Positions-controlled growth of rutile TiO_2 nanorods and their optical and electronic properties

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Rutile TiO_2 nanorods are semiconducting 1D structures with a band gap of 3.1eV. Beside their high chemical stability, they have beneficial electronic and optoelectronic properties. Furthermore their fabrication via a hydrothermal growth process is quite simple and inexpensive. Thus rutile TiO_2 nanorod arrays (NRAs) are useful for various applications such as gas sensors [1], supercapacitors [2], photocatalysis devices [3], hybrid solar cells [4], lithium batteries [5], superhydrophobic/superhydrophilic surfaces [6], data storage devices [7] and medical engineering [8]. For many of the listed applications it is advantageous to have position-controlled nanorod fabrication techniques available in order to achieve a space-resolved mode of operation. Local gas or molecule sensing, steep gradients on superhydrophobic/superhydrophilic surfaces, local light scattering, high resolution surface roughness gradients or microchannels are important tools for lab-on-a-chip devices for instance. Here we demonstrate and explain different techniques for the position-controlled growth of rutile TiO_2 nanorods on a submicron scale such as advanced optical and electron lithography, focused ion beam milling, advanced scanning probe lithography and a new concept of laser lithography. For all methods we are manipulating the seed layer locally in order to promote or suppress the growth of nanorods. We developed completely new concepts for scanning probe lithography and laser lithography by inducing either mechanically supported or thermally induced phase transitions in order to get a structured seed layer. We achieved structure sizes with less than 100nm with some of our techniques. Experimental results are shown in the figure below. In the second part the influence of crystal defects and impurities on the optical and electronic properties of rutile TiO_2 nanorods is shown briefly. Especially the influence on the electrode/TiO_2 contact is discussed. Doing so we present the applied measuring techniques as well such as wavelength dependent current over voltage and current over time measurements.

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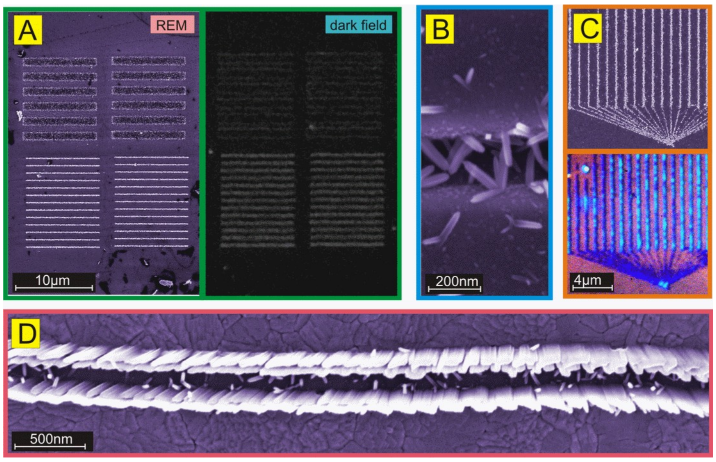

Figure: A) About 300nm long TiO_2 nanorods grown on 60nm wide linear seeds using electron beam lithography. On the left side the structure is imaged with a reflection electron microscope (REM). On the right side the same structure is imaged with an optical microscope in dark field mode. B) Horizontally grown TiO_2 nanorods grown on a sample treated with focused ion beam (FIB) milling. C) About 300nm long rutile TiO_2 nanorods grown on a complex structure drawn with a new scanning probe lithography methods on an anatase TiO_2 film (top: REM, bottom: optical dark field microscope). D) Microchannel consisting of TiO_2 nanorods as side walls on a silicon/TiO_2/SiO_2 substrate fabricated by laser lithography.