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Microfabricated Systems for Electron Microscopy of Nanoscale Processes: In-situ TEM Creation of Si Nanowire Devices and in-situ SEM Electrochemistry

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We are developing novel methods for imaging of complex processes in-situ SEM and TEM, based on microfabricated chip systems. Microfabrication technology enables a wide range of functionality to be incorporated into small systems that can be used in TEM and SEM. For instance we have previously used microcantilever systems to characterize carbon nanotube circuits in TEM [1] and we here explore the use of such systems with local micro-scale heaters for in-situ TEM CVD to create nanowire devices. To study processes in liquids at ambient conditions, we are developing microchips with silicon nitride membrane windows transparent to the electron beam. There is a range of novel microchip systems being developed for imaging liquid samples, such as commercially available polymer membrane SEM capsules [2], and TEM devices, used in a variety of studies, such as high temperature CVD[3], nanoscale chemical processes in liquids [4][5], or biological samples [6]. We here report on our work on incorporating a complete set of environmental sensors into such liquid cell systems to perform in-situ studies under controlled physical and chemical conditions.

In-situ TEM creation of nanowire devices

For environmental TEM applications we have created monocrystalline Si microcantilever devices with heaters [7] to study high temperature gas processes (Fig 1). The developed system enables direct TEM observation of epitaxial nanowires during growth. The growth rate can be used to measure the local temperature[8]. By growing nanowires from one cantilever to another, we have created electrically connected nanowire devices in-situ TEM [9]. The specific conditions during contact of the hot nanowire to the cold surface strongly influence the contact structure. The electrical IV properties of the nanowire bridges between cantilevers have been measured in-situ. The presented microcantilever system has opened a new window into the processes occurring in nanoscale devices, and it offers unique opportunities for in following the creation process and the influence of changes to the device structure on the electrical and mechanical properties of the nanosystem.

In-situ SEM electrochemistry

To study processes in liquids at ambient conditions, we are developing microchips with silicon nitride membrane windows where we can integrate microelectrodes, temperature sensors, and pressure sensors in the chip system. The system enables us to follow electrochemical processes, such as electrodeposition (Fig 2), and maintain the system at 37^{o}C for studies of living cells. The thin membrane with temperature sensors also make it possible to characterize ultrafast cryo fixation of the sample when plunged into a cryogen, opening for the possibility of high time resolution of fast processes.

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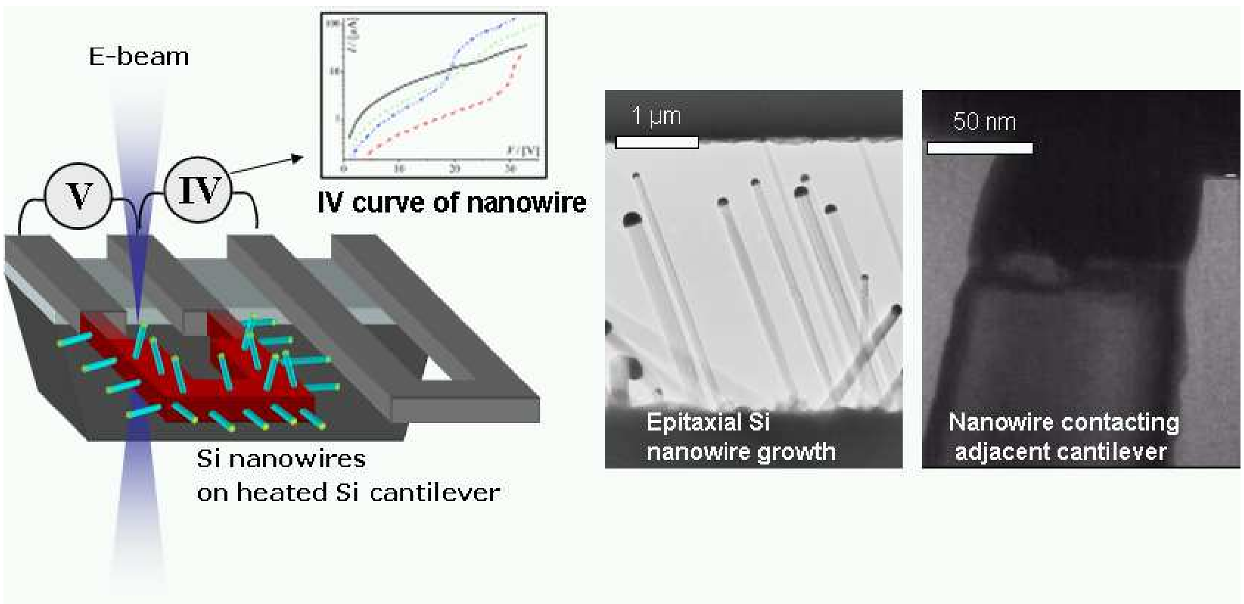

Fig 1: Illustration of the TEM chip system with heated monocrystalline silicon microcantilevers supporting epitaxial nanowire growth. The wires can be grown to reach an adjacent cantilever, enabling in-situ electrical IV measurements on individual nanowires.

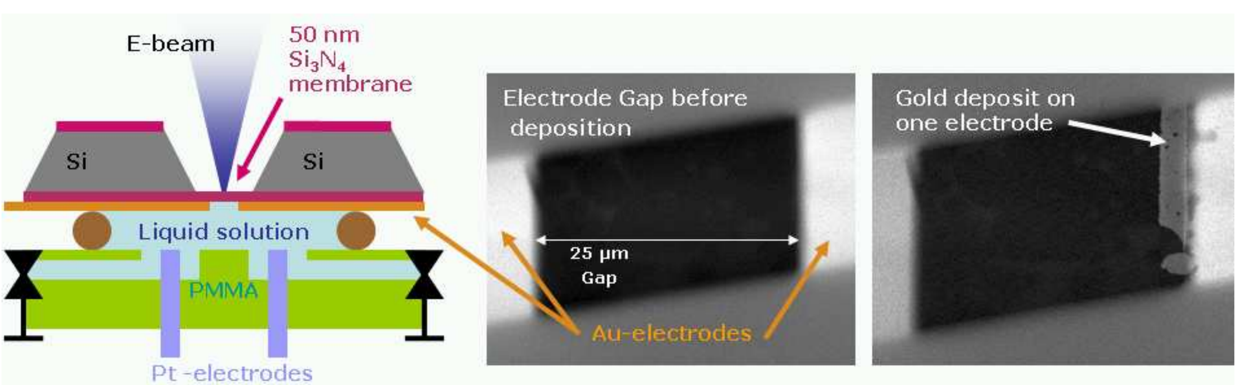

Fig 2: The microchip system for imaging liquid processes in-situ SEM. Here gold is deposited from solution onto one of two gold thin film electrodes on a 50nm electron transparent Si_3N_4 membrane.

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