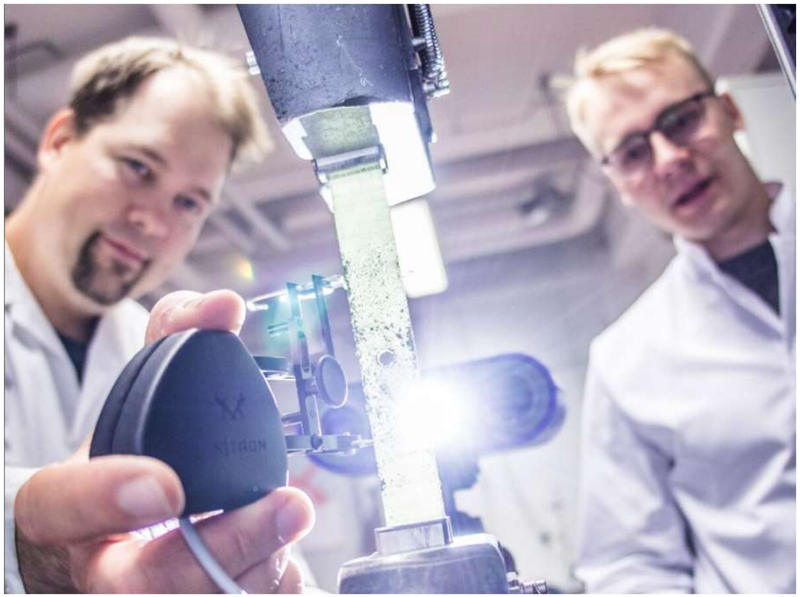
Tampere University

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 H2 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



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Operando research infrastructure for energy materials and systems – OperaRI

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Materials Science and Environmental Engineering
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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

UNIVERSITY OF OULU

VTT

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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

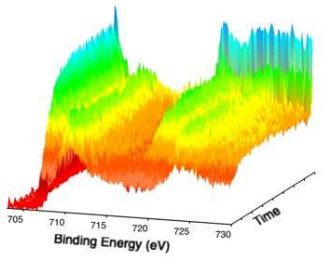
- APT
- TOF-SIMS

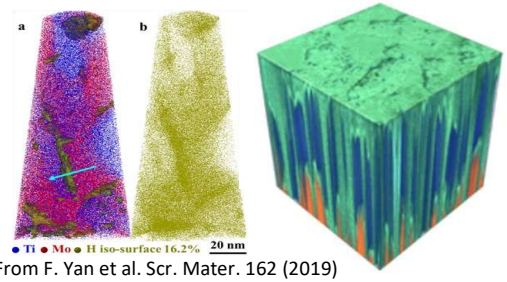
Microscale

- IN-SITU SEM TESTS
- ALD-PVD

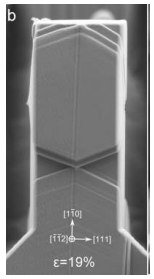
Macroscale characterization

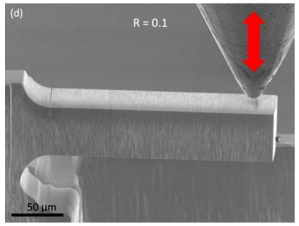
- TRIBOMETERS
- LOAD FRAMES
- SINGLECELL & MULTI-SINGLECELL

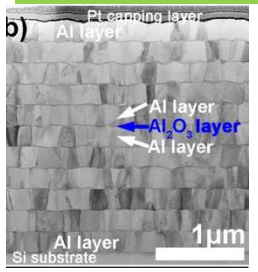


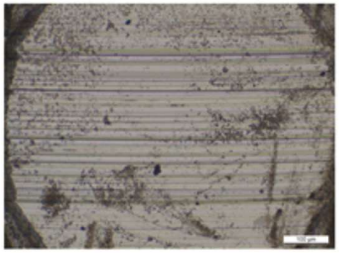


From F. Yan et al. Scr. Mater. 162 (2019)





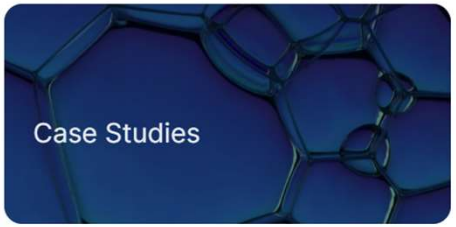




From T. Xie et al. Thin Solid Films (2020)

Electronic/atomic/molecular level — Nano- and microscale — Macroscale — System/component level

Online portal: h2miri.fi



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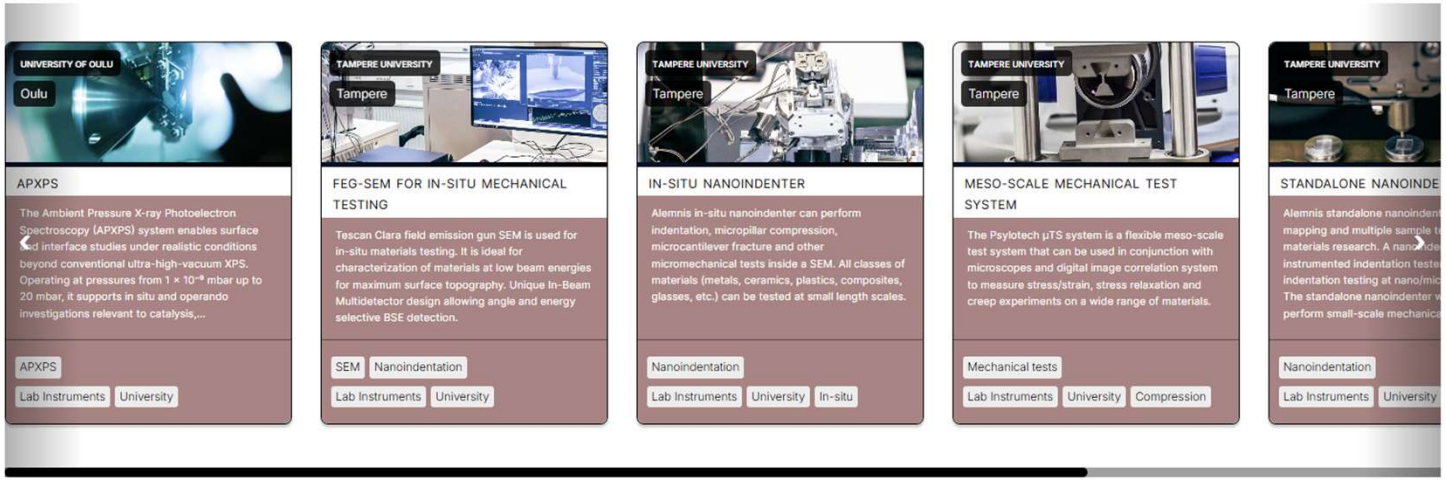
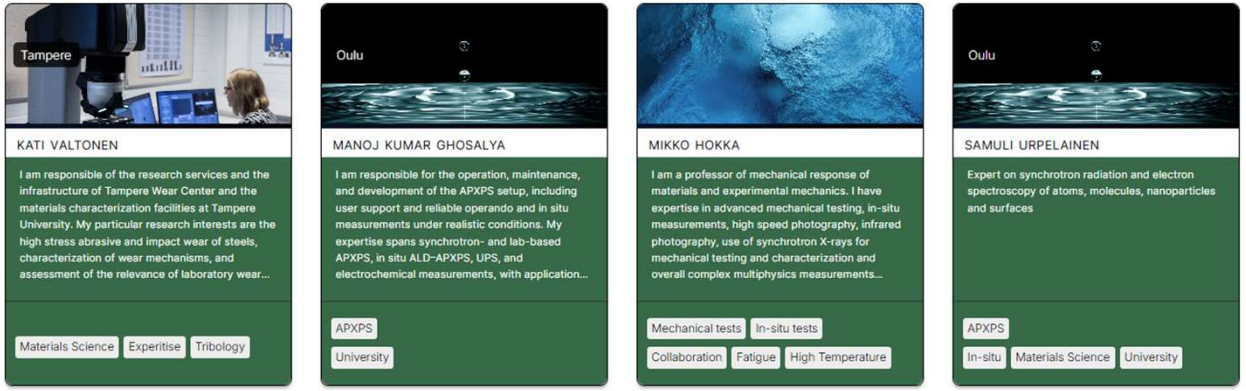
Infrastructures



Users



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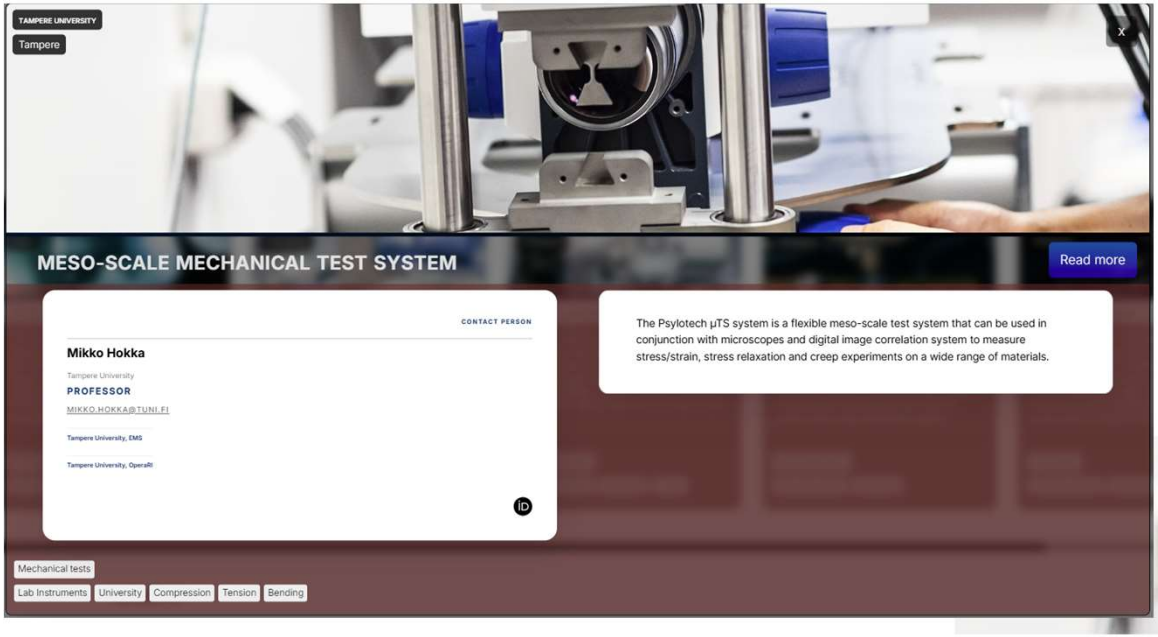
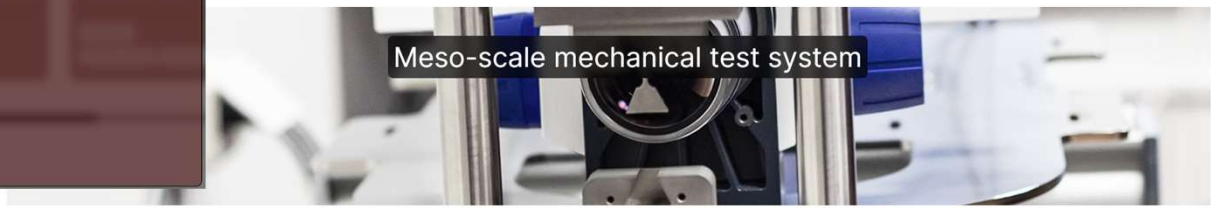
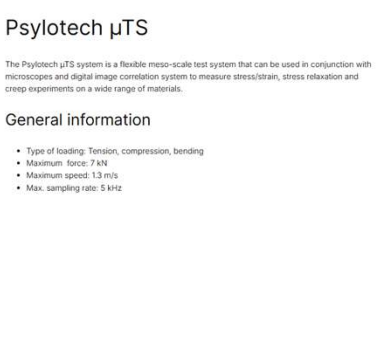
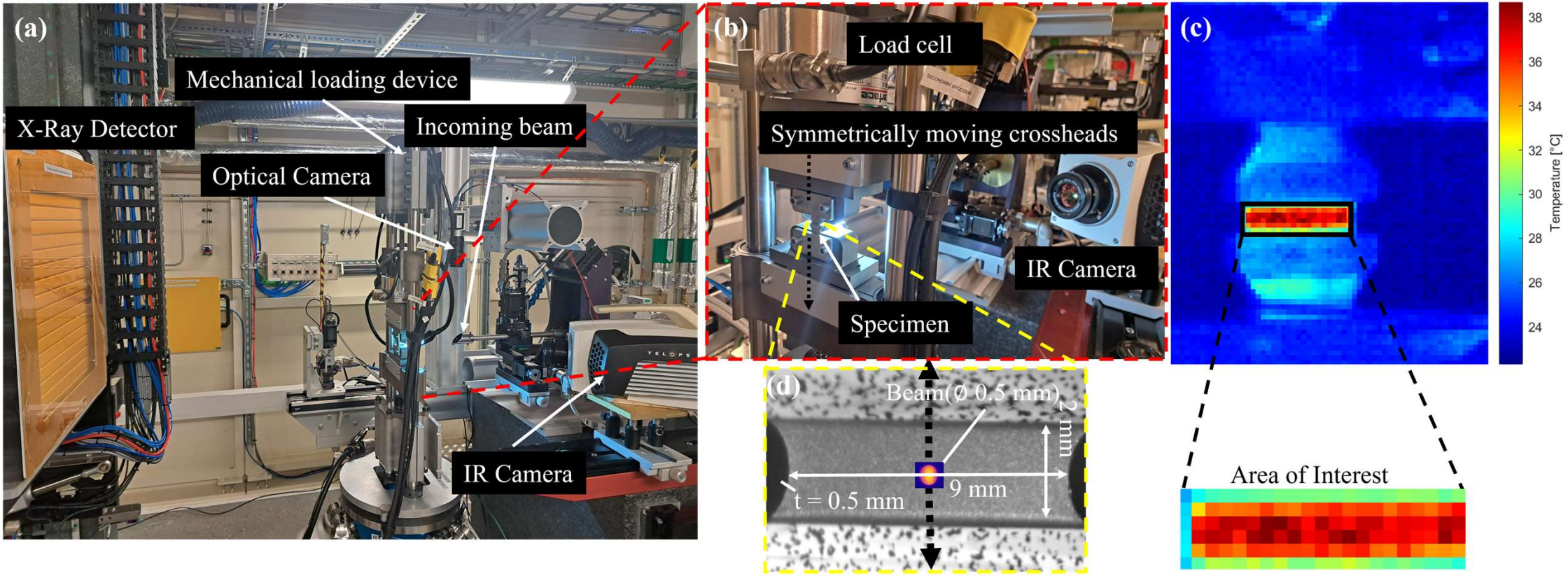






A Selected Highlight

OperaRI facilitates access to large scale international research infrastructures



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

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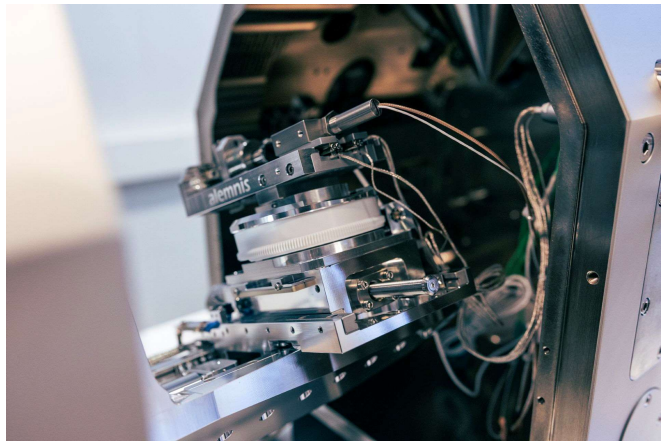
TUNI Luottamuksellinen

More technical details on our website

Microscale – Existing and future infrastructure

Coming next:
- in-situ H2 charging
- H2 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 μm^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} 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 µ-scale DIC, in-situ EBSD,…
- ❑ Test all classes of materials – metals, ceramics, polymers, glasses, semiconductors, composities, …

Photographs by Jonne Renvall.

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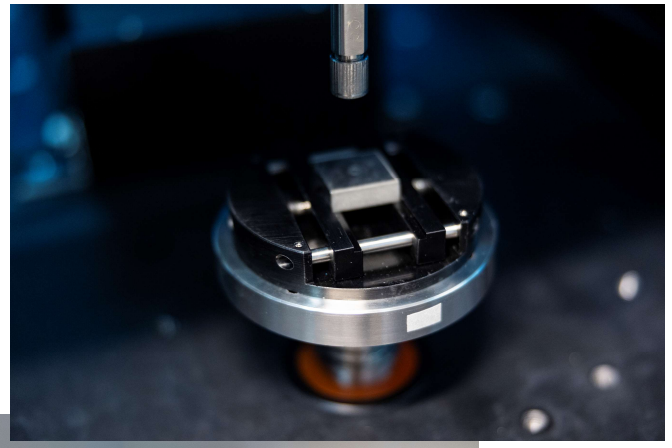
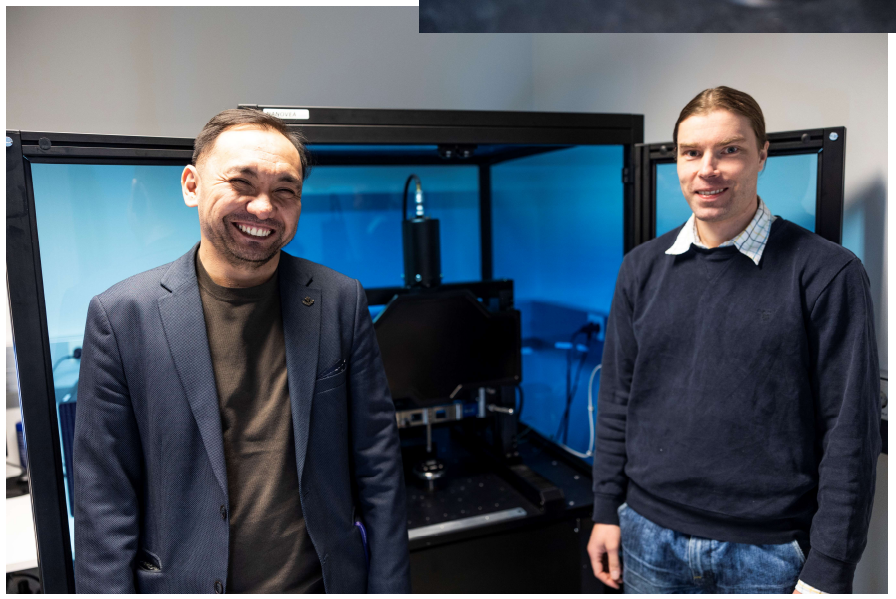
Macroscale – Existing and future infrastructure



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.

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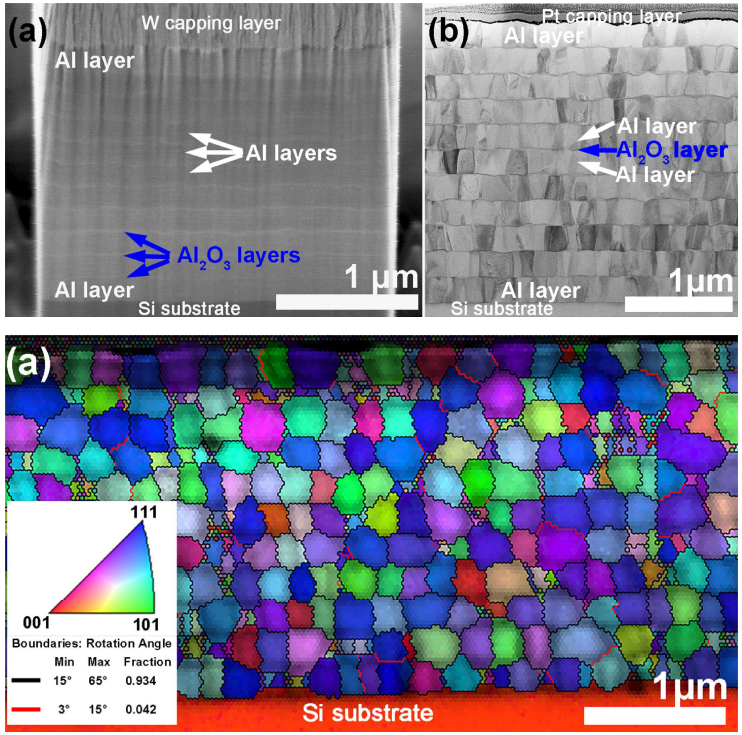
Coming soon

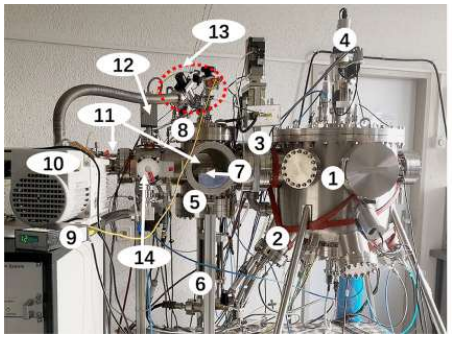
ALD-PVD combination!

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-Al2O3 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



Commercial ALD-PVD setups

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Noodi

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

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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
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