keV to 30 keV, doses of 0.01 to 1.8 nC per spot and a stepsize of 100 to 30 nm on p-type silicon.



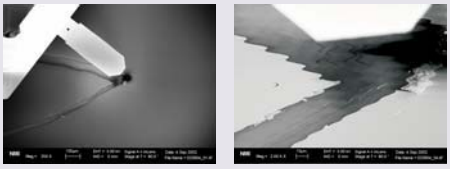
The glass drain tubes were 10 to 50 μm in diameter and arranged to the point of deposition at a lateral distance of about 50 μm.

Setup

This tool is based on a LEO Gemini 1550 VP field emission SEM that is supplied with three micro manipulators (Kleindiek Nanomotor Micro Manipulator MM3A). We attached a piezo-resistive AFM cantilever (Nascatec Piezocantilever) to one manipulator, the others can guide a glass drain tube for precise local gas injection or be used for any other purpose like wiring of parts of the sample. It is useful to arrange the manipulators around the SEM lens to be independant of any stage movements. An external pattern generator (Raith Elphy Quantum lithography tool) allows direct

In-situ AFM

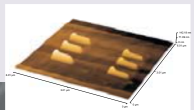
A piezo-resistive cantilever with a high force constant of 100 N/m and a silicon tip is used for static AFM imaging in the constant force mode. The scannning software (Kleindiek ScanControl) is able to drive either a micro manipulator or a tube scanner, that is integrated into the SEM stage. The tube scanner offers a maximum scan range of 6 μm. Due to its high force constant the AFM can also be applied to defined scratching [1].

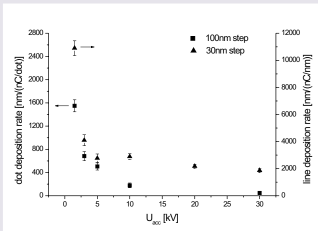


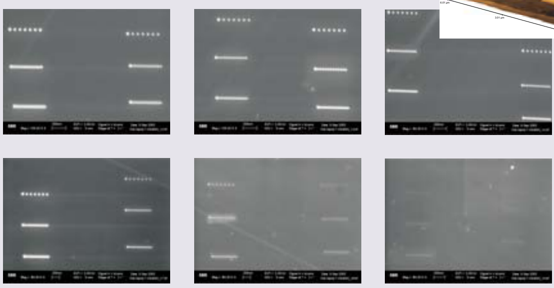
In-situ AFM above a sample for EBID (p-Si partially coated with 20nm Pt) left: cantilever and holder after coarse positioning
right: micrograph taken while scanning the stage for AFM

Characterization by SEM and AFM analysis

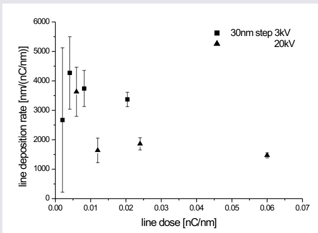
Conventional AFM image for determination of the deposition rate.



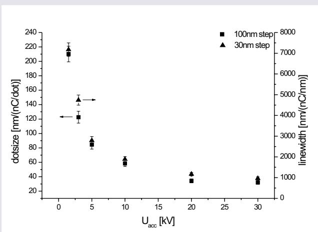


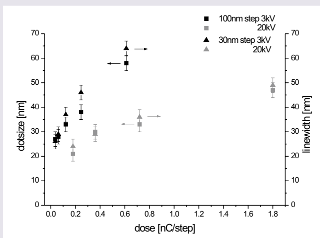


EBID at $p_{base} < 3\ 10^{-6}$ mbar, $p_{EBID} = 2\ 10^{-5}$ mbar, WD = 12 mm and step = 100/ 50/ 30 nm
Top: deposition at electron energies of 1.5, 3, 5, 10, 20 and 30 keV
Bottom: deposition at 3 keV and doses of 0.61, 0.25, 0.12, 0.06, 0.04 and 0.01 nC



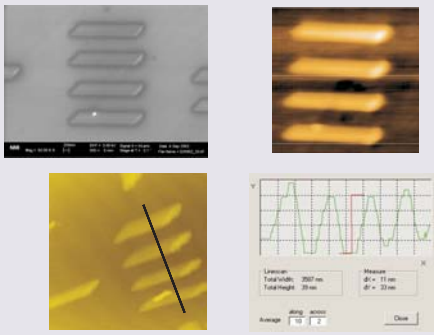
Deposition rate at different electron energies (top) and





Dotsize (step=100 nm) and linewidth (step=30 nm) of the obtained tungsten structures at different electron energies (left) and exposure doses (right).

In-situ Imaging



Tungsten structures of 40 nm in height: SEM micrograph (top left), conventional AFM image (top right) and images obtained by in-situ AFM

Conclusions

A new tool is proposed that combines SEM and AFM analysis and allows electron beam induced chemical reactions. EBID of tungsten was carried out and characterized relative to patternsize and deposition rate. The latter is comparable to or higher than results presented elsewhere [2] and the global chamber pressure of $2\ 10^{-5}$ to even $6\ 10^{-6}$ mbar is much below typical setups [2,3]. Characterization of EBID calls for precise lateral and topography measurements and thus shows the benefit of in-situ AFM monitoring in a SEM.

References
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