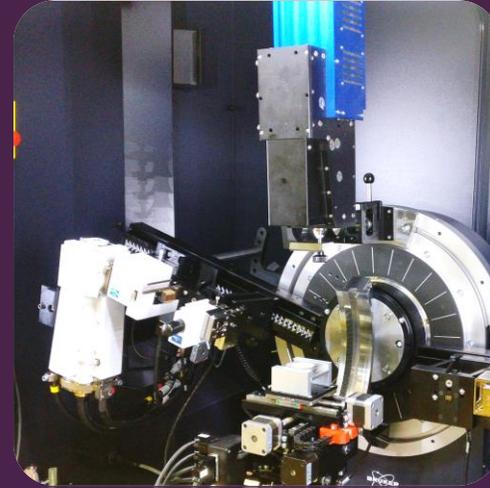
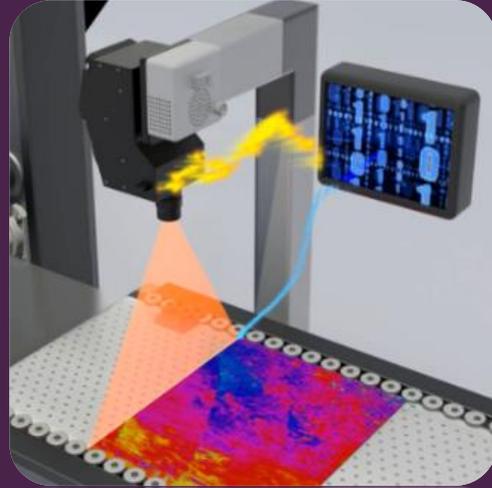


NanoQI



Multimodal X-ray and Hyperspectral Thin-Film Nano-material Evaluation and Quality Imaging

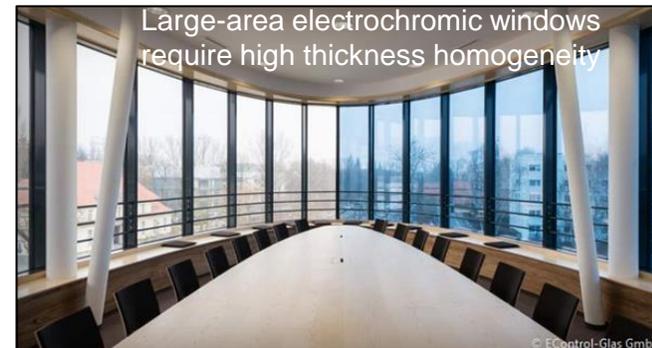
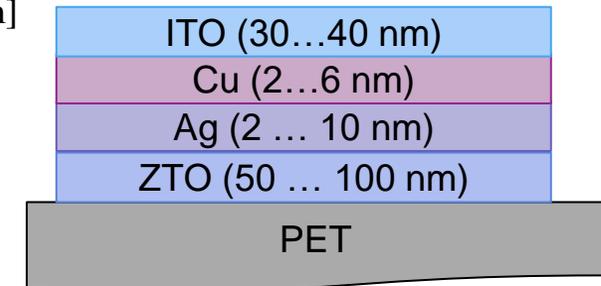
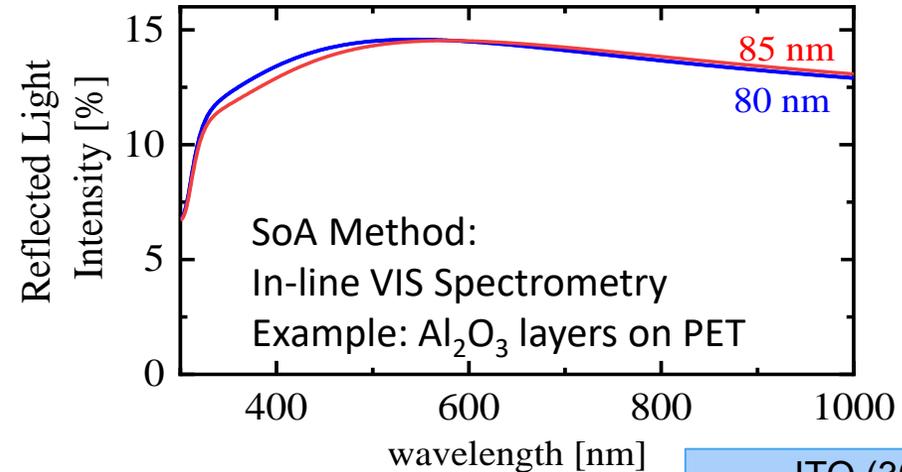
NanoQI M18 Review Meeting, 12th Oct. 2021

Grant Agreement No 862055

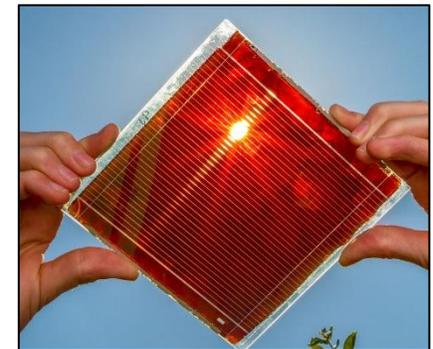


The demand....

- **We need** precise ($< \pm 1\%$) control of
 - Thin film thickness
 - chemical composition
 - Solid-state phase / crystallinity
 - Surface roughness / morphologyin thin film processing on large area in multi-layer stacks
- **We miss** *fast, efficient and accurate* methods to measure
 - thickness of ultrathin transparent layers (≤ 100 nm)
 - individual layer thickness in stacks
 - „insitu“ access to solid state phase
 - access to nano-roughness / density
 - inline access to functional properties
- **Question:** How can we map/image homogeneity of crystallinity on large areas? (~ 100 cm² ... ~ 10 m²)

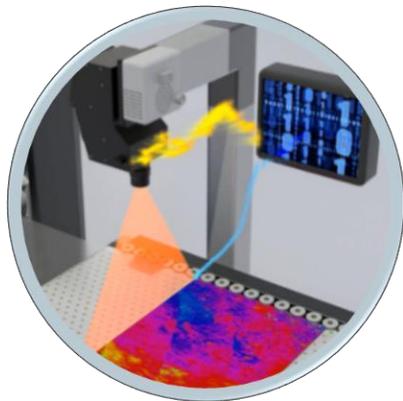


source: EControl-Glas, GmbH, Plauen



The NanoQI Idea ...

ultra-fast XRD | XRR



real-time
hyperspectral imaging



at-line nano-material
quality assessment

calibration
data



at-line, fast 100%
surface inspection

**In-line XRD/
XRR/HSI in thin-
film equipment**

accelerated
measurement



industrial atomic
layer deposition

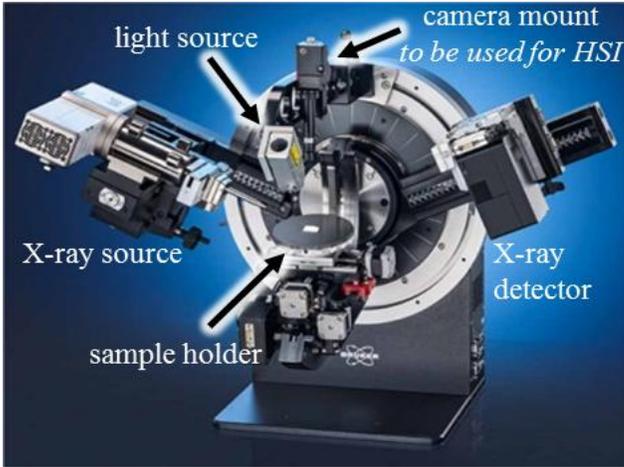


roll-to-roll
vacuum
web coating



thermal curing
and sintering

Methodology ...



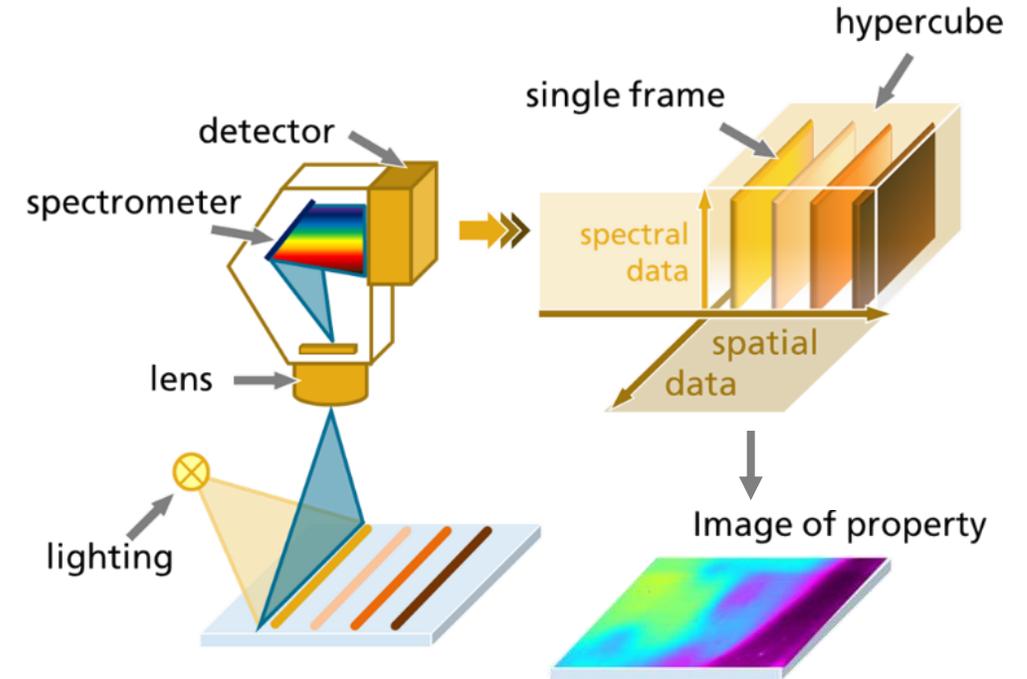
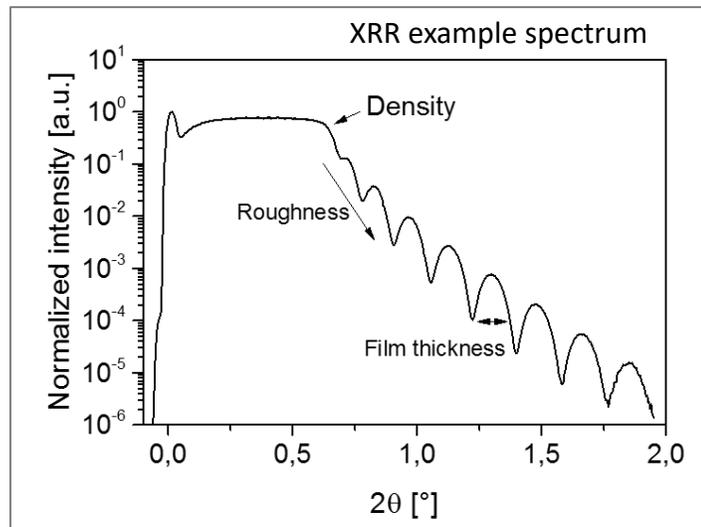
- **X-ray diffraction analysis**

- Solid-state phase
- Crystal orientation

- **X-ray reflectometry**

- Thickness
- Roughness
- Electron density

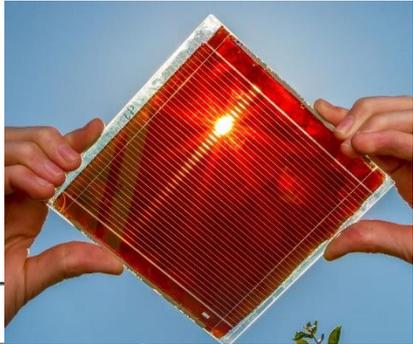
- Accelerated measurement
- Automated + fast sample evaluation for quality control
- Calibration of hyperspectral imaging
- In-situ superposition of XRD + HSI



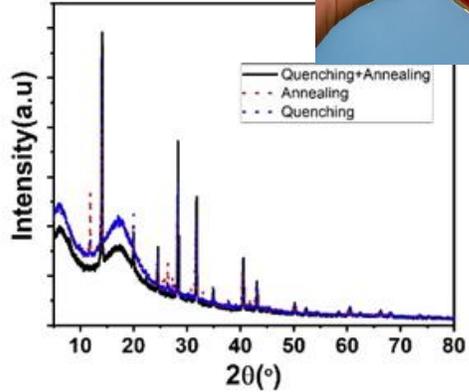
- **Hyperspectral Imaging**

- Spatially resolved optical transmission/ reflection spectrometry
- Detect defects, gradients, property drifts
- Large area imaging of functional properties
- Inline integration to thin film processing

Technology Demonstration

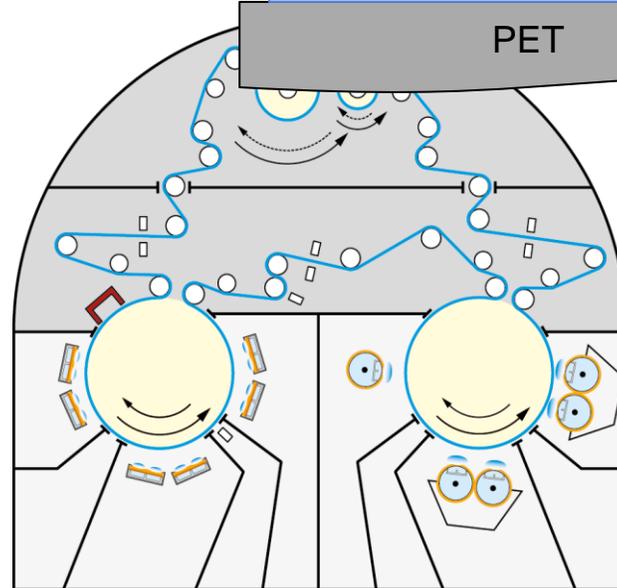
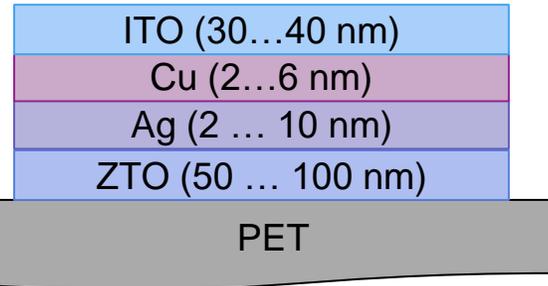


www.solliance.eu



At-line verification and in-line imaging

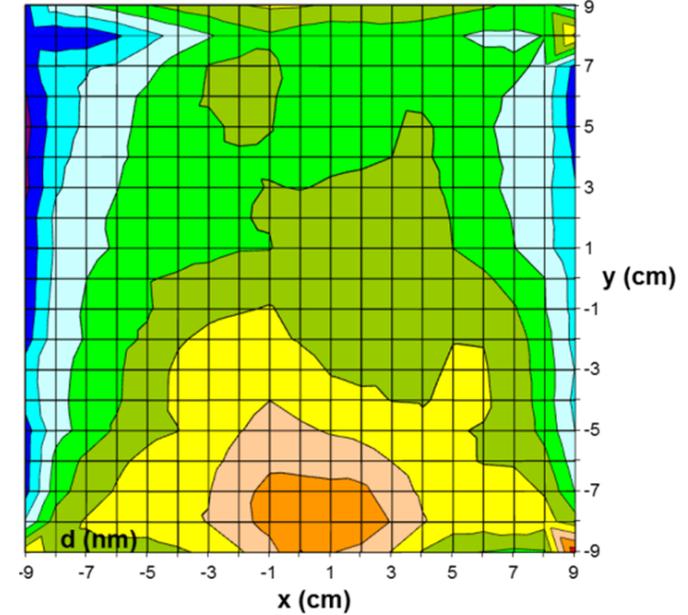
Thickness and uniformity in roll-to-roll coating of electronic layer stacks



Real-time in-line measurement

Sintering and quenching of perovskite layers for highly efficient solar cells

ALD Al_2O_3 layer thickness map
(red = 53 nm; blue = 47 nm)



Real-time and layer-by-layer assessment
Layer growth and uniformity of ultra-thin ALD layers and nano-laminates

NanoQI Consortium and Stakeholders

Technology

Industrial Validation

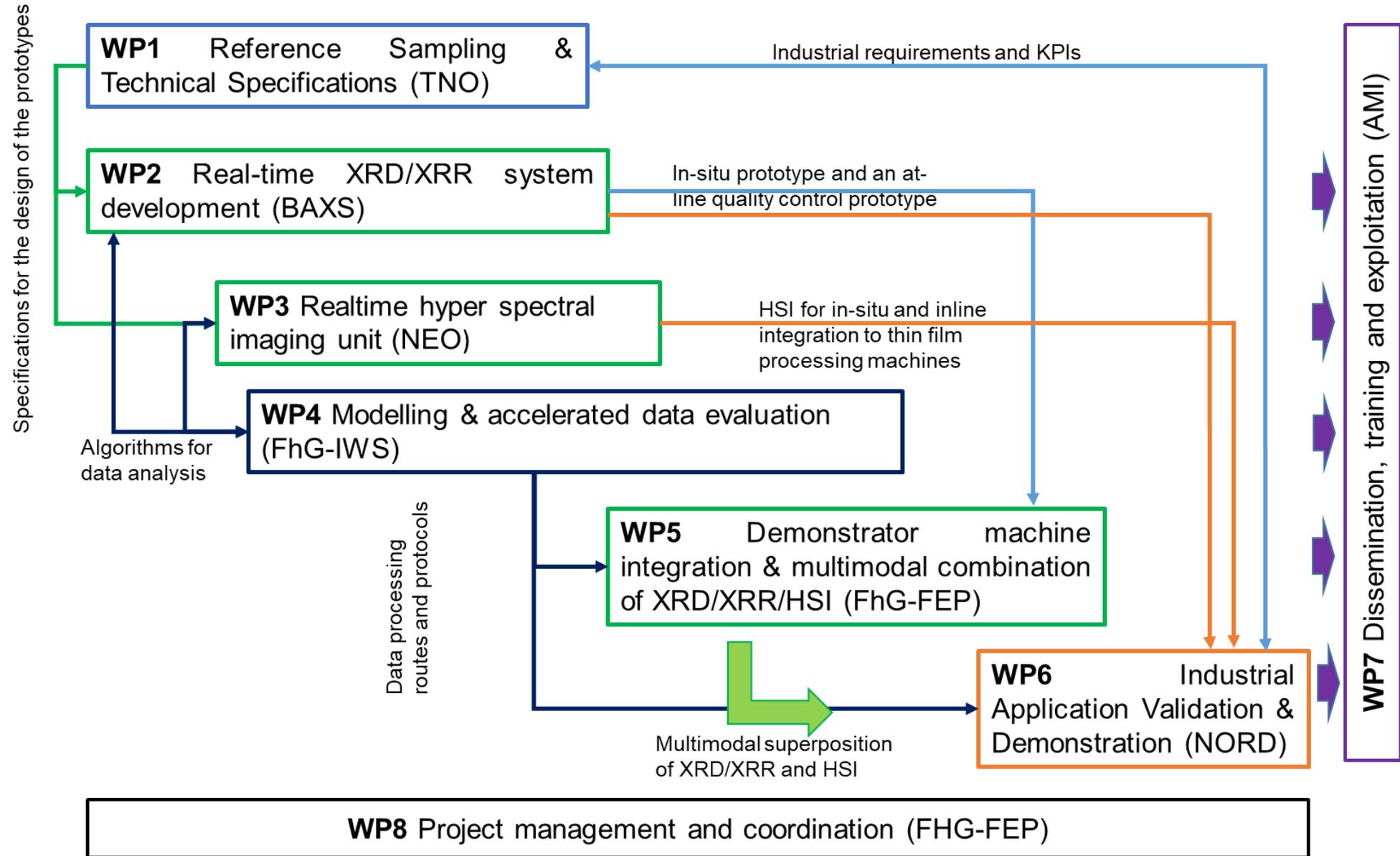
Business Development

BRUKER
TNO innovation for life
SOLLIANCE SOLAR RESEARCH
tu technische universität dortmund
SMIT THERMAL SOLUTIONS
Fraunhofer IWS
nordmeccanica group
neo NORSK ELEKTRO OPTIKK AS
HySpex
Fraunhofer FEP
AMIRÈS
Fraunhofer IAP

VON ARDENNE
KIT Karlsruher Institut für Technologie
External Advisory Board
hereon Helmholtz-Zentrum
EMCC

picosun
AVERY DENNISON
GENESINK SMALLER. FURTHER. FASTER
Industry Advisory Board
Hanita Coatings
HUECK FOLIEN
SOLARONIX
amcor

NanoQI – Work Plan



Key Results at Project Halftime

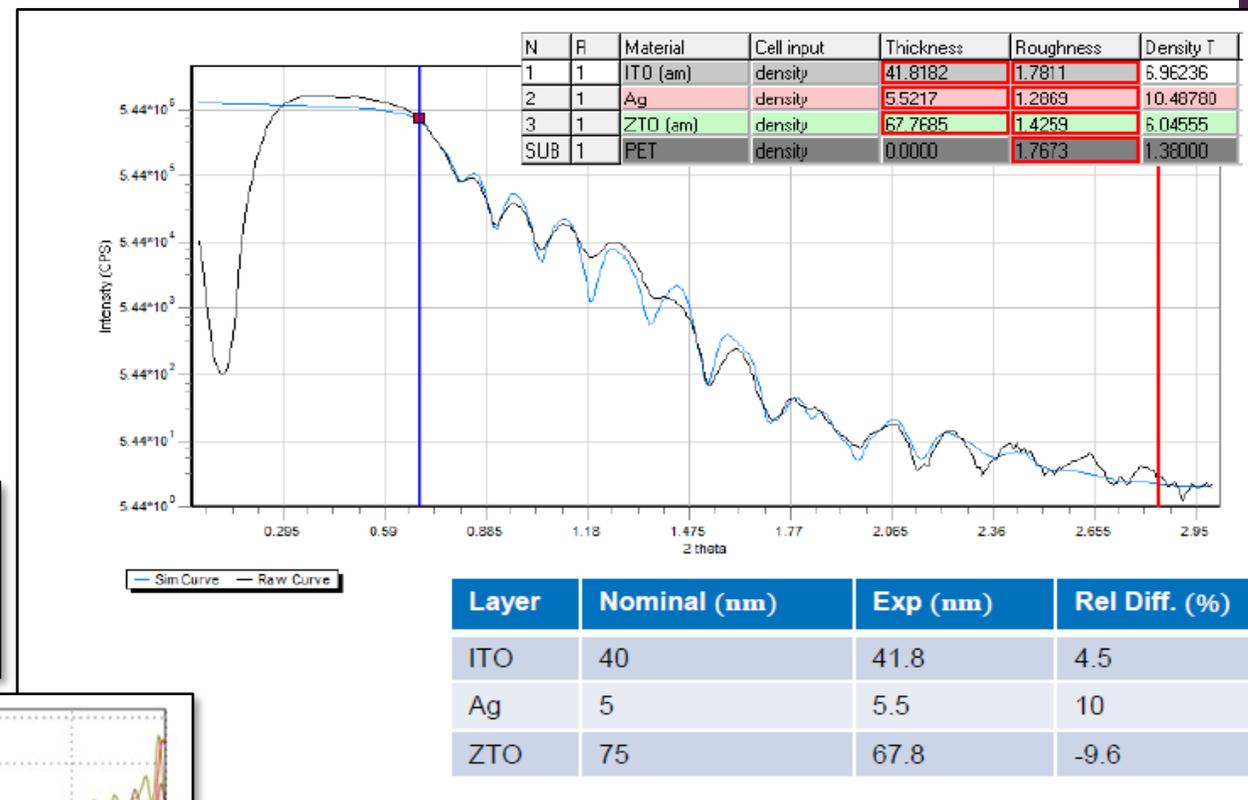
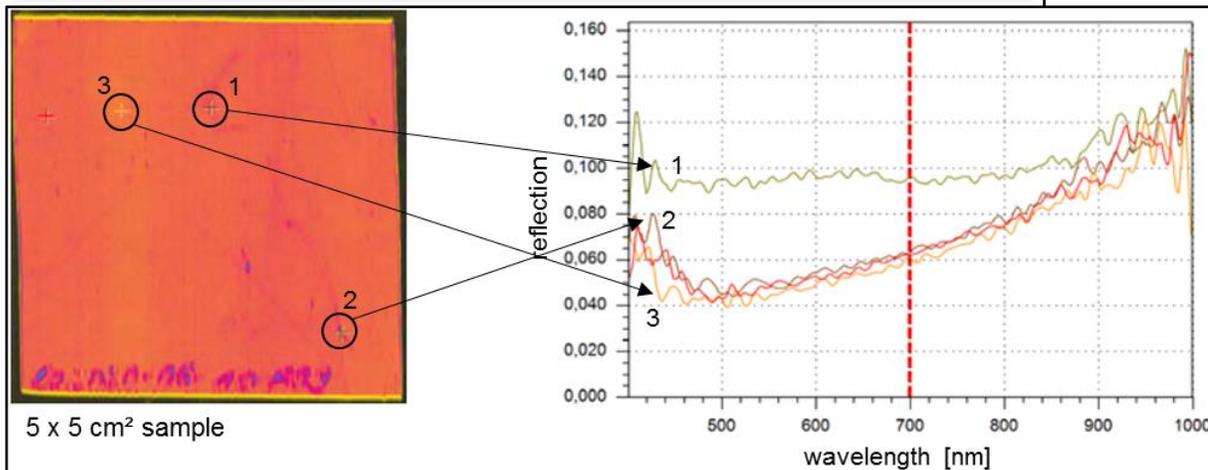


WP1: Reference Materials and Specifications

- Deep investigation of reference samples

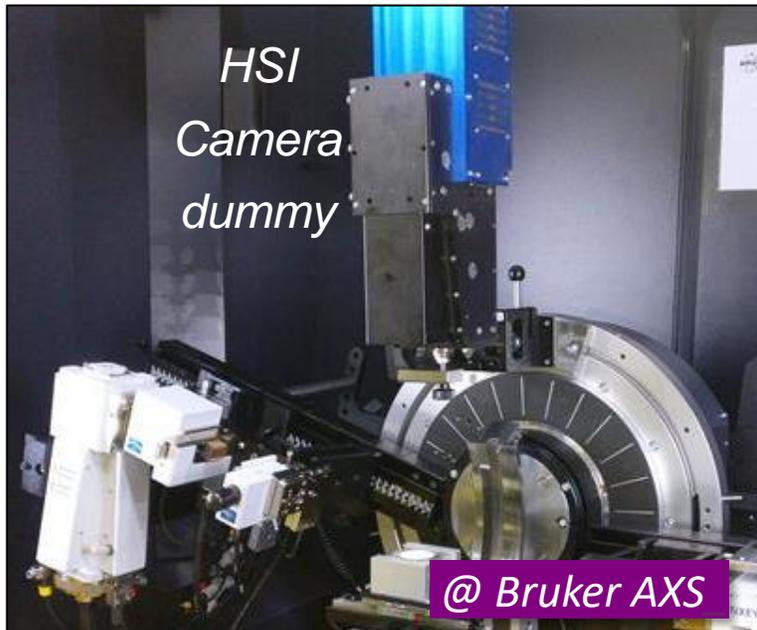


- Specification Sheets for
 - XRD / XRR prototypes
 - HSI cameras and optical components
 - Machine interface for inline-tools
 - Machine and radiation safety measures



WP2: XRD and XRR prototypes...

... for advanced at- and in-line X-ray thin film analysis



@ Bruker AXS

In-situ superposition of XRD and HSI property imaging on 10 x 10 cm²

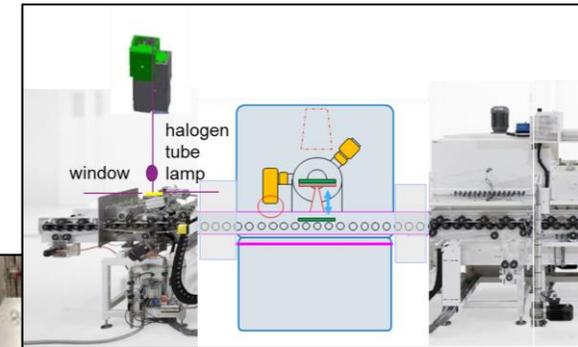
✓ completed



@ Fraunhofer FEP

fast, „daily-use“ XRR and XRD for at-line quality control

✓ completed

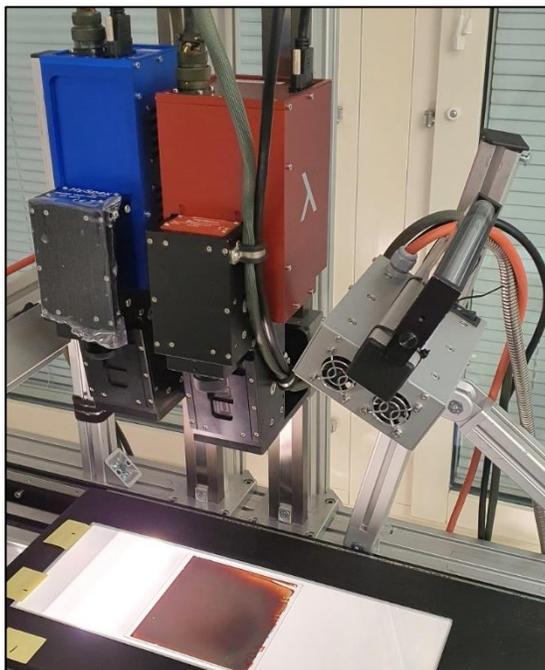


@ TNO / Solliance

In-situ XRD for perovskite solar cell processing

⌚ delivered at place

WP3: Realtime in-line Hyperspectral Imaging



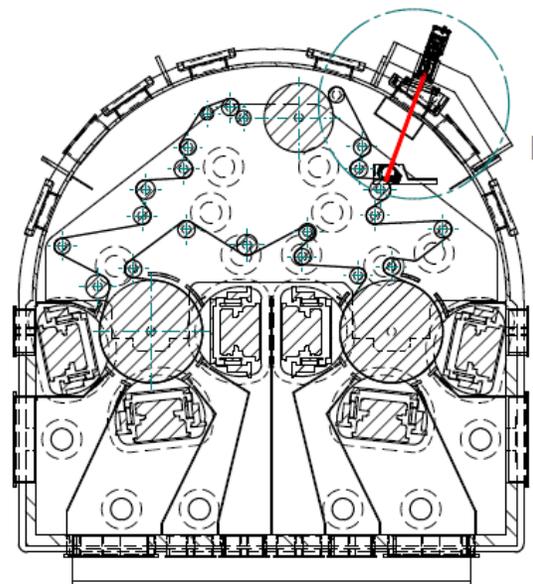
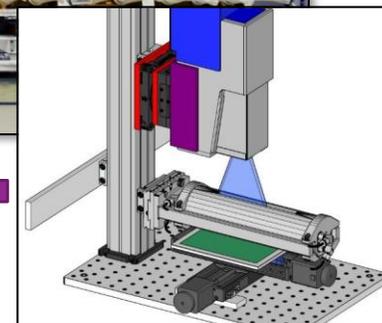
Adapted HSI camera setups

→ 2 specialized models:

- VNIR : $\lambda = 400 - 1000 \text{ nm}$
- SWIR : $\lambda = 950 - 2500 \text{ nm}$
- Prototype lenses for 40° field of view



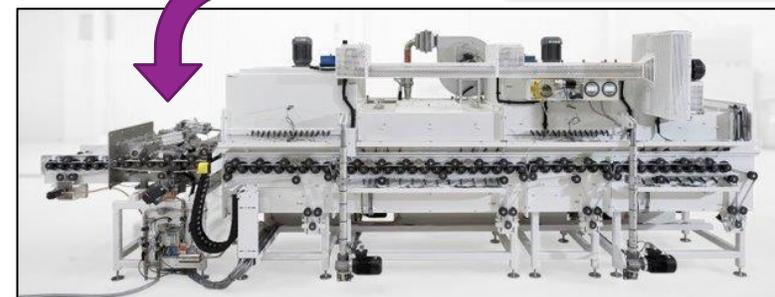
HSI next to ALD chamber in $15 \times 15 \text{ cm}^2$ printed electronics processing



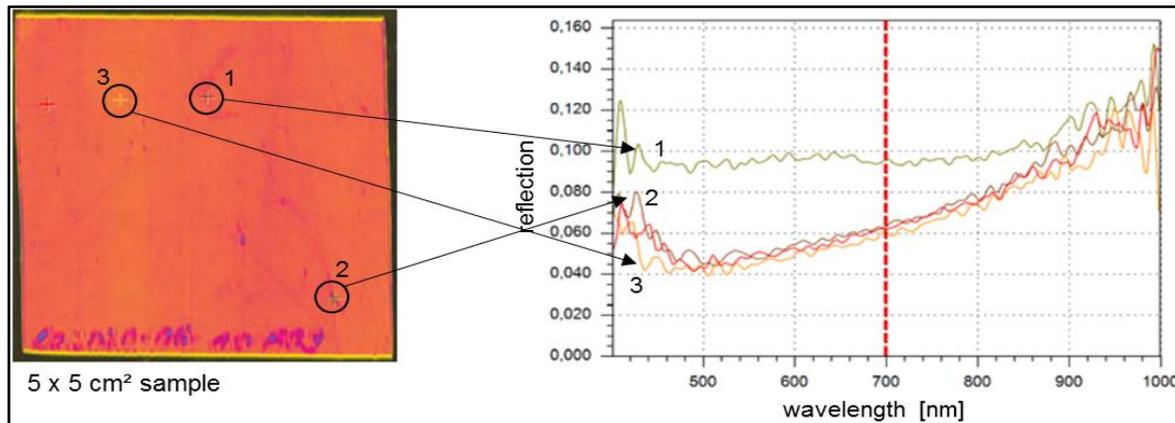
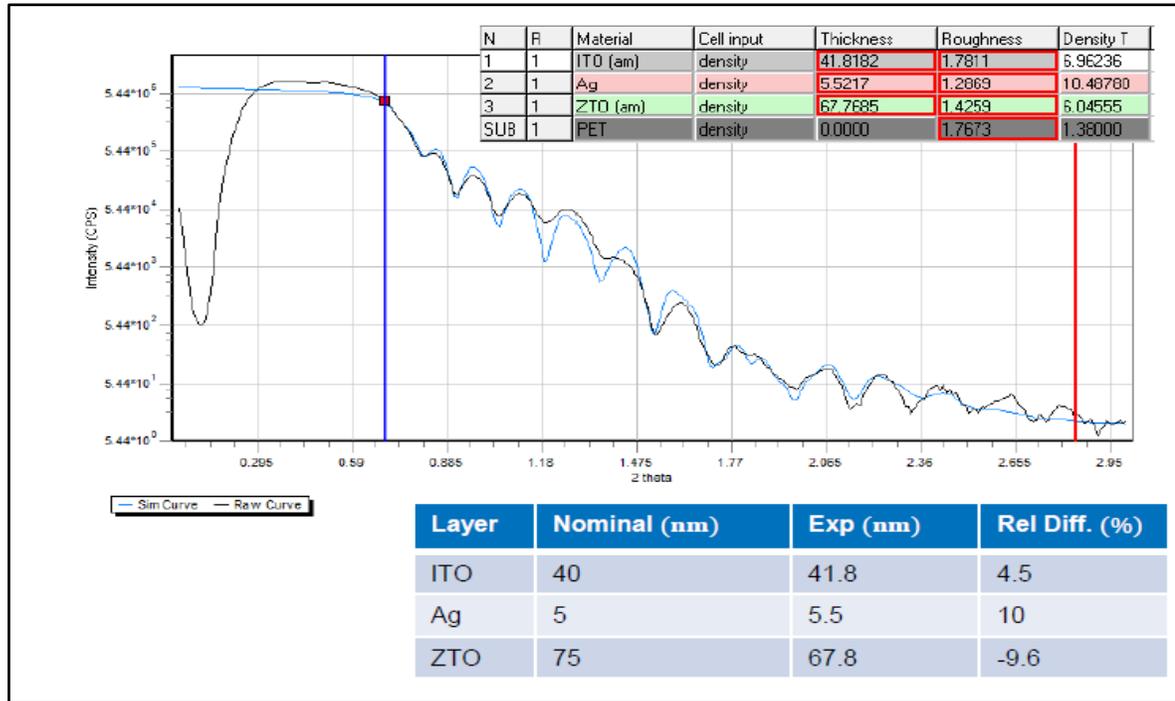
HSI in winding chamber in roll-to-roll vacuum coating @ 650 mm width



HSI in perovskite layer quenching chamber

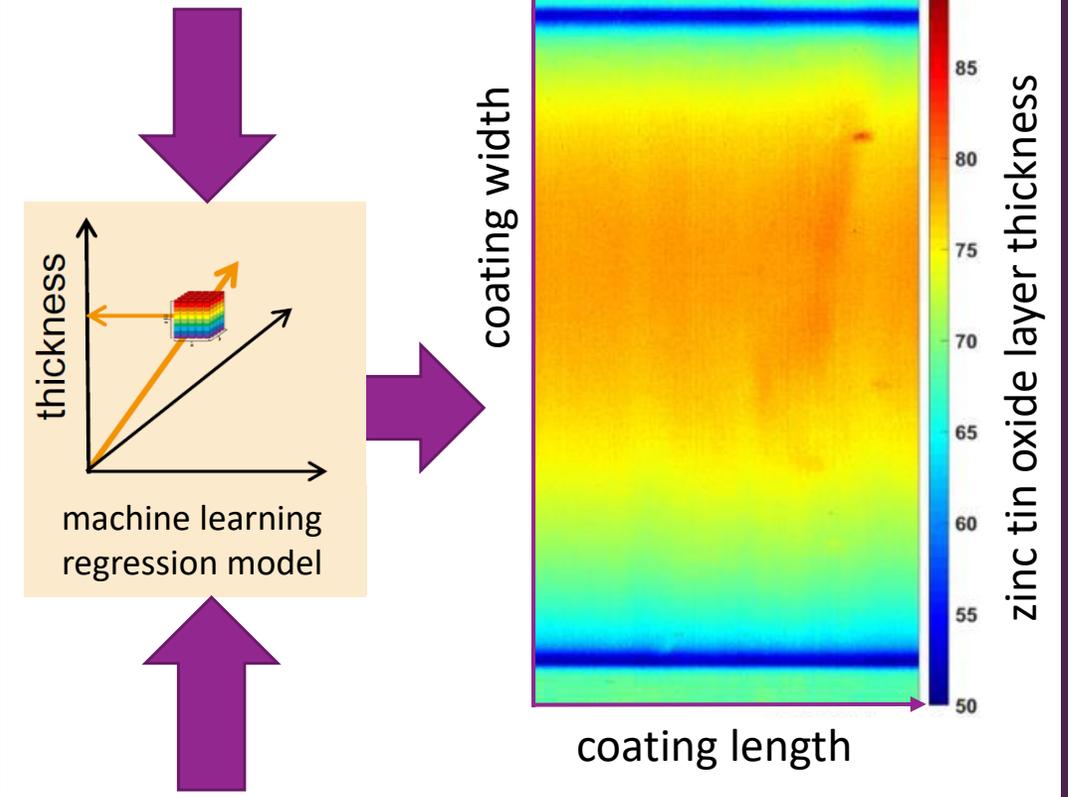


WP4: Data evaluation and machine interfaces



XRR layer thickness

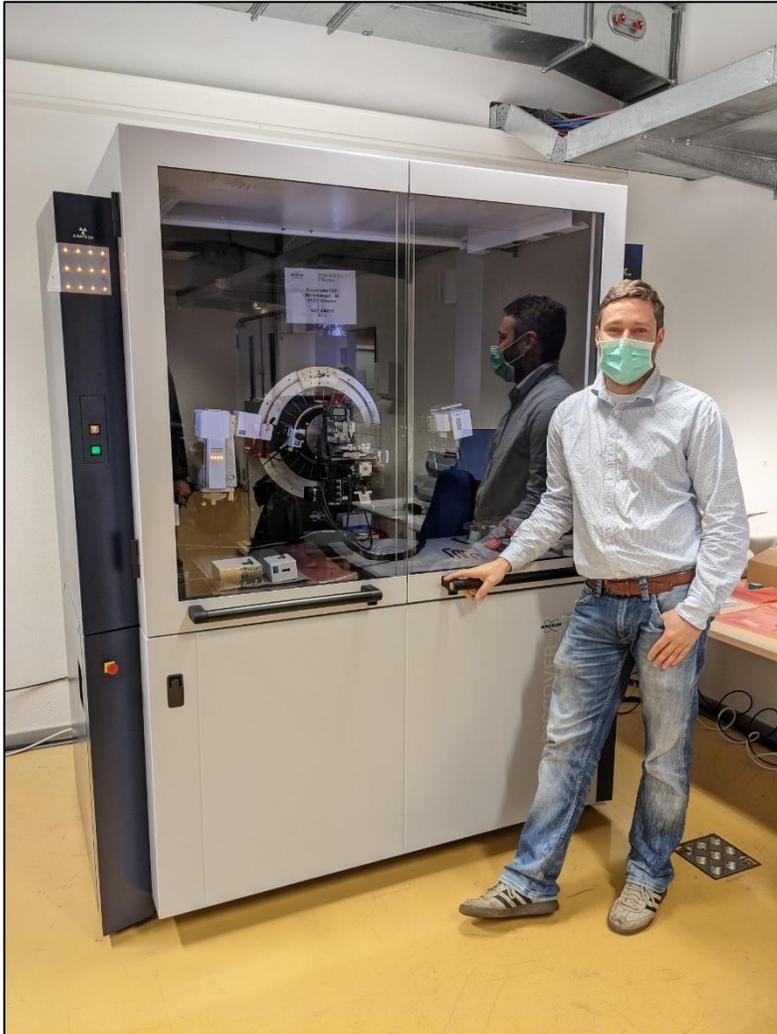
Imaging of relevant properties



HSI set of hypercubes

WP5 Demonstrator Machine Integration

- **XRD/XRR prototype at FhG-FEP installed and operational**
 - Safety Clearance received in May 2021
 - Teaching of FEP Personnel → for WP6 actions.
- **XRD prototype at TNO:** Installation ongoing
- **HSI prototypes at FhG-IAP and FhG-FEP:** Install in Nov. 2021



XRD installation



XRD teaching at FEP



NORD coFlex parts HSI package

WP7 – Dissemination and Outreach

- Project website updates & metrics
www.nanoqi.eu
- Social media accounts set up,
[LinkedIn](#); [Twitter](#)
- NanoQI @ pro flex 2021



- 5 NanoQI Presentations
with great positive feedback from Industry
- 1 presentation from partner project RealNano
- In Finalisation: Press Release on NanoQI Mid Term Achievements
- Outlook: Public Teaching Material (Inline Quality control in Production) planned
based on XRD Teaching @ FHG-FEP
- Outlook: Continued Interaction with EMCC // OYSTER CEN-CWA // CHADA platform

Thank you for Listening!

Coordinator Contact:

Dr. John Fahlteich, Fraunhofer FEP, Winterbergstrasse 28, 01277 Dresden

Phone: +49 351 2586 136; E-Mail: john.fahlteich@fep.fraunhofer.de



www.nanoqi.eu



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862055