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# The exquisite art of tailoring coatings

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Innovation Fund Denmark



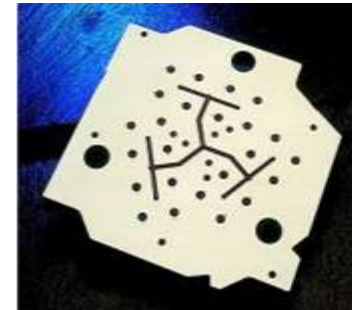
# Outline

- Who are we?
- Motivation
  - Modifications of the surface
  - Introducing coatings
- PVD coatings
  - Coating technology (sputtering)
  - How to tailor coating properties
  - Examples
- Summary



# Danish Technological Institute

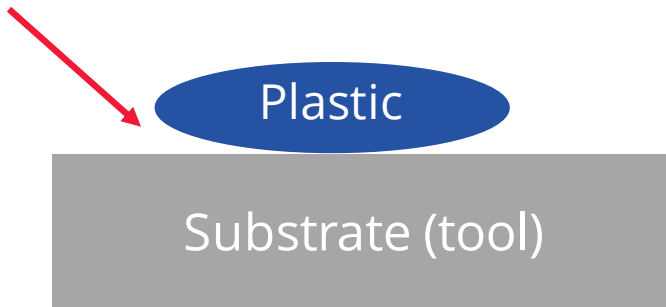
- An independent, non-profit institution
- Approved as a technological service institute by the Danish Ministry of Science, Technology and Innovation
- ~1000 employees in 40 centres, mainly in Høje Taastrup and Aarhus
- Facilitate technology transfer from universities to enterprises
- Tribology Centre in Aarhus
  - Commercial job coating
  - Research & Development
  - Facility with 5 coating units and 2 ion implanters
  - 18 employees



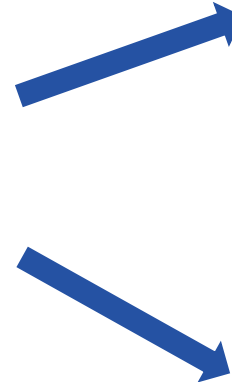


# Modification of surface properties

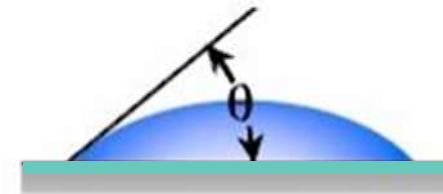
Interaction with polymers  
at the surface



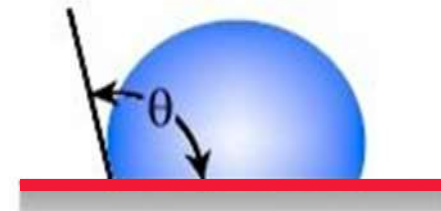
Coating of tool



Hydrophilic  
Surface



Hydrophobic  
Surface

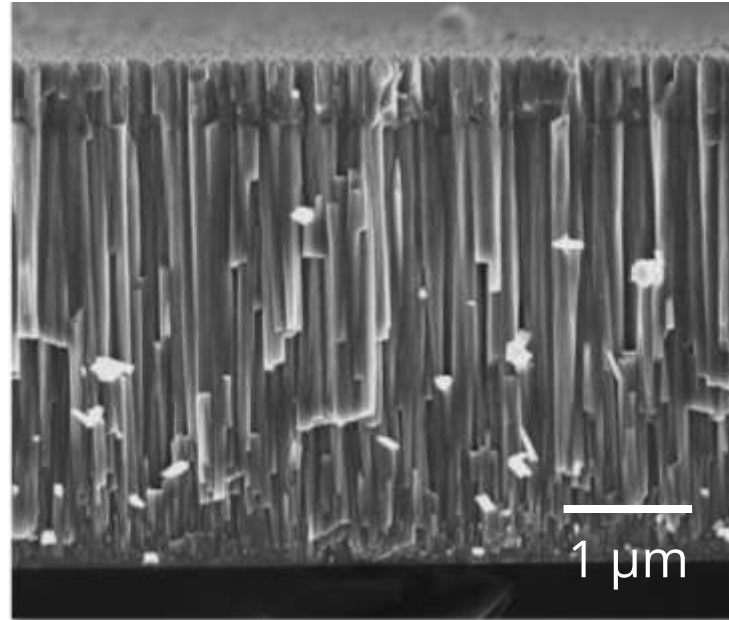


Different coating  
properties change  
interactions with  
water, polymers etc.



# Coatings (or thin films)

- A layer of material ranging from a few atomic layers up to about  $\sim 5 \mu\text{m}$  deposited on a substrate
- Can be metals, ceramics, polymers, composites, ...
- High hardness, low friction, specific optical properties etc. can be achieved



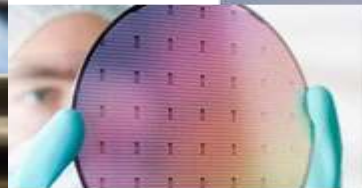
Electron microscopy image of cross sections of coatings on test substrates.

Note:  
The diameter of a  
human hair is  
around  $100 \mu\text{m}$ .



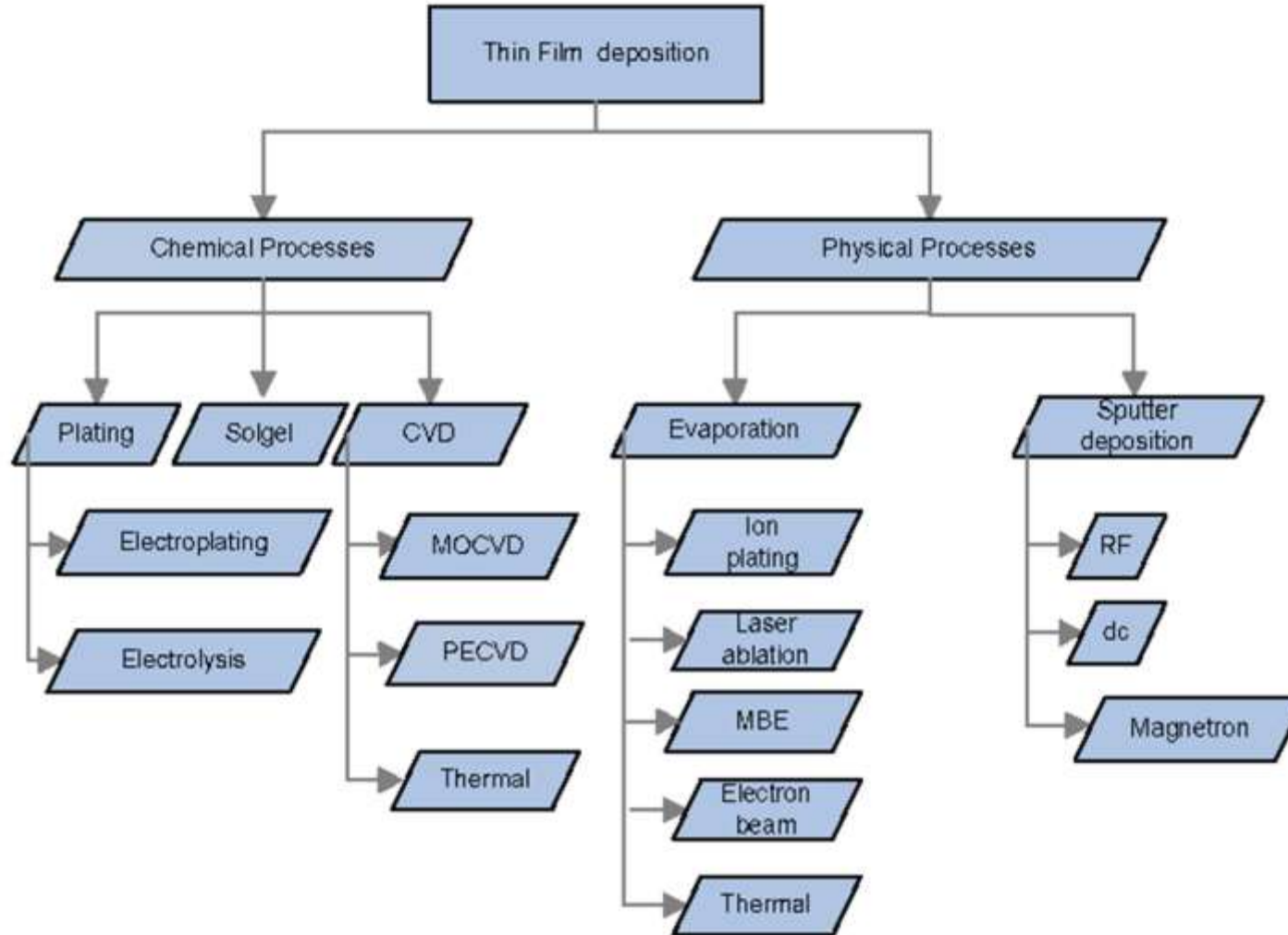
# Use of coatings

- Tribological problems (wear and friction)
- Optical coatings
- Decorative coatings
- Microelectronic devices
- Medico
- Food packaging



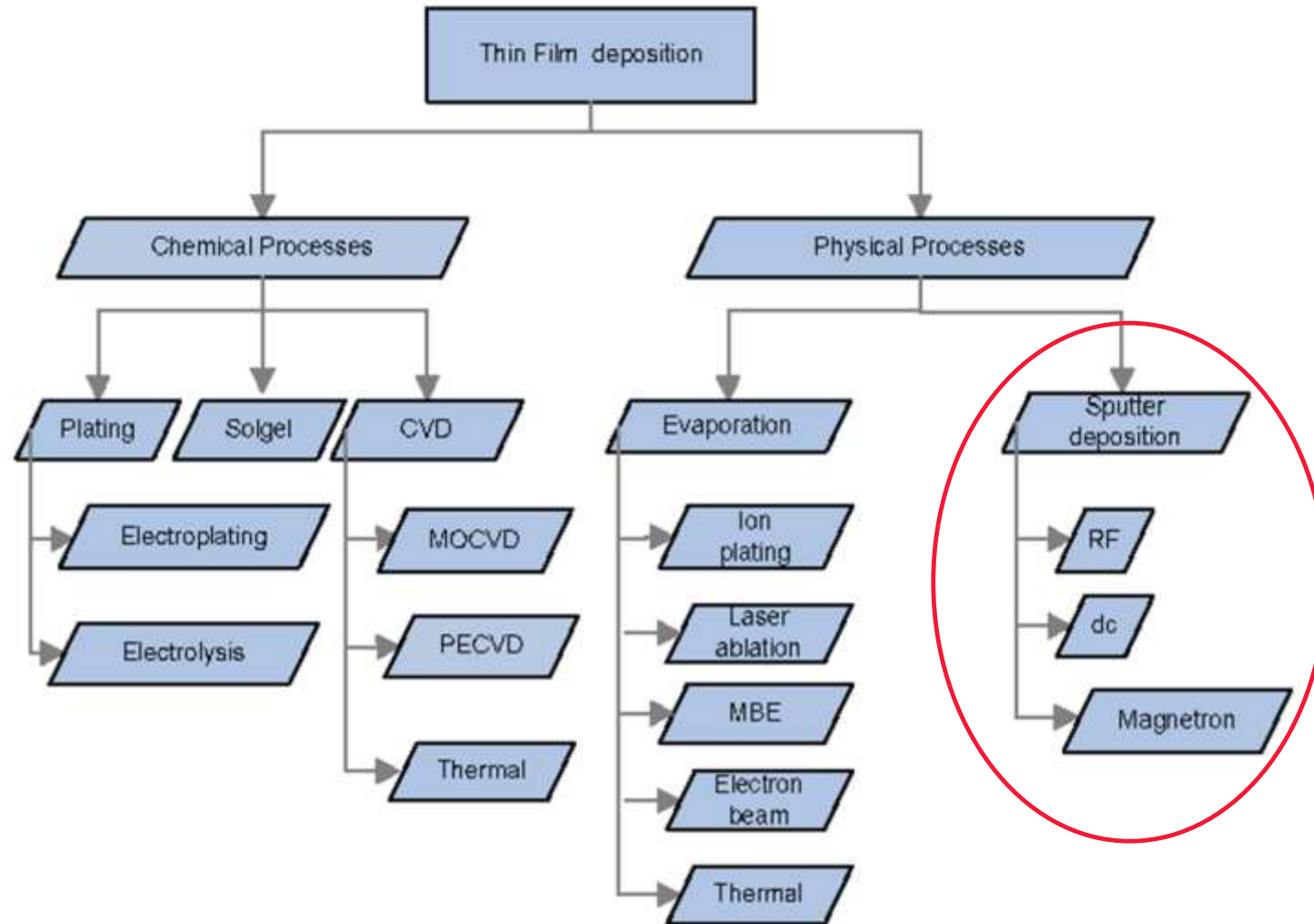


# Thin film deposition processes





# Thin film deposition processes



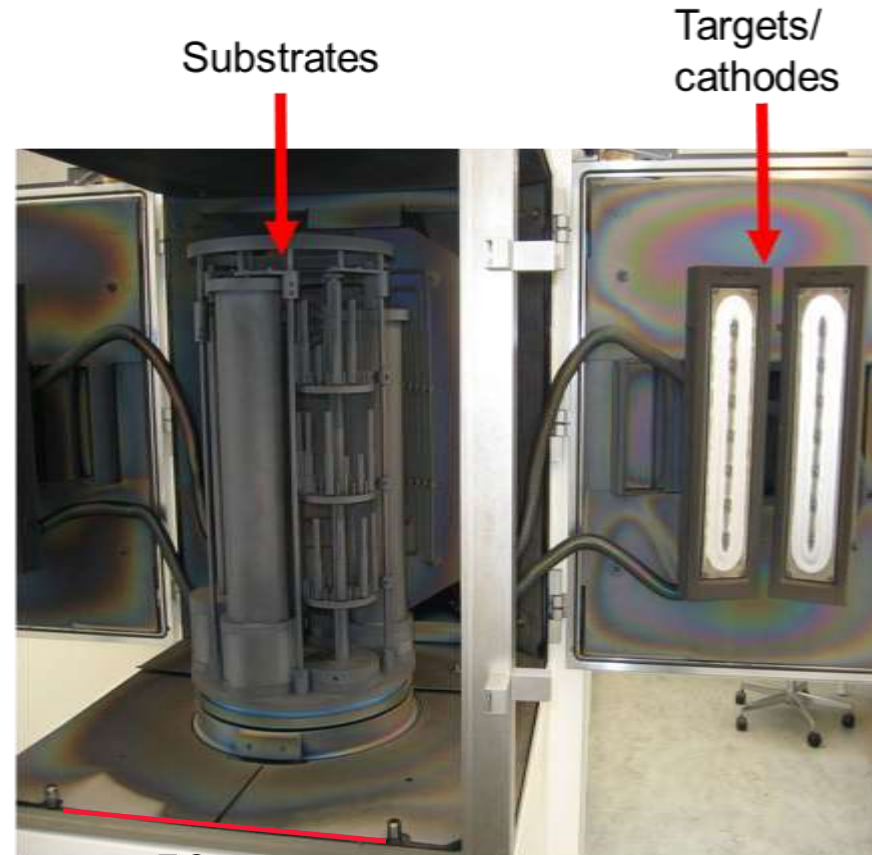




# Industrial sputter coater at DTI



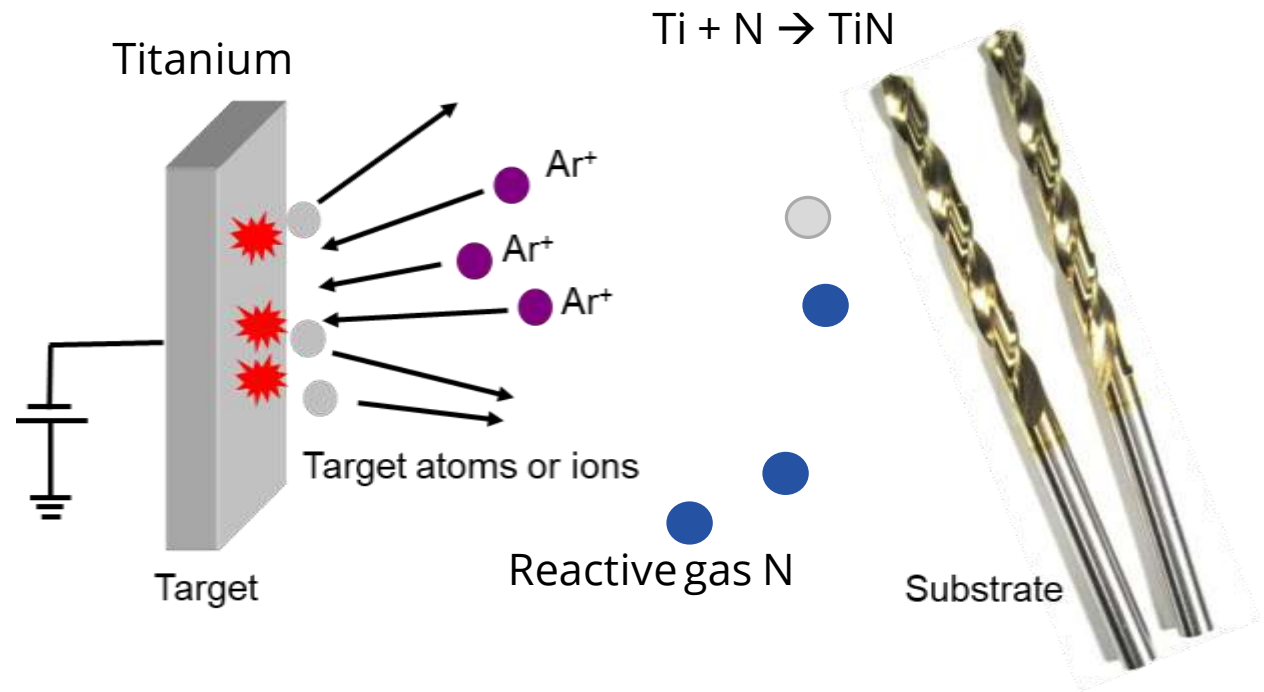
Vacuum chamber



50 cm



# Sputter deposition (sputtering)





# Sputter deposition – in brief

- Vacuum and plasma based - relatively expensive equipment
- Wide range of materials can be sputtered
- Coating thicknesses  $\sim 1 \mu\text{m} - 5 \mu\text{m}$  (few nm to  $>10 \mu\text{m}$ ), no change of roughness
- Process temperatures  $\sim 50 - 600^\circ\text{C}$  (can be higher)
- Substrate materials can be metals, ceramics, plastics, ...
- Possible to accurately tailor coating properties – unique materials
- Environmentally friendly compared to e.g. electroplating
- Line-of-sight (sputtered atoms move in straight lines), difficult to coat into holes
- Large-scale production possible – tailor-made production equipment (reel-to-reel, batch, in-line,...)



# Examples of coatings

- Diamond-Like Carbon (DLC)
- Chromium Nitride (CrN)
- Titanium Nitride (TiN)
- Titanium Aluminum Nitride (TiAlN)
- Titanium Diboride (TiB<sub>2</sub>)
- Aluminum Oxide (Al<sub>2</sub>O<sub>3</sub>)





# Important properties of coatings

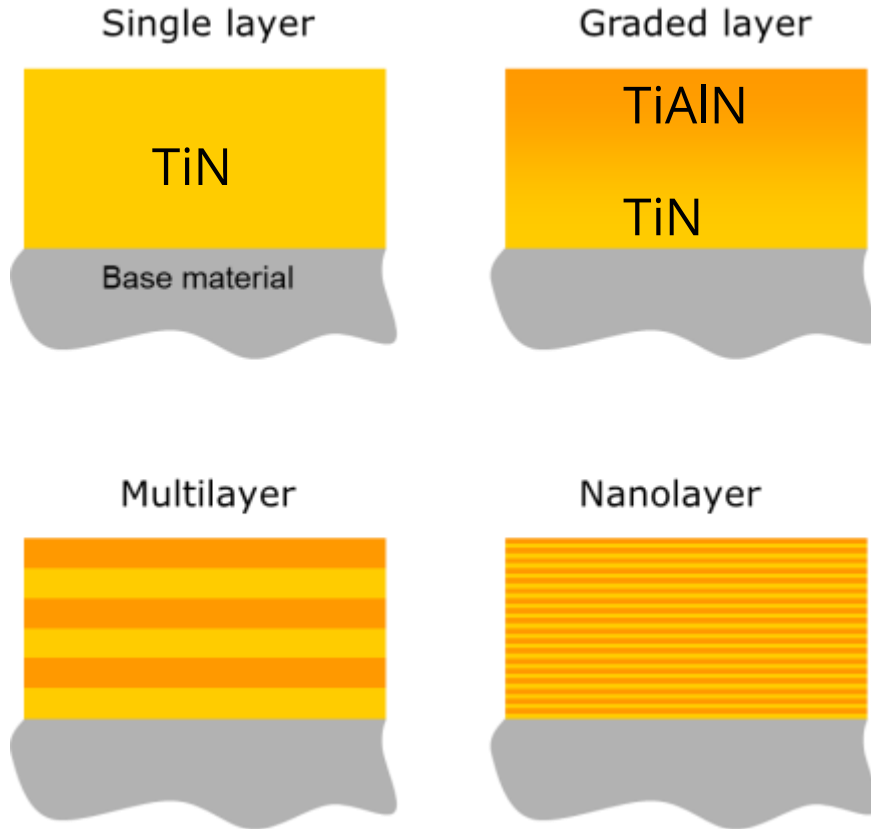
- High hardness – important for wear resistance (lifetime of tool, component,...)
- Low friction – important for wear resistance, energy consumption, demoulding...
- Special optical properties
- Special electrical properties
- ...



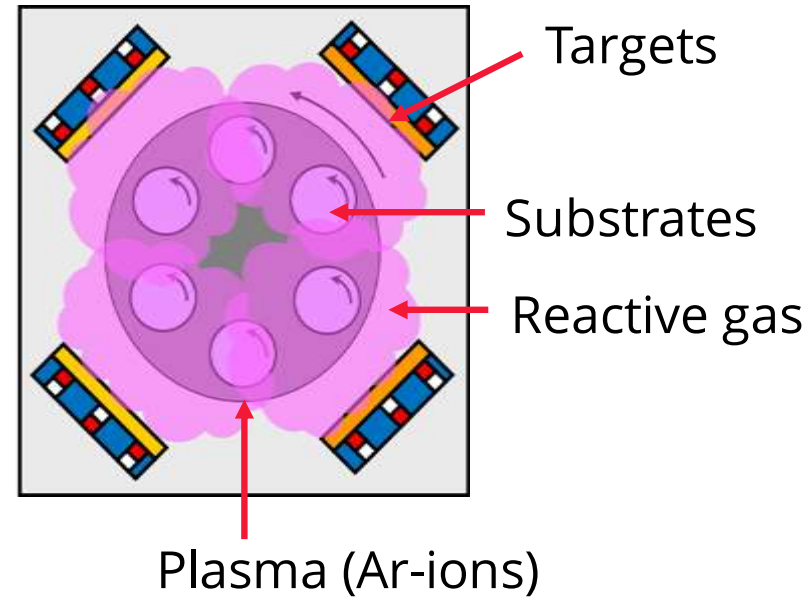
**Coating chemistry and microstructure are critical**



# Controlling chemical composition

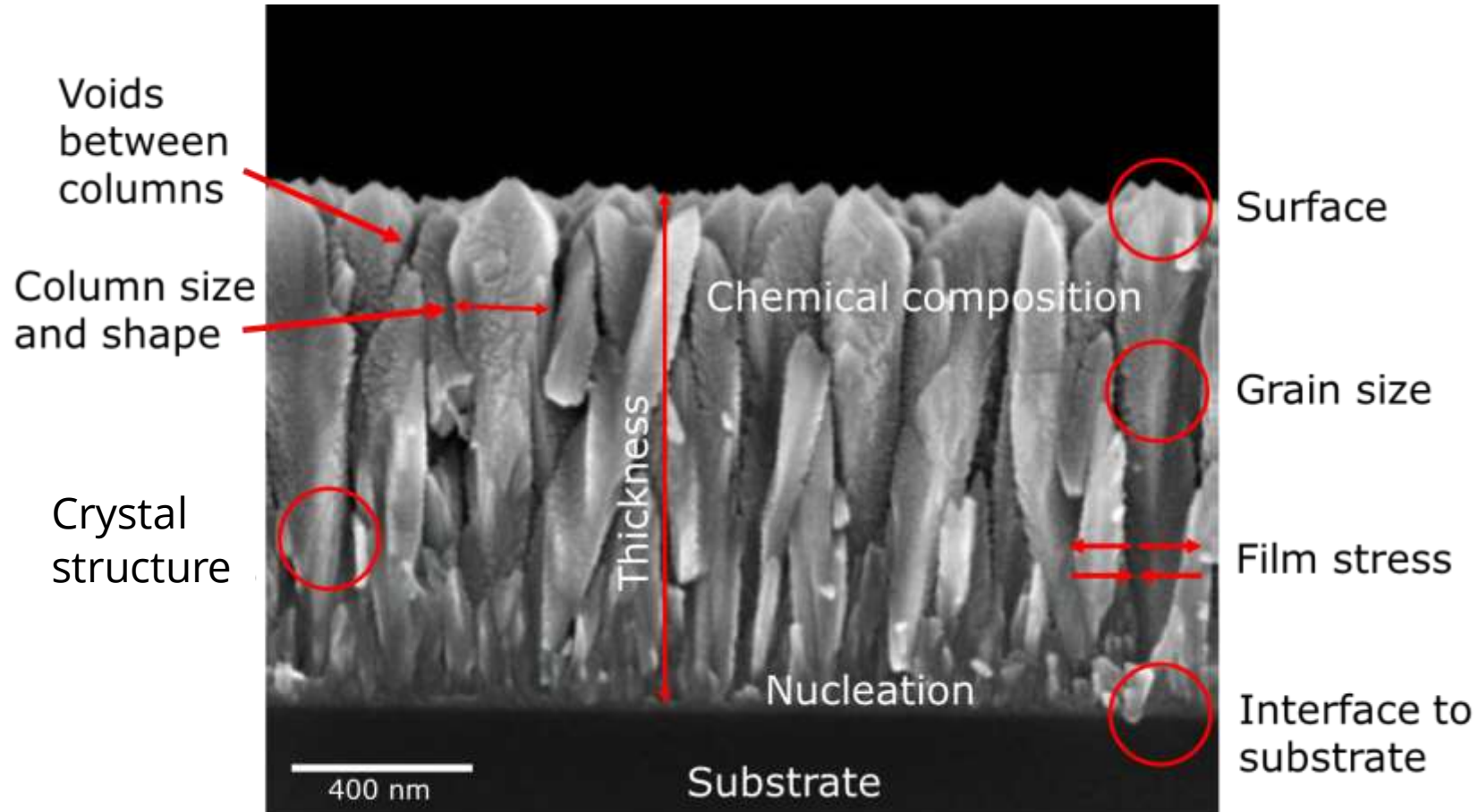


Schematic top-view of coating unit





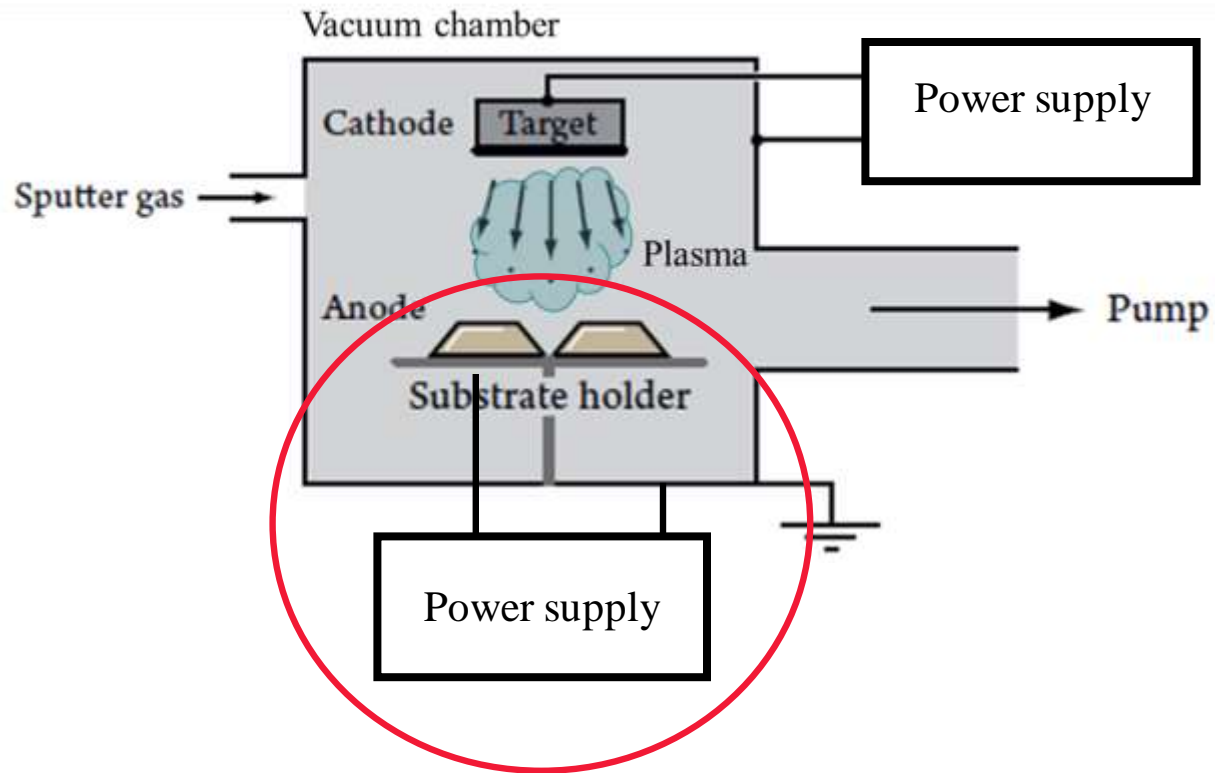
# Structure of thin film



Complex interplay between multiple atomistic / microscopic effects determine the overall thin film properties.



# Controlling microstructure - bias voltage



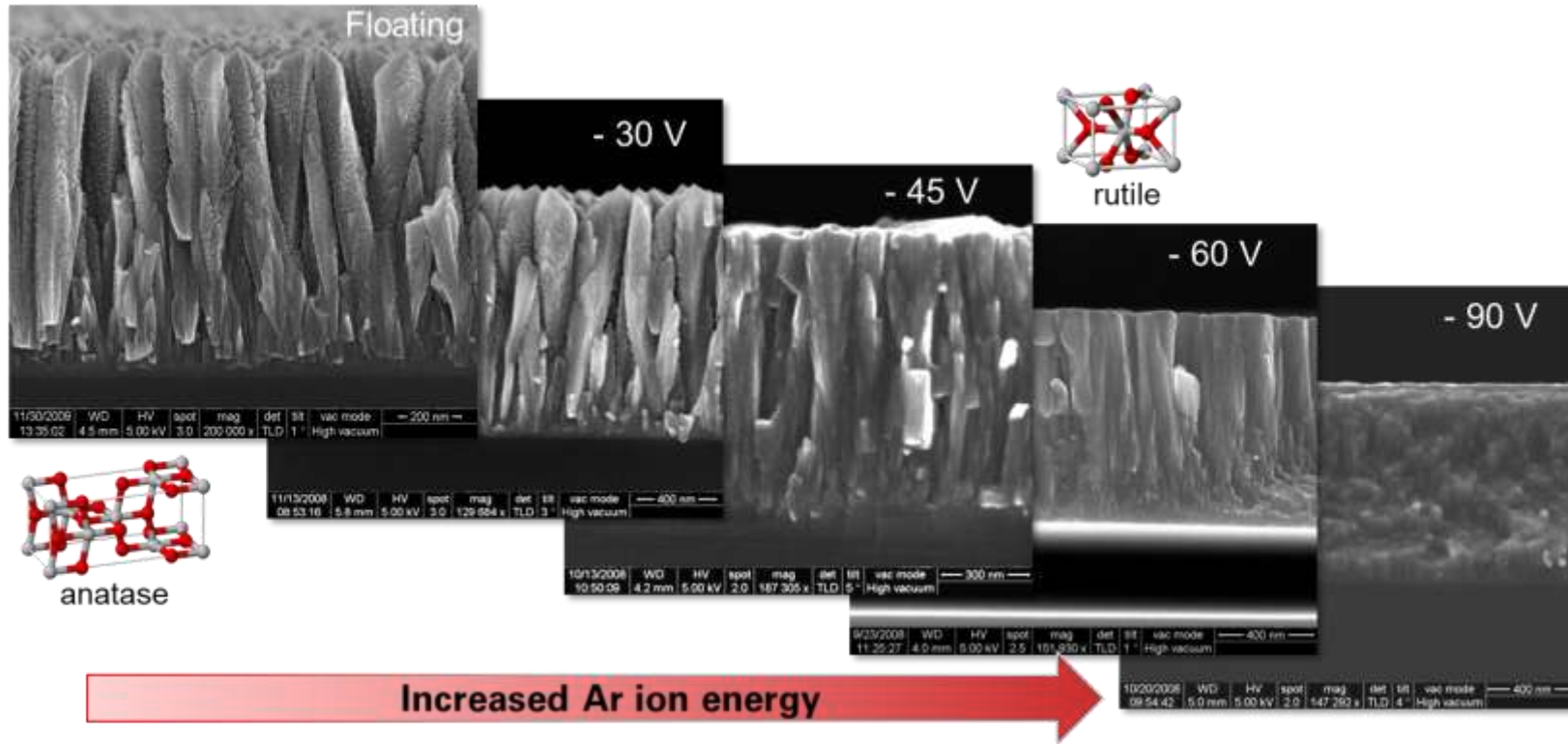
- Ions attracted to growing film
- Energy input leads to densification





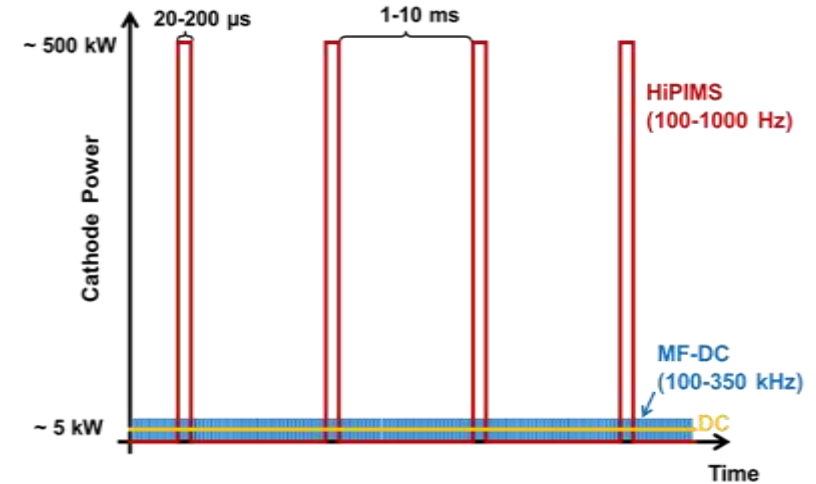
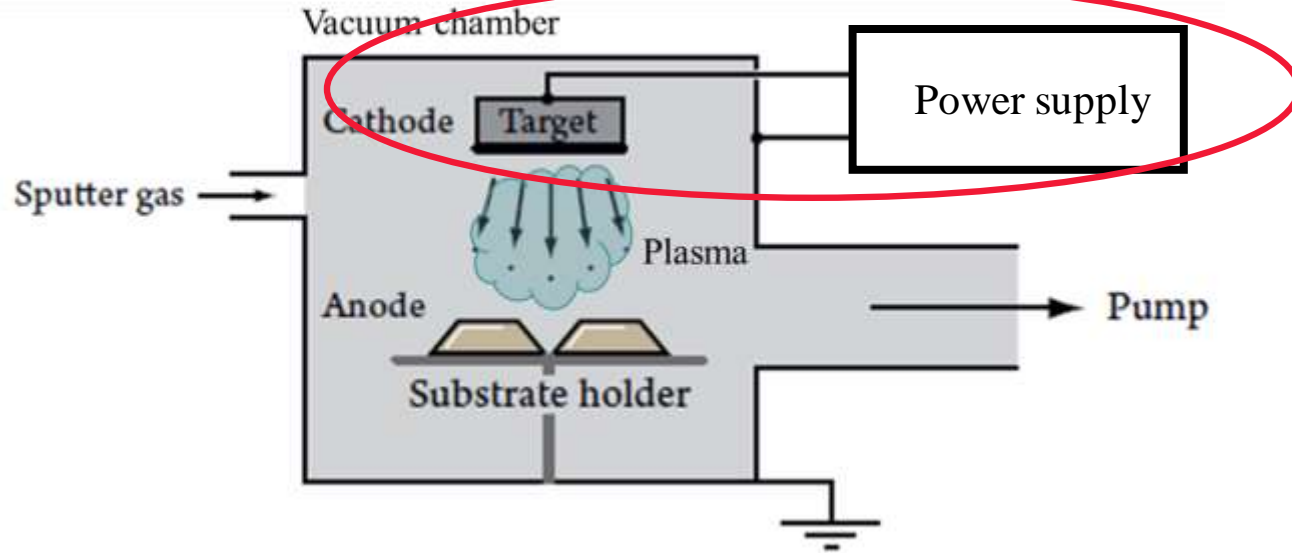
# Example: Densification of TiO<sub>2</sub>

TiO<sub>2</sub>





# Controlling microstructure - HiPIMS



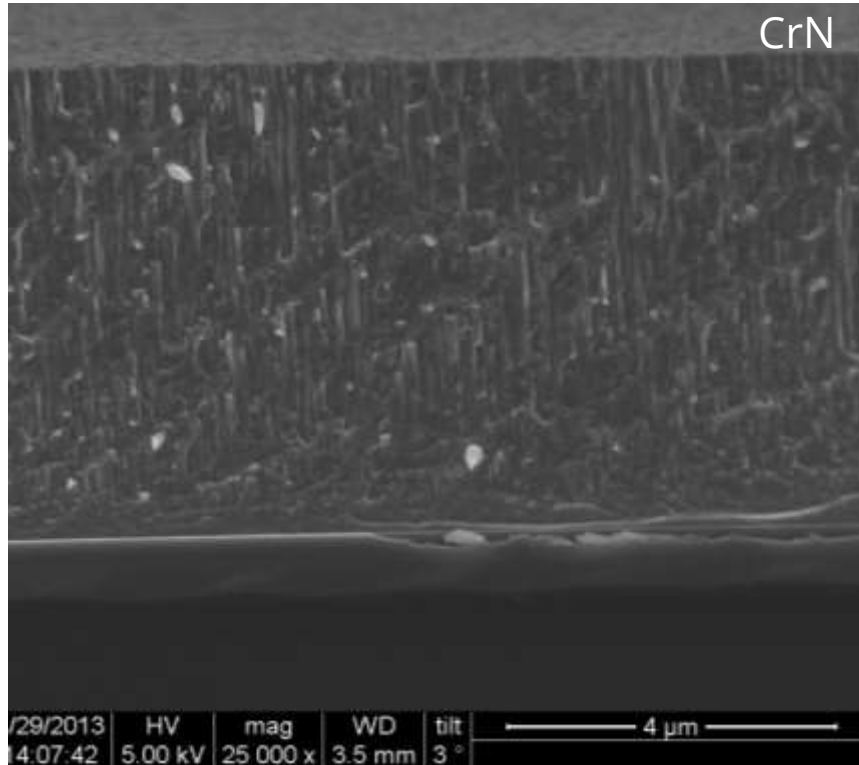
HiPIMS: High Power Impulse Magnetron Sputtering

- All energy in short pulses
- Increase the energy of the depositing atoms
- Lower deposition rate (compared to DC)
- Special power supply required

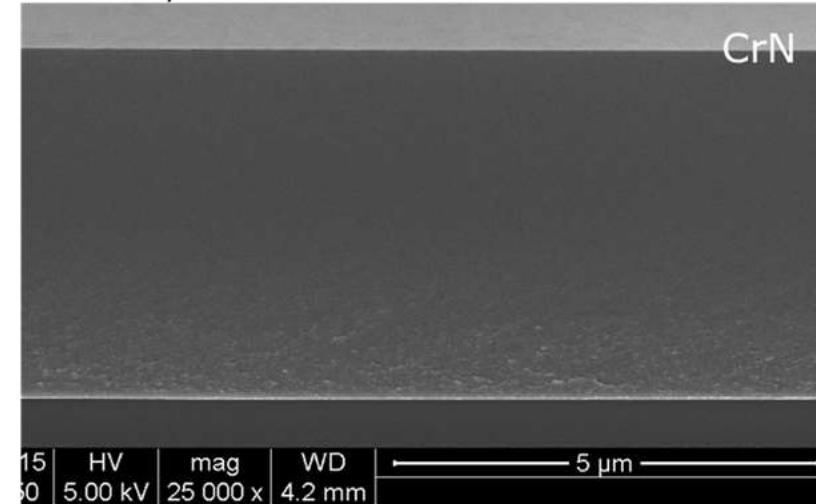


# Example: CrN HiPIMS

Columnar



Dense, featureless

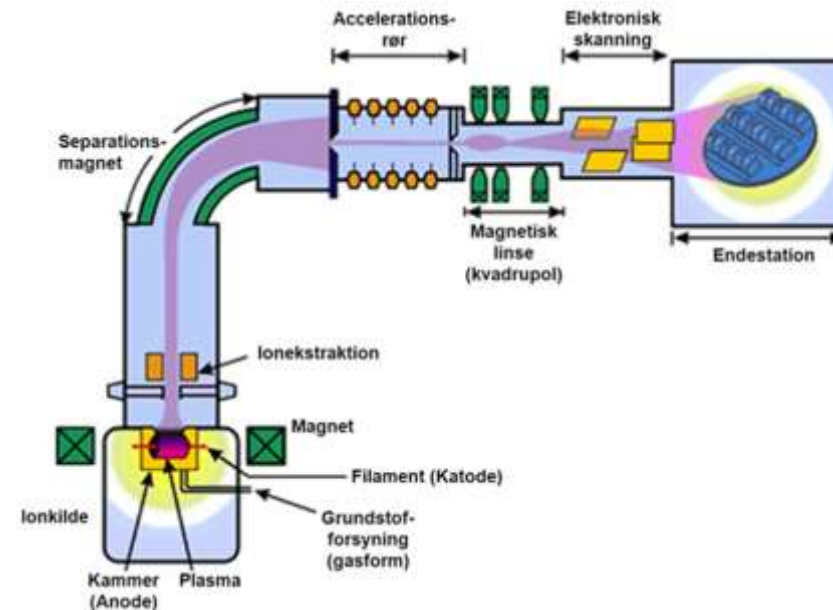


- Identical chemical composition
- Identical lattice structure
- Different morphology



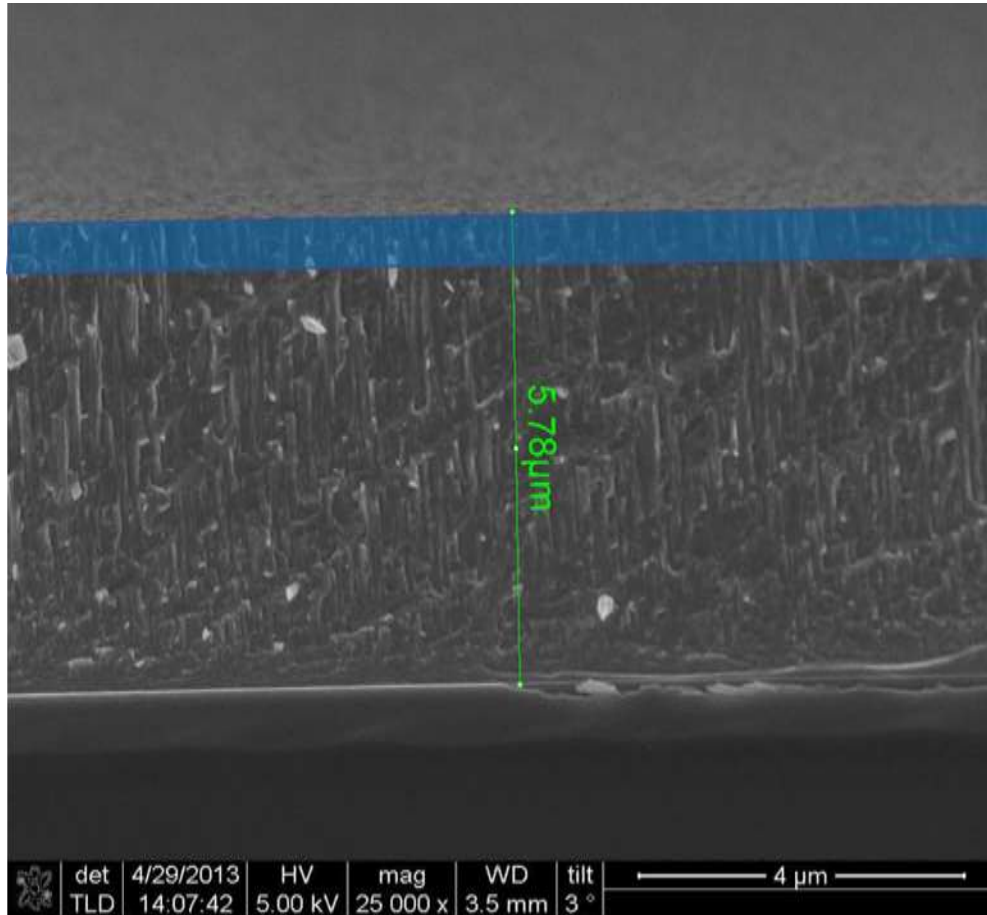
# Ion implantation

- Ion energy has huge impact on the microstructure (and hence macroscopic properties)
- High energy ions can be *implanted* into material using an ion implanter
- Many types of ions and doses can be used





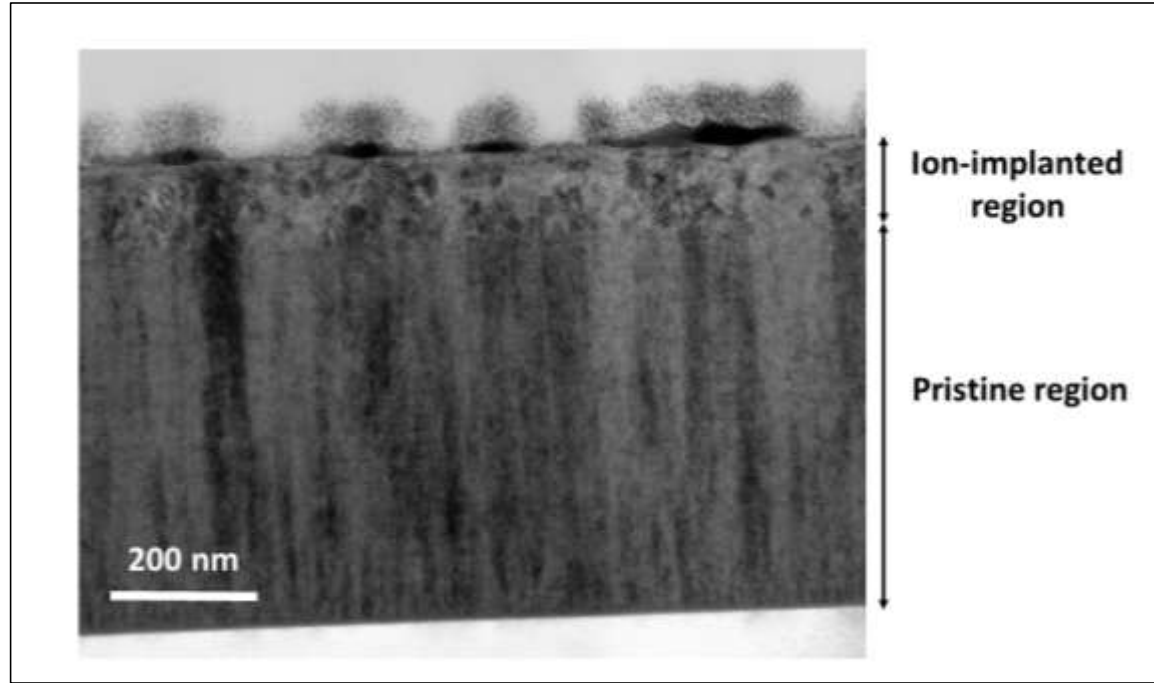
# Example: CrN coating (CrN-SS)



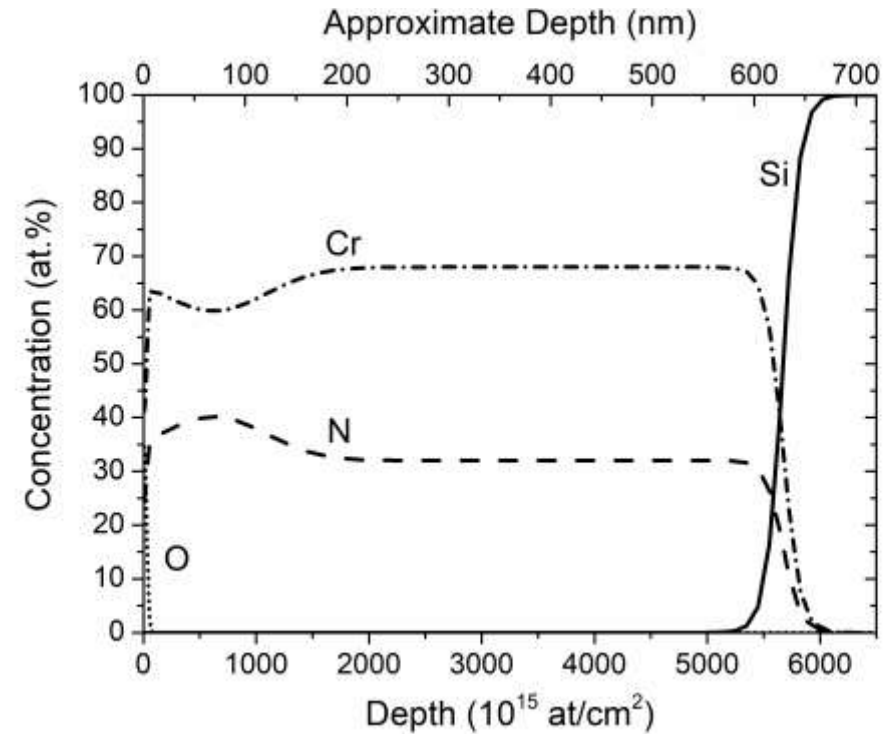
← Implanted part



# Example: CrN coating (CrN-SS)



Transmission electron microscopy image



Chemical profile through coating

- Morphology altered by implantation
- Improved performance in injection moulding compared to standard CrN



# Applying coatings to plastic moulding tools

## Why coatings?

- Wear protection of tool (longer service life)
- Improve demoulding (enabling demoulding → faster cycle time)

## Which coating?

- Depends on
  - Tool geometry
  - Tool material
  - Plastic type
  - Etc.
- Knowledge from field: CrN HiPIMS and CrN-SS are often useful
- Correlation between surface energy and ejection force?



# Summary

- Introduction to PVD coatings
- A coating is not just a coating
- A CrN coating is not just a CrN coating

