Tampere University
Tampere University of Applied Sciences

Supercritical carbon dioxide ($scCO_2$) processing of Ceramic Materials

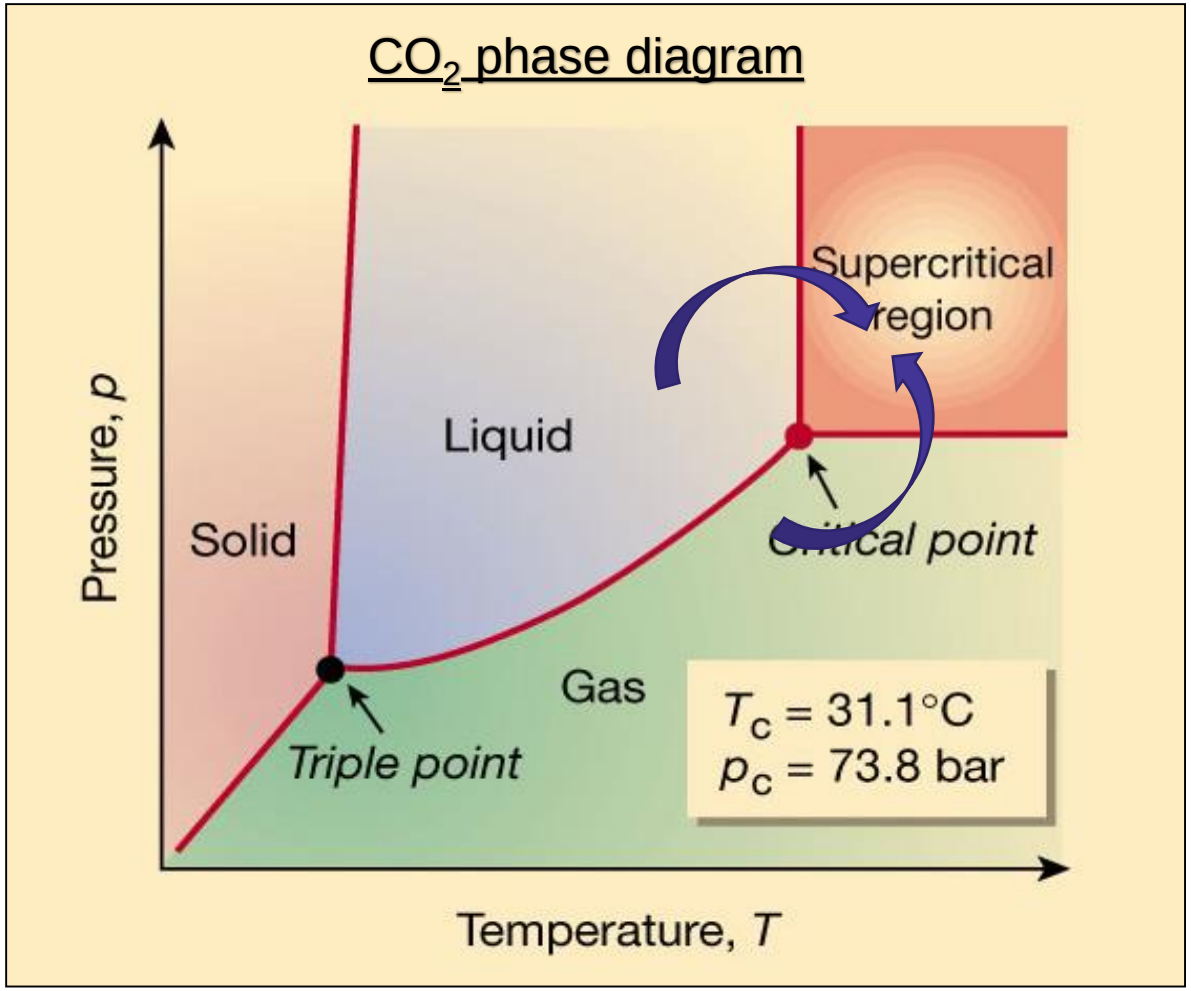
Aaretti Kaleva
Advanced Ceramic Materials Group

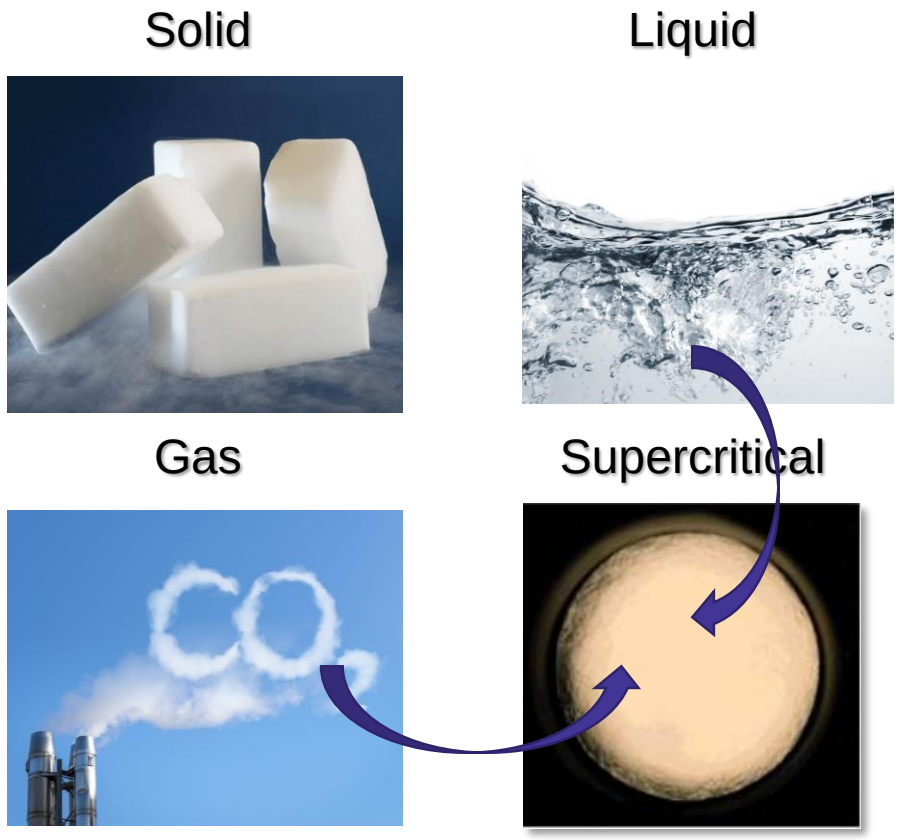
Materials Science 50 years anniversary seminar 24.10.2019

Contents

- Introduction to $scCO_2$
- Potential and applications of $scCO_2$ processing
- Research in ceramic materials group

What is supercritical CO_2





Tampere University
Tampere University of Applied Sciences

Supercritical CO_2 ($sccO_2$)

Gas-like ⟵ *Properties from both* ⟶ **Liquid-like**

- High diffusivity & mass transfer
- Flowing properties (e.g. viscosity)
- No surface tension

- High density

Flow properties & Diffusion through structures

$scCO_2$

Better solvability & Tunable solvability

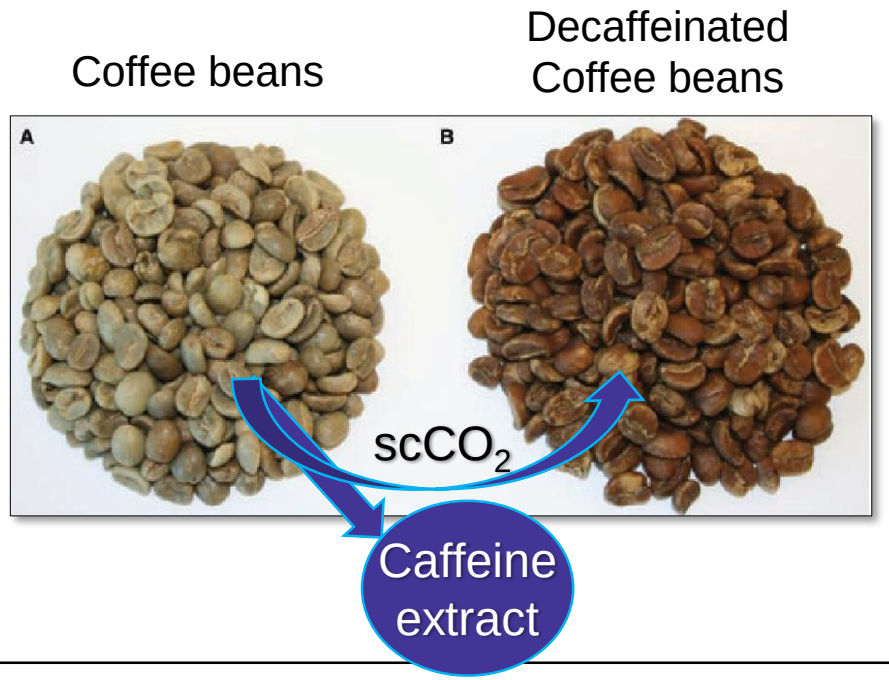
Other processing benefits:

- Inexpensive
- Easily available
- Low supercritical point
- Non-toxic

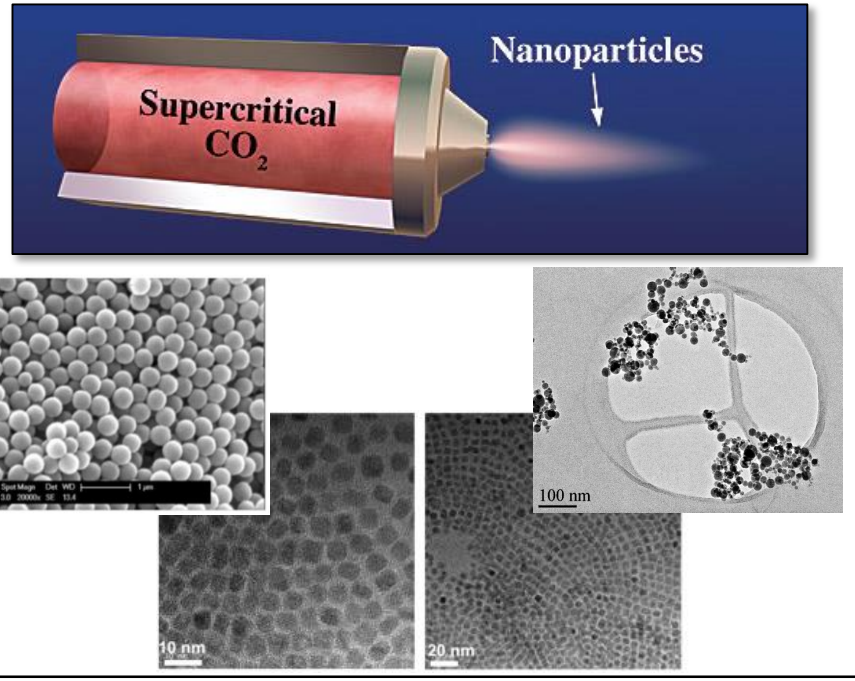
Tampere University
Tampere University of Applied Sciences

$scCO_2$ application areas

Extraction



Nanomaterial synthesis and preparation



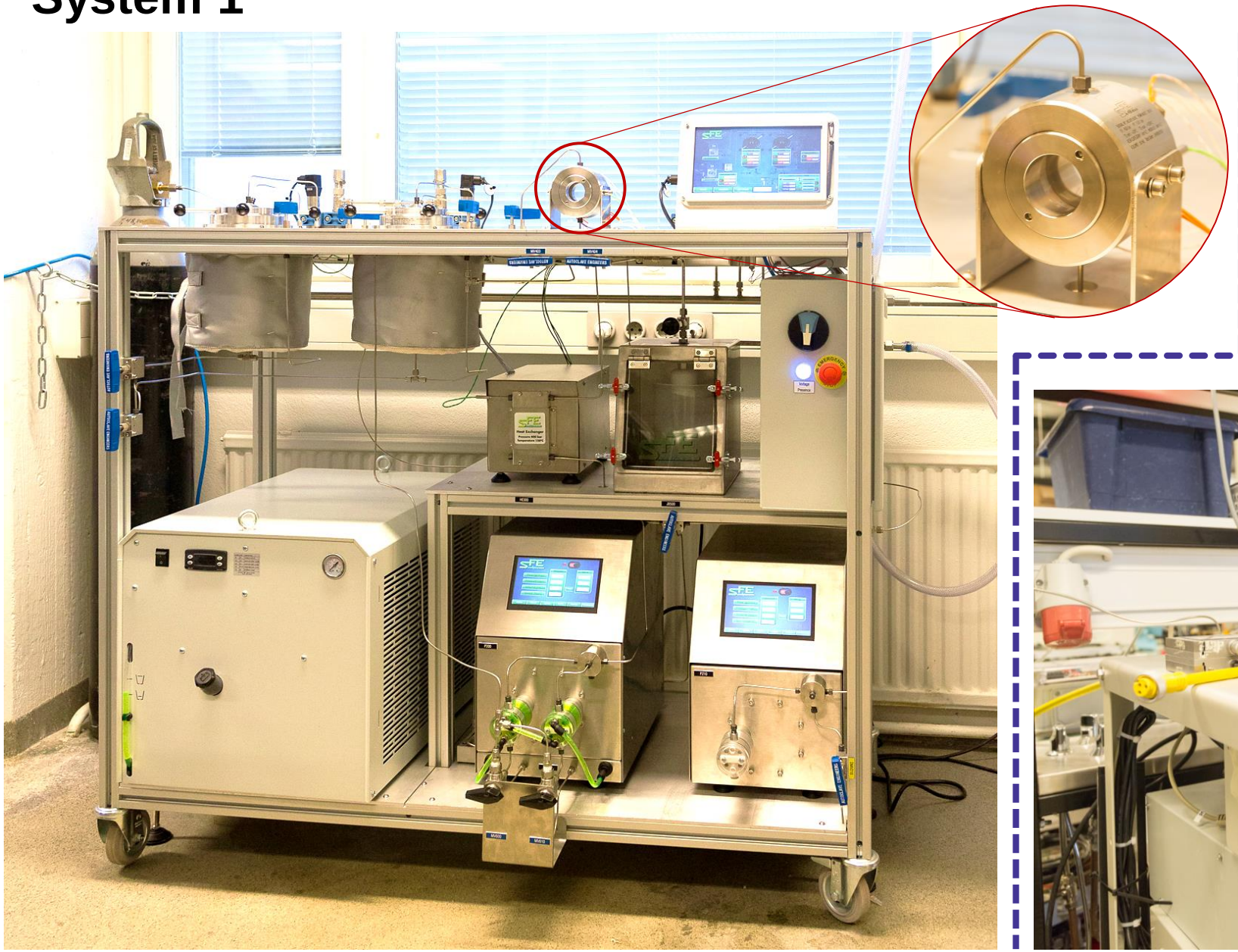
Other areas:

- Polymer/chemical synthesis
- Carbon storage
- Pharmaceuticals
- Dry cleaning
- Etc…

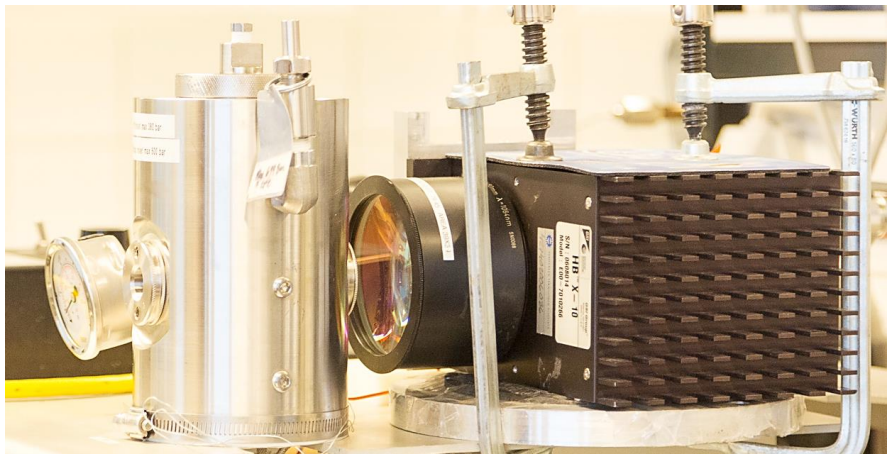
Tampere University
Tampere University of Applied Sciences

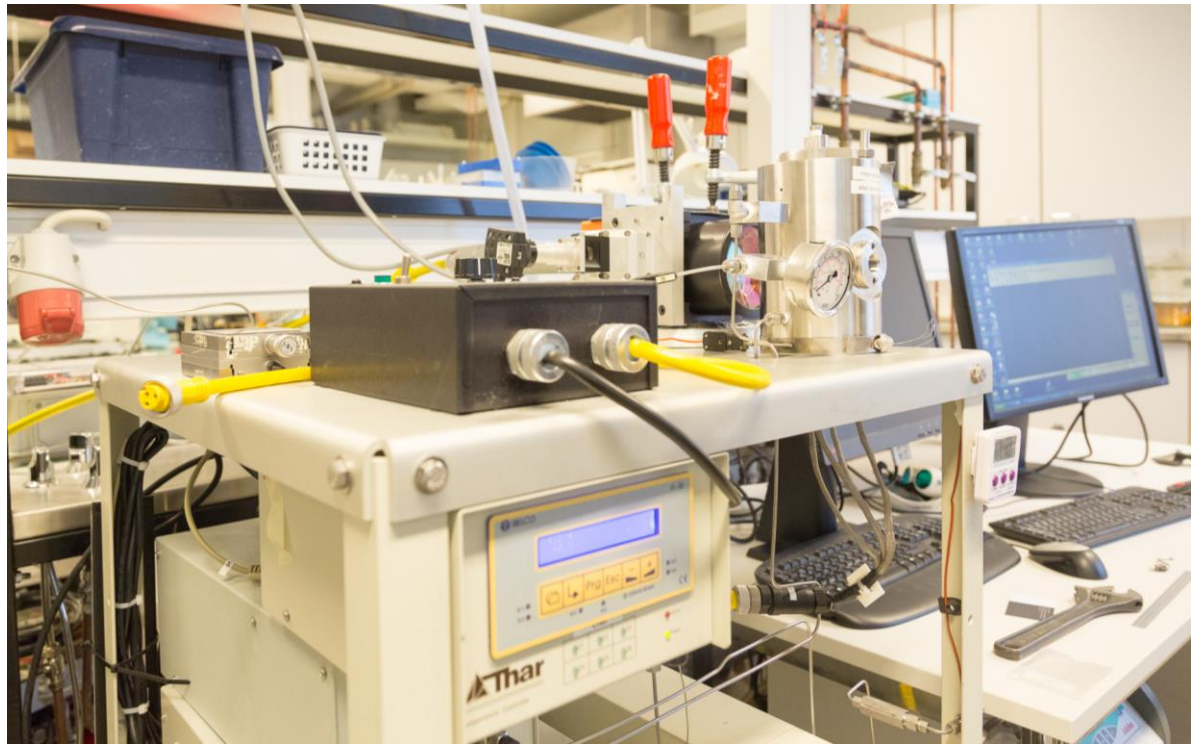
Our equipment

System 1



System 2





$scCO_2$ research in Ceramic Group

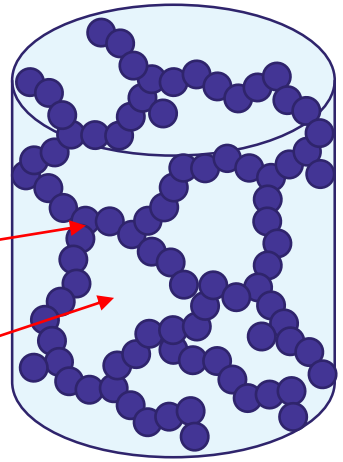
1. **SiO_2 Aerogel drying**
2. **Artificial zinc patina**
   a) Pretreatment for painting
   b) Conversion to ZnO
3. **Laser ablation of Titanium target**

Tampere University
Tampere University of Applied Sciences

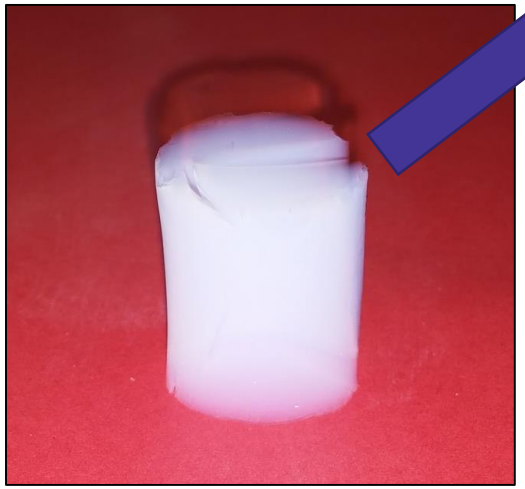
1. SiO_2 aerogel drying

© Sandiegouniontribune, 2010, Mae Anderson

SiO_2 Gel



Solvent removal with $sCCO_2$



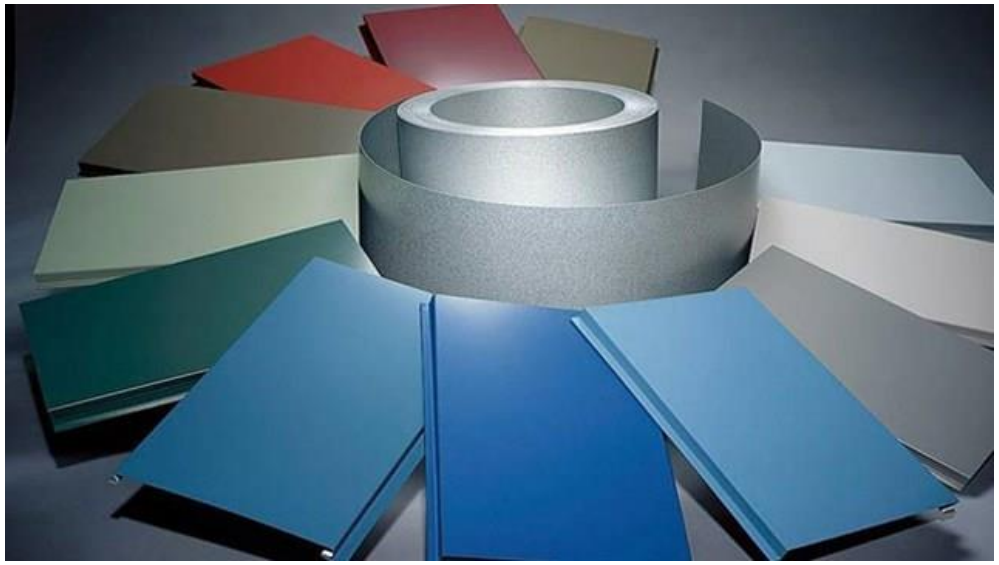
Aerogel

- No aging
- Porosity ~ **97 v-%**
- Surface area **598 m^2/g**

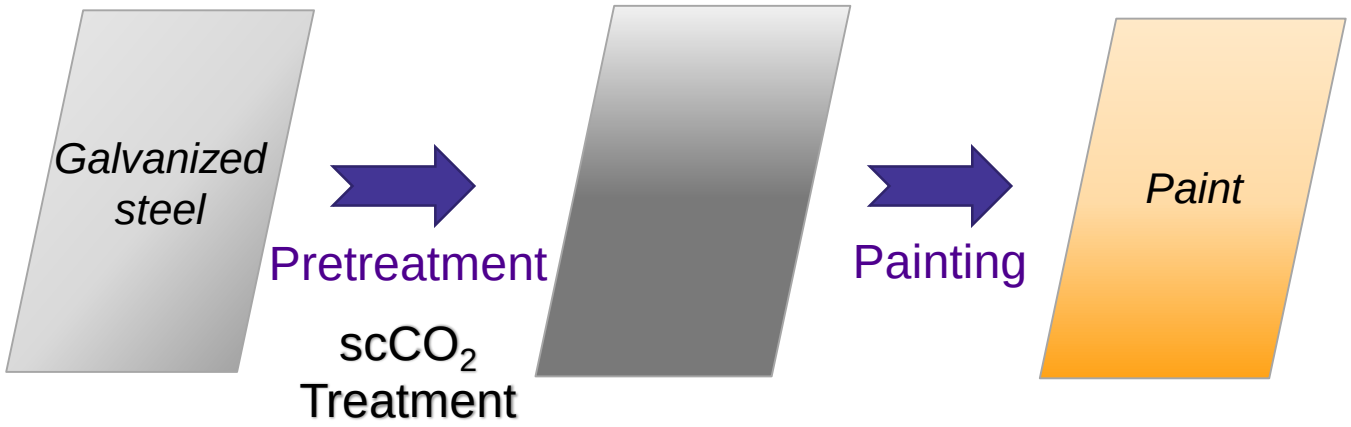
Tampere University
Tampere University of Applied Sciences

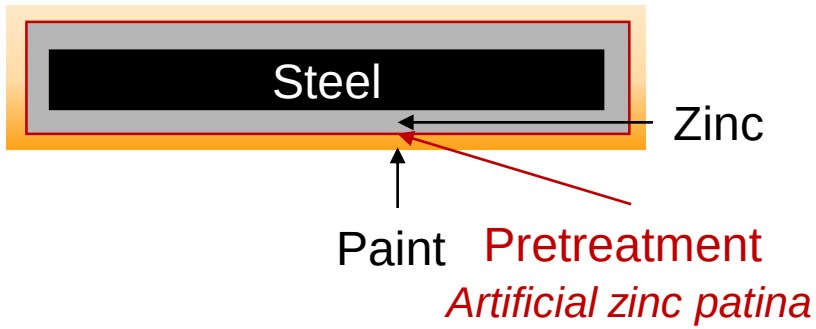
2. Artificial zinc patina:
a) *Pretreatment for painting*

SSAB



Painting process



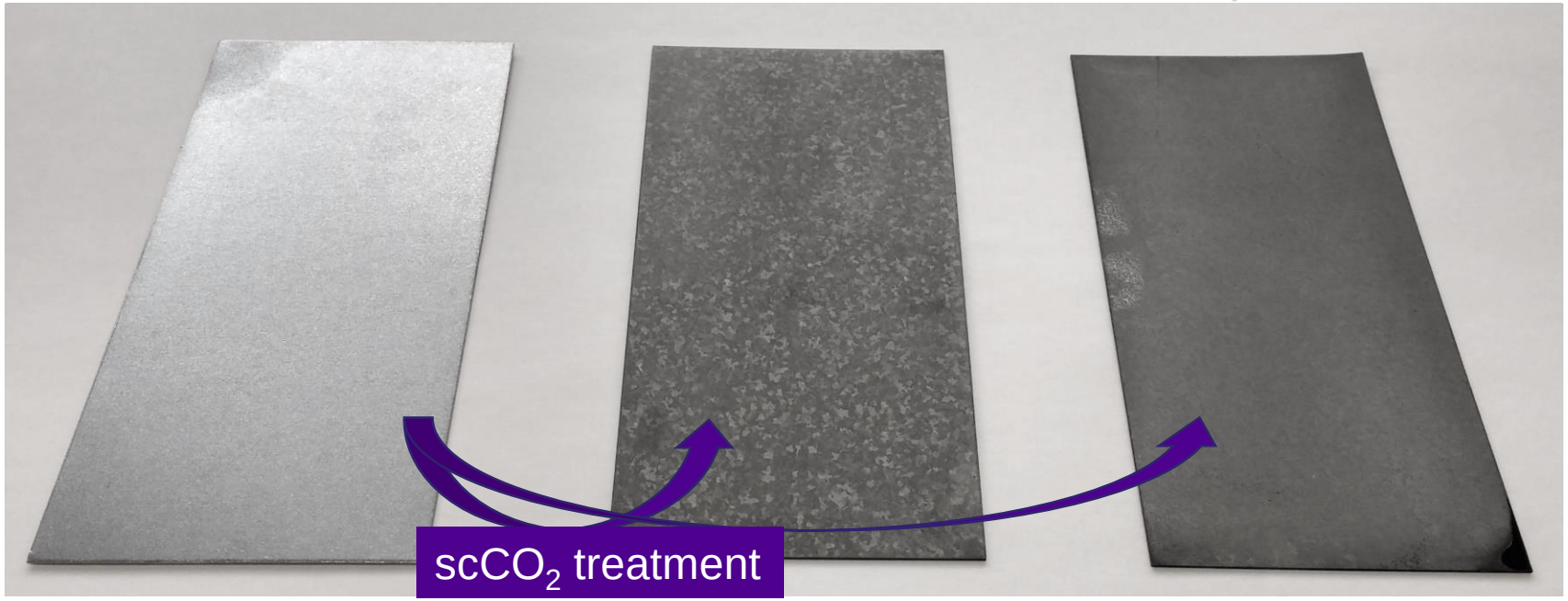


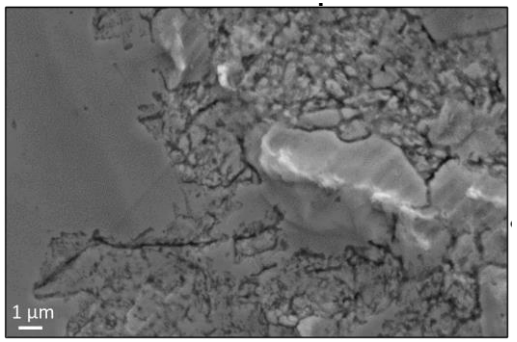
Tampere University
Tampere University of Applied Sciences

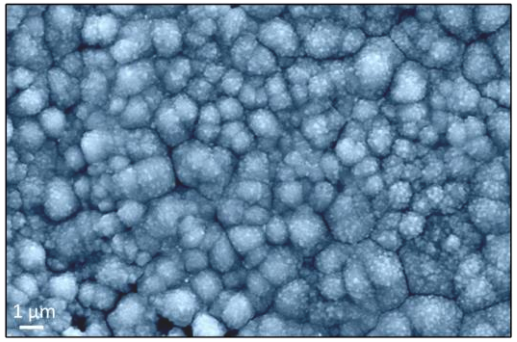
2. Artificial zinc patina:

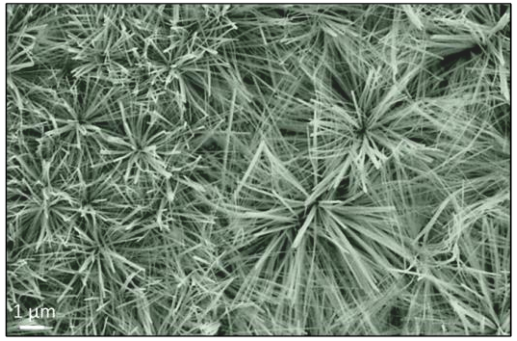
a) *Pretreatment for painting*

Galvanized steel *Dense patina* *Porous patina*





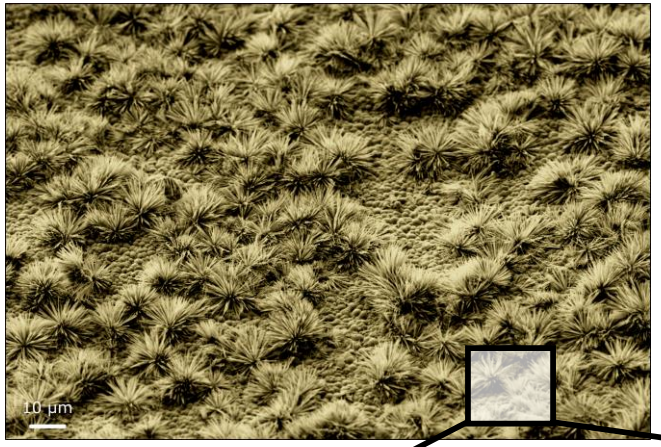


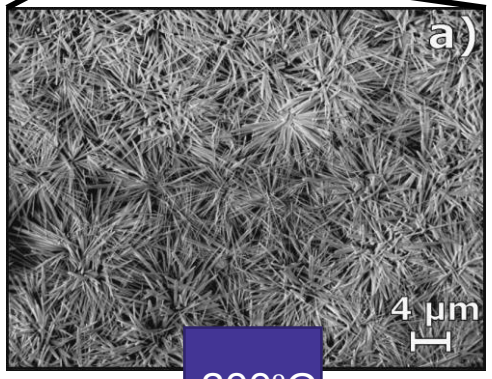


Tampere University
Tampere University of Applied Sciences

2. Artificial zinc patina

b) Conversion to ZnO

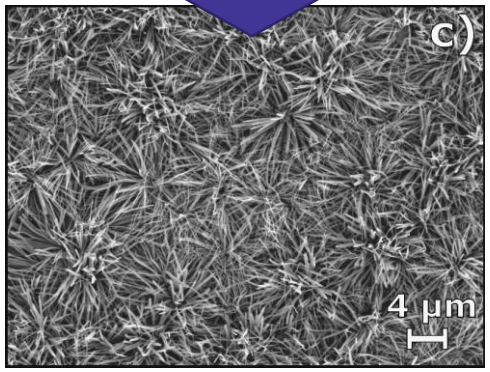




Zinc patina
$(Zn_x(CO_3)_y(OH)_z)$

Release of CO_2 and H_2O

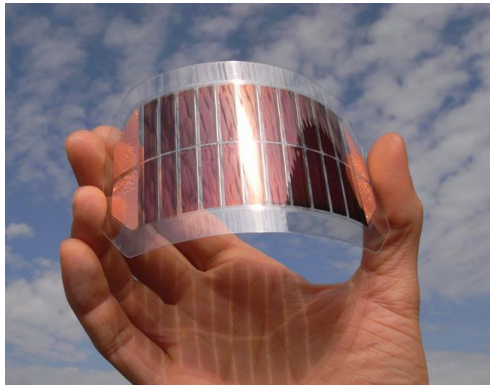
300°C



Zinc oxide
(ZnO)

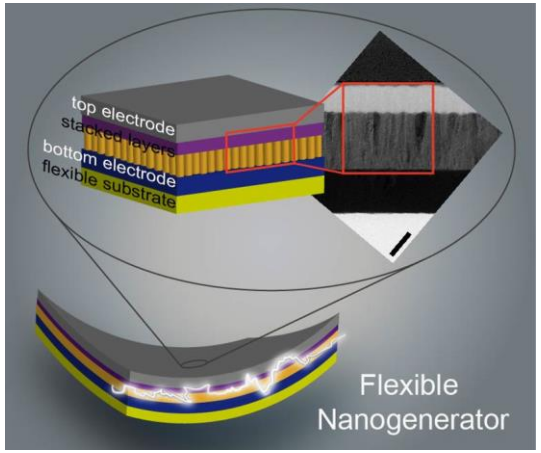
Applications

DS Solar cells



Gas sensor

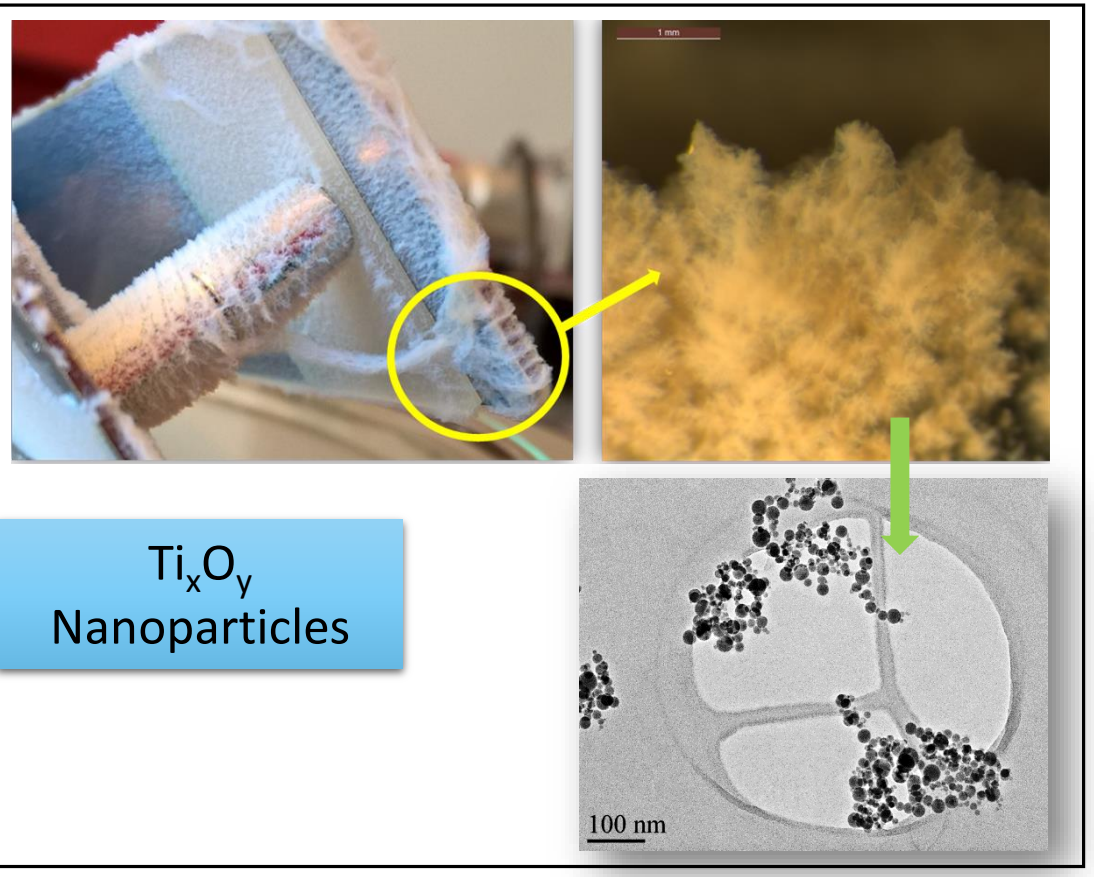
Energy harvesting



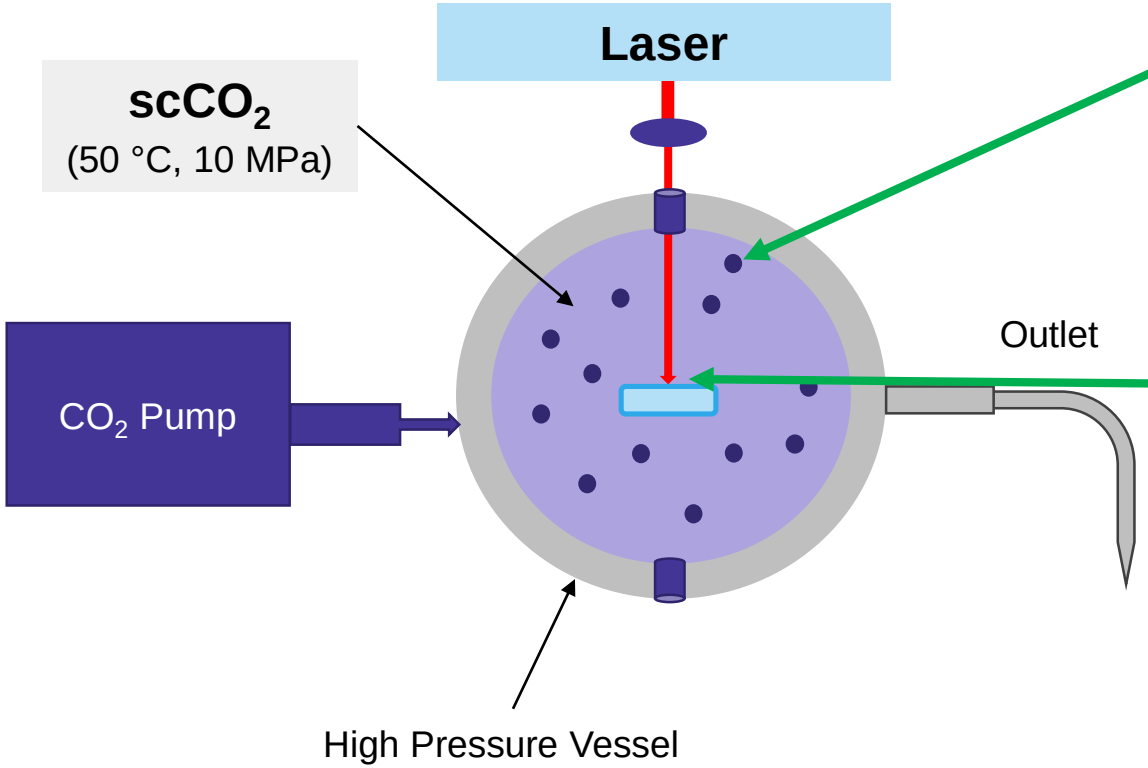
3. Pulsed laser ablation in $scCO_2$

Photoactive nanoparticles & Functionalized surfaces

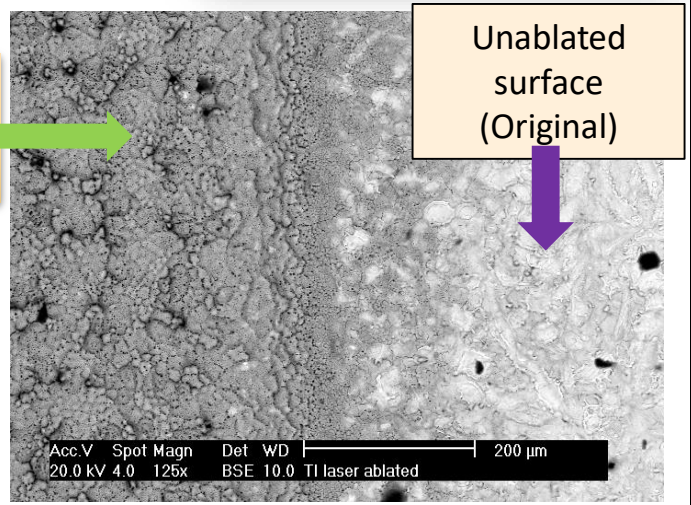
Amandeep Singh



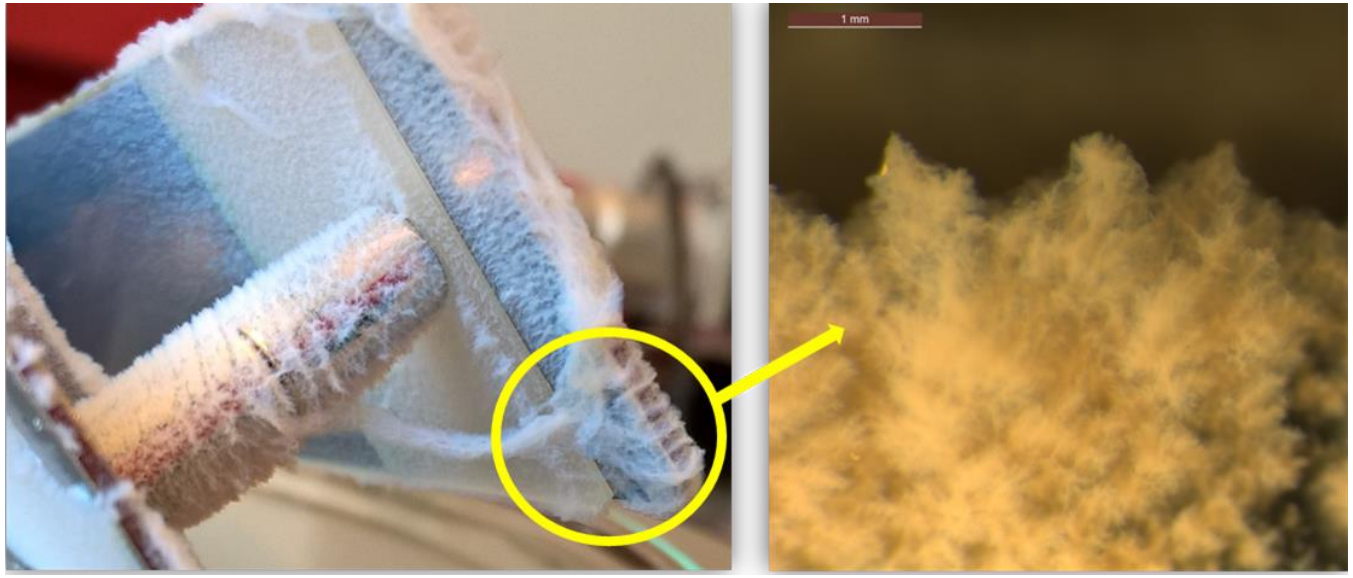
Ti_xO_y Nanoparticles

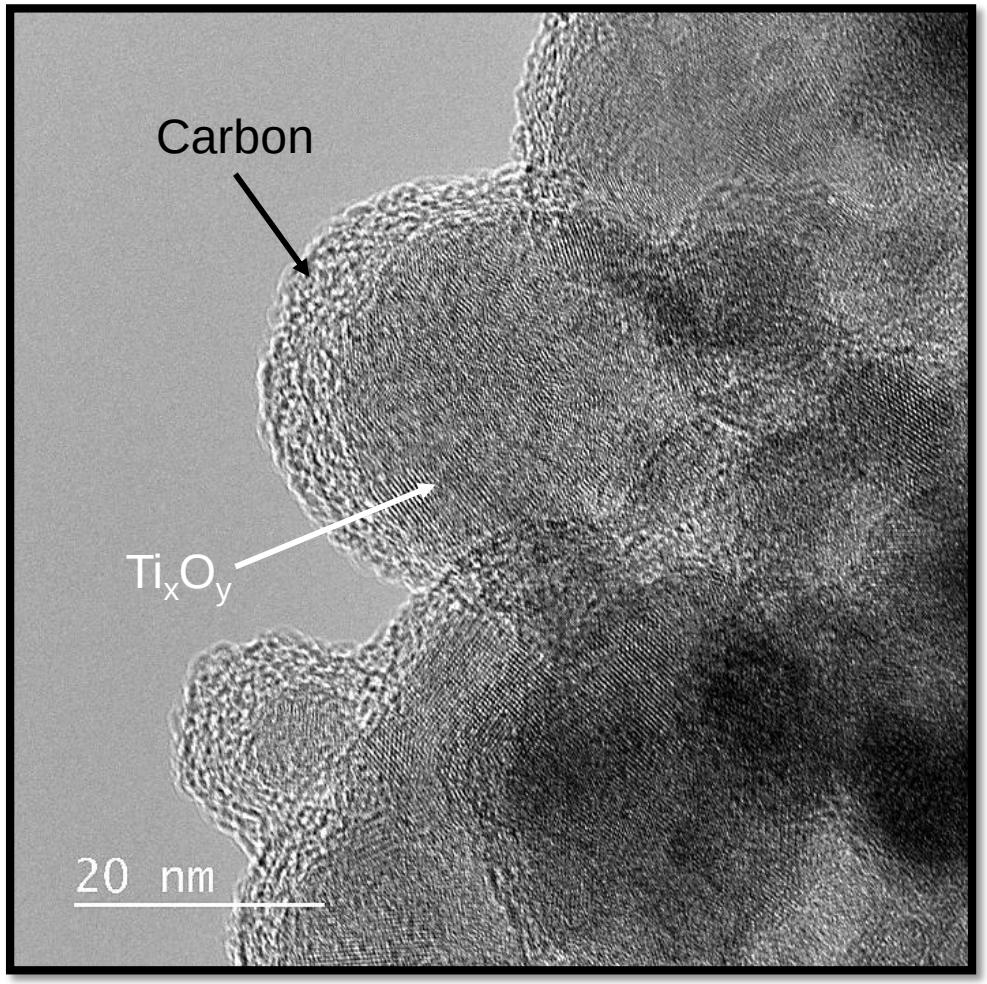


Ablated surface (Functionalized)



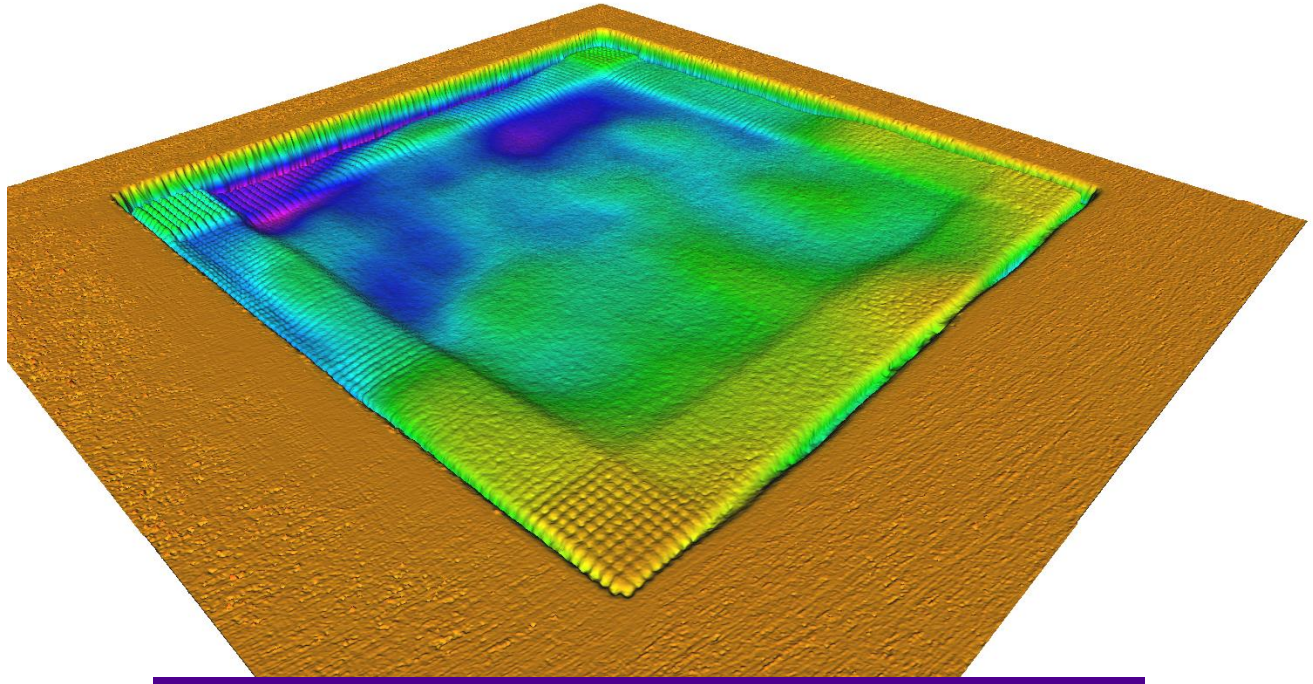
Ti_xO_y Nanoparticles



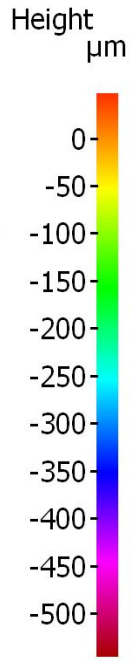


Tampere University
Tampere University of Applied Sciences

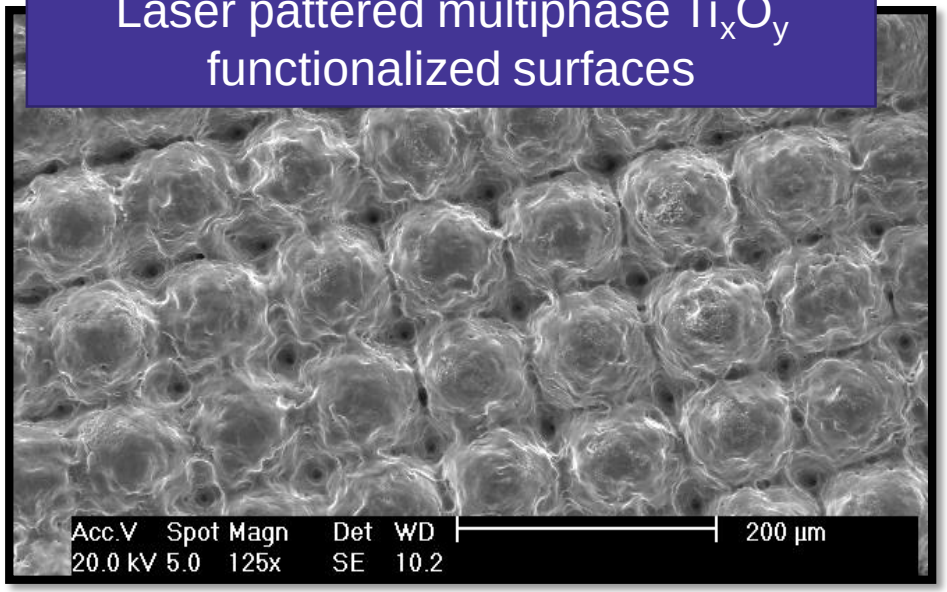
Functionalized Ti_xO_y surface

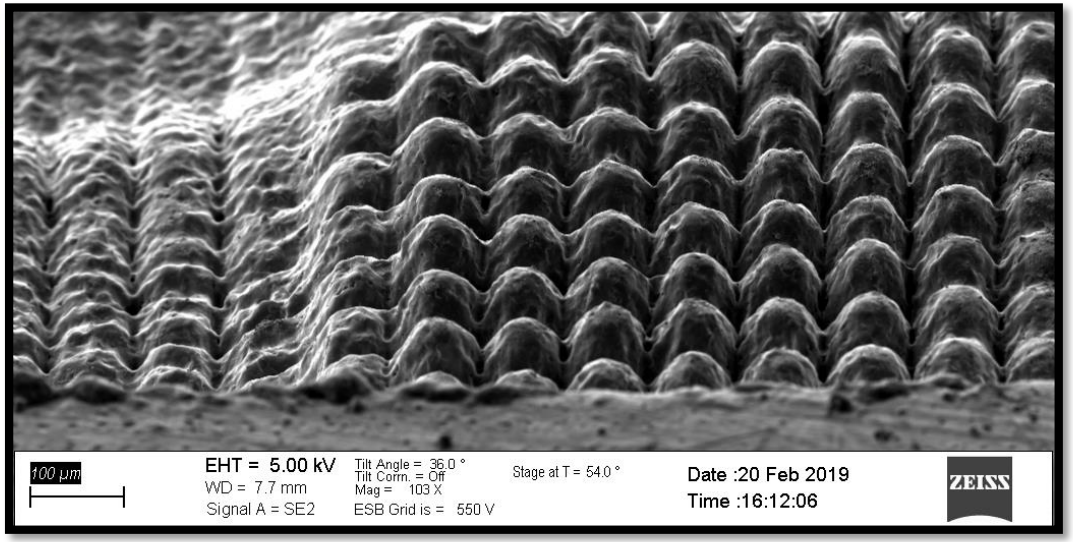


Possibility to make variable surface profiles by selecting laser parameters



Laser pattered multiphase Ti_xO_y functionalized surfaces





Conclusions

- Supercritical carbon dioxide is a versatile processing method with utilization potential in various industries
  - **Food**
  - **Pharmaceutical**
  - **Materials processing**
  - **Ceramic processing**
  - **Chemical engineering**
- Green processing method that utilizes already produced carbon dioxide (no extra emissions)
  - **In some applications reduces emissions**
- New application areas emerging constantly


Thank you for your attention!
HOUSTON
Advanced ceramic materials group

Figure references:

CO2 Phase diagram: https://www.nature.com/articles/35012181

Caffeine extraction: doi:10.1111/j.1750-3841.2011.02304.x

Nanoparticles with scCO2: https://www.eurekalert.org/features/doe/2004-08/dnnl-sfn082404.php

Pharmaceutical nanonization: https://nanoform.fi/technology/

Aerogel jacket: http://www.nbcnews.com/id/36934946/ns/business-consumer_news/t/man-climb-everest-supersuit/#.XbbQOsRS9hE

Energy harvesting: https://publishing.aip.org/publishing/journal-highlights/zinc-oxide-materials-tapped-tiny-energy-harvesting-devices

Gas sensor: doi:10.3390/s90604669

Solar cells: http://sinovoltaics.com/solar-basics/solar-cell-guide-part-4-organic-and-dye-sensitized-solar-cells/

Painted galvanized sheet: https://www.englertinc.com/blog/tag/metal-roof-colors/page/2/