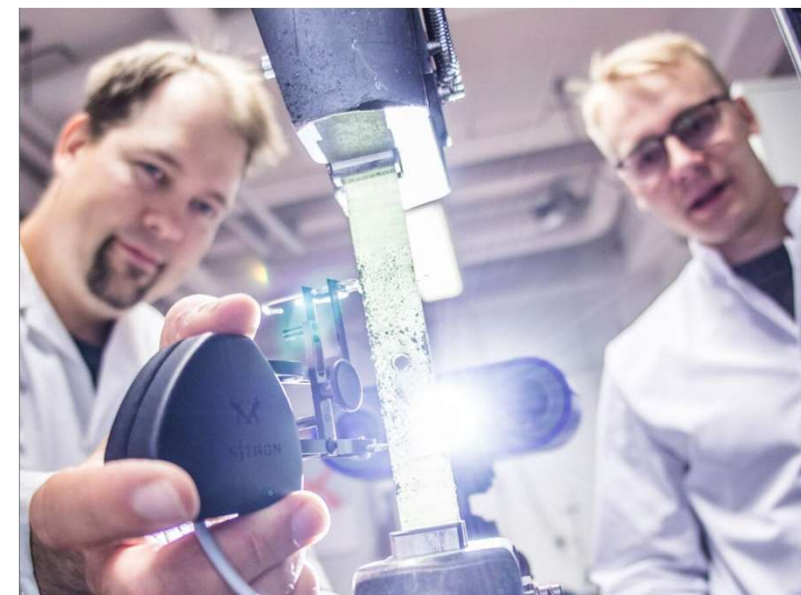


# Boosting and Predicting Product Lifetime: New Research Infrastructure for Hydrogen Technology for Industry and Academia

## Program

- Operando research infrastructure for energy materials and systems – OperaRI, Prof. **Mikko Hokka**, **Tampere University**
- In-situ H<sub>2</sub> mechanical testing infrastructure development at Tampere University: current status and next steps, Dr. **Matti Isakov**, Tampere University
- Towards safe hydrogen transport: a multiscale assessment of hydrogen embrittlement in pipeline steels, Prof. Assist. **Mahdieh Safyari**, Tampere University
- Hydrogen transmission network design in Finland - material challenges and research needs, Development Manager, RDI & technology **Hanna Kinnunen**, **Gasgrid** Finland Oy





# Operando research infrastructure for energy materials and systems – OperaRI

Mikko Hokka

*Materials Science and Environmental Engineering*

*Faculty of Engineering and Natural Sciences, Tampere University, FI-33014, Tampere, Finland*



**Euroopan unionin  
osarahoittama**



**Euroopan unionin  
rahoittama**  
NextGenerationEU

# Local and Roadmap infrastructures

**H2MIRI - Hub for Hydrogen-Materials Interaction Research Infrastructures, 2023-2025**

**OperaRI - Operando research infrastructure for energy materials and systems, 2025-2029**



**Euroopan unionin osarahoittama**



**Euroopan unionin rahoittama**  
NextGenerationEU

## Further development to OperaRI – Offering specific instruments as well as sample environments with sample transfer capabilities for operando research

OperaRI Distributed Instrument Pool

Sample environments, sample transfer and sample sharing

Spectroscopy & diffraction

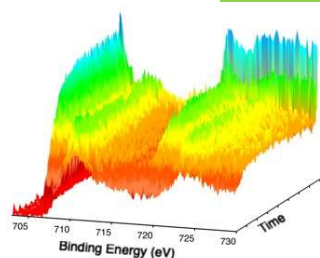
APXPS

XAS

IR

XRD

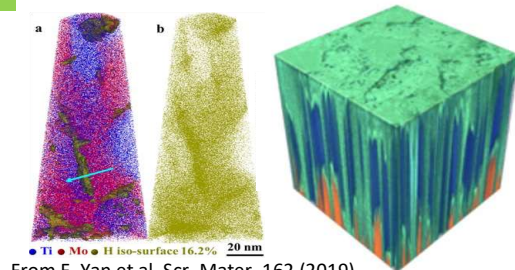
DRIFTS



Nano-imaging

APT

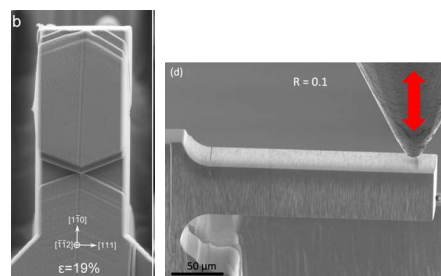
TOF-SIMS



Microscale

IN-SITU SEM TESTS

ALD-PVD

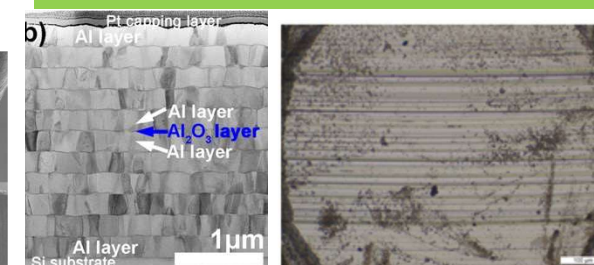


Macroscale characterization

TRIBOMETERS

LOAD FRAMES

SINGLECELL & MULTI-SINGLECELL



From T. Xie et al. Thin Solid Films (2020)

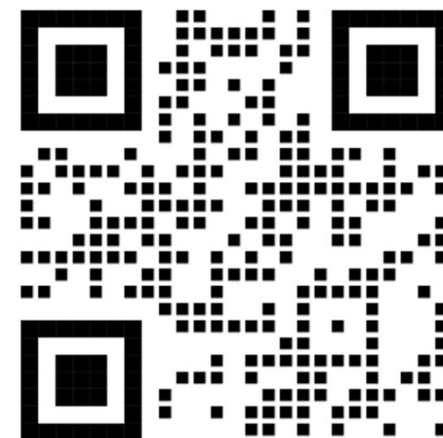
Electronic/atomic/molecular level

Nano- and microscale

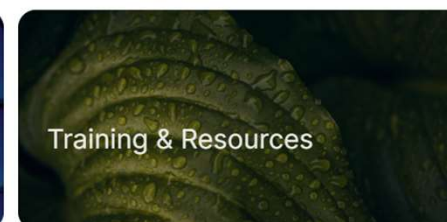
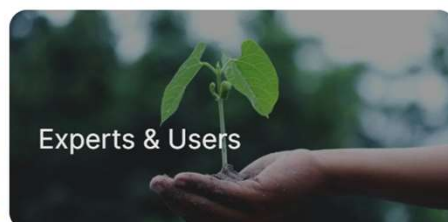
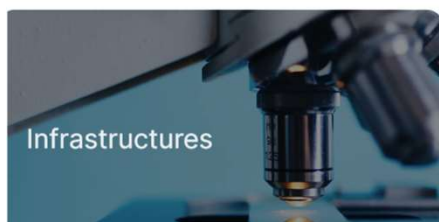
Macroscale

System/component level

# Online portal: [h2miri.fi](https://h2miri.fi)

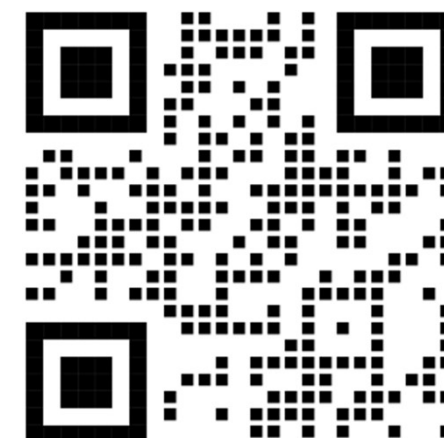


## *Hydrogen-Materials Interaction Research Infrastructures*


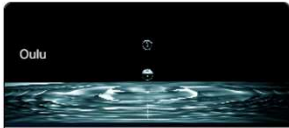

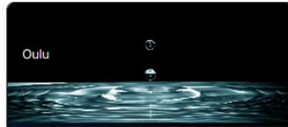


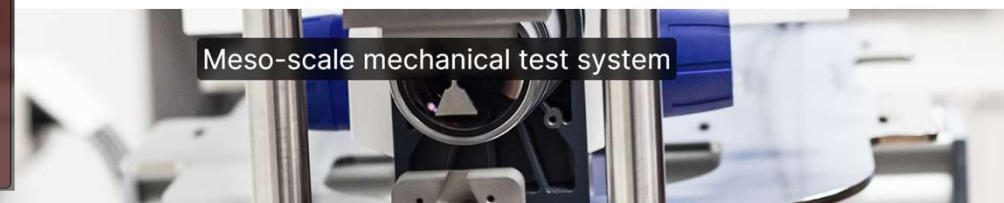
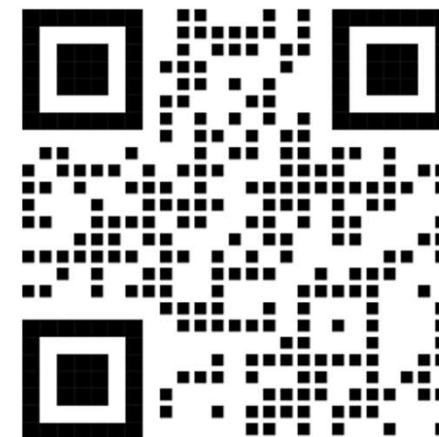
## Infrastructures

 <p><b>UNIVERSITY OF OULU</b> Oulu</p> <p><b>APXPS</b></p> <p>The Ambient Pressure X-ray Photoelectron Spectroscopy (APXPS) system enables surface and interface studies under realistic conditions beyond conventional ultra-high-vacuum XPS. Operating at pressures from <math>1 \times 10^{-2}</math> mbar up to 20 mbar, it supports in situ and operando investigations relevant to catalysis...</p> <p>APXPS Lab Instruments University</p>	 <p><b>TAMPERE UNIVERSITY</b> Tampere</p> <p><b>FEG-SEM FOR IN-SITU MECHANICAL TESTING</b></p> <p>Tescan Clara field emission gun SEM is used for in-situ materials testing. It is ideal for characterization of materials at low beam energies for maximum surface topography. Unique In-Beam Multidetector design allowing angle and energy selective BSE detection.</p> <p>SEM Nanoindentation Lab Instruments University</p>	 <p><b>TAMPERE UNIVERSITY</b> Tampere</p> <p><b>IN-SITU NANOINDENTER</b></p> <p>Alemnis in-situ nanoindenter can perform indentation, micropillar compression, microcantilever fracture and other micromechanical tests inside a SEM. All classes of materials (metals, ceramics, plastics, composites, glasses, etc.) can be tested at small length scales.</p> <p>Nanoindentation Lab Instruments University In-situ</p>	 <p><b>TAMPERE UNIVERSITY</b> Tampere</p> <p><b>MESO-SCALE MECHANICAL TEST SYSTEM</b></p> <p>The Psylotech <math>\mu</math>TS system is a flexible meso-scale test system that can be used in conjunction with microscopes and digital image correlation system to measure stress/strain, stress relaxation and creep experiments on a wide range of materials.</p> <p>Mechanical tests Lab Instruments University Compression</p>	 <p><b>TAMPERE UNIVERSITY</b> Tampere</p> <p><b>STANDALONE NANOINDE</b></p> <p>Alemnis standalone nanoindenter mapping and multiple sample materials research. A nano-scale instrumented indentation tests indentation testing at nano/micrometers. The standalone nanoindenter can perform small-scale mechanical tests.</p> <p>Nanoindentation Lab Instruments University</p>
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## Users

 <p><b>Tampere</b></p> <p><b>KATI VALTONEN</b></p> <p>I am responsible of the research services and the infrastructure of Tampere Wear Center and the materials characterization facilities at Tampere University. My particular research interests are the high stress abrasive and impact wear of steels, characterization of wear mechanisms, and assessment of the relevance of laboratory wear...</p> <p>Materials Science Expertise Tribology</p>	 <p><b>Oulu</b></p> <p><b>MANOJ KUMAR GHOSALYA</b></p> <p>I am responsible for the operation, maintenance, and development of the APXPS setup, including user support and reliable operando and in situ measurements under realistic conditions. My expertise spans synchrotron- and lab-based APXPS, in situ ALD-APXPS, UPS, and electrochemical measurements, with application...</p> <p>APXPS University</p>	 <p><b>MIKKO HOKKA</b></p> <p>I am a professor of mechanical response of materials and experimental mechanics. I have expertise in advanced mechanical testing, in-situ measurements, high speed photography, infrared photography, use of synchrotron X-rays for mechanical testing and characterization and overall complex multiphysics measurements...</p> <p>Mechanical tests In-situ tests Collaboration Fatigue High Temperature</p>	 <p><b>Oulu</b></p> <p><b>SAMULI URPELAINEN</b></p> <p>Expert on synchrotron radiation and electron spectroscopy of atoms, molecules, nanoparticles and surfaces</p> <p>APXPS In-situ Materials Science University</p>
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CONTACT PERSON

Mikko Hokka

RELATED CARDS

Mikko Hokka

### Psylotech $\mu$ TS

The Psylotech  $\mu$ TS system is a flexible meso-scale test system that can be used in conjunction with microscopes and digital image correlation system to measure stress/strain, stress relaxation and creep experiments on a wide range of materials.

#### General information

- Type of loading: Tension, compression, bending
- Maximum force: 7 kN
- Maximum speed: 1.3 m/s
- Max. sampling rate: 5 kHz

Details

Host Organisation

Tampere University

Additional Links

Tampere University, EMS  
Tampere University, Opera@

Tags

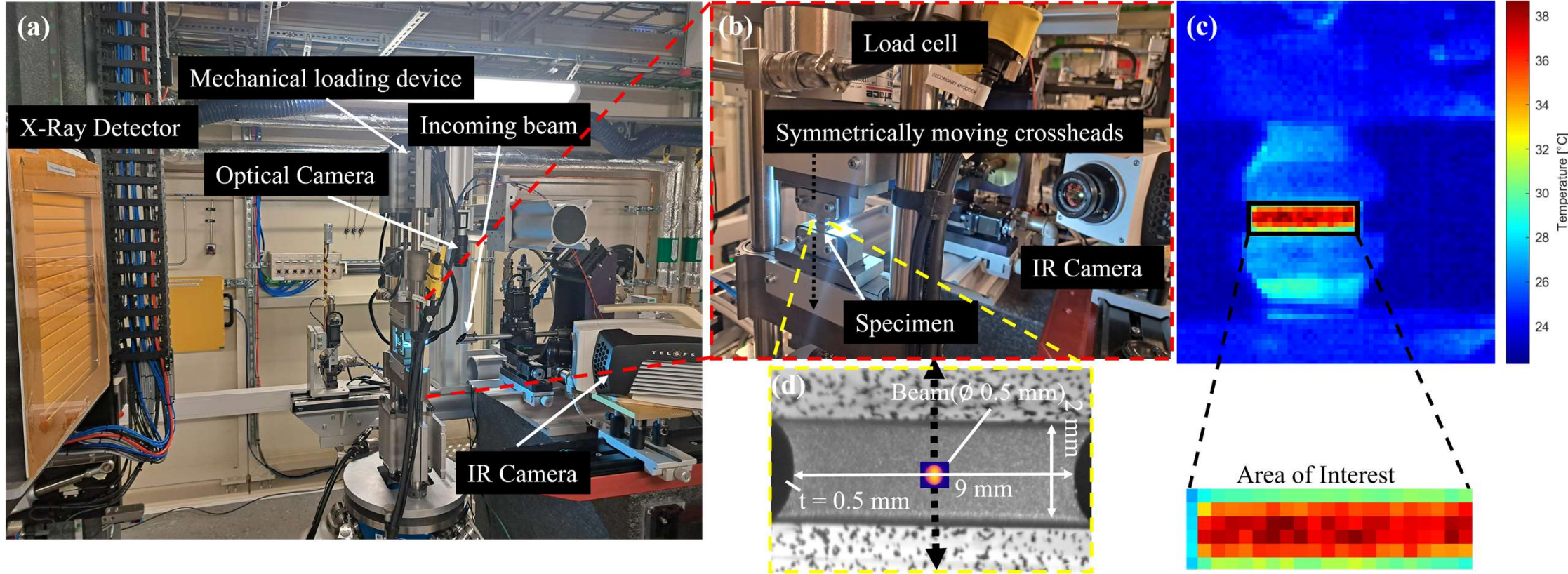
Lab Instruments University Compression  
Tension Bending

Methods

Mechanical tests

# A Selected Highlight

# OperaRI facilitates access to large scale international research infrastructures



A combination of mechanical loading, optical and infrared cameras, and high speed XRD (+H2 charging)



# Microscale – Existing and future infrastructure

Coming next:

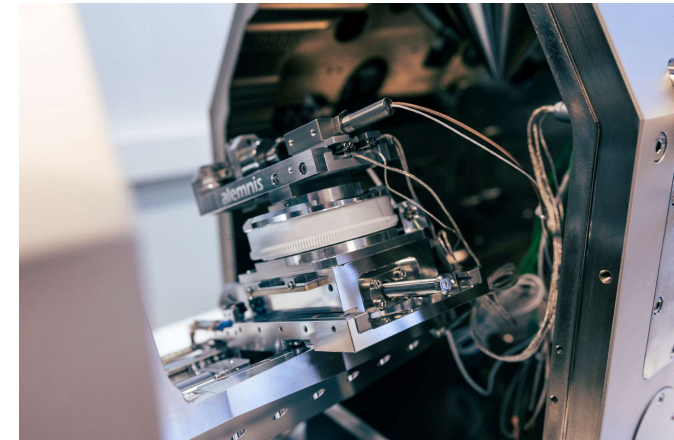
- in-situ H<sub>2</sub> charging
- H<sub>2</sub> detection capabilities

## Tescan Clara FEG-SEM

- ❑ Dedicated for **in-situ testing**
- ❑ Equipped with SE, BSE, EBSD and EDS detectors
- ❑ High speed **Oxford Symmetry 3** EBSD detector: > **5700 patterns/sec**, cover hundreds of  $\mu\text{m}^2$  in minutes!
- ❑ Perform **in-situ mechanical** testing and **heating/cryo tests**.  
Open for other multi-physics test types!

## Alemnis in-situ nanoindenter

- ❑ Most advanced in-situ nanoindenter in the world
- ❑ Testing capability: **-150 to 1000°C**,  $10^{-5}$  to  $10^4 \text{ s}^{-1}$ , up to **10 kHz** frequency, 1MHz data acquisition
- ❑ **Test types**: indentation, micropillar compression, microcantilever bending, micro-tension, fracture, fatigue, ...
- ❑ FE-SEM: In-situ testing videos, nano to  $\mu$ -scale **DIC**, in-situ EBSD, ...
- ❑ Test all classes of materials – metals, ceramics, polymers, glasses, semiconductors, composites, ...



Photographs by Jonne Renvall.

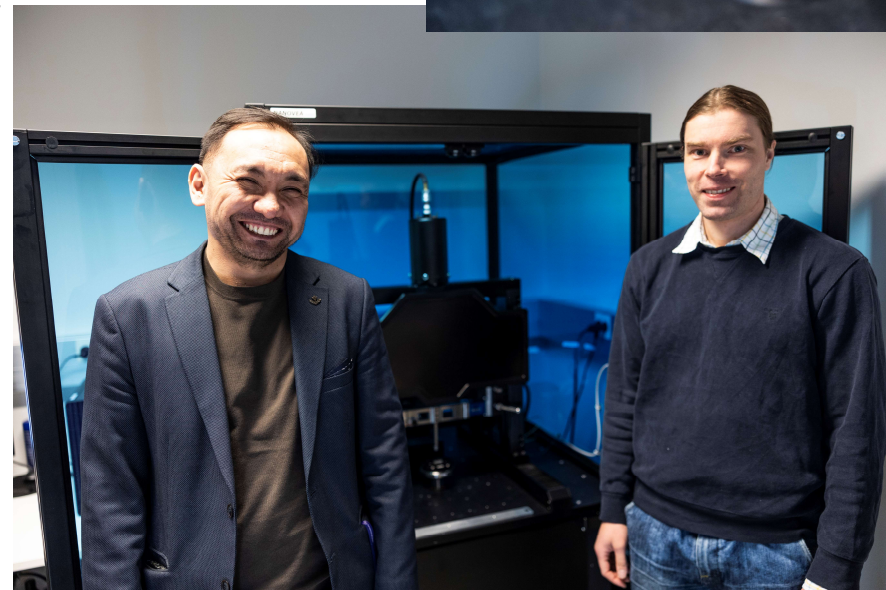
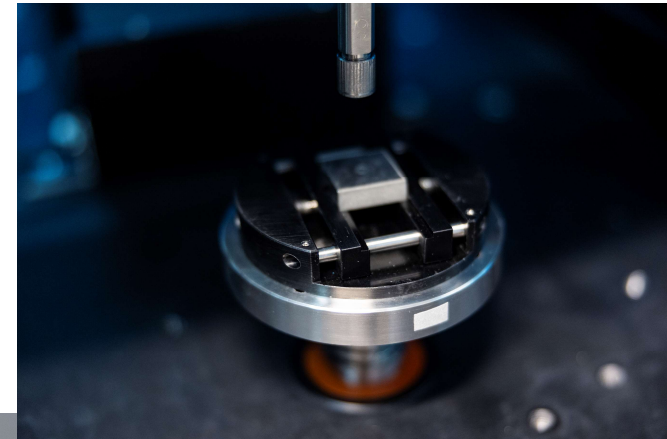
# Macroscale – Existing and future infrastructure

## Nanovea T2000 Universal tribometer

Advanced Pneumatic Technology allows for stable applications of normal force at speeds of 0.001 to 15000 rpm (10+ m/s) for highly accurate wear, scratch, friction, lubrication and mechanical property evaluations.



More technical details on our website

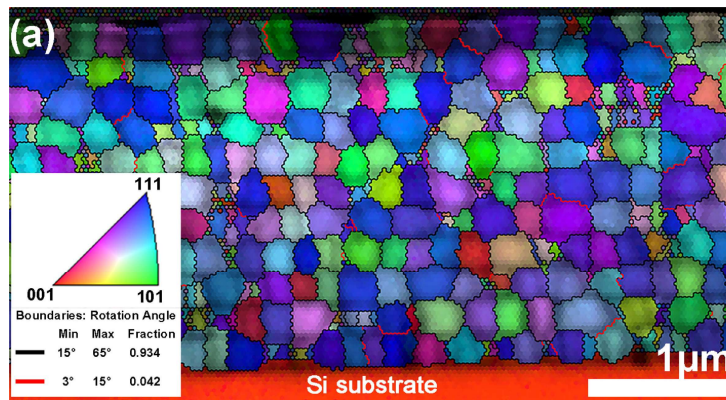
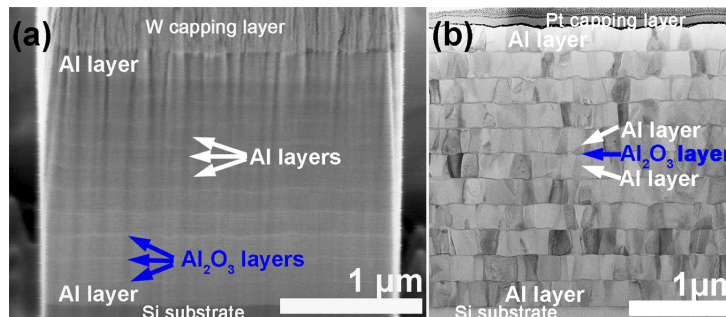


Photographs by Jonne Renvall.

# ALD-PVD combination!

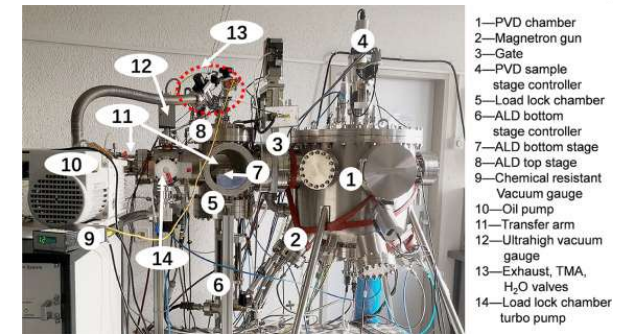
## Future acquisition (2027-2028)

- ❑ **Combine ALD & PVD:** metal+ceramic multilayers without breaking vacuum! Unique in Finland
- ❑ **Hydrogen barrier films/coatings:** Develop unique films/coatings for hydrogen applications
- ❑ Multiple PVD targets – **Composition gradients** and **multilayers** for accelerated materials design
- ❑ Multiple ALD precursor lines
- ❑ **In-situ monitoring** of film deposition – fast optimization of process parameters
- ❑ **Temperature gradient stage:** Combinatorial thermal treatments!



Al-Al<sub>2</sub>O<sub>3</sub> multilayers deposited in a PVD-ALD setup showing BF-TEM and TKD images; T. Xie, T. Edwards, et al. Thin Solid Films 711 (2020) 138287

TUNI Luottamuksellinen - Confidential (3Y)



Commercial ALD-PVD setups

# Noodi

27.10.2025 9.30



**Dedicated for experimental research with strong material focus – Impacting the TAU research for decades**

# Summary

**At TAU, we are investing in the future:**

- Personnel
- Facilities
- Equipment

**Strong focus on:**

- Material – H2 interactions
- Improved performance, durability, and cost-effectiveness
- National and international collaboration



# Thank you for your attention!

## Acknowledgements



Funded by  
the European Union  
NextGenerationEU

  
Research Council of Finland



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