

# ERC Starting Grant „CHROMTISOL“

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European Research Council  
Established by the European Commission

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**20<sup>th</sup> September 2017, ERC seminar, Pardubice**

*PPT contains images that are courtesy of Beneq*

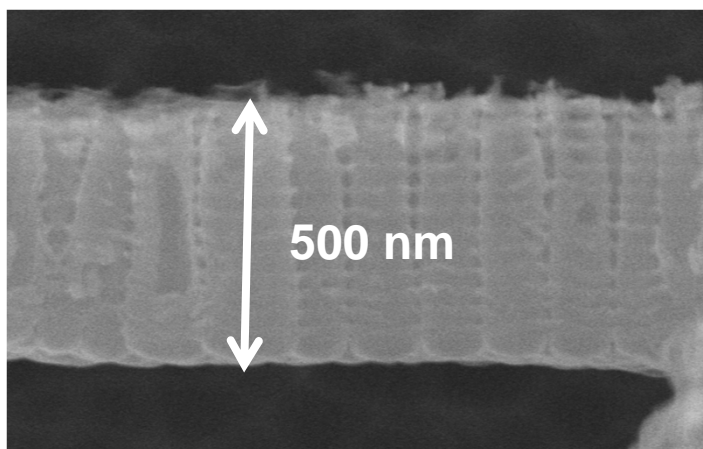


# Curriculum Vitae

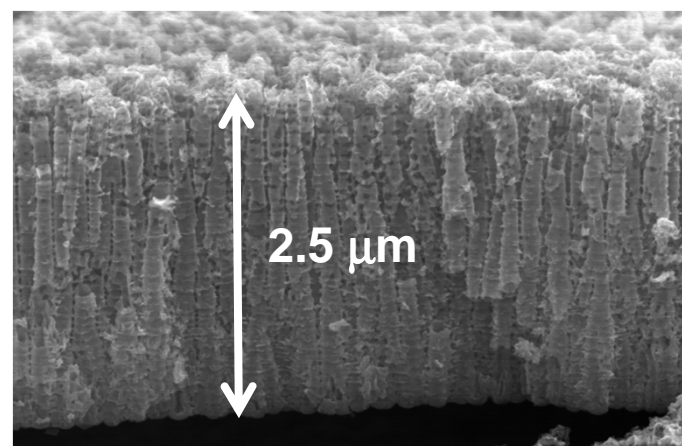
- Born 1979, Pardubice
- ICT Prague 1998-2003 Power engineering
- FAU Erlangen 2003-2008 Ph.D. in materials science
- 2008-2011 Elmarco Ltd., Liberec
- Since 2012 at Uni Pardubice (researcher)
- Since 1.3.2015 Senior scientist, group leader and vice-head of Center of Materials and Nanotechnologies (CEMNAT)
  
- 105 publications (80)
- 12000 citations (10 000)
- H-index: 56 (45)
- 10 awards incl. Neuron Award for Young Scientist 2015, 4x Elsevier award for most cited paper
- Membership in ECS, ISE, MRS (going conferences)
- PI of 5 grant projects with total budget of 2.730.000,- EUR

# Different generations of TiO<sub>2</sub> nanotube layers

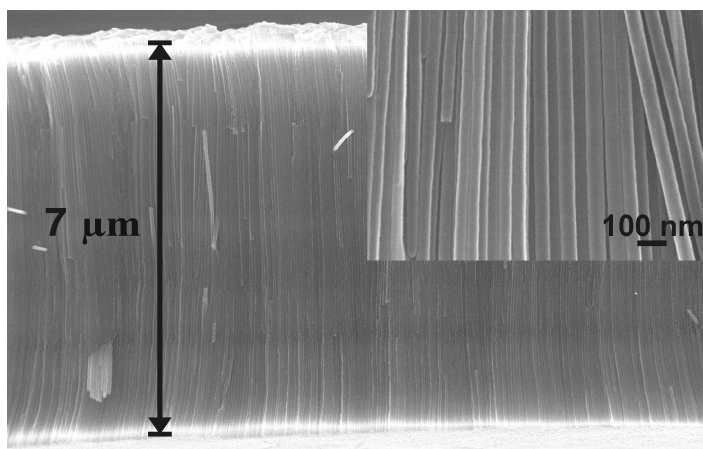
AR  $\approx$  5



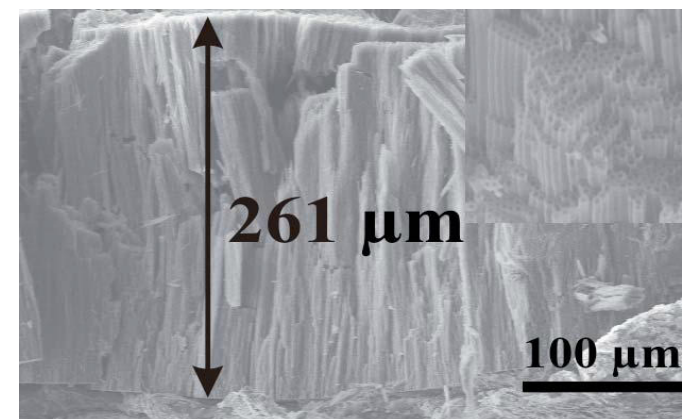
AR  $\approx$  25



AR  $\approx$  140



AR  $\approx$  1400



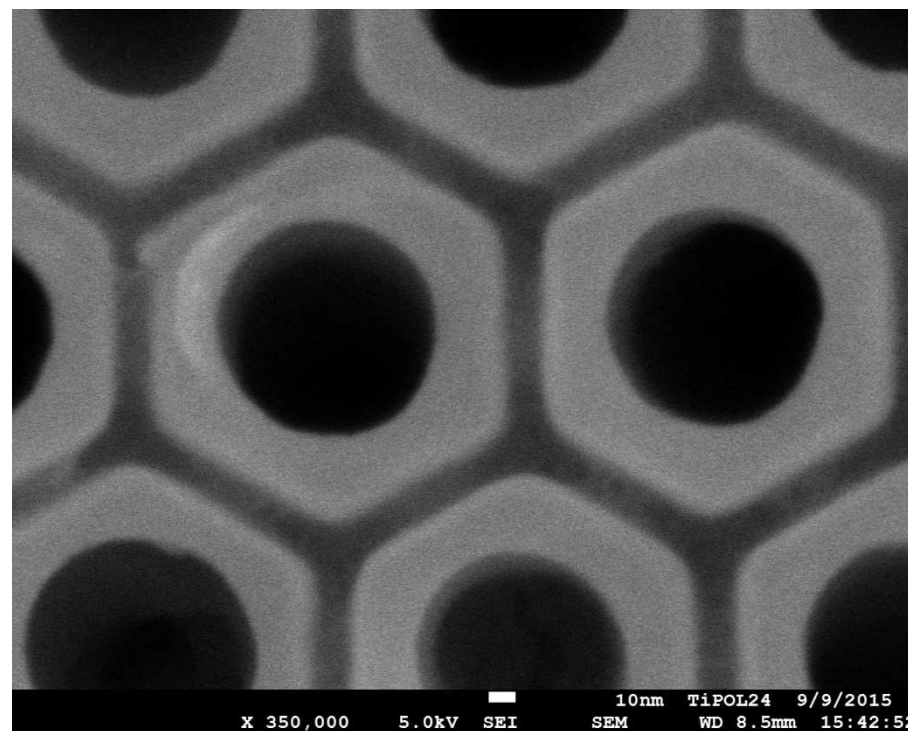
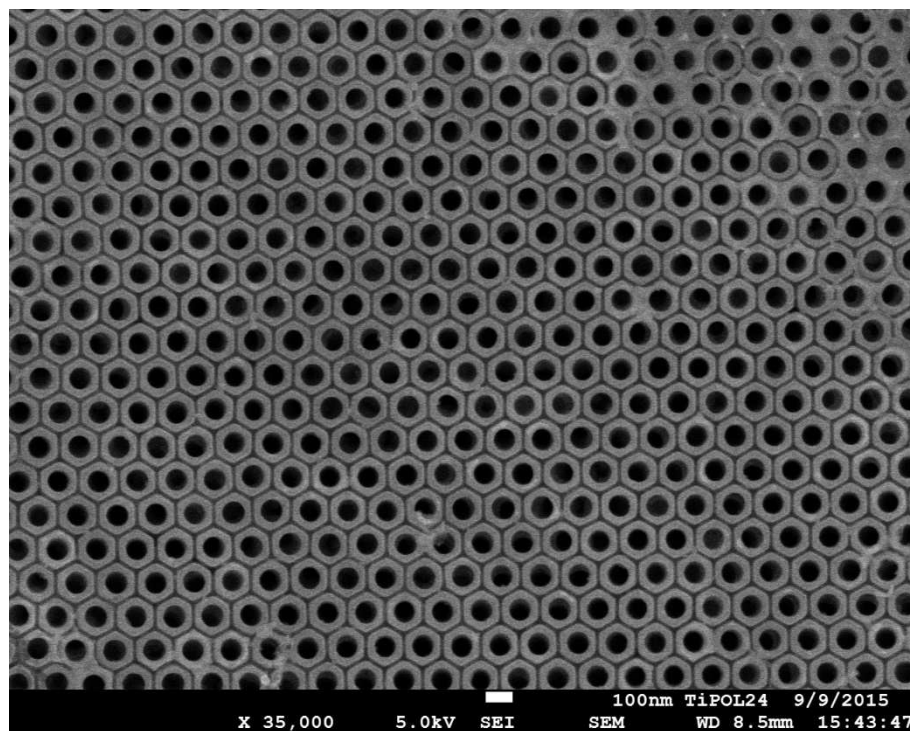
For review see:

J.M. Macak & P. Schmuki et al.: *Curr. Opin. Solid St. Mater. Sci.* **11** (2007) 3

K. Lee, A. Mazare, P. Schmuki, *Chem. Rev.* **114** (2014) 9385.

# Towards ideally ordered $\text{TiO}_2$ nanotubes

- SEM images show ideal hexagonal arrangement of  $\text{TiO}_2$  nanotubes

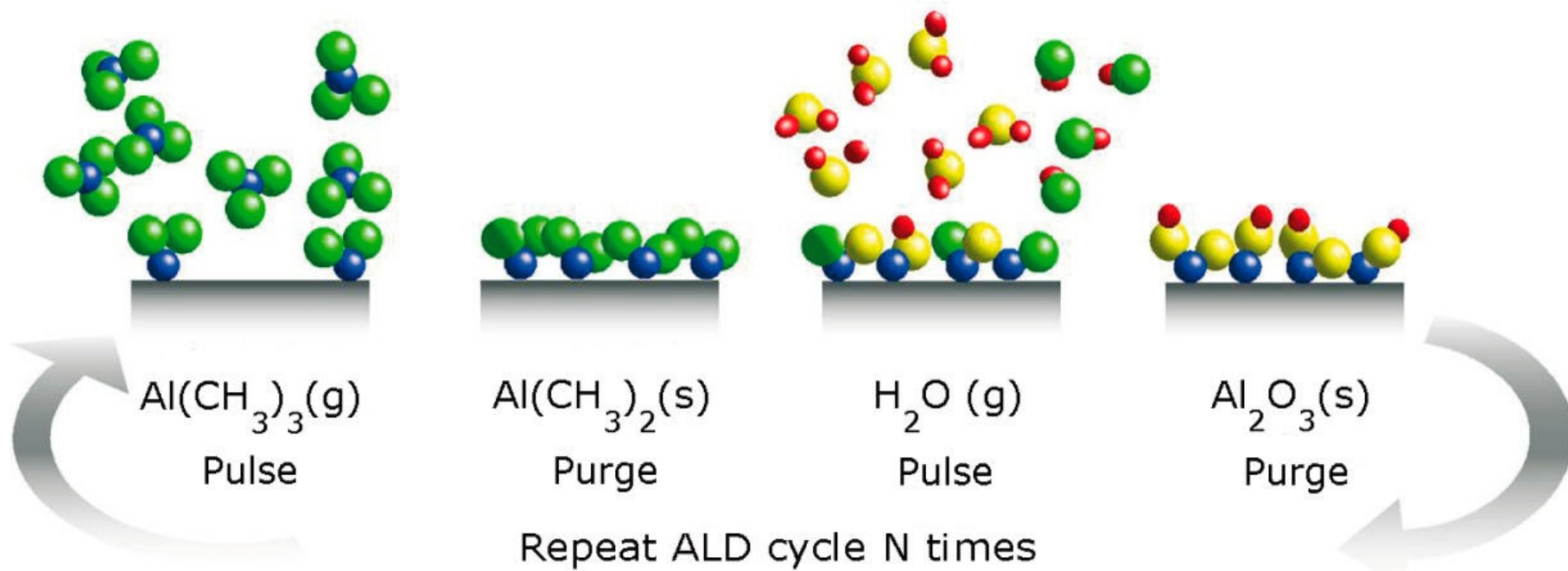


H. Sopha, & J.M. Macak et al., ChemistryOpen 2017,  
DOI: 10.1002/open.201700108



# Atomic Layer Deposition process

Tri-methyl Aluminum (TMA) + water ( $\text{H}_2\text{O}$ ) =  
Aluminum oxide ( $\text{Al}_2\text{O}_3$ ) + methane ( $\text{CH}_4$ )

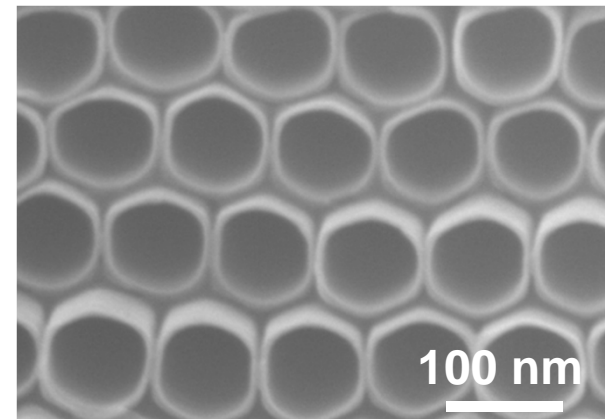


Growth per cycle 0.02...0.16 nm (depending on process chemistry and temperature)  
Cycle time 0.5...30 s (depending on flow dynamics and temperature)  
Example: 100nm deposition takes 50min (0.1nm/cycle; 3s/cycle)

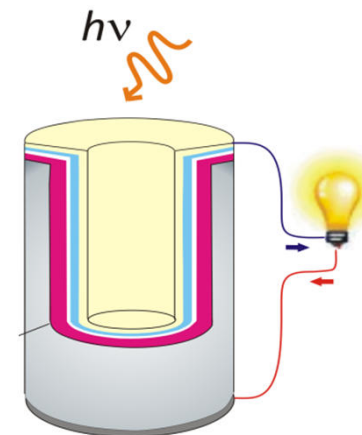
# CHROMTISOL

## Goals:

1] Filling of high-aspect ratio nanotubular  $\text{TiO}_2$  arrays with inorganic and organic chromophores



2] Introduction of new type of solar cell with fast and loss-reduced photo-generated carrier transfer from high absorption coefficient chromophores infilled in  $\text{TiO}_2$  nanotubes.



# Preparation of the project

- Idea development
- Getting info about ERC
- Writing proposal
- Submitting proposal
- Evaluation of the proposal – 1<sup>st</sup>, 2<sup>nd</sup>
- Acceptance of the proposal

## Idea development

- I knew what I would like to do
- I had previous knowledge in  $\text{TiO}_2$  (and nanotubes) and no in ALD
- That was the main risk, I was not sure, if it will work, but felt yes
- Literature on other structures gave me confidence
- Literature and patent survey
- Putting all ideas on one page A4



## Getting info about ERC

- Talk of Prof. Jungwirth here
- Talk to Prof. Holčápek and other several ERC grantess
- ERC webpage
- TC AV CR webpage

## Writing proposal

- Naturally most complicated and most time consuming (3 months)
- Templates were specific, but I had prior knowledge on writing proposals
- One has to really high-light all of its best (no modesty at this point)
- One has to clearly outline (and demonstrate on schemes and supported by WPs, milestones, risk) what should be done
- Text cross-checked by colleagues and Yellow Research Coach
- Getting together some base of the team (project admin, key researchers)

## Submission of the proposal

- Process itself easy
- However, negotiations involved with FCHT dean and UPa rector in parallel with the preparation
- Hosting agreement was OK (its just a form), but:
- Negotiations and arrangements about co-financing were made, negotiations about salaries had to be done too, who will be involved and why.
- Where to locate the project, why, how to embeed in FCHT structure (luckily, CEMNAT was just in its infancy)

## Evaluation of the proposal

- Took few months
- Got written letter that evaluation was great for me and invitation to Brussels' second round outstanding
- Got prepared for the 10 min talk (polishing with coaching, need to be in a good shape)
- Interview itself not easy in my case, I had unpleasant questions and had to demonstrate lots of things
- Afterwards (2 months), I got email that it was accepted for funding

## Acceptance of the proposal

- Celebration first 😊
- Afterwards, tedious recalculation of the budget (some money cut off)
- Closely working with responsible ERC person on agreements and brought all to signatures (great help of ORMV, UPa appreciated)
- Took from 18.11.2014 to Feb 2015 to prepare all.
- Had to defend salaries of people from 1.1.2015 to 28.2.2015
- In parallel, had to redesign architecture of laboratories and begun preparation of the tenders and putting together a team

# ALD $\text{Al}_2\text{O}_3$ deposition in $\text{TiO}_2$ nanotube layers

High aspect ratio ( $\approx 180$ ) nanotube layers  
homogenously coated

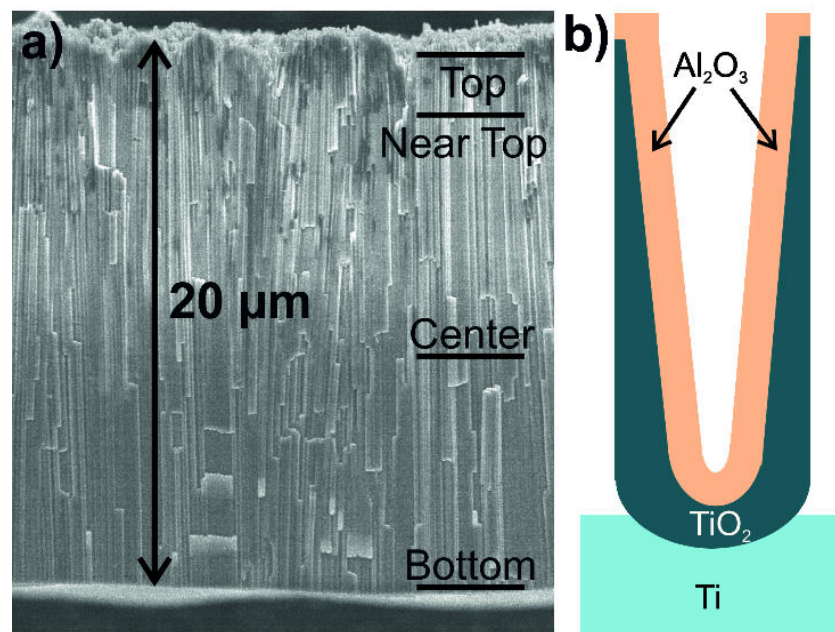


Figure 1: a) cross-sectional SEM image of the  $20\ \mu\text{m}$  thick  $\text{TiO}_2$  nanotube layer with four different depth levels, b) cross-sectional profile of the nanotubes showing a gradient in the inner tube diameter and the  $\text{Al}_2\text{O}_3$  coating of the tube interiors  
TMA,  $\text{H}_2\text{O}$ , 5 sec pulse,  $200^\circ\text{C}$ , FHR Anlagebau

R. Zazpe et al., *Langmuir*, 32 (41), 2016, 10551

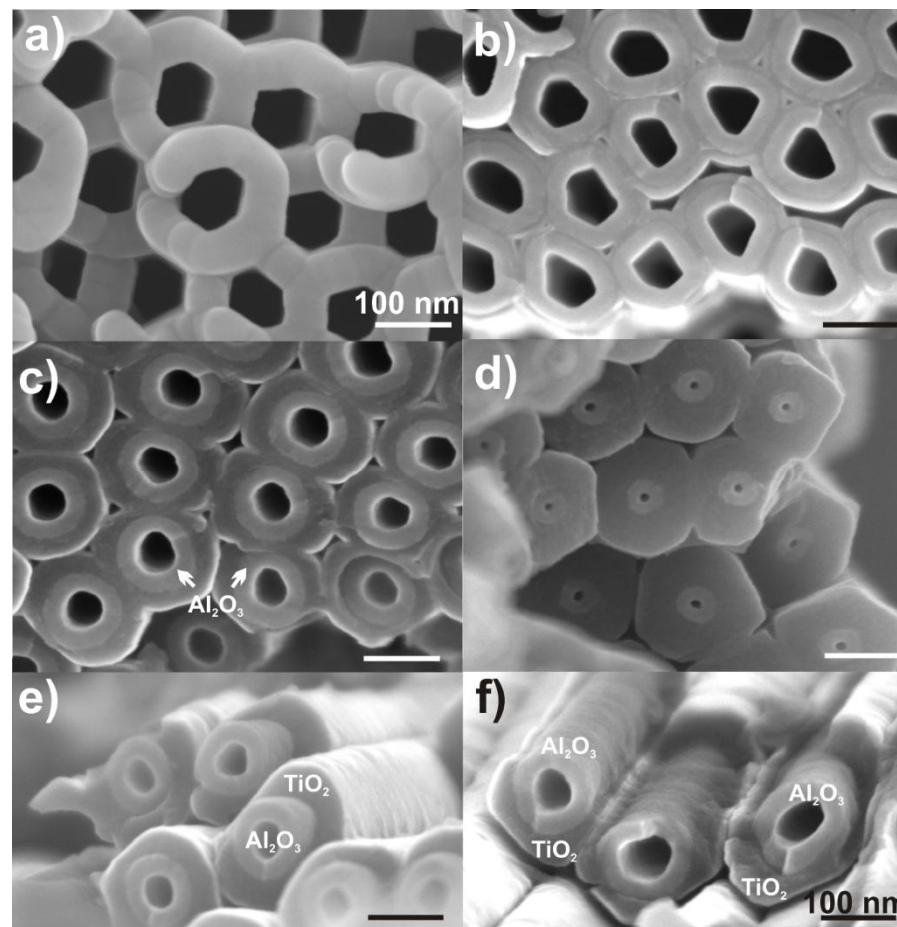


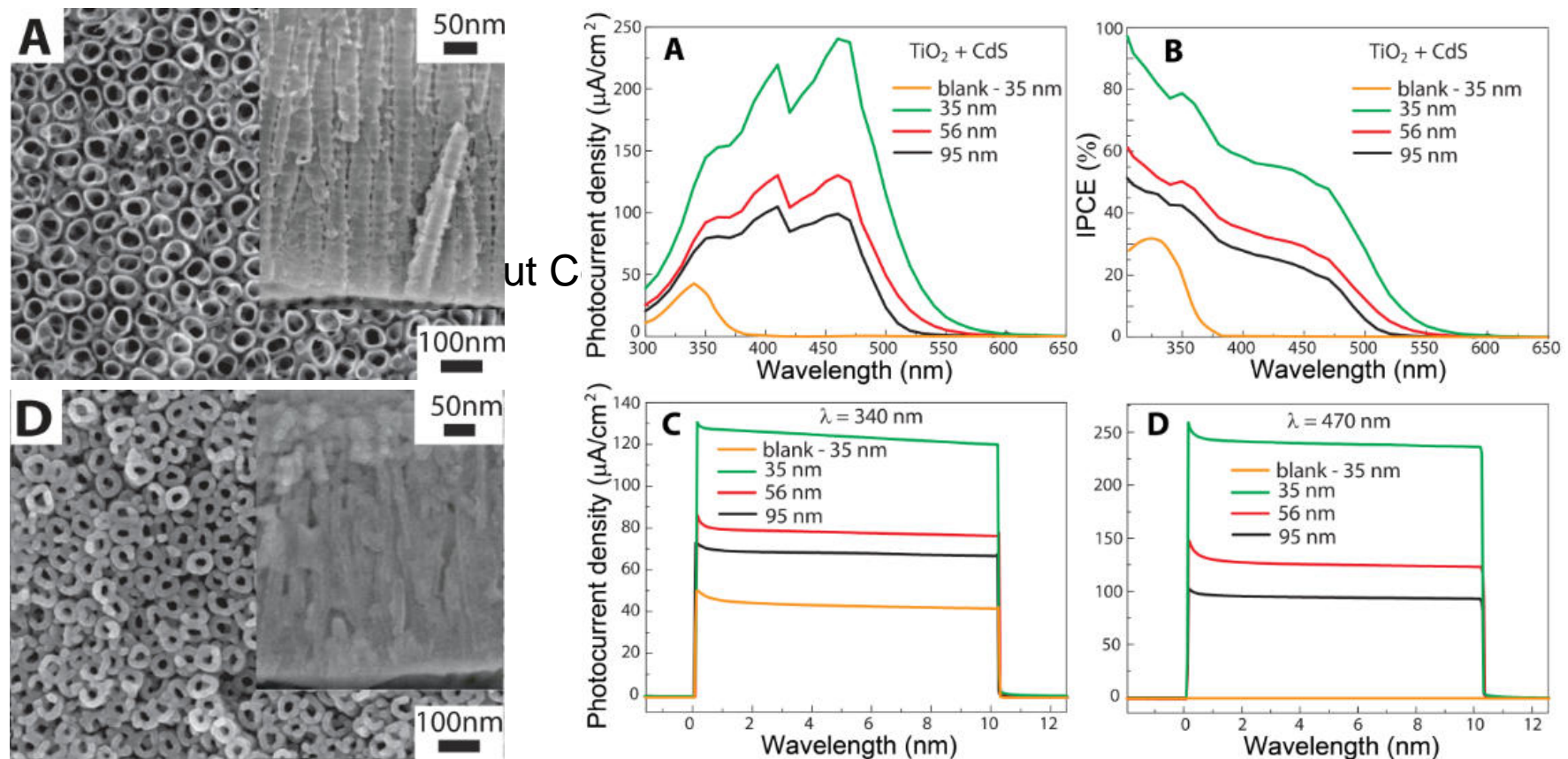
Figure 2: SEM images of  $\text{TiO}_2$  nanotubes coated by  $\text{Al}_2\text{O}_3$  using ALD. Images taken at four depth levels. The scale bar represents the distance of  $100\ \text{nm}$ . Nominal coating thickness  $\approx 27\ \text{nm}$ .



# The CHROMTISOL concept

Initial results are already very promising.....

**New type of heterostructured solar cell based on thin CdS absorber ALD coating of extremely high surface area**



# Potential groundbreaking CHROMTISOL results

Expected groundbreaking results in:

- Opening new pathways in the construction of advanced solar cells – combination of ordered nanotube structure and  $\text{TiO}_2$  nature is unique and possess lots of opportunities
- Creating solutions for depositions of other functional materials inside nanotubes and thus to generation of new applications and devices
- Moving forward the currently existing technical limits in the deposition of chalcogenide and organic materials, in particular by means of ALD (and other techniques as well)
- New advanced architectures of nanotubes, including novel compositions, shapes



**Large room for publications in great journals + patent application**

# CHROMTISOL

- Starting grant
- Begun 1<sup>st</sup> of March 2015
- Budget  $\approx$  1.7 Mio EUR
- All together 12 people employed (5 women, 5 nationalities)
- Hosting institution: Uni Pardubice, FCHT, CEMNAT
- FCHT added 300 k Euro for investments

# CHROMTISOL impact\*

## **Scientific and technological:**

- anodic self-organized nanostructures (new geometries, ordering, upscale)
- Atomic layer deposition (novel coatings utilized inside nanotubes, new interfaces)
- hybrid photovoltaic (new materials combinations, improved charge separation)

## **Personal:**

- significant freedom (I could select people I wanted, limited budg. restrictions)
- new team set with great coworkers (ERC good for their career too)
- significant workload (but I can handle it 😊) focused on few challenges
- my creativity is higher (no need to write numerous project proposals during the year)
- satisfaction (I feel good, my coworkers too)
- many internal and external cooperations
- jealousy and public visibility

## **Institutional:**

- increased visibility of Uni Pardubice, FCHT and CEMNAT
- new funding opportunities for research infrastructures (CEMNAT on the Roadmap)
- new scientific and technological opportunities

# Macak's group

- Dr. Hanna Sopha
- Dr. Miloš Krbal
- Dr. Raul Zazpe
- Jan Přikryl
- Luděk Hromádko
- Denisa Janebová
- Dr. Veronika Podzemná
- Siwoon Ng
- Dr. Anitha V. Chandran
- Dr. Filip Dvořák





# Acknowledgements

- European Research Council



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- Czech Science Foundation

- HERALD



## Thank you for your attention