Presented at the 4th international conference on Multifunctional, Hybrid and Nanomaterials, 2015 March 9-15, Sitges, Spain; Poster Session 1, [P1.131]

Electro-optics of TiO_2 nanowire dispersions in PDMS matrix

Andris Šutka[1,2], Martin Timusk[1,3], Kristjan Saal[1,3], Vambola Kisand[1,3], Rünno Lõhmus[1,3].
1. Institute of Physics, University of Tartu, Riia 142, 51014 Tartu, Estonia
2. Institute of Silicate Materials, Riga Technical University, Azenes 14/24, Riga, LV-1048, Latvia
3. Estonian Nanotechnology Competence Center, Riia 142, 51014 Tartu, Estonia

Background

Low-cost electro-optical devices with fast, easy controllable and simple operation mechanisms are highly desirable for future generations of smart window technologies. There are different types of smart window technologies, for example thermochromics, photochromics, electrochromics, gaschromics, reflective metal hydrides, polymer-dispersed liquid crystals, gel-glass dispersed liquid crystal and dipole particle suspension (DPS) (also called suspended particle devices). From these solutions, the DPS devices allow great control of the transmittance of solar radiation and are also relatively simple. Transmittance in DPS devices can be regulated electrophoretically by applying an electric field to nanowire-containing active layers between the two planar transparent electrodes.

Objectives

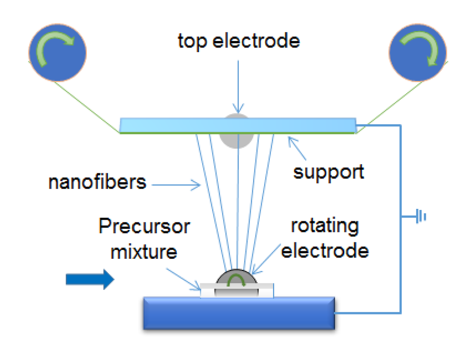
- Obtain uniformly dispersed TiO_2 nanowire dispersions in viscous PDMS matrix.
- Establish the NW diameter and electro-optical effect relationship by transmittance measurements on the electrospun TiO_2 nanowire suspensions in PDMS matrix.
- Explain origin for observed electro-optical behaviour.

Conclusions

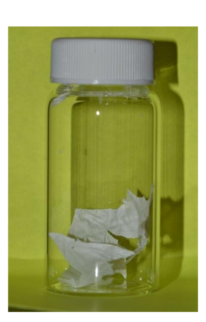
A relatively simple and effective technology for producing uniform electrospun nanowire based electro-optical devices is demonstrated. For the first time either positive or negative changes (or both) in transmittance can be induced by NW alignment parallel to electric field depending on the NW diameter, thus showing the potential possibility to regulate visible or even infrared transparency, and reducing energy consumption by air conditioning systems in buildings and automobiles in the future. Used methods - electrospinning and high shear mixing can be easily scaled-up to volumes used on an industrial scale. Experimental results shows, that the negative change in transmittance can be induced due to light confinement between adjacent aligned nanowires. Experimental findings reported here are important for smart window applications or to predict properties of advanced composites where nanowires are suspended in optically transparent medium. Overall, it was concluded that electro-optical devices can be created that enable selective control of light transmittance by the proper engineering of nanowire diameters.

Methods

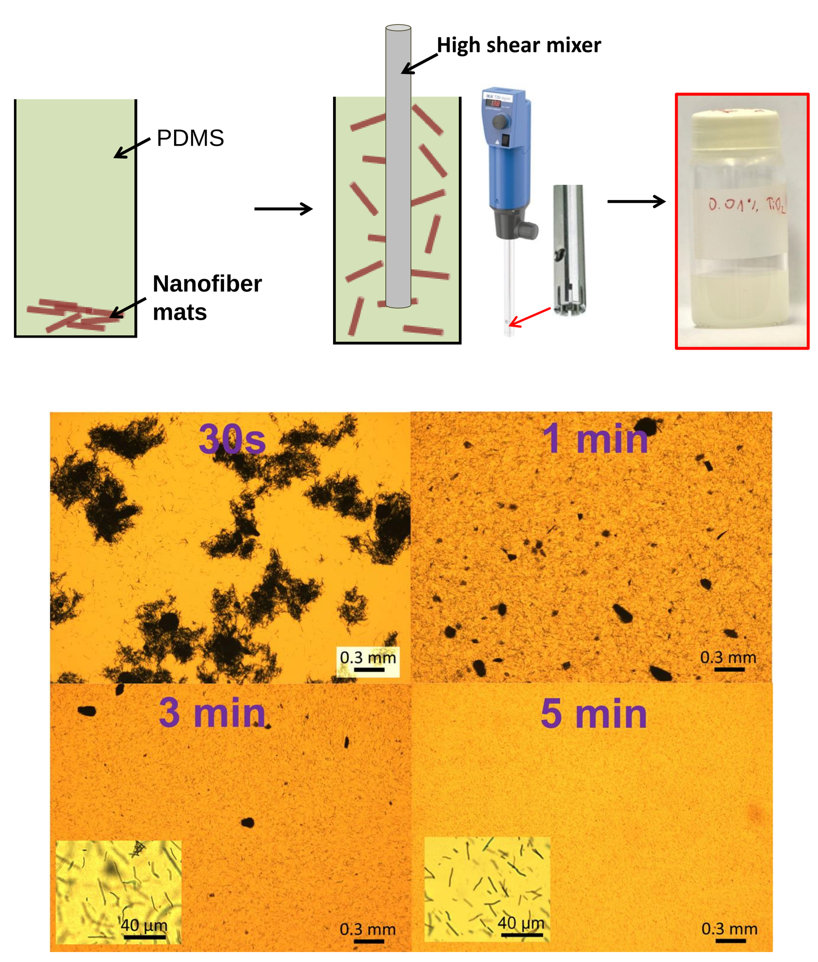
Electrospinning



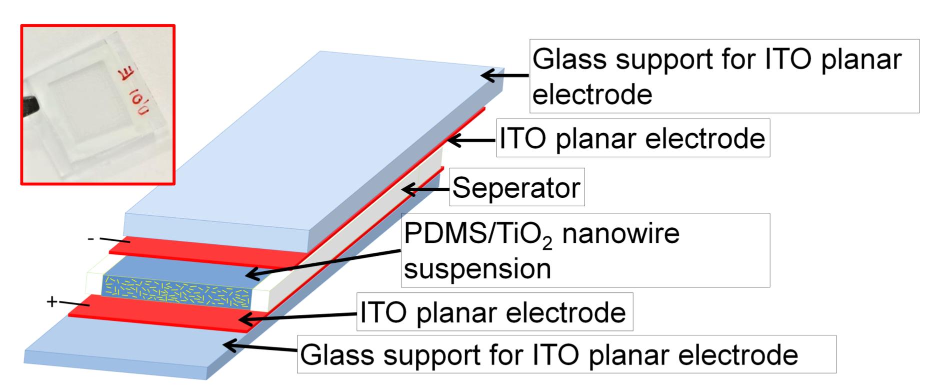
Annealing at 500°C

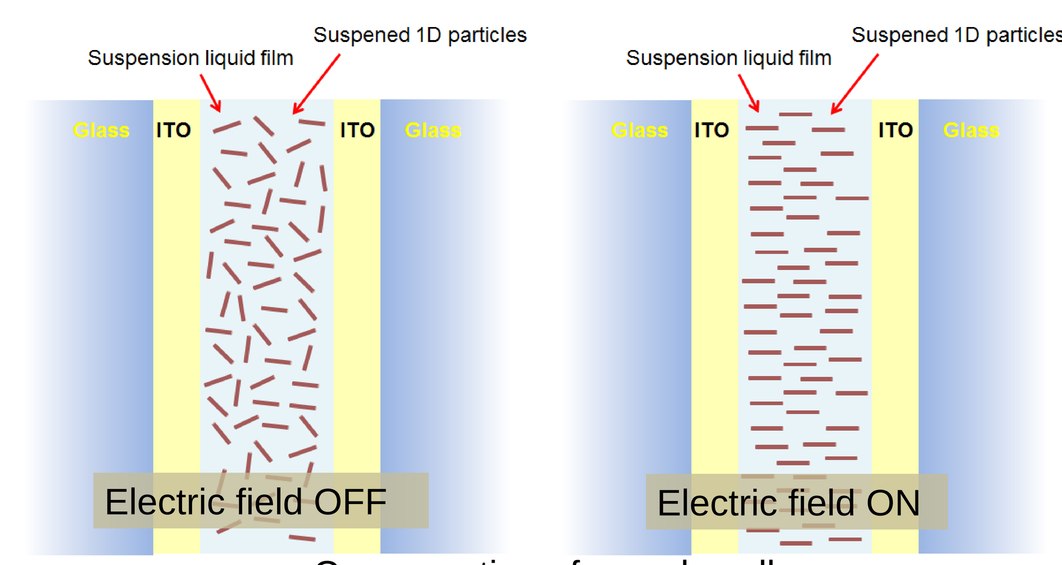


High shear mixing



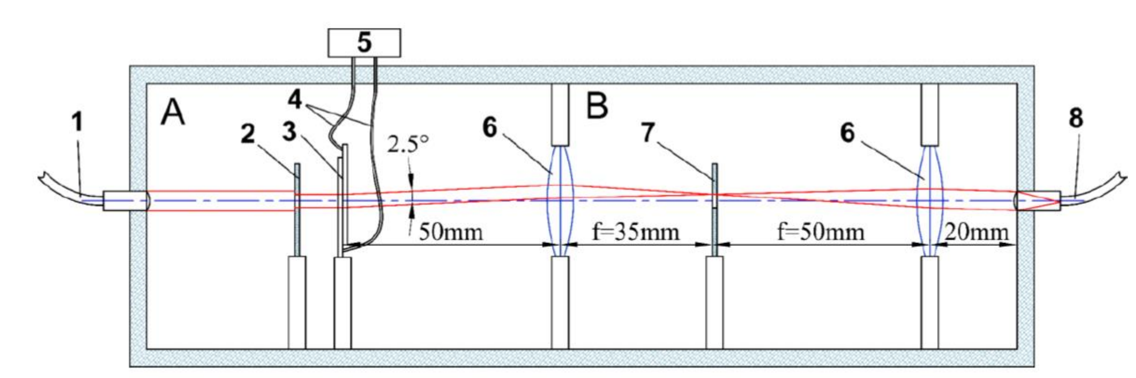
Sandwiching





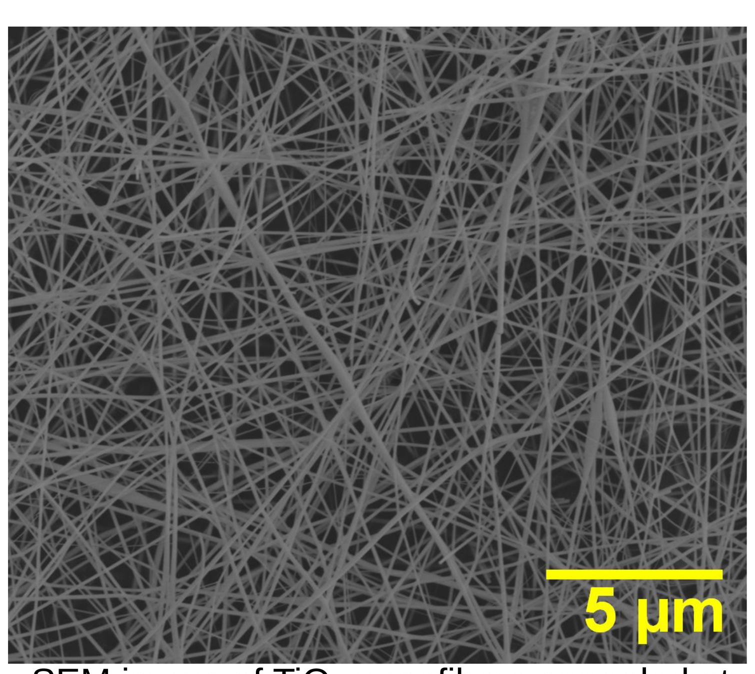
Cross-section of sample cell

Transmittance measurement

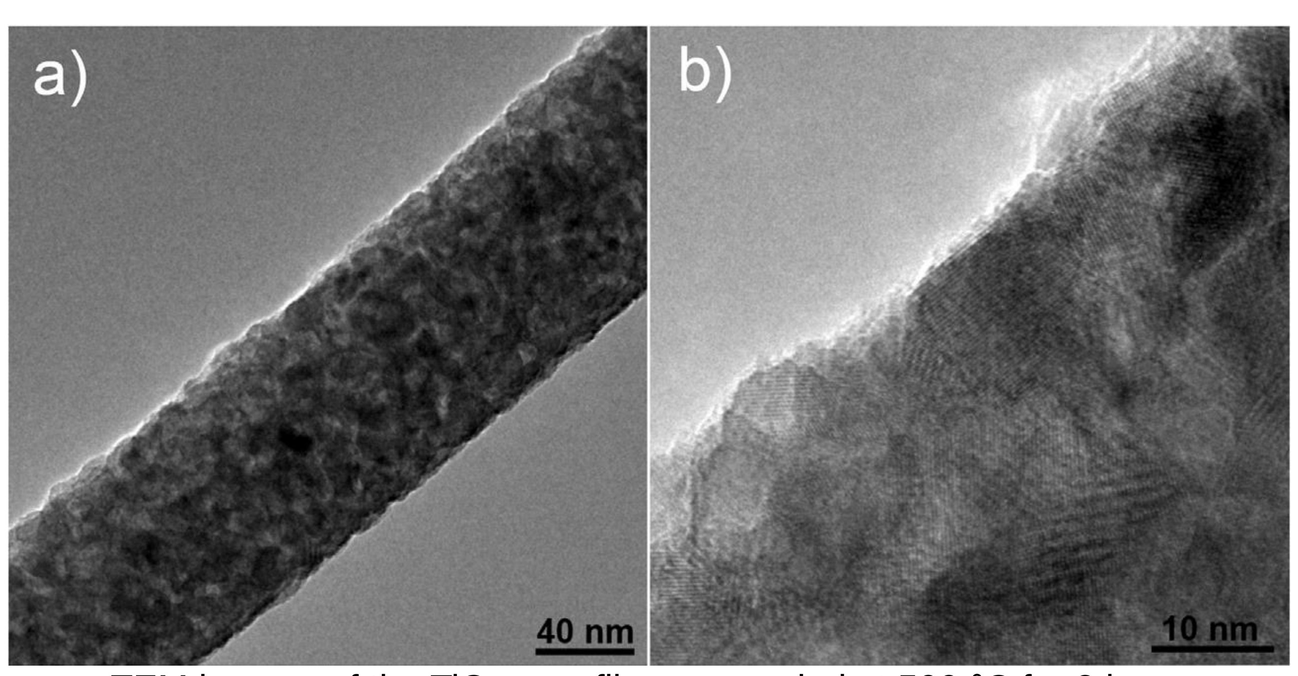


Schematic representation of the setup used for transmittance measurement at ±2.5° collection angle. 1 – optical fiber connecting white light source and collimator lens via SMA 905 connector, 2 – diaphragm Ø 3mm, 3 – sample that is being measured/characterized, 4 – wires through which the voltage is applied to the sample, 5 – AC voltage generator, 6 – high quality optical lenses, 7 – diaphragm Ø 3.056mm, 8 – optical cable with 600 µm core diameter, connecting spectrometer and collimator lens via SMA 905 connectors.

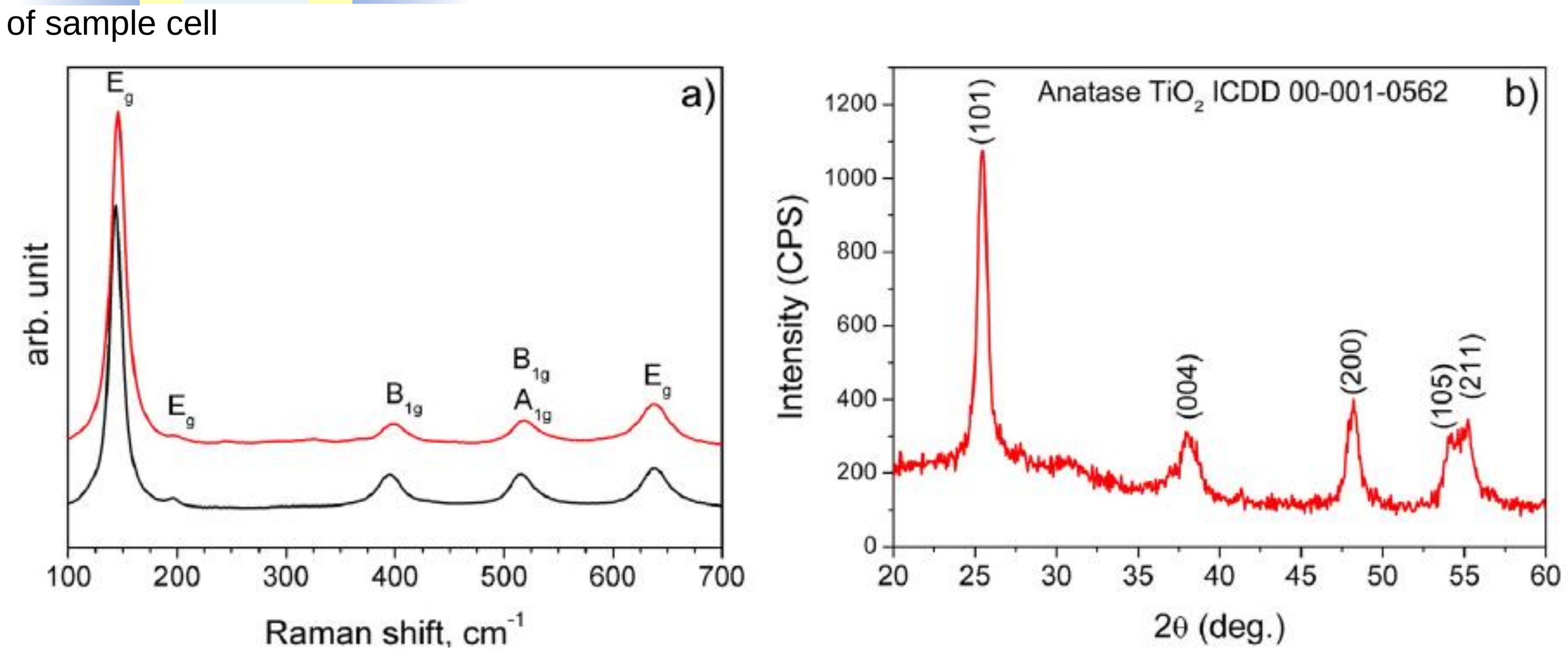
Results



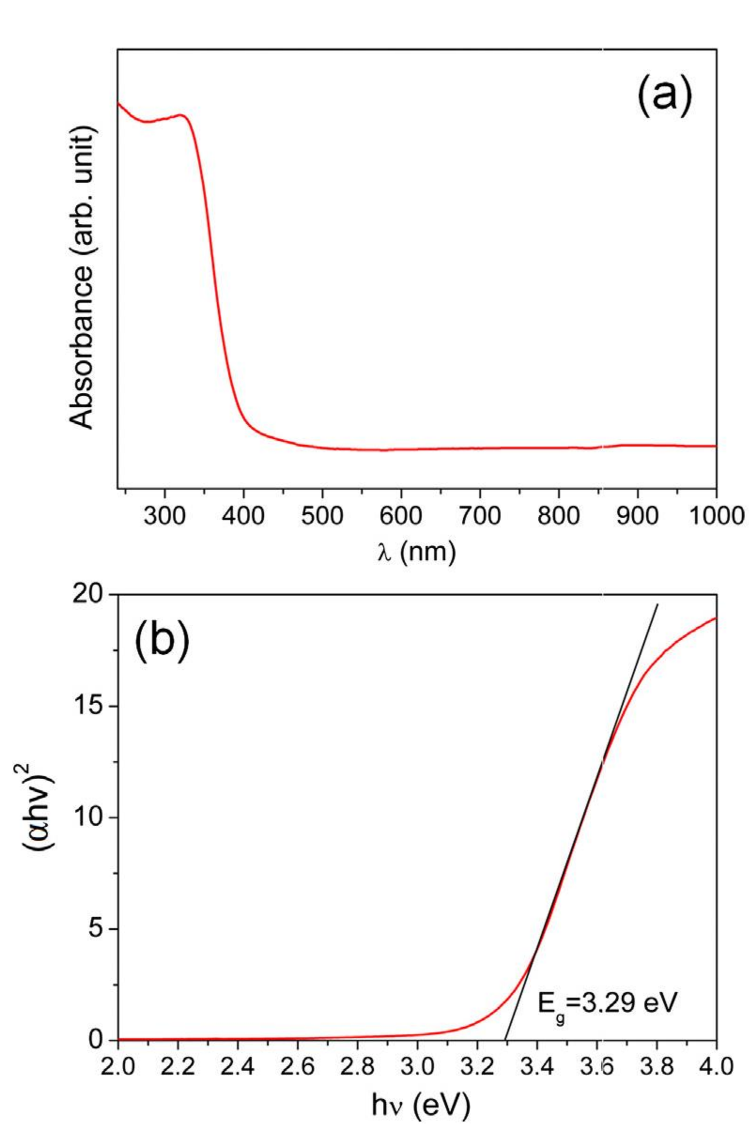
SEM image of TiO_2 nanofibers annealed at 500 °C for 3 h.



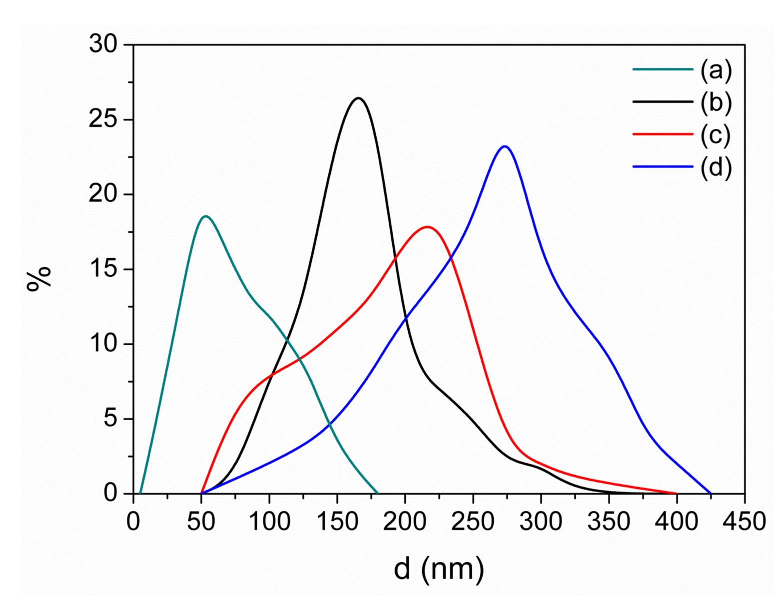
TEM images of the TiO_2 nanofibers annealed at 500 °C for 3 h.



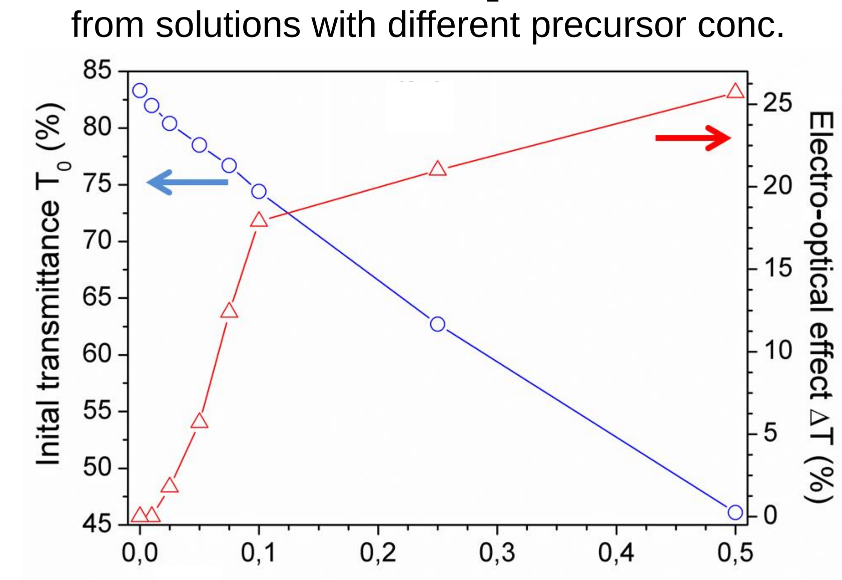
The Raman spectrum (a) and XRD pattern of the anatase TiO_2 electrospun nanofibers annealed at 500 °C for 3 h.



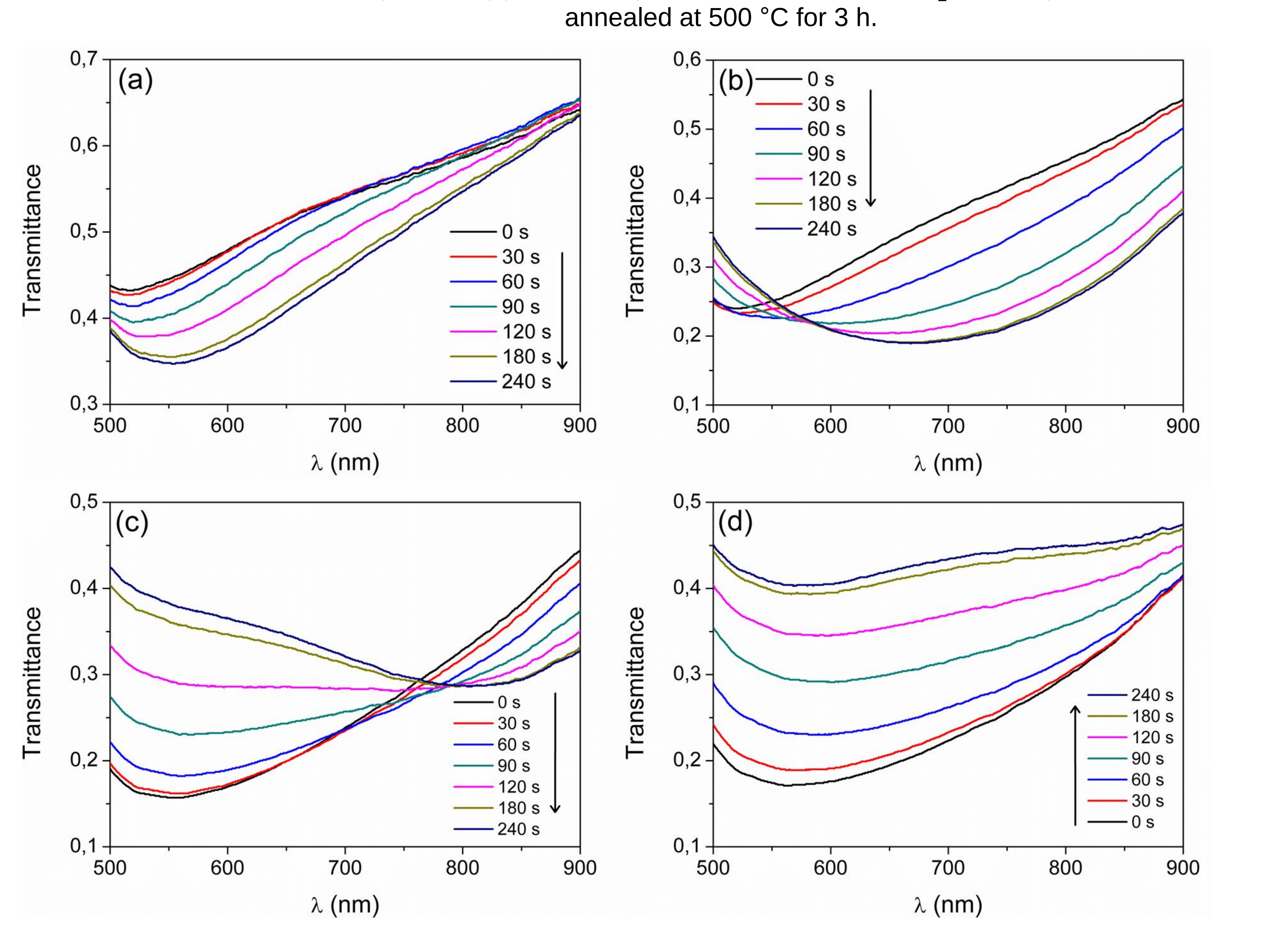
The diffuse absorbance (Kubelka–Munk function) UV–vis absorption spectra for TiO_2 nanofibre mats (a) and Tauc plot of $(ahv)^2$ as a function of photon energy (eV).



Diameter distribution for TiO_2 nanowires obtained from solutions with different precursor conc.



Changre of initial transmittance and electro-optical effect by changing NW concentration



Evaluation of transmittance during TiO2 nanowire orientation for fibres with different average diameter: (a) 75 nm, (b) 150 nm, (c) 190 nm, (d) 260 nm.

Acknowledgements: Authors kindly acknowledge for the financial support by the Estonian Research Council to the post-doctoral research grant of personal research funding in project PUTJD29.