Low Dimensional Materials and Catalysts

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In-situ chlorine etching of nanowires by focused electron beam - a direct-modification approach for tailoring nanowire properties

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Scanning electron microscopy is not only a high-resolution imaging technique for nanocharacterisation of materials, but the focused beam of electrons can also be used for inducing chemical reactions in the nanometer-regime. For focused electron beam induced processing (FEBIP) precursor gas is introduced into the vacuum chamber and the electrons interact with precursors adsorbed on the sample surface. It has already been demonstrated, that metalorganic precursors lead to deposition of materials including noble metals such as Pt or Au as well as magnetic metals such as Fe or Co [1,2]. Also the deposition of carbon, tungsten and even of dielectrics such as silicon oxide have been demonstrated.

We have recently introduced a controlled etching process (Fig. 1) that is sustained by the irradiating electron beam. With the semiconductors Si and Ge we have not observed spontaneous etching, while material could be etched in the areas exposed to the electron beam. A clean vacuum chamber is a prerequisite for this process [3] and has been achieved with an in-situ ozone cleaning procedure of the chamber.

In this work we report on the controlled etching of Si-nanowires and of Ge-nanowires. Nanowires themselves are smart nanomaterials with very promising characteristics and may be used for nanoelectronic devices, innovative sensor concepts and for photovoltaics applications. Focused electron beam induced etching (FEBIE) offers a further alternative to modify these nanomaterials in-situ in a SEM. With dynamic experiments in the SEM we have investigated the chemical reactions on the nanoscale. The material modification with regard to, its composition and its electrical has been investigated.

Typically properties of nanowires are defined during synthesis. The custom-designed tailoring of electrical properties of nanowires is essential for the development of new devices. Semiconductor nanowires are already low-dimensional materials but with FEBIE we have managed to modify the shape of nanowires by selectively thinning the nanowires diameter in preselected sections (Fig. 2). FEBIE is a versatile approach for trimming of Si-nanowires as the low-energy electrons inflict no significant crystallographic damage and cause no contamination of the silicon nanowire. This in-situ preparation allows to keep specimens as close as possible to their native state.

With chlorine as etch gas even without geometrical thinning of nanowires the short-term irradiation was observed to result in a change of electrical properties towards a diode-like characteristics. The effect of electron exposure under the presence of molecular chlorine was investigated. Additional to structural studies also an electrical characterisation of contacted Si-nanowires and a TEM nanostructure analysis was performed.

FEBIE has been established as a novel approach that allows for tailoring of material properties by controlled in-situ modification of nano-scaled materials. Potential future applications of FEBIE to design and to develop of new nonmaterial for sensor applications and for photonics applications will be discussed.

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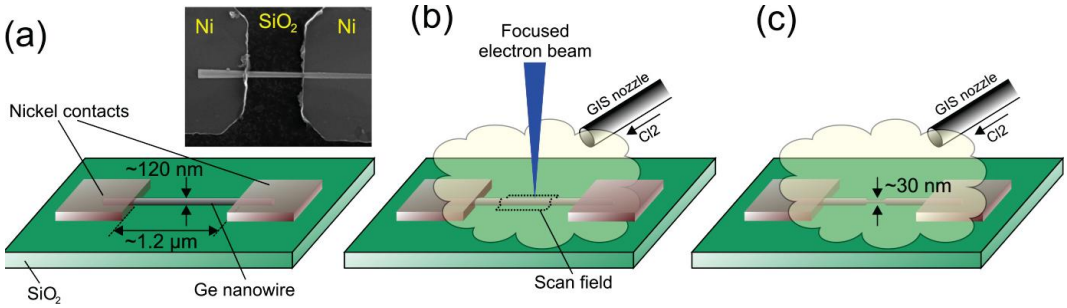

Figure 1. Panorama Schematic process of chlorine-based etching of Si-nanowire with an electron beam

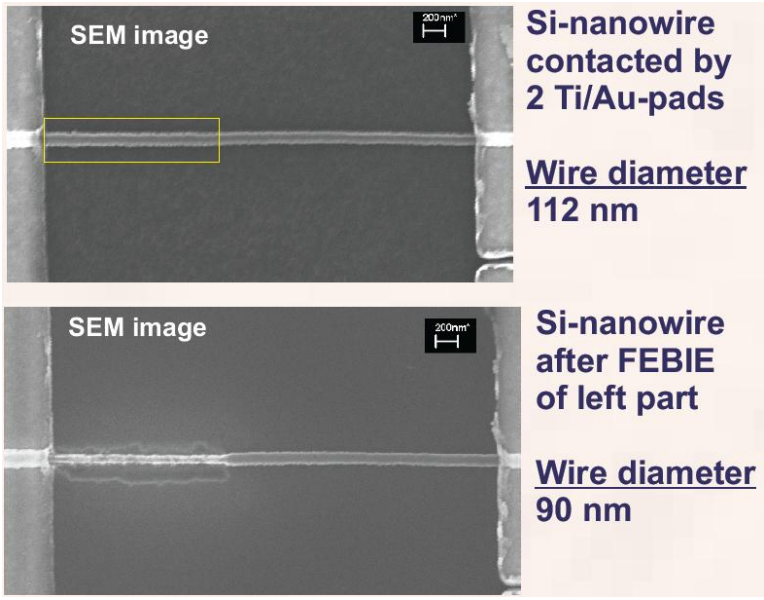

Figure 2. Top view SEM image of a Si-nanowire before and after FEBIE process. Etching by chlorine only occurred in the region scanned with the electron beam.