

Scotland's Critical Technologies Supercluster

Scottish Government

Suresh Kumar

Deputy Director for Innovation and Industrial Transformation





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Suresh Kumar, Deputy Director, Industrial Transformation

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Semiconductors



Scotland has the most diverse semiconductor cluster in the UK

- Semiconductors have been manufactured in Scotland for over 50 years. Today, compound & analog semiconductors are fabricated in Scotland for global markets.
- Varied supply chain in Scotland (wafers, equipment, design software) serving Europe.
- Strong analogue and mixed signal design community in Edinburgh.
- Groundbreaking academic research producing innovative spin-outs.



Diodes 200mm silicon digital, analogue and mixed signal wafer fab in Greenock, employing 300 staff

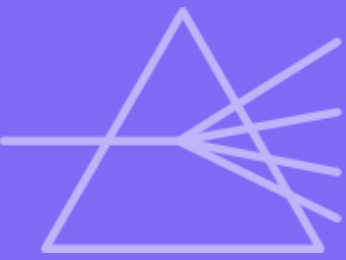


Billions of smartphones use components developed in Scotland for auto-focus, music and cryptography.



Semiconductor companies in Scotland





Photonics & Quantum

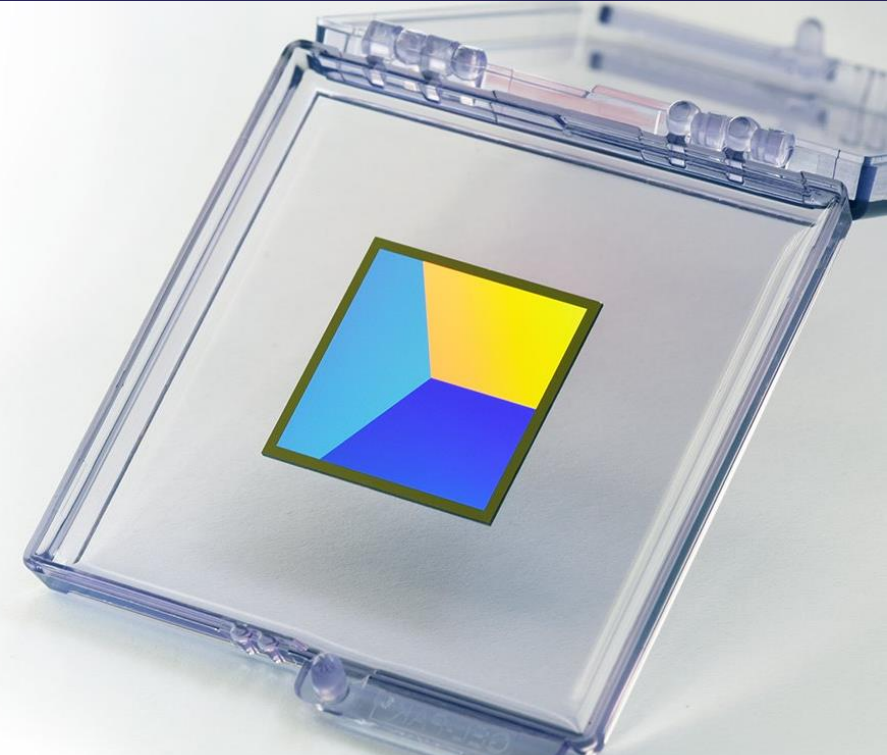


Scotland is home to a world class cluster in photonics:

- £1.5bn industry.
- Supporting 7,500 highly skilled jobs.
- Photonics Scotland

Scotland has an ambition to create a billion-dollar quantum industry:

- 2 of the 5 UK National Quantum Hubs are led from Scotland (Scottish institutions active in all 5).
- World leading capabilities in quantum component/device development and manufacture.
- Greater Glasgow quantum cluster ranked 5th in the world due collaboration and brokerage capability.



**Magneto Optical Trap Grating
Manufactured by KNT**

Developed by KNT, NPL, University of Strathclyde,
University of Glasgow and Imperial College

Research and Development



Five high-ranking research
universities working across the
Critical Technologies

Several Research and Technology
Organisations *e.g.*, Fraunhofer Centre
for Applied Photonics

Five nanotech / semiconductor
research fabs

R&D grants available from UK and
Scottish governments

Critical Technologies Supercluster



**>160
Companies**

**£4.5bn
Income**

**£3.4bn
Exports**

**11,500
employees**

**£339m
R&D
Investment**

**GVA /
Employee
3* National
Average**



Our mission

Exploit Scotland's existing strengths and synergies across critical technologies to achieve **£10 billion** turnover by 2035, creating **7,200** additional high-quality jobs

Thank you



Scottish Government
Riaghaltas na h-Alba
gov.scot



How NPL Supports the UK and Global Semiconductor Ecosystem

National Physical Laboratory

Professor Fernando Castro, FInstP
FIMMM,

**Department Head of Science -
Materials and Semiconductors, NPL
Fellow**



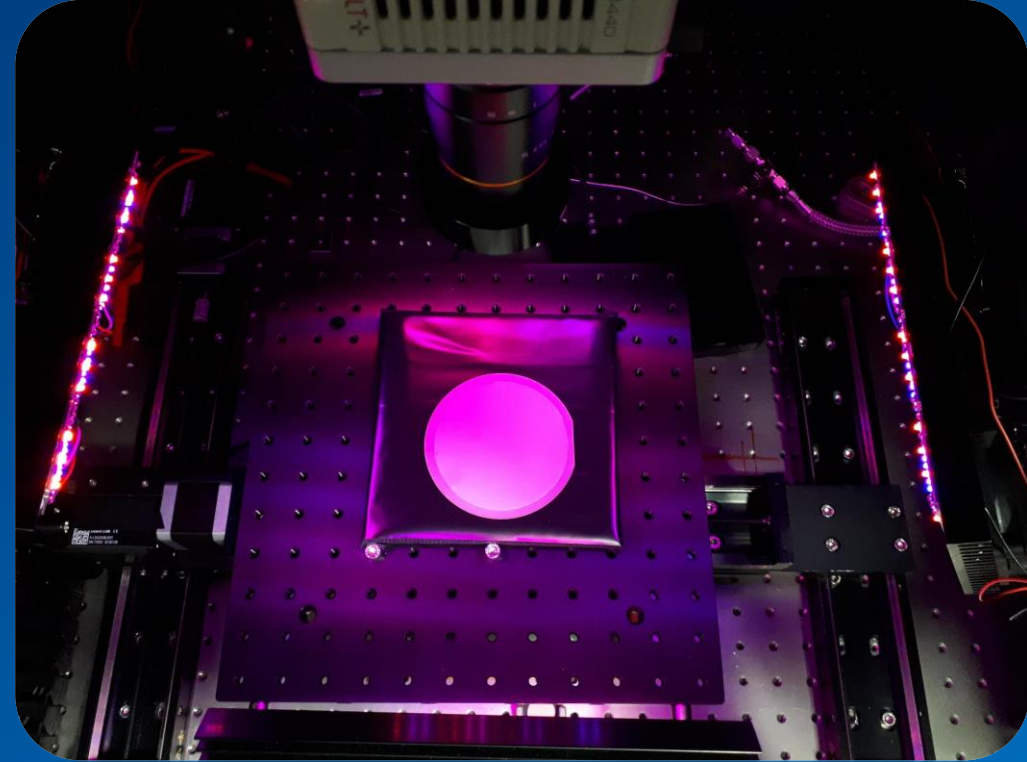
Metrology to support innovation and global trade of Semiconductors

Prof Fernando Castro

Dept Head of Science (NPL)

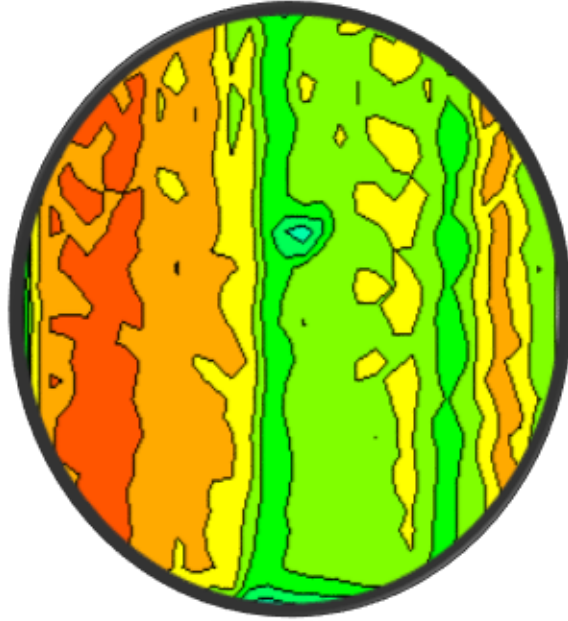
Chair - European Metrology Network on Advanced Manufacturing (Euramet)

Chair – Versailles Project on Advanced Materials and Standards (VAMAS)

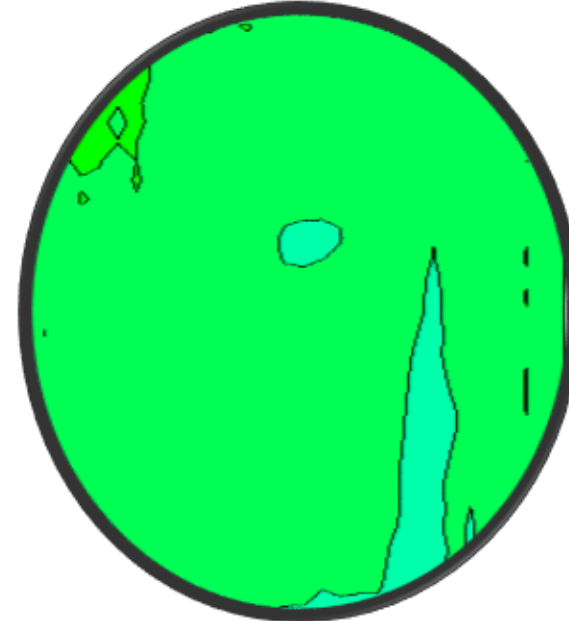


Trust in measurement is critical

Bad process?



Good process?



Two spatial maps above are from the same semiconductor device!!!

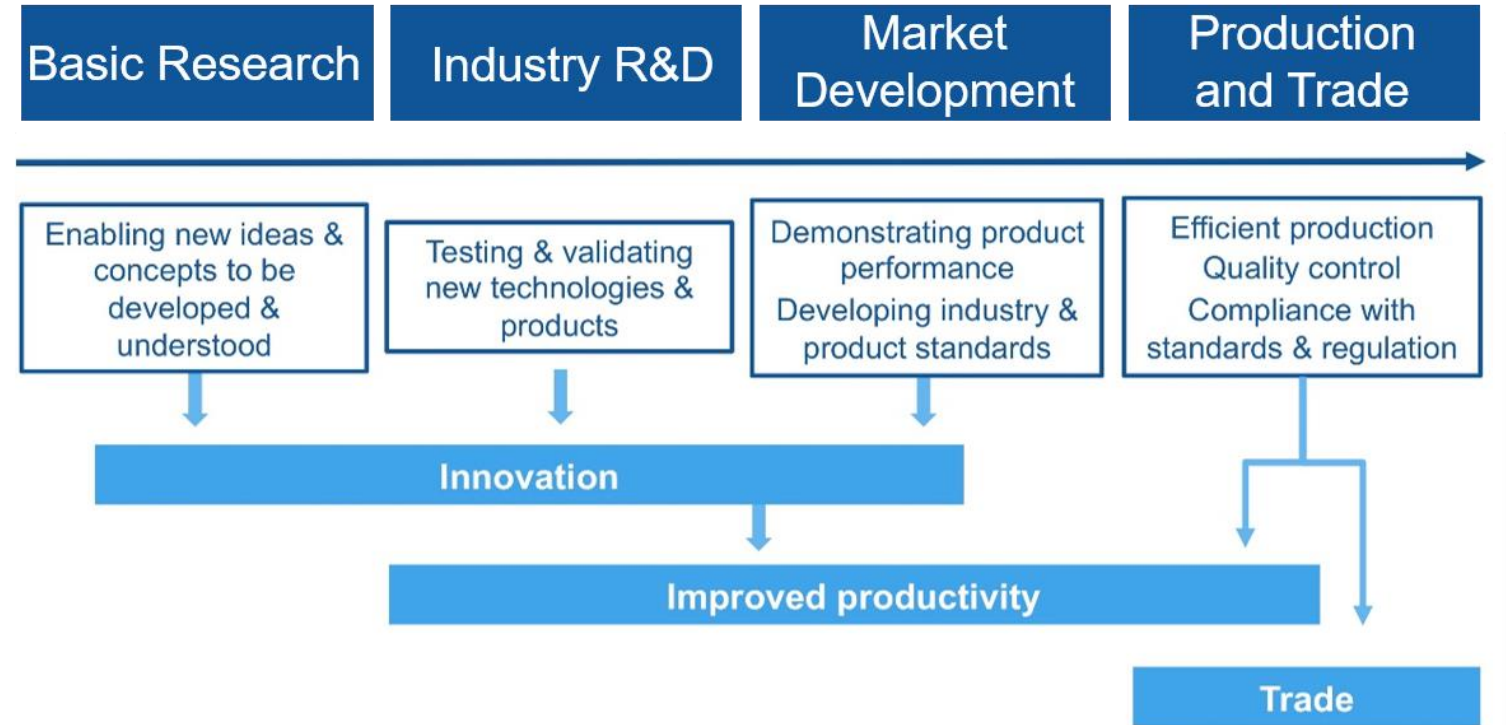
Only 1 measurement parameter was different

Which map is correct?



Metrology provides confidence to **NPL**

accelerate innovation and support trade



Reliable and reproducible measurements and inspection provide trust between research partners, within industry and across supply chains

National Physical Laboratory

126 Years providing confidence in measurements



 A **National Laboratory** and the UK's **National Metrology Institute (NMI)** founded in 1900

 Provides the measurement capability that underpins UK prosperity and quality of life

 Public Corporation and Public Sector Research Establishment owned by BIST

 1400+ staff
200+ visiting researchers

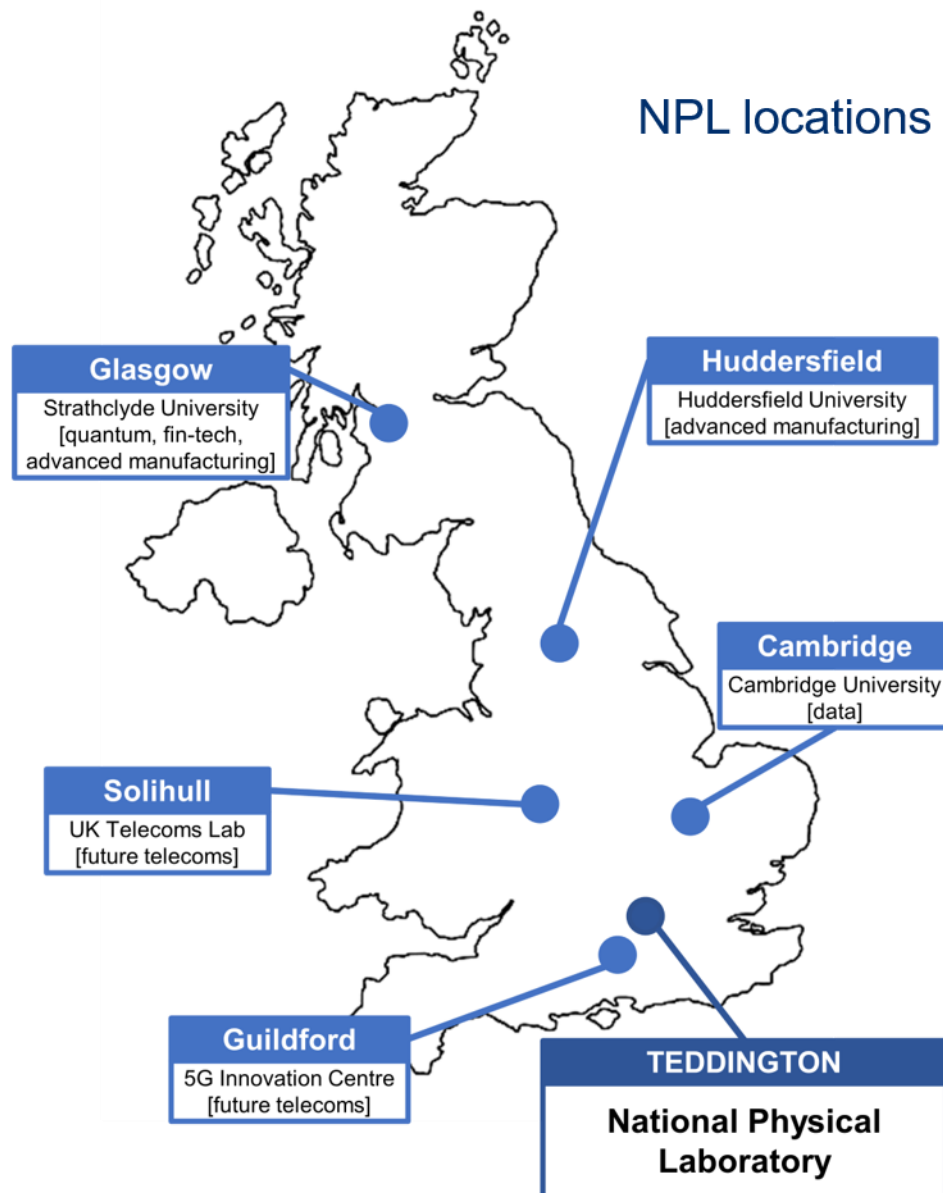
 Provide independent & impartial advice to government, the public and private sector

 World-leading breadth & depth of science, engineering & metrology expertise



What we do

NPL locations



Excellent Science

- ☐ Highest point of reference
- ☐ Unique facilities



National Challenges

- ☐ Accelerating R&D and innovation
- ☐ Improving quality of life
- ☐ Enabling trade

International Leadership

- ☐ International representation
- ☐ Foresighting
- ☐ Future metrology challenges



Impact from science (examples)

Commercial advantage

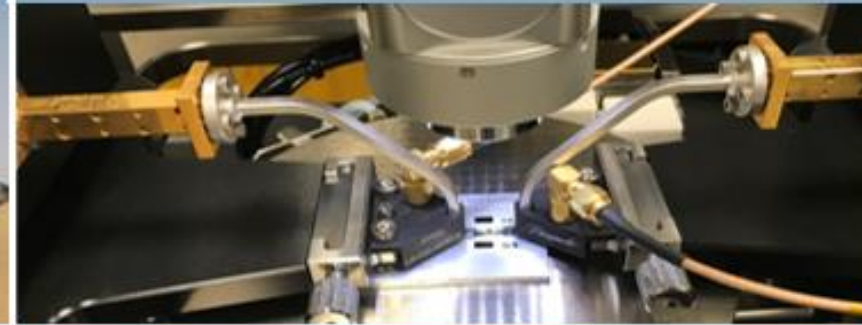
Accurate performance of solar tech is critical to ensure investability and deployment of new technologies



NPL's expertise and novel methods helped Rina UK assess financial risks of new solar tech and deliver deployments worth >£100M +

Faster Innovation

Advanced semiconductor circuits operate at increasing frequencies.



NPL on-wafer test facility and expertise saves money and helps innovation. Working with NPL, Filtronic accelerated development of new product lines.

Develop Skills

Every aero-engine requires hundreds of thousands of exacting measurements and use over 200,000 measurement devices



Rolls-Royce has trained over 1,500 of its staff in NPL Measurement training and works closely with the NMS to implement best practice

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Impact for UK Industry



Impact case studies



1,000+ businesses directly supported every year



75,000+ businesses indirectly supported every year



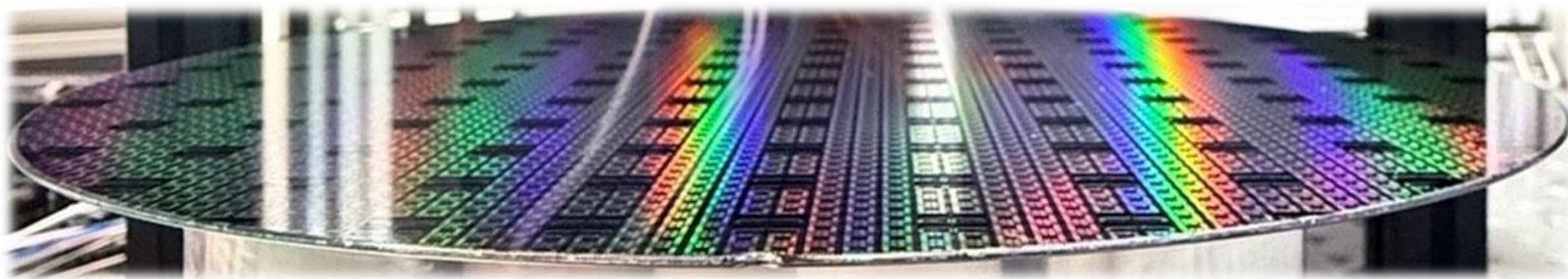
400+ businesses “regularly supported” every year



Regularly supported firms attribute to NPL:
an extra 6.3 employees annually
a wage premium of £4,080 for each new employee
Total benefit to the UK economy >£340m pa

<https://www.npl.co.uk/case-studies>

Metrology for Semiconductors

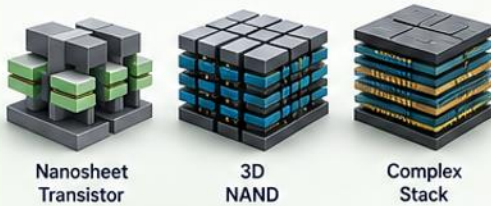


Converging trends driving next generation semiconductor innovation

1 COMPLEX DEVICE ARCHITECTURES

Pushing the limits of scaling and performance

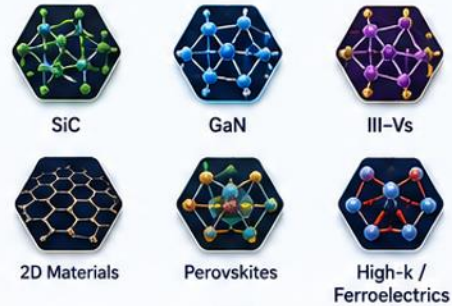
GAA / Nanosheets • 3D Devices
Complex Stacks



2 ADVANCED MATERIALS

Expanding the performance envelope beyond silicon

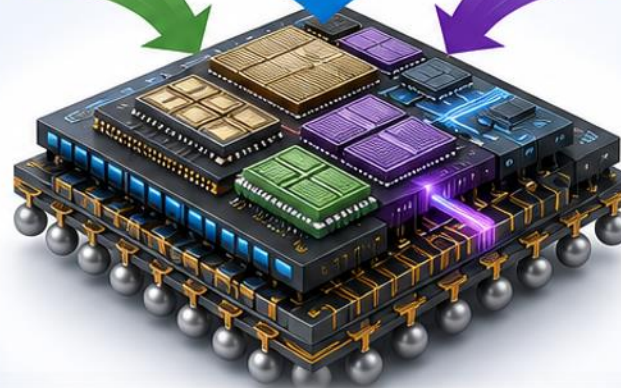
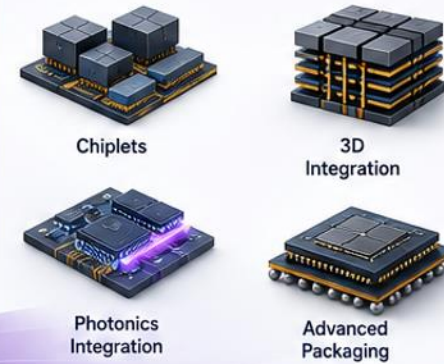
SiC • GaN • III-Vs • 2D Materials
Perovskites • High-k / Ferroelectrics



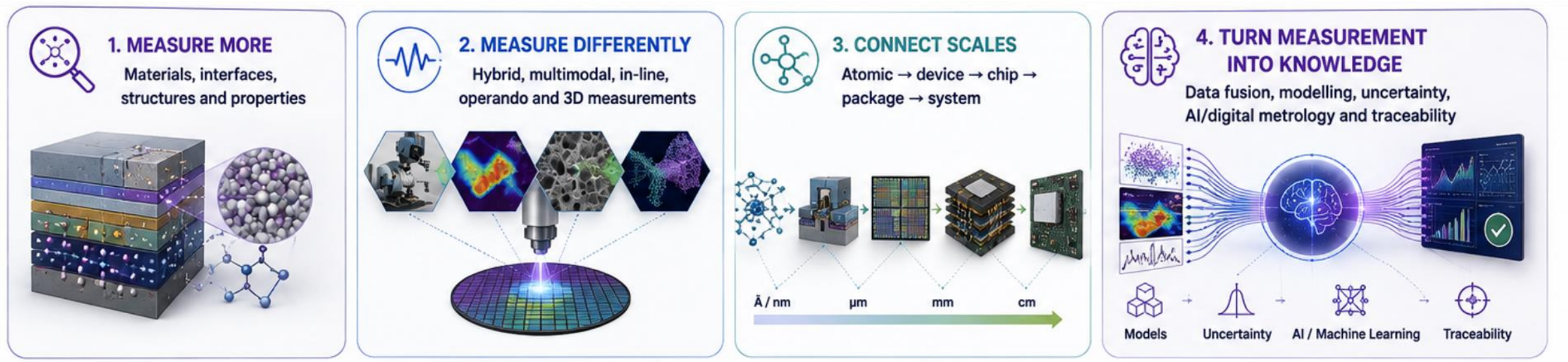
3 HETEROGENEOUS INTEGRATION

Bringing diverse functions together in new ways

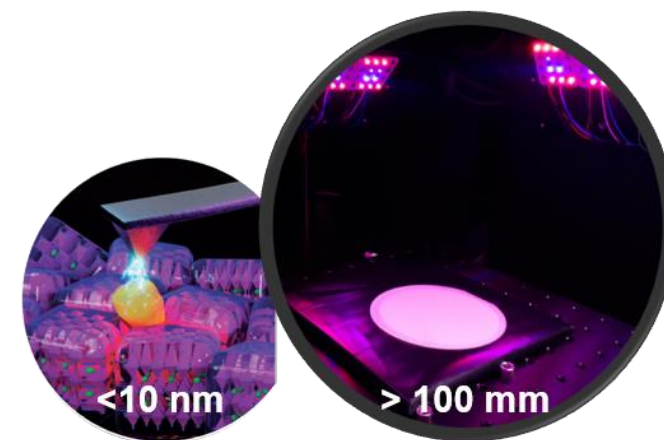
Chiplets • 3D Integration
Photonics • Advanced Packaging



Trends in semiconductor metrology



- ❑ Nanoscale-to-wafer scale metrology for materials & devices
- ❑ Digital metrology for semiconductor manufacture
- ❑ In process monitoring and hybrid metrology
- ❑ Defect and failure analysis
- ❑ Metrology for emerging materials and structures (3D Nanostructures, 2D materials, organic/hybrid, ultra-wide bandgap...)



Metrology is a critical enabler for innovation



UK priorities to drive innovation and growth

- Extensive consultation with >500 experts over 3 years.
- UK workshops & roadshow with Industry and Academia

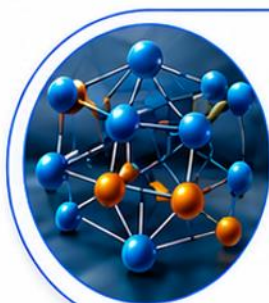


- International engagement and workshops with semiconductor experts across 30 meetings in 12 countries



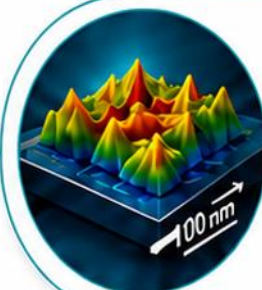
npl.co.uk/research/semiconductor-metrology

NPL semiconductor metrology



MATERIALS & SURFACES

- Composition & chemistry
- Interfaces & thin films
- Contamination & depth profiling



NANOSCALE PROPERTIES

- Structure & dimensions
- Nano positioning calibration
- Advanced multimode SPM



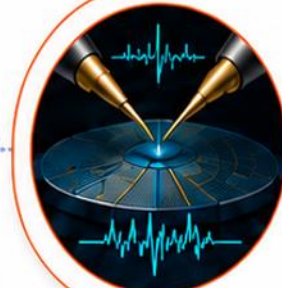
ELECTRICAL & ELECTRONIC

- I-V & electrical transport
- Carrier concentration & mobility
- Cryogenic measurements



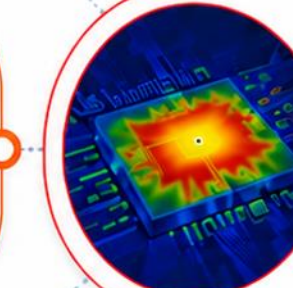
OPTICAL & PHOTONIC

- Spectral response
- Raman / Photoluminescence
- Detectors, emitters & photonics



RF, mm-WAVE & THz

- On-wafer measurements
- S-parameters & impedance
- Power, gain, phase & noise
up to 750 GHz



THERMAL & RELIABILITY

- Temperature & thermal mapping
- Interconnect reliability
- Accelerated aging & failure analysis

Hybrid and Digital Metrology

THE NPL METROLOGY FOUNDATION



TRACEABILITY

Linked to national & international standards



UNCERTAINTY

Quantified & transparent measurement confidence



REFERENCE METHODS & MATERIALS

Validated methods and reference standards



INTERLABORATORY COMPARISONS

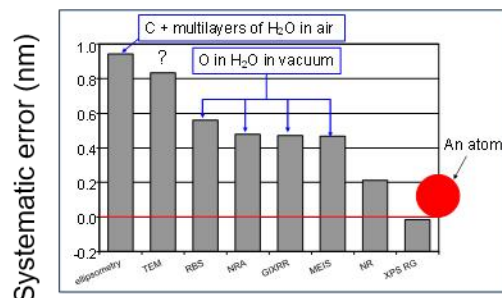
Global equivalence & measurement capability



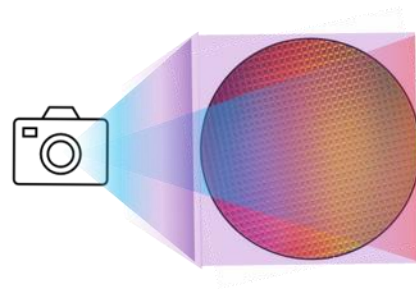
STANDARDS & IMPACT

Enabling innovation, trade & societal benefit

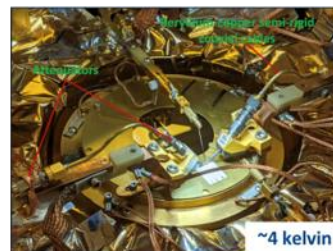
A few examples of NPL's capability in semiconductors



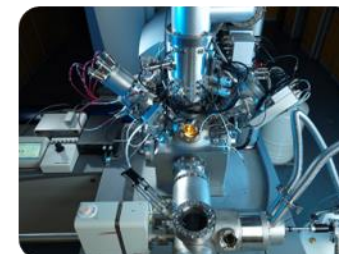
Film thickness and composition, including at subsurface



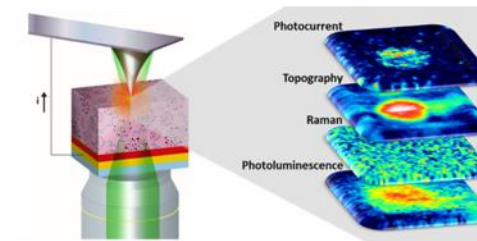
Fast spectral PL imaging technology (patented tech)



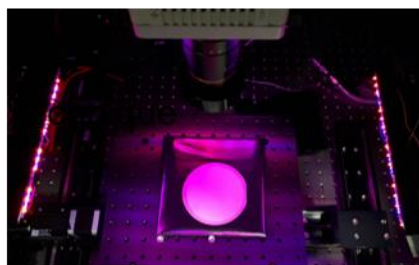
Cryogenic electronic measurements for quantum circuits



Chemical depth-profiling, film thickness and composition



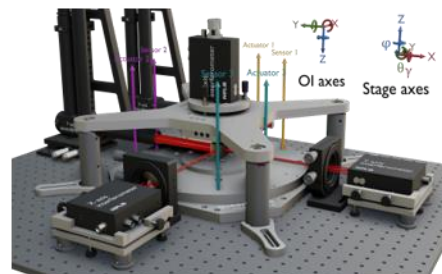
Advanced scanning probe and high speed AFM



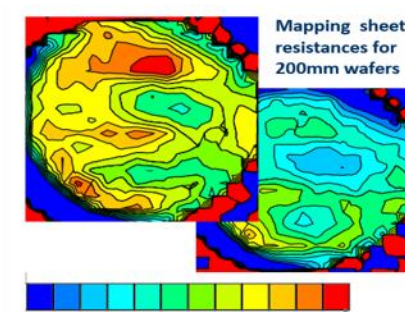
UV photoluminescence imaging - wafer scale compound semicon.



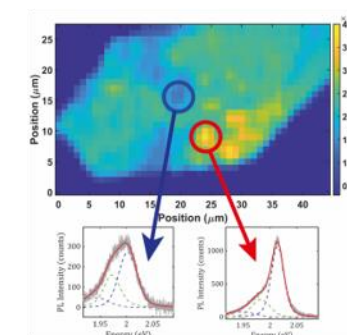
RF on-wafer measurement (750 GHz in ambient, 40 GHz cryogenic)



Validating wafer stage positioning technology



Contactless conductivity and sheet resistance (patented tech)



Quality assessment of 2D semiconductors

A few examples of recent NPL's UK collaborations



Novel Power Materials

SiC and diamond. Etching, polishing and material quality.



Material property measurement



SiC Device Reliability

High voltage testing of SiC MOSFET for automotive reliability standards.



Swansea University
Prifysgol Abertawe



Device reliability standards



RF Performance

GaAs/GaN RF module performance testing for high-speed satellite comms



Next-generation device performance testing



Novel Photovoltaic Materials

Wide-angle and low-light response for perovskite photovoltaics



Optoelectronic Quality Control

MicroLED spectral emission measurements for passivation process improvement



UNIVERSITY OF CAMBRIDGE



Process metrology and in-line inspection



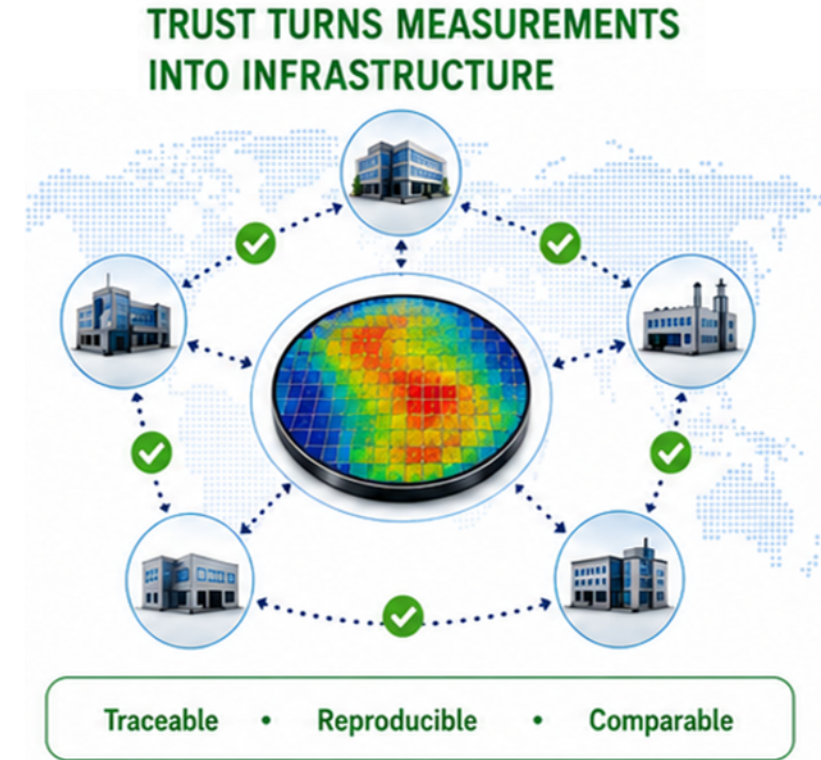
International Collaboration Opportunities



- ❑ Validate methods for emerging semiconductor technologies
- ❑ Engage in setting standards
- ❑ Build global collaborations

NPL currently leads

- ❑ VAMAS – global pre-standards organisation
- ❑ Chair of BSI Committee on Standards for Semiconductors
- ❑ UK Experts in IEC, ISO and many other standards committees
- ❑ Chair - European Metrology Network on Advanced Manufacturing



**New VAMAS Technical Working Area (TWA 46)
on Semiconductors recently launched
Project opportunities available**

For information contact www.vamas.org info@vamas.org



**UK-Taiwan semiconductor
metrology program**

Collaboration opportunities
Contact: fernando.castro@npl.co.uk

Final remarks

NPL supports academia and businesses through:

- Advanced measurement science
- Testing, characterisation and validation services
- Standards development and quality assurance
- Reliability testing and performance verification
- Access to specialist expertise and facilities
- National and Global networks





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Thank you!

Register to our Global
Innovation network and join
our community

