MEMS Fabrication Techniques

There are three basic building blocks in MEMS technology

- **Deposition (Additive Method)** :
  - Thin Film Deposition

- **Etching (Subtractive Method)** :
  - Wet Etching
  - Dry Etching

- **Patterning (Pattern Transfer Method)** :
  - Photo Lithography
  - E-beam Lithography
  - Nano-imprinting Lithography
  - LIGA

MEMS Deposition Technology

MEMS deposition technology can be classified in two groups:

- **Deposition via physical reaction**
  - Physical Vapor Deposition (PVD)
  - Casting
- **Deposition via chemical reaction**
  - Chemical Vapor Deposition (CVD)
  - Electrodeposition
  - Epitaxy
  - Thermal oxidation

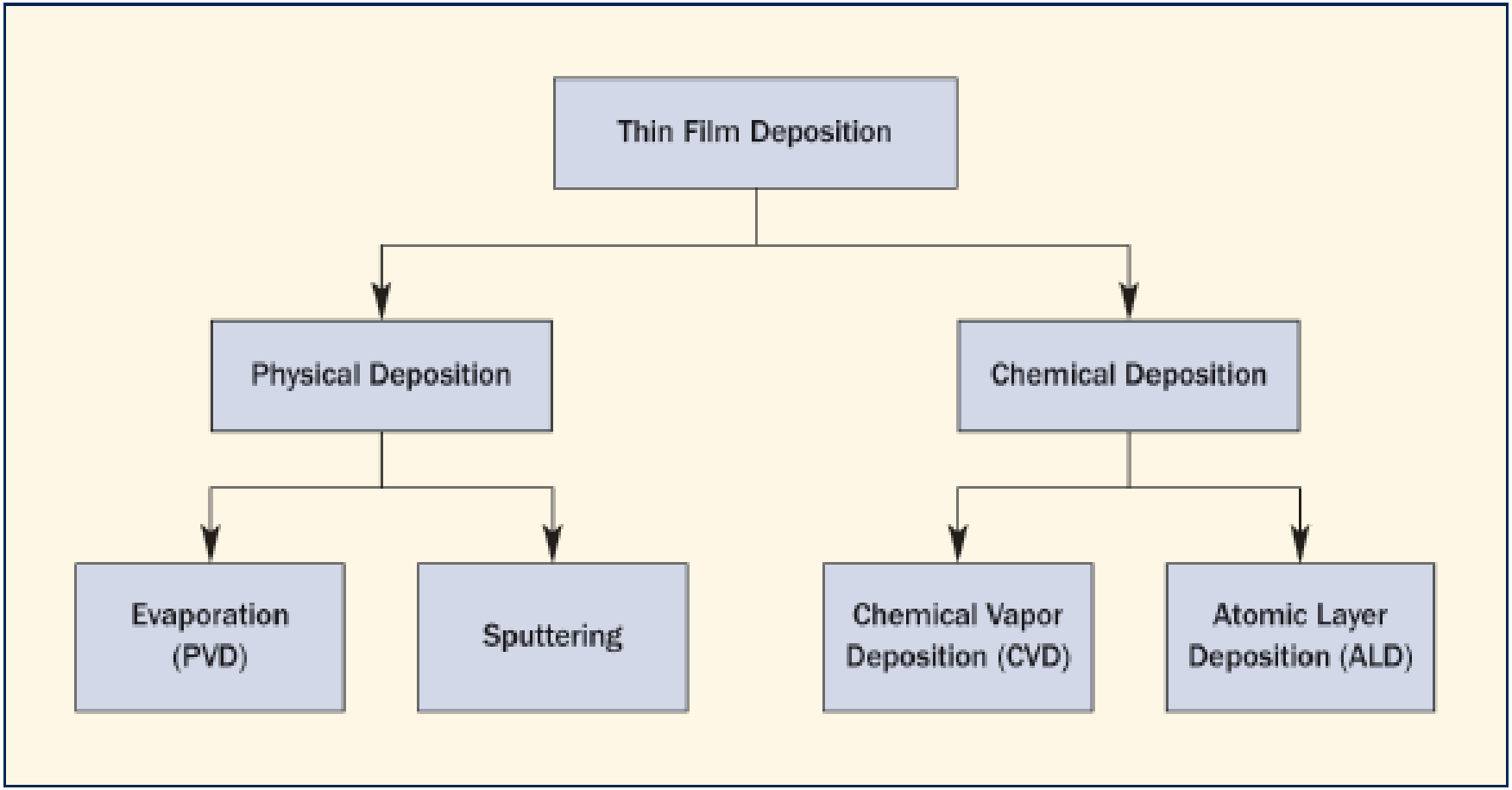
MEMS Deposition Technology

Deposit thin film of material (mask) anywhere between a few nm to 100 micrometers onto substrate

- **Physical**: material placed onto substrate, techniques include sputtering and evaporation
- **Chemical**: stream of source gas reacts on substrate to grow product, techniques include chemical vapor deposition and atomic layer deposition

- **Substrates**: silicon, glass, quartz
- **Thin films**: polysilicon, silicon dioxide, silicon nitride, metals, polymers

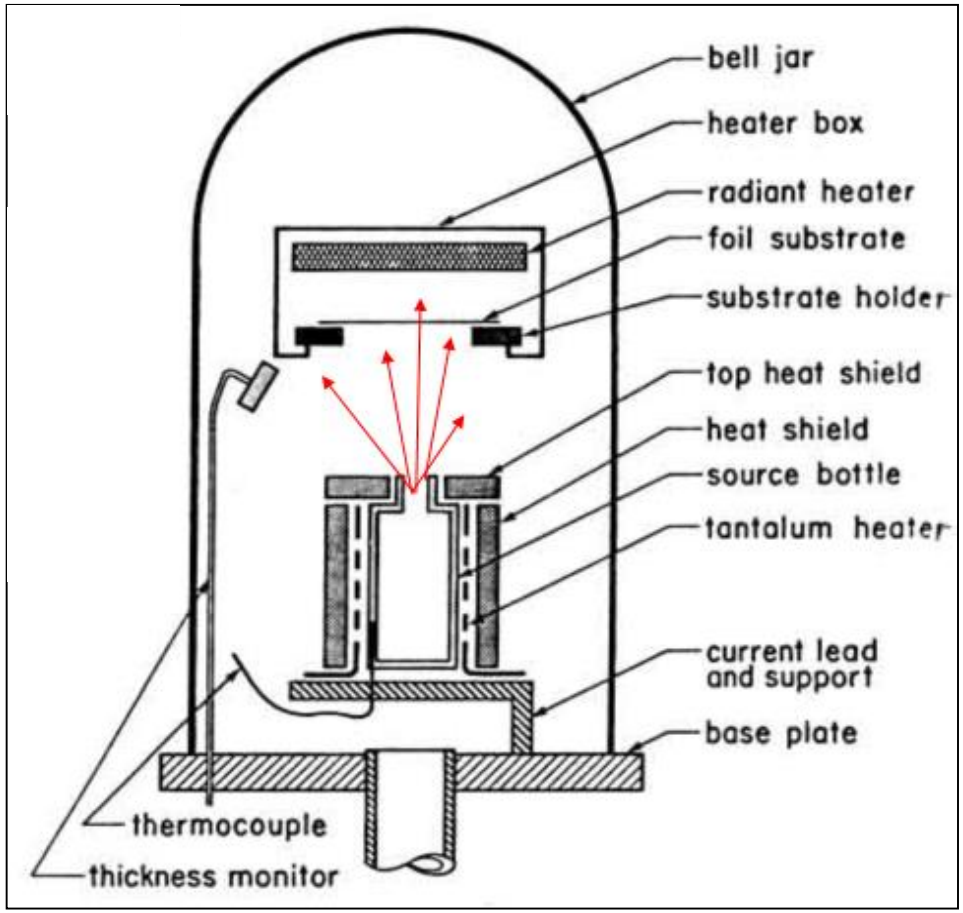
MEMS Deposition Technology



Additive Methods:
Thin Film Deposition

- **Physical Vapor Deposition (PVD)**
  - Thermal Evaporation
  - Sputtering
- **Chemical Vapor Deposition (CVD)**
  - PECVD (Plasma Enhanced)
  - LPCVD (Low Pressure)
- **Electroplating**
- **Atomic Layer Deposition**

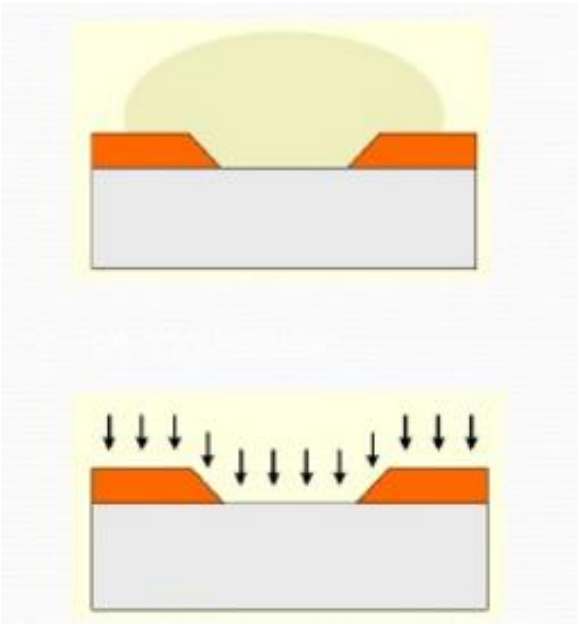
PVD: Thermal Evaporation

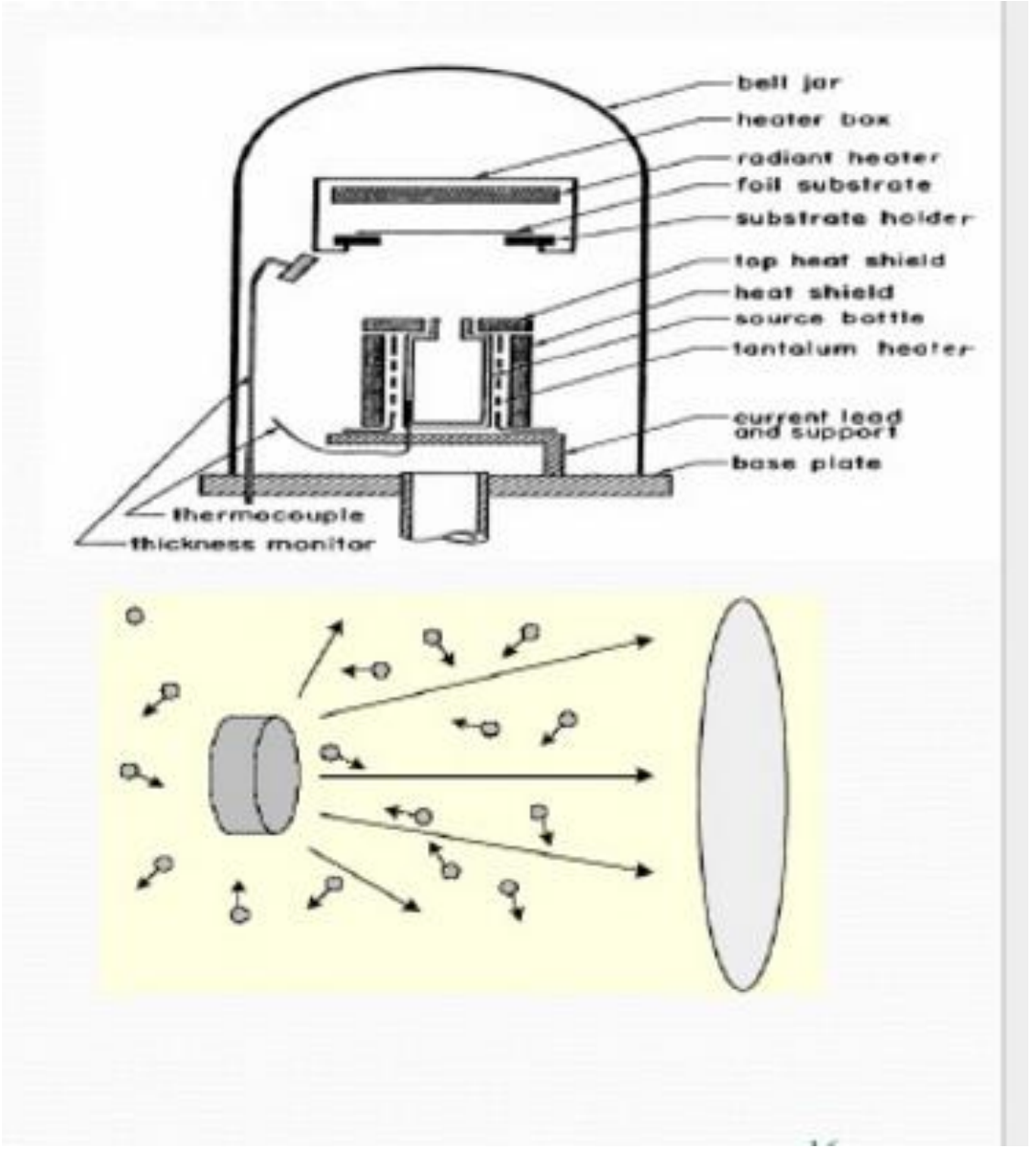


- Low working pressure to increase mean free path
- Low surface damage
- Faster than sputtering
- Limited material

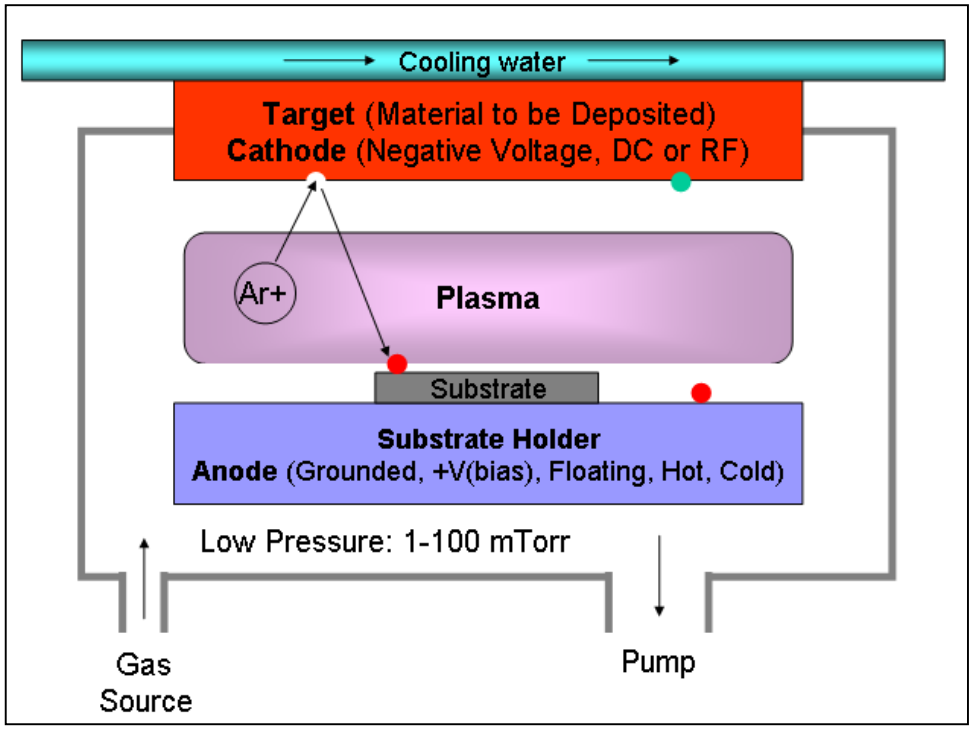
http://www.icmm.csic.es/fis/english/ evaporacion_resistencia.html

Additive Processes

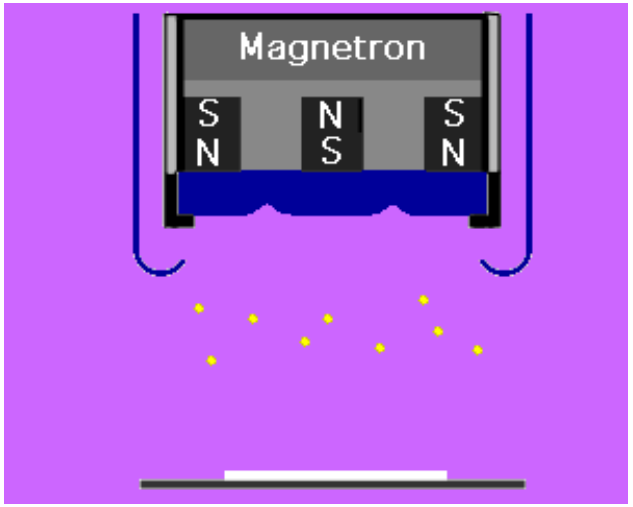




PVD: Sputtering



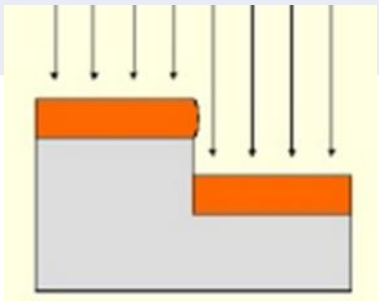
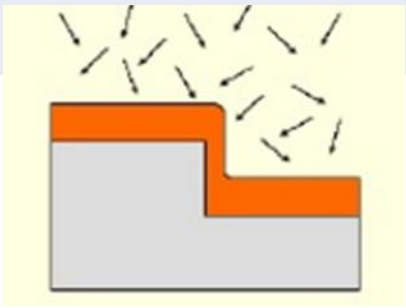
- Based on Ion bombardment
- Unlimited material
- Possible surface damage
- Excellent adhesion
- Expensive



http://web.kth.se/fakulteter/TFY/cmp/research/sputtering/images/sputtering_anim.gif
http://www.ee.ucla.edu/~jjudy/classes/ee150L/lectures/EE150L_Lecture_Dry_Etching_files/frame.htm

Video: PVD Sputtering

Additive Processes

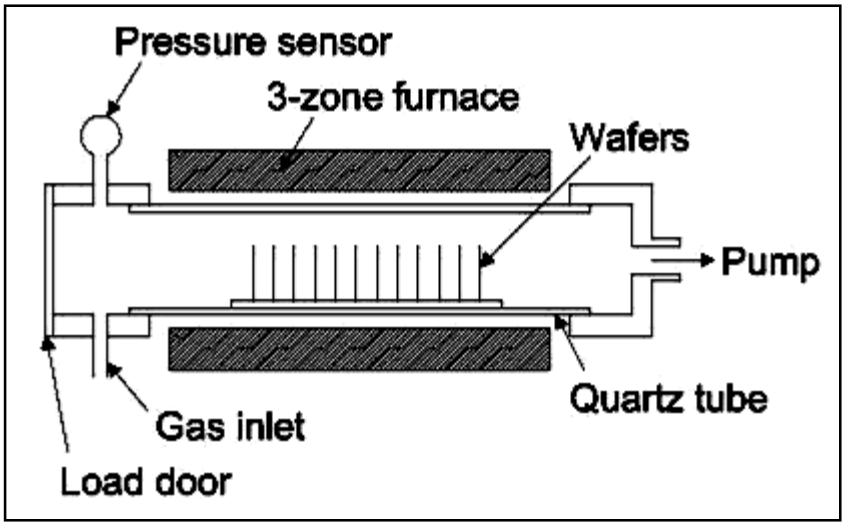
	Thermal Evaporation	Sputtering
Rate	Thousand atomic layers at a time	One atomic layer at a time
Choice of materials	Limited	Almost limited
Surface damage	Very low	Ionic bombardment damage
In-situ clearing	Not available	Can be easily done
Adhesion	Poor	Good
Uniformity	Difficult to control	Easy control
Film properties	Difficult to control	Can be controlled by pressure, bias and temperature
Step coverage		

Additive Processes: CVD

-
  - Gaseous reactants are introduced into chamber at elevated temperatures.
  - Reactant reacts and deposits onto substrate
-
  - LPCVD (Low Pressure CVD),
  - PECVD (Plasma Enhanced CVD)
-
  - CVD results depend on pressure, gas, and temperature
  - Can be diffusion or reaction limited
  - Varies from film composition, deposition rate and electrical and mechanical properties

CVD: Low Pressure

- **LPCVD**

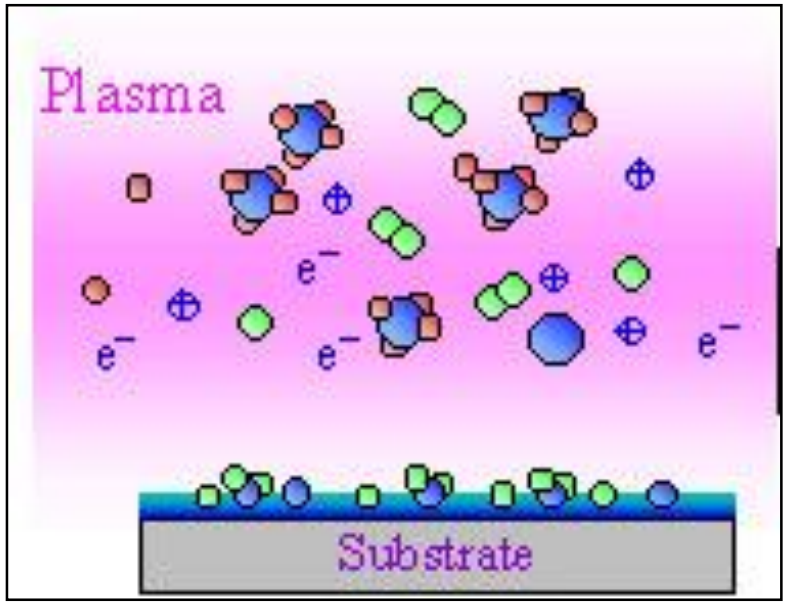


- **< 10 Pa**
- **Excellent purity**
- **Low stress**
- **High temperature**
- **Low deposition rate**

http://www.memsnet.org/mems/beginner/ images/cvd_reactor.jpg

CVD: Plasma Enhanced

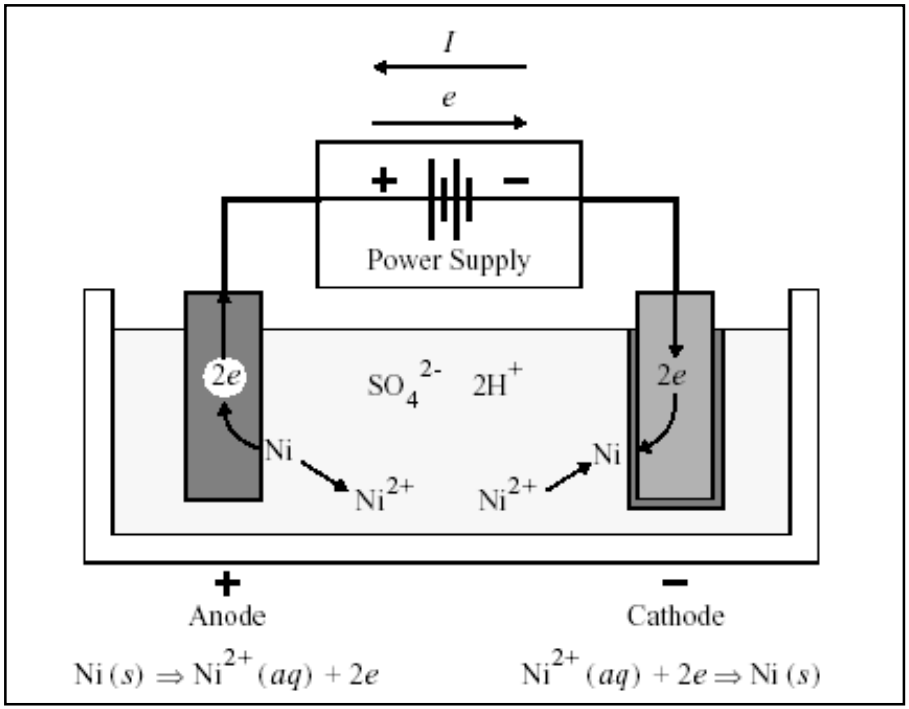
- **PECVD**



- Plasma helps reaction
- Low substrate temperature
- Good step coverage
- Chemical contamination

http://www.seas.ucla.edu/Chang/pictures/ research-pecvd.jpg

Electroplating



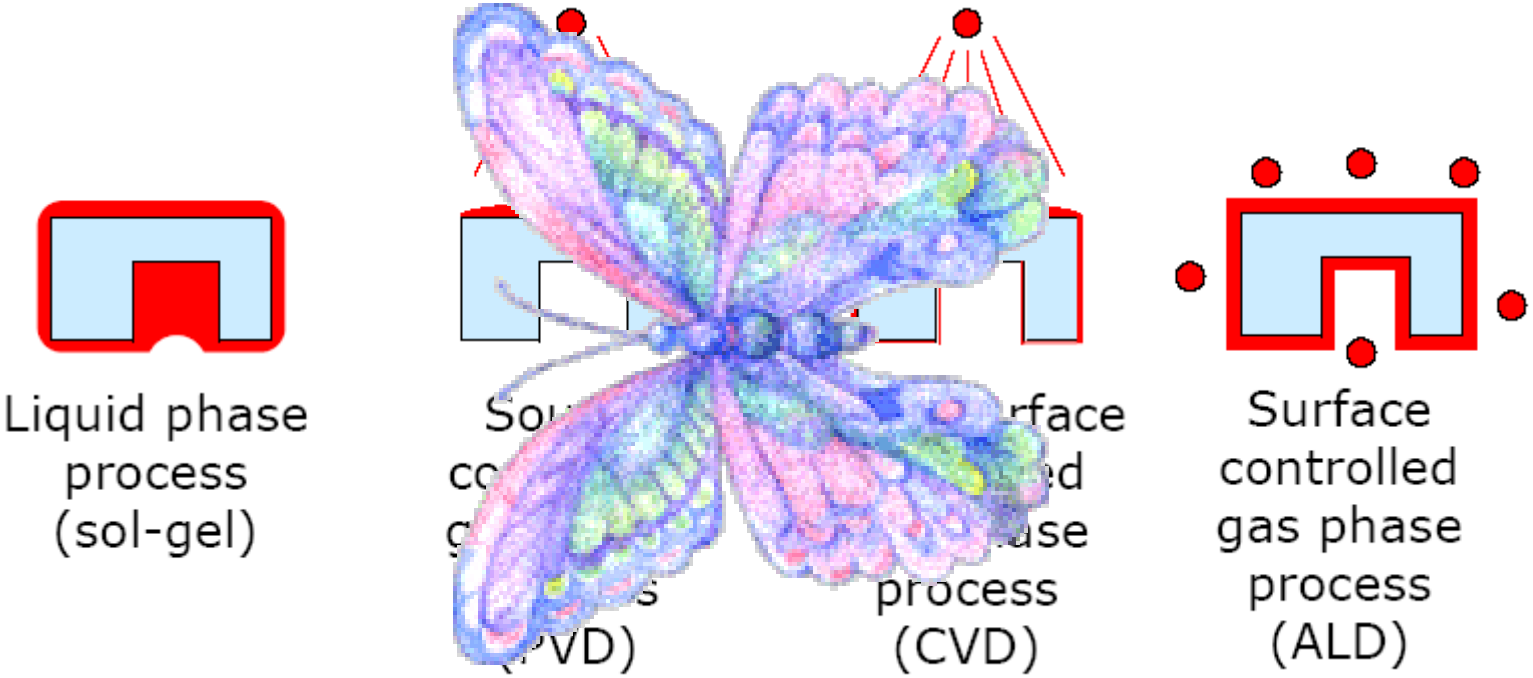
- **Various metal (Au, Ni, etc)**
- **Fast**
- **> 10 μm**
- **Hydrogen bubble generation**
- **Difficult for sub-μm features**
- **Needs seed layer**

Sulfuric acid (H_2SO_4)

Electroplating: Video

Atomic Layer Deposition

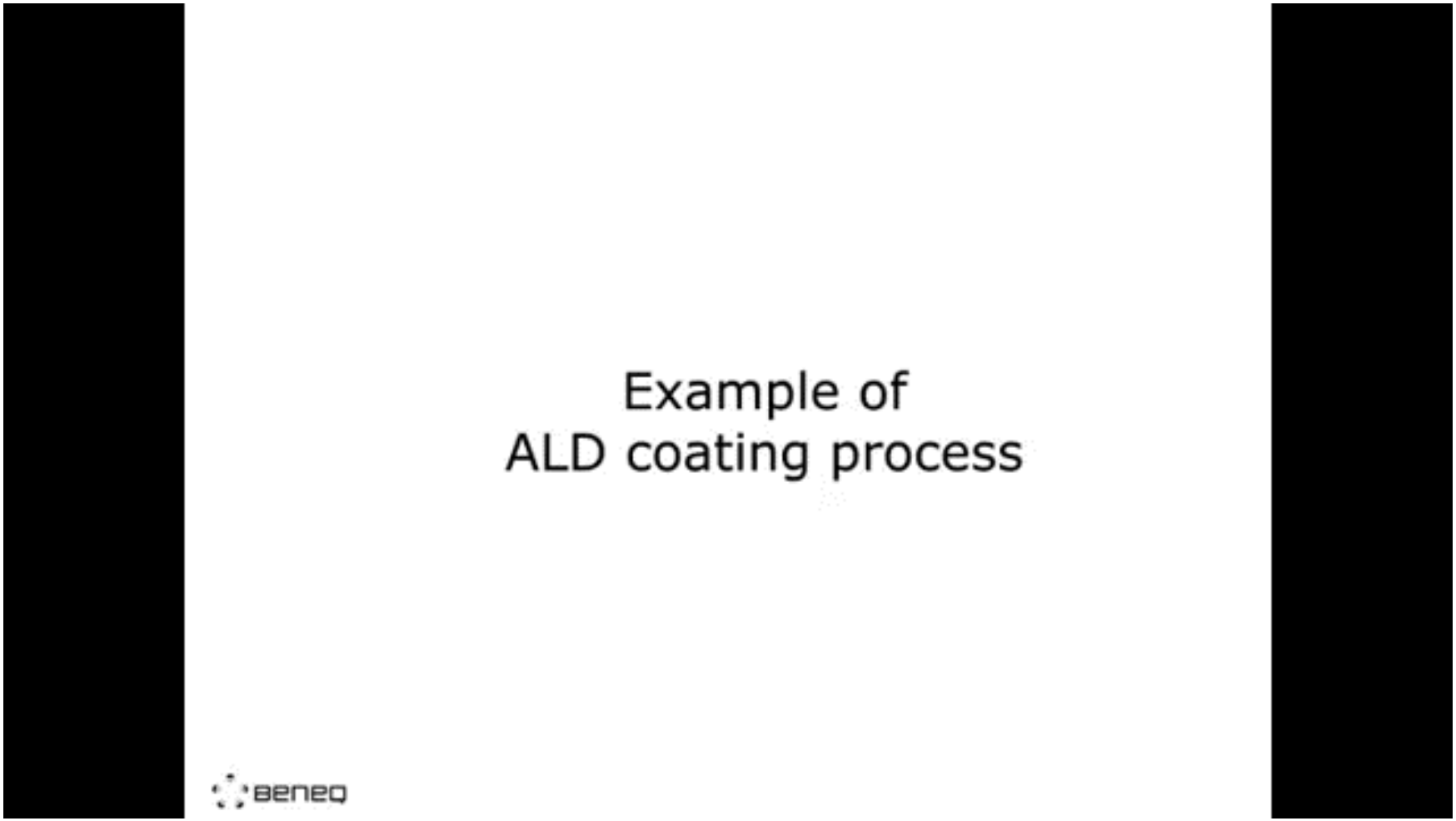
Film thickness uniformity with different methods



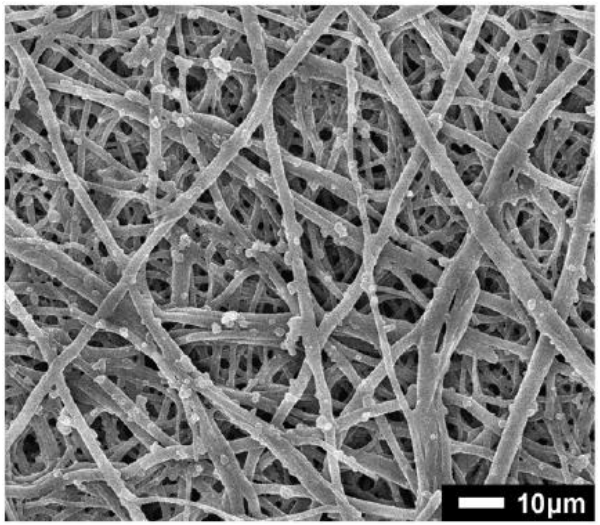
Advantages:

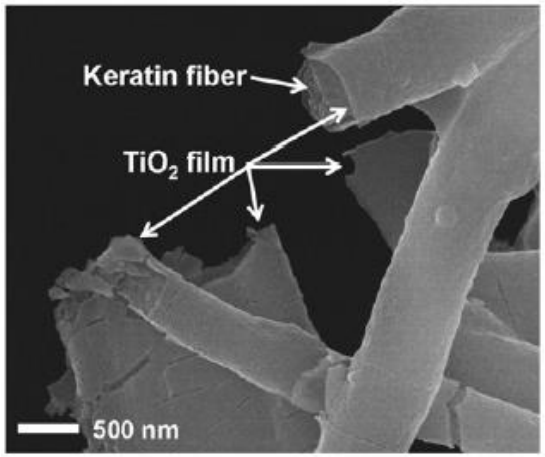
- excellent **conformality**
- **reproducibility**
- large area **uniformity**
- accurate and easy **film thickness control** down to an atomic level

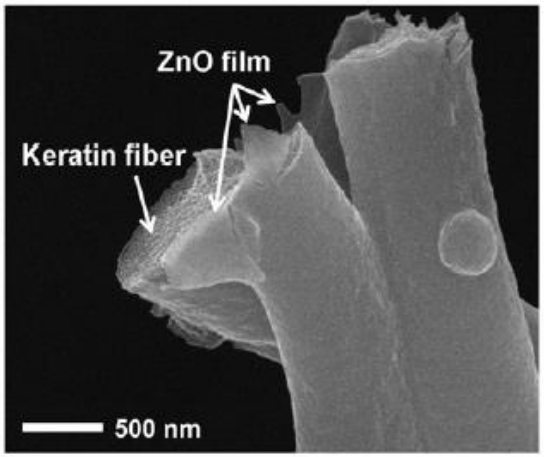
Atomic Layer Deposition: Movie

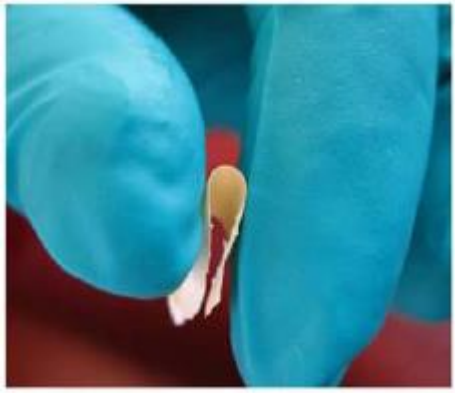


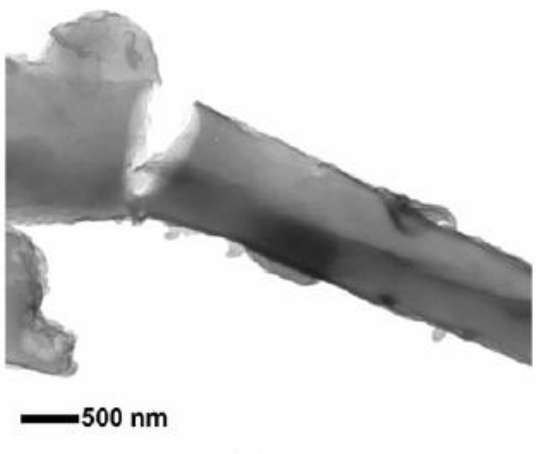
Highly Flexible Photocatalytic Metal Oxide Structures Templated from Eggshell Membranes

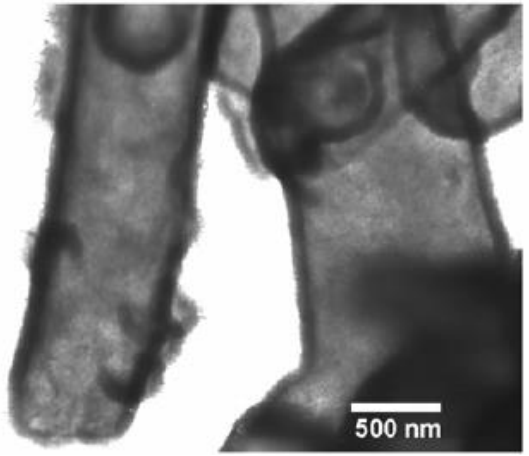








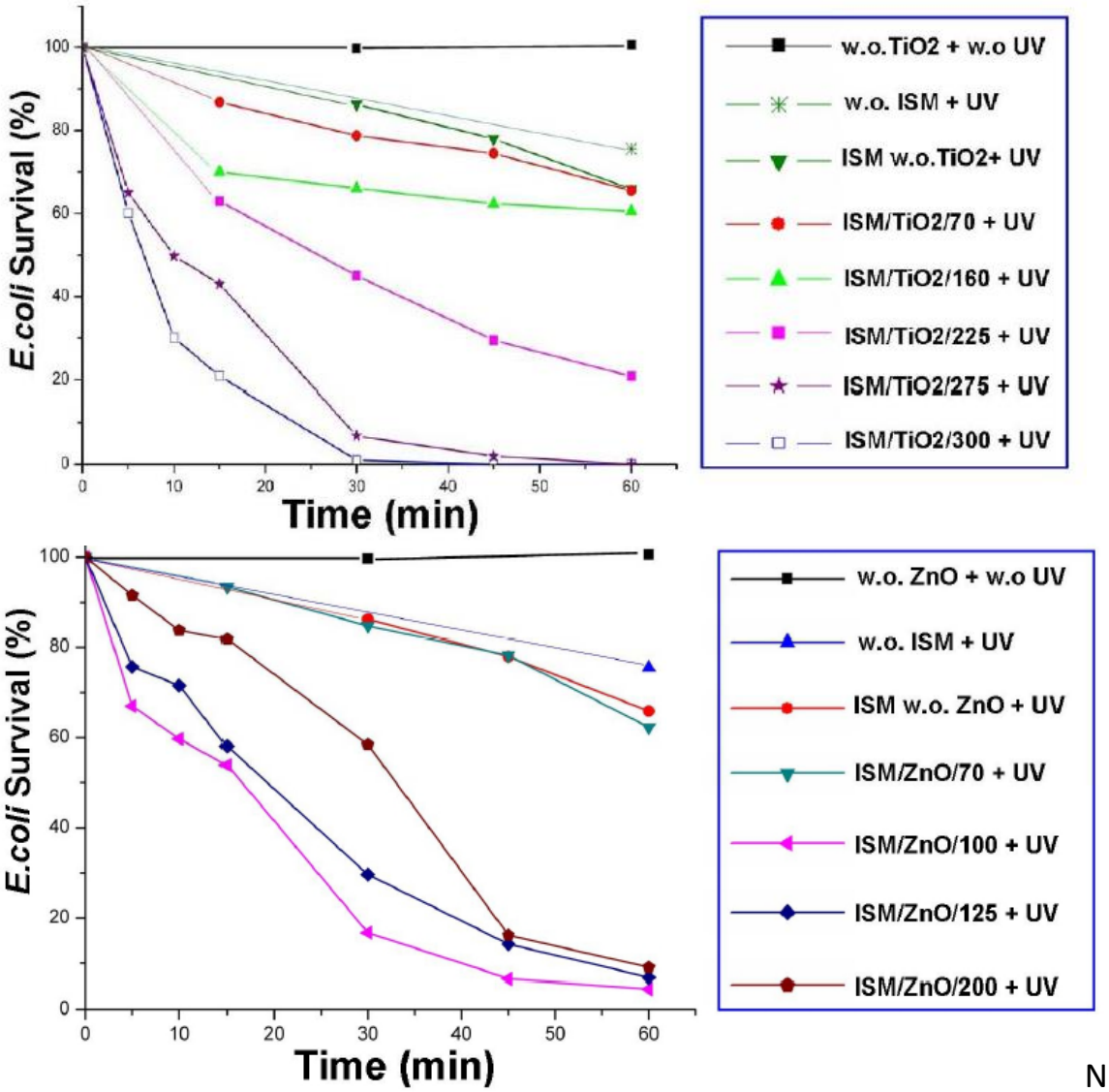




Nature Materials submitted

Anti-Microbial Activity

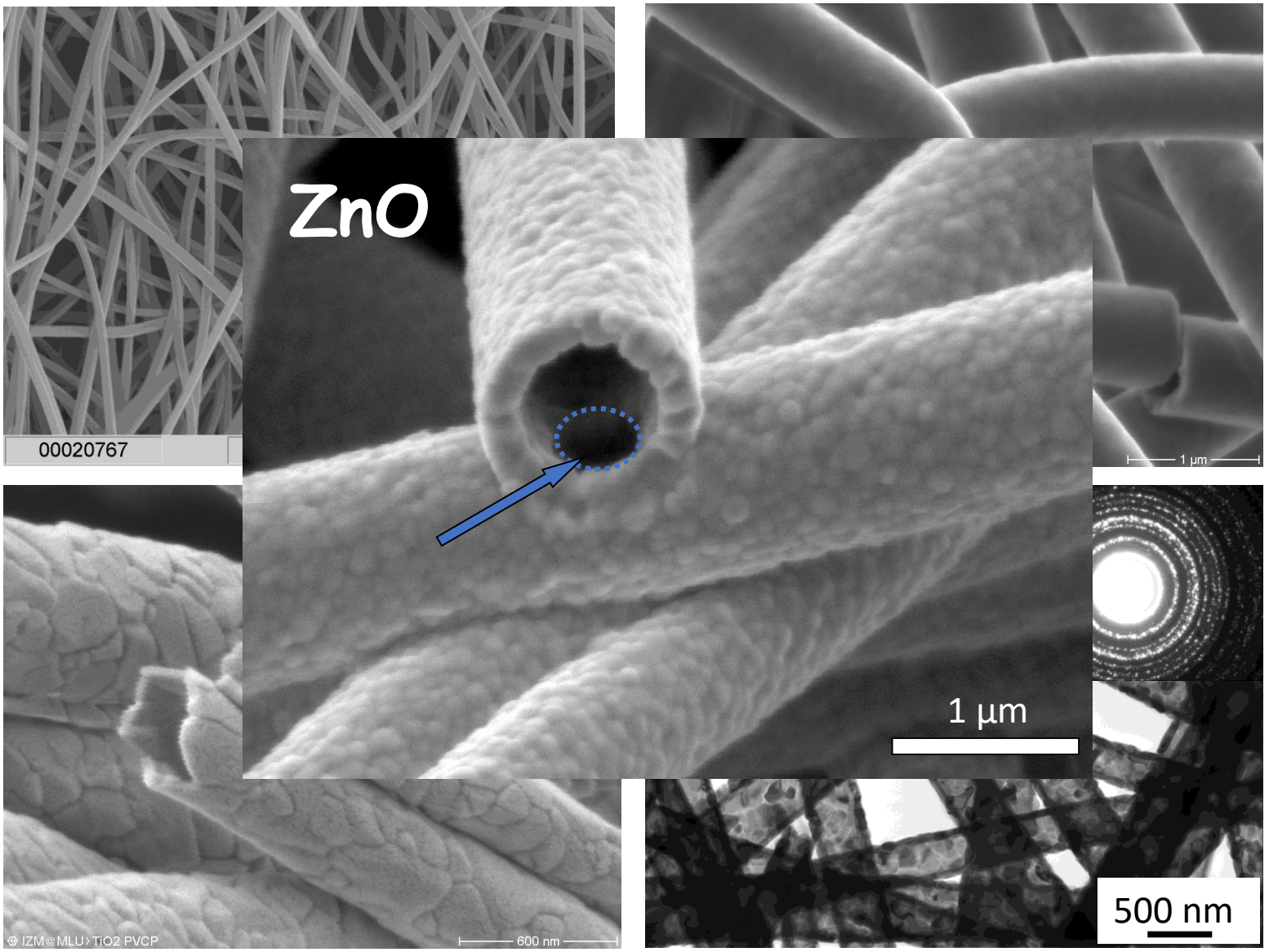
***E.coli* survival curves**



Nature Materials submitted

Metal Oxide Nanotubes: templating ES-fibers

TiO_2



Chemistry of Materials submitted

Mechatronics MEMS in Mechatronics