## CONCLUSIONS

It has been known for a long time that material properties change on the nanoscale and are different from those of single crystals or conventional microstructured, monolithic or composite materials[32]. The presented thesis aimed at demonstration of the diversity in these properties for various morphologies of $TiO_2$. Despite the fact that the chemical composition is identical, the structure of different morphologies matters and it is respon-sible for their specialty. The successfully mastered syntheses of desirable particle size materials open the pathway towards applications taking advantage of size dependent properties. DSC employing 2µm mesoporous $TiO_2$ film as a photoanode exhibited the solar conversion efficiency as high as 4.63% due to the large surface area (roughness fac-tor). Optimized pore size together with the framework consisting of anatase nanocrystals are responsible for the high dye adsorption capacity improving the performance.

Incorporating an additional inverse opal layer in DSC represents an example of its further possible upgrade. This optimized set up can increase the short circuit photocurrent effi-ciency of this device of about 26 % (Ref.39).

Owing to the diffusion coefficient of an order of $10^{-13}$ $cm^2/s$ for microcrystalline spinel and even less for nanocrystalline spinel particles, the particle size represents an important factor for battery applications. While $Li^+$ diffusion into material of 100 nm in diameter takes about 2000 s, 10 nm particle can be fully charged in 20 s. Despite the drop of the solid-state $Li^+$-diffusion coefficients by orders of magnitude for nanocrystalline particles , obviously due to the larger stress induced by the $Li^+$-$Li^+$ repulsion, the charging of nano-crystalline particles is still much faster as compared to microcrystalline ones. The slow

$Li^+$-transport in small particles is not rate limiting, because the insertion occurs only in short distances underneath the surface and in overall performance it is fully compensated by the increase of the active electrode area.

Synthetic protocol leading to the preparation of phase pure nanocrystalline $TiO_2$(B) enables to produce this material in sufficient quantity and quality for possible applica-tions based on the unique electrochemical behavior of this titanium dioxide polymorph. The $TiO_2$(B) host accommodates lithium by a pseudocapacitive faradaic process, which is not controlled by diffusion.

To improve further an electrochemical performance of this material, composites of $TiO_2$ nanocrystals with single walled carbon nanotubes (SWNT) were prepared and their be-havior was studied recently[101,102]. The nanocrystals deposited on SWNT by electrochemi-cal deposition correspond to anatase phase with small amount of monoclinic $TiO_2$(B). While explored by cyclic voltammetry of $Li^+$ insertion, the $Li^+$ insertion coefficient, $x$ of 0.42 was found[101].

In general, the particle size and morphology of titanium dioxide materials seems to be almost of the same importance as their phase composition, as far as chemical and electro-chemical properties, and applicability is concerned. Tailoring of the synthetic procedure towards products with desirable morphology is the right way to obtain materials with de-sirable properties and, subsequently, of a great application potential.