Open Consultation on Metrology for Semiconductor Technologies

# European Metrology Network for Advanced Manufacturing

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Online stakeholder session for EURAMET & the EMN for Advanced Manufacturing

Friday 8 July 2022 | 10:00 - 12:30 CEST





ADVANCED ANUFACTURING



### Introduction: Advanced Manufacturing



### Advanced manufacturing (EC): one of six Key Enabling Technologies (KETs)

R

anuFU

vision

- Applications in multiple industries
  - Full exploitation of KETs: creating advanced & sustainable economies
- European Technology Platform <u>MANU*Future*</u>:
   Vision 2030 strategy document (HLG, 12/2018):
- Manufacturing: backbone of European economy
- 2014: 2.1 million enterprises, 30 million people, 1 710 B€. However: European manufacturing has been losing ground
- In 2030, European manufacturing will be competitive at global level due to its high-performance and technological level, targeting

# zero-defect, zero-delay, zero-surprise and zero-waste production processes

NO mentioning of Metrology or Measurement, but Quality => Awareness and "Translation" needed!



prioritised KETs in the Horizon EuropeQualityprogramme 2021-2027 (EC)

### **EMN for Advanced Manufacturing**

- EURAMET
- EMN for Advanced Manufacturing formally established in September 2021 (18 NMIs/DIs as members)
- EMN Partner-Organisations: ETP Manu*Future*, EFFRA/Made in Europe, NanoFabNet, euspen
- Stakeholder Council (SC): Zeiss, Renishaw, Siemens, Vestas, STMicroel., DTU/CIRP, CERN, BfR, BASF, ...
- EMN organized in 3 Sections:





 Stakeholder-Dialogue: Larger companies & SME, Industry org., Networks, Univ., R&D-Institutes)

 Strategic Research Agenda (SRA) for Metrology for AdvanceManu

 ⇒ 1<sup>st</sup> Draft by end of 2022

 ⇒ In 1/2023 will be an EPM call on Metrology for Industry

### EMN Advance Manu: Key Industry Sectors (KIS)





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### Examples of Joint Research Projects related to support Semiconductor Technologies



	Project #	Acronym	Project name For details, please check websites!	
EL => KDT EMPIR => EPM • HE	20IND04 20IND09 20IND12 20IND08 20IND06 20FUN02 17IND04	ATMOC PowerElec Elena MetExSPM PROMETH2O POLight EMPRESS 2	Traceable metrology of soft X-ray to IR optical constants and nanofilms for advanced manufact Metrology in manufacturing compound semiconductors for power electronics Electrical nanoscale metrology in industry Traceability of localised functional properties of nanostructures with high speed SPM Metrology for trace water in ultra-pure process gases Pushing bOundaries of nano-dimensional metrology by Light Enhancing process efficiency through improved temperature measurements	uring
	4IND07	<u>3D Stack</u>	Metrology for manufacturing 3D stacked integrated circuits	
	KDT JU KDT JU	<u>IT2</u> MADEin4	IC Technology for the 2nm Node (Start: 06/2020, 3 y) Metrology Advances for Digitized ECS Industry 4.0 (Start: 04/2019, 3 y)	NanoScale 2019
	KDT JU	Tapes3	Technology Advances for Pilot line of Enhanced Semiconductors for 3nm (Start: 10/2018, 3 y)	<ul> <li>12<sup>th</sup> Seminar on Quantitative Microscopy (QM</li> <li>8<sup>th</sup> Seminar on Nanoscale Calibration Standards and Methods</li> </ul>
H202(	H2020 In additio	<u>CHALLENGES</u> on: => Coopera	Real-time nano-CHAracterization reLatEd techNoloGiEeS (Start: 04/2020, 3 y) tion projects between Industry and NMIs (some under NDA)	Dimensional and related measurements in the micro- and nanometre range PHYSIKALISCH-TECHNISCHE BUNDESANSTALT BUNDESALLEE 100 BRAUNSCHWEIG, GERMANY

=> Dedicated workshops/conferences:

such as the Nanometrology Workshop at PTB-Berlin in 2018 (report),

or the Nanoscale conference series:

=> Next Nanoscale: @VTT, FI in Sep. 2023

ar on Quantitative Microscopy (QM) &

October 15th-16th, 2019

Organized by

P

13/07/2022

Examples of <u>cooperations</u> related to support <u>Semiconductor Technologies:</u> => EUV lithography



### Carl Zeiss SMT AG EUV-MET-Tool at PTB/BESSY: resist images



1<sup>st</sup> EUV imaging demonstrated at:





and presented at:

2<sup>nd</sup> International **EUVL Symposium** Antwerp 2003

Carl Zeiss SMT AG: Enabling the Nano-Age World™

ZEINS

P. Kürz, 2nd Int. EUV Symposium (2003), 879-899

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#### Examples of cooperations related to support EURAMET <u>Semiconductor Technologies:</u> => Optics for EUV Sources 0.6 0.5 eflectance 0.4 0.3 MLS Phi 180° 0.2 Phi 270° 0.1 50 100 150 200 300 350 0 250 radius / mm 13.60 13.55 /nm relength 13.50 13.45 Phi 0 5 sr collector, 670 mm outer diameter Phi 90' 13.40 Phi 180° 34 m design Phi 270° 13.35 Fraunhofer Institut coating Angewandte Optik 300 50 100 150 200 250 350 und Feinmechanik clean radius / mm mounted for measurements at PTB room

Proc. of SPIE Vol. 8679 (2013) 867921-1

Proc. of SPIE Vol. 8679 (2013) 86790C-1

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7

42 m

### Examples: => Structure and material characterization



Traceable Spectral responsivity scale from IR to hard X-ray



8

calibrated tools => reference-free XRF



Chemically resolved structure by scattering & GIXRF

**Optical material** properties



0.08

0.07

0.06

0.05

•

β

Binary masks ./N

Ni<sub>3</sub>Al

Te

PtTe

Binary mask with

phase shift

phase

0.12

0.14



### https://www.ocdb.ptb.de

Complementing optical methods at different wavelengths:

- <u>Scatterometry</u>
- <u>Müller-Matrix ellipsometry</u>
- Innovative imaging methods -

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**EURAMET** 

### Examples of <u>cooperations</u> related to support **EURAMET** <u>Semiconductor Technologies:</u> => Length traceability Encoder Reference mirror head **Straightness** grating scale Zerodur sample carriage **3 Y-Interferometer** Long range mirror Moving slide

Length traceability by vacuum interferometry (NMC):

- Calibration of line scales, encoder systems, masks and interferometer over a range of up to 550 mm
- Displacement interferometer in vacuum (2 Pa)
- Measurement uncertainty for encoders:  $U_{95\%} = [(1 \text{ nm})^2 + (2 \cdot 10^{-9} \text{ L})^2]^{\frac{1}{2}}$

- Development of comparator in cooperation with Heidenhain
- Encoders used in prec. positioning applications



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510

507

(2016), 1, !

**CIRP Annals:** 

C. Weichert

### Examples of <u>developments</u> related to support <u>Semiconductor Technologies:</u> => Material stability & CTE



Temperature induced length relaxation at

LTE glass ceramic material samples

Precision imaging interferometer for absolute length measurements under vacuum using stabilized lasers



### Examples of <u>cooperations</u> related to support <u>Semiconductor Technologies:</u> => 3D-AFM metrology





(a) **LR-AFM** (b) G. Dai et al., 2018, MST, 29, 054012





METAS: Scanning near field microwave microscopy

Intensity of Si crystal-lattice

1000 1500 2000 2500 3000

Line profile of Si line image

x, pixel

d<sub>111</sub>=25.92 pixel

8.0<sup>°</sup> x10<sup>3</sup>

7.5

6.5

ntensity, u.a.



G. Dai et al., euspen Proc. 2022



**CD comparison with NIST** G. Dai et al., MST, 28 (2017), 6, 065010-1-065010-12

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## Examples of <u>cooperations</u> related to support <u>Semiconductor Technologies:</u> => Temperature metrology



Applications in Semiconductor Technologies:

- Rapid thermal processing (RTP): wafers heated at a rate of 200-300 °C/s above 1000 °C
- <u>Fibre-Bragg Grating thermometry</u> for very high temperature measurements: tested at a plant for silicon production at temperatures up to 1600 °C.
- <u>Automated testing equipment</u> (ATE): increased requirements and tight tolerances in MEMS/NEMS thermal testing

### <u>Photonic Thermometry</u> with Si Photonic Integrated Circuits:

- Basic Idea:

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- Direct CMOS-comp. meas. of chip temperature
- Monitoring of quantum & telecomm. applications
- Part of a future integrated Lab-on-Chip



More information: t1p.de/ptl

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### Acknowledgement

Thanks to all colleagues who provided input for this presentation, in particular those from JNP AdvManuNet and EMN for Advanced Manufacturing

=> <u>https://www.euramet.org/european-metrology-networks/advanced-manufacturing/</u>
=> <u>advancemanu@euramet.org</u>

Metrology Network

### Thank you for your attention!

Mock-up of EMN website

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