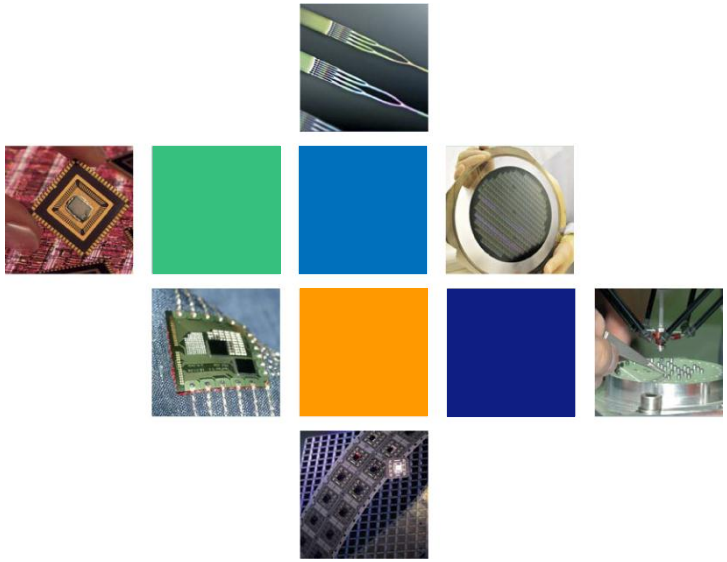
8th esa round table on micro and nano technologies
15 - 18 october 2012
European Space Agency

The HTA Reliability Platform



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csem cea leti liten VTT Fraunhofer MIKROELEKTRONIK

Heterogeneous Technology Alliance

What is the HTA: Joint Forces in Microtechnology

Division Recherche Technologique

Grenoble

Empl. 1’400

Turnover : 240 M€

Clean room : 8’000 m²

Espoo, Oulu

Empl. 400

Turnover : 60 M€

Clean room : 2450 m²

Dresden, Berlin, München

Empl. 2’800

Turnover :305 M€

Clean room : 8450 m²

Neuchâtel

Empl. 350

Turnover: 35 M€

Clean room : 1200 m²

Enhanced Cooperation Agreement signed in 2008.

Why?

- Because products are more **complex and diversified;** no single organisation can afford all technologies needed.
- Because market / product needs are and will remain **fragmented**.
- Because value chains, from material to services are more and more **long** and **specialised**; such value chain cannot be maintained without ad-hoc products**.**

HTA – The Mission

The mission of the comprehensive HTA alliance is **to ensure competitiveness of European industry through cutting-edge research and technology transfer services**.

This will be done by:

- Developing **innovative solutions and products** for industry
- Developing key enabling technologies in **microtechnologies, nanoelectronics and smart systems**
- Developing **infrastructure in coordination and collaboration** for research, piloting and small scale production

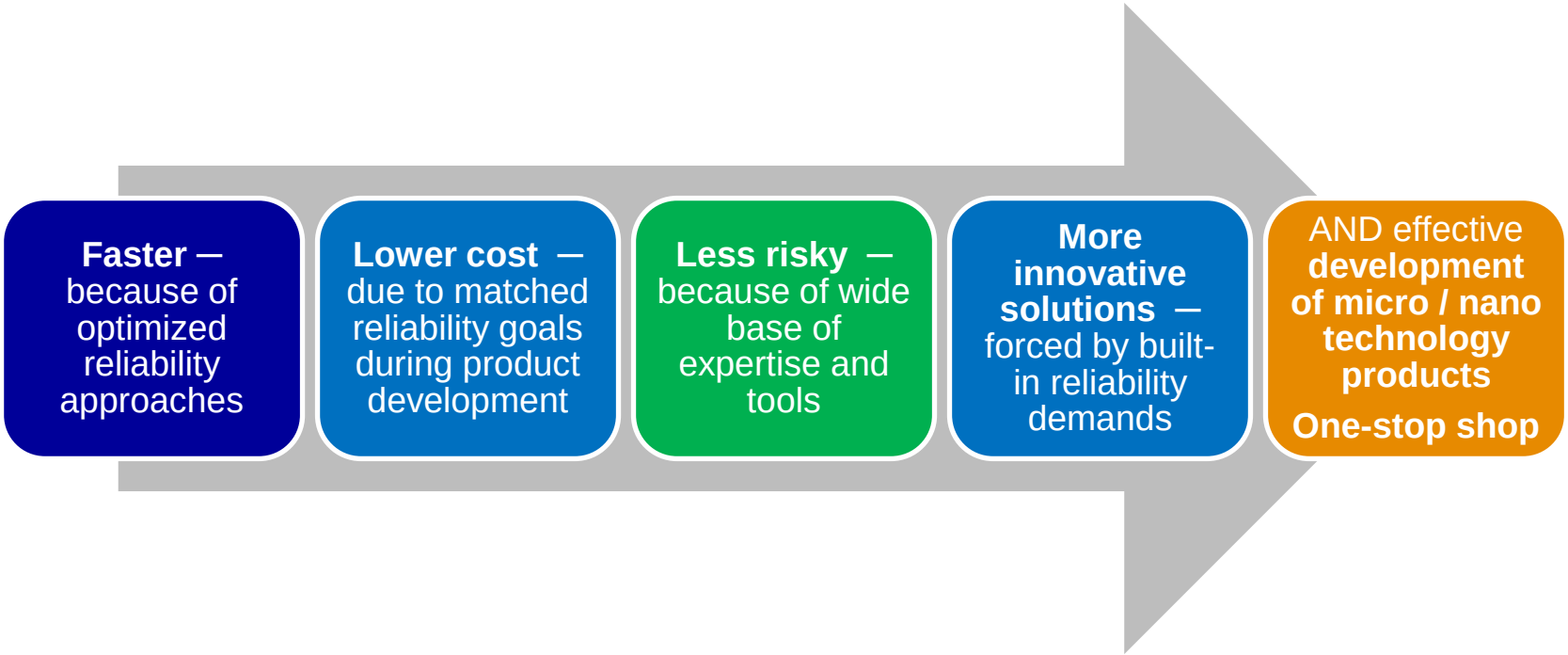
HTA – The Tools

Operational tools

- Technology mapping: what we have
- Roadmaps: the environment
- Flagships: speed up commercialisation
- Platforms: the common force

HTA Reliability Platform

Added value of to customers:



Attractive offering of HTA Reliability Platform
One-stop shop

1	**Merger of key reliability labs** integrated in different R&D environments
2	Can provide complex **reliability analyses and failure avoidance strategies**
3	**Incorporates whole value chain** to achieve product reliability
4	Striving for **reliability on structure, component and system level**
5	Large set of **standard and unique equipment** for reliability analyses
6	Comprises **simulation, reliability assessment, testing, standardization**

Reliability Platform

VISION

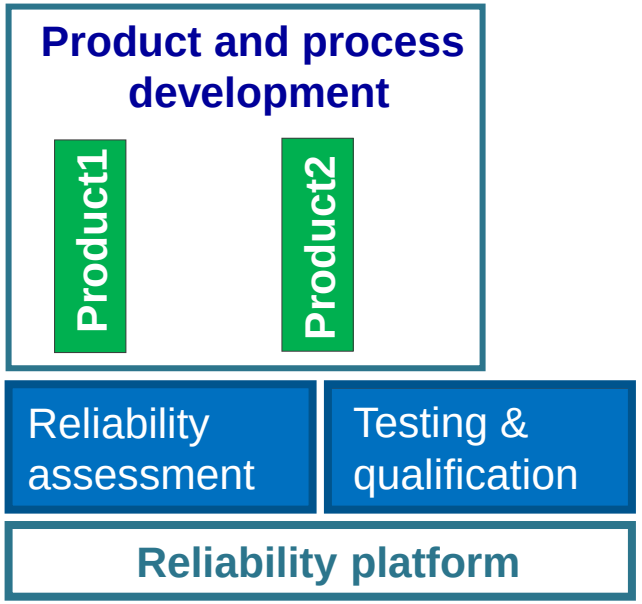
- HTA offers leading reliability platform for process and product development, aiming at **understanding of failure mechanisms and failure avoidance**, testing and health monitoring of devices

MISSION

- Makes the **large arsenal of tools available for customers** and all HTA partners
- Chaining of quite **different reliability methods and expertises**
- **Strengthening European products** by Made-in-Europe Quality
- Helping R&D engineers to select **and link most efficient methods and equipment for reliability driven purposes**

Platform purpose and definition

- **Platform purpose**
  - To accompany all product development steps by appropriate reliability measures
  - **Making the right choice among a variety of analysis and testing methods at HTA labs**
  - Linking HTA partners to an efficient team
- **Definition**
  - Platform composes reliability predictions methods and respective equipment
  - Platform provides accelerated testing including component / system qualification
  - **Platform partners support qualification of testing procedures and respective standardization**



Competences - I

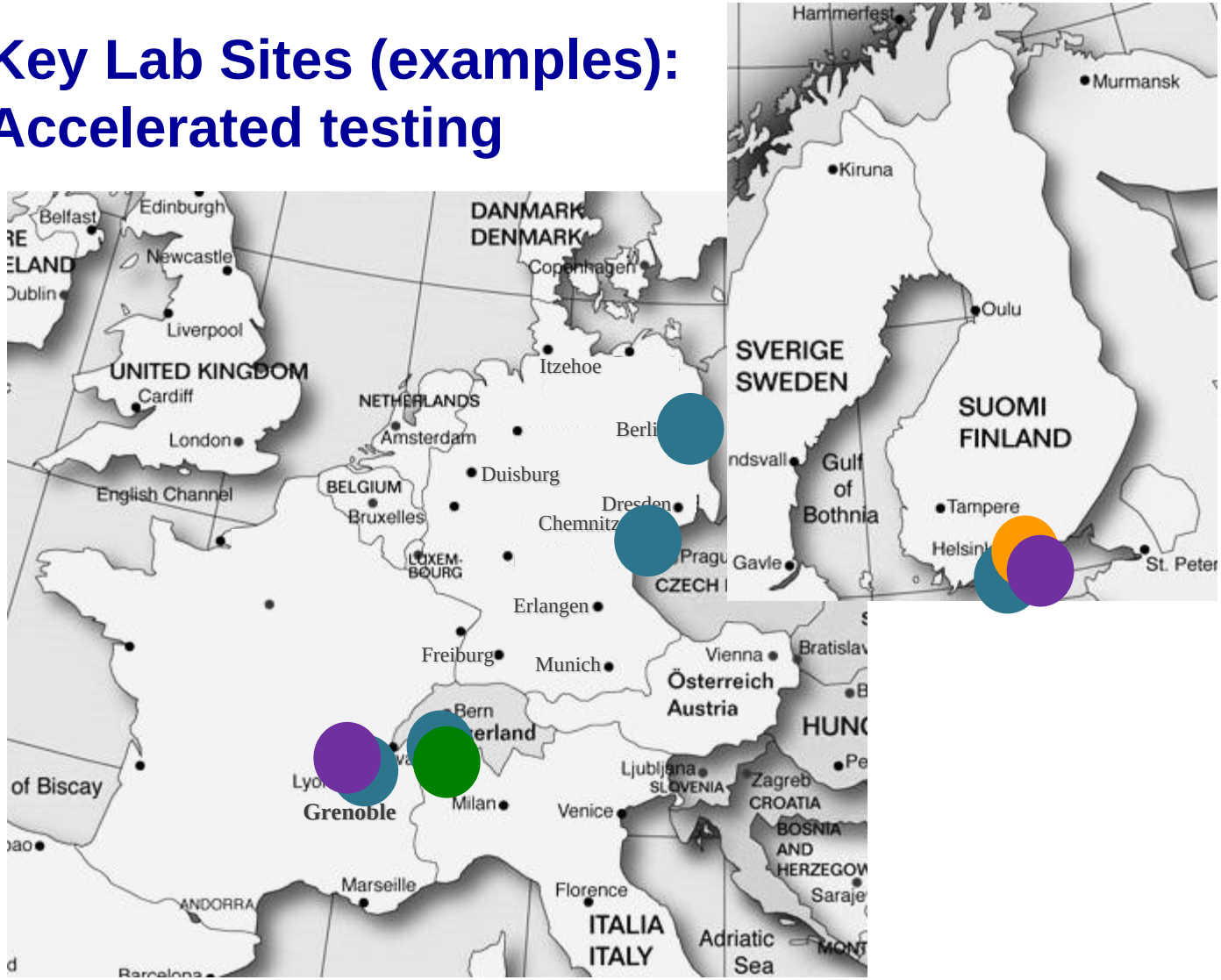
Methods / Approaches	CEA-LETI	CSEM	FhG	VTT
Accelerated Testing	X	X	XX	X
Failure Detection, Failure Analysis / Failure Mechanisms	XX	XX	X	X
Finite Element Analysis (FEA), Design of Experiment (DoE) for FEA	X	XX	XX	XX
Material characterization / Material Properties	XX	XX	X	X
Mechanics of failure initiation & propagation (fracture mechanics, fatigue, damage mechanics, …)	X	XX	XX	
Stress/strain measurements	X	XX	XX	
Nanoanalytics (FIB preparation, defect detection, component characterization, …)	XX	X	X	X

Competences - II

Methods / Approaches	CEA-LETI	CSEM	FhG	VTT
Hermeticity testing	XX	X	XX	X
Impact of radiation on MEMS		X		
Charging effects on MEMS	X			X
Electrical Testing (full wafer, automated)	XX			XX
Electrical Testing (single device)	XX	X	XX	XX
Cryogenic testing (single devices, modules)				XX

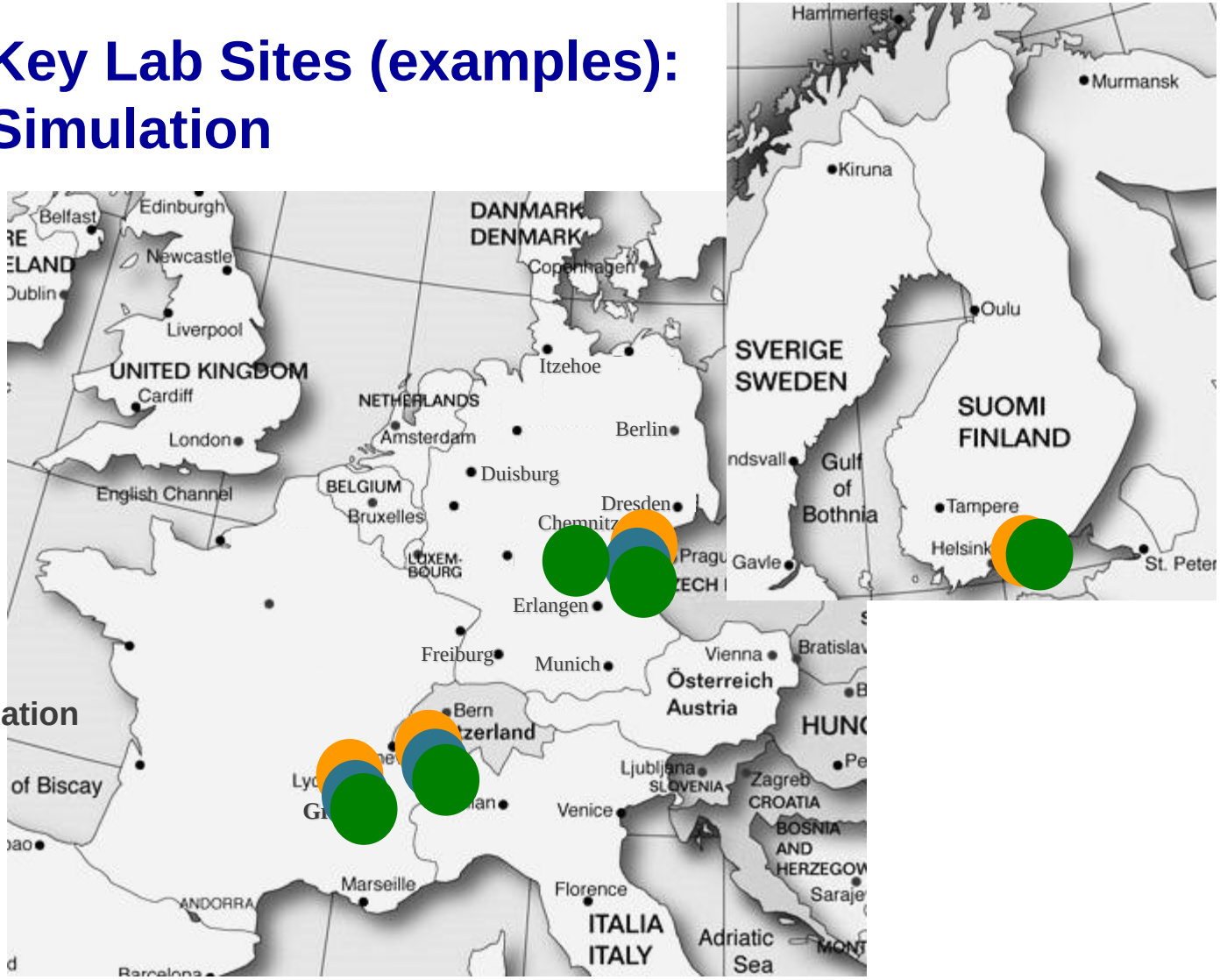
Key Lab Sites (examples): Accelerated testing

- Cryogenic Testing
- Mechanical Testing
- Radiation Testing
- Charging Effects

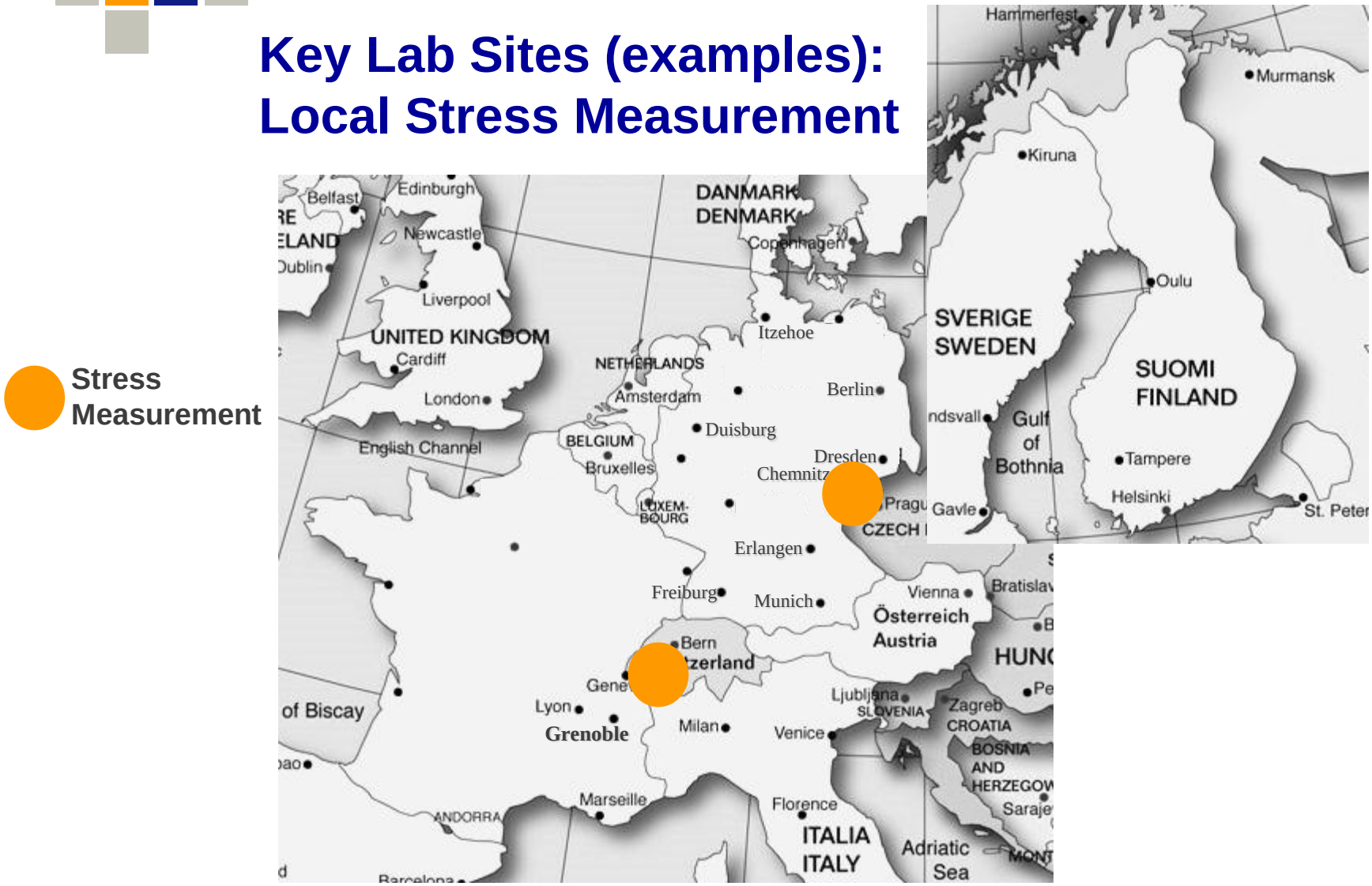


Key Lab Sites (examples): Simulation

- Finite Element Analysis
- Mechanical Failure Modeling
- Material Characterization



Key Lab Sites (examples): Local Stress Measurement



HTA Complete Offer

Built-in reliability solutions

Reliability Platform

- Life Time Assessment
  - IC, MEMS
  - RF
  - Power
  - System
- Failure Modeling
- Failure Mechanisms

- Electrical and Mechanical Testing
- Hermeticity
- Analytics
- Material and functional device charact.

- Layout optimization
- Material selection
- Process Windows
- Design Rules
- Applications

- HTA complete offer covers all key competencies to create solutions for our customers
- Key mission of HTA is to enable reliable integration and combination of different micro- and nanotechnologies
- Reliability Platform managers offer a communication channel between the partners

CSEM Contribution to Reliability Platform

Competitive edge

- Development and small series production for reliable MEMS and packaging applications (fabrication on 100, 150mm wafers)
- **ISO9001:2008 certified quality control laboratory**
- In-house developments of **unique tools and techniques for in-situ characterizations**
- Combined structural and mechanical testing for **materials fatigue studies through defect and strain analysis**
- Extended equipment for material and device characterization (100, 150, 200 mm wafers)
- Simulations for the study of failure mechanisms
- Experienced, well-trained personnel
- **R&D contract experience with SME's in development projects and small series production** support
- World-class partners through HTA and ESA projects

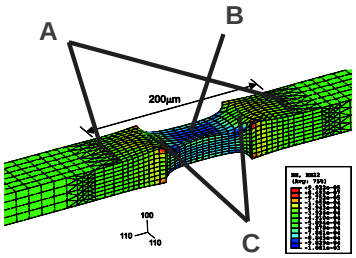
Technical description

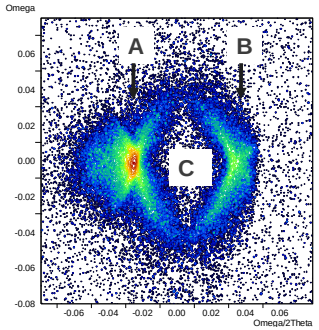
- **In-situ structural characterization of materials and systems using HRXRD**
  - **Defect and strain analysis combined with mechanical testing** such as tensile and bending and deformation of flexible Si-based structures and MEMS)
  - Aging analysis
- In-situ characterizations using XRD
  - Coupled with HT $\leq$ 1600°C in O_2, N_2, Ar, He
  - Coupled with humidity (definition of T and level of humidity, cycling).
- Morphology characterization
  - ESEM, FIB, SEM, TEM
- **Determination of mechanical materials properties**
  - Scratch test, nanoindentation
- Finite Element Analysis
  - Device and packaging stresses
- Standard Accelerated aging tests
  - Thermal cycling, thermal shock

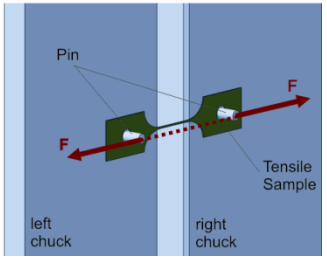
CSEM Examples

Combined structural and mechanical testing using HRXRD: defects, strain and deformation analysis during mechanical load.

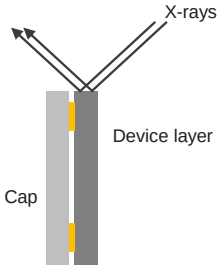
FEA + Characterization by HRXRD + Testing

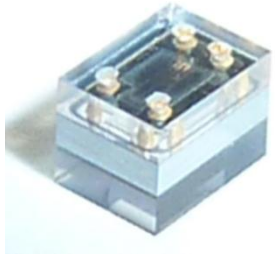


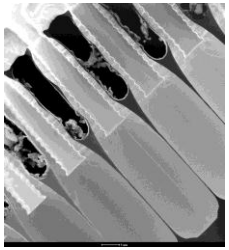




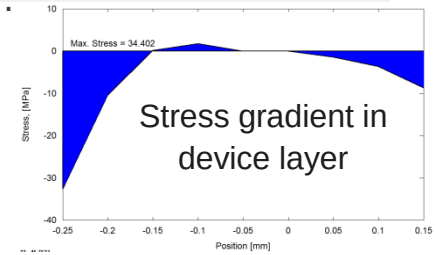
Packaging support: defect and strain gradients combined with functional testing in aging analysis.

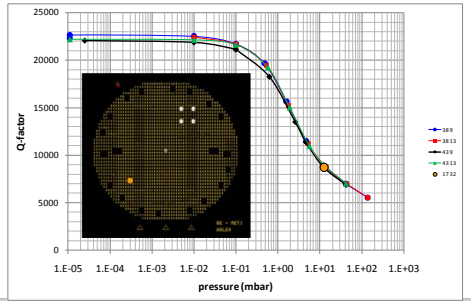


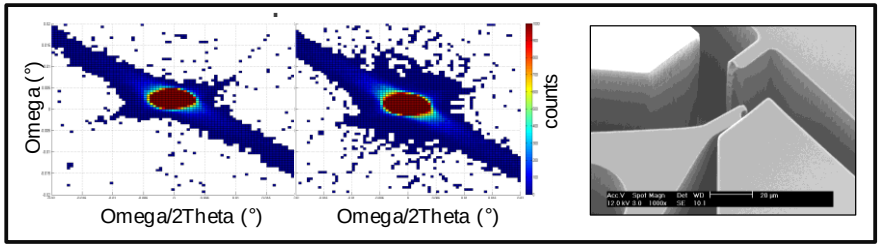




Defect analysis on MEMS related to MEMS fabrication, MEMS operation, device irradiation (radiation damage in space). Accelerated aging studies.







CEA Leti Contribution to Reliability Platform

Competitive edge

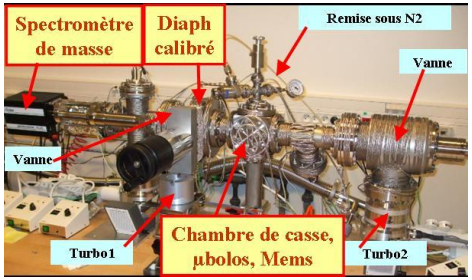
- 200 mm MEMS/NEMS fabrication line ➔ bare/packaged devices testing & statistical sampling
- MEMS & NEMS Characterization Expertise : BAW, SAW, RF switches, resonators, gyros, pressure & magnetic sensors, packaging…
- **3D integration reliability**: materials, TSV, micro-inserts…
- Combined failure mechanisms approach
- **Thermo-mechanical & structural simulation**
- Extended equipment for material and device characterization (200-300 mm wafers)
- **Accelerated testing, combined multi-physics testing**
- **R&D partnerships with CMOS/MEMS industry**
- World-class partners through HTA and EU projects

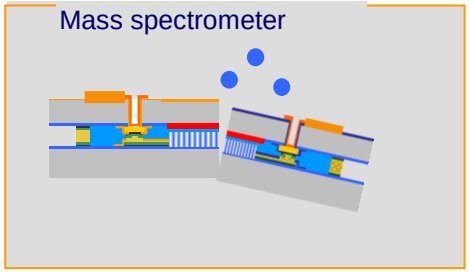
Technical description

- Material and thin layers mechanical/surface properties
  - Nanoindentation
  - AFM
- **Dynamic mechanical measurement techniques**
  - Scanning Laser Interferometry coupled with vacuum prober
- Simulation: (Solid Works, ANSYS)
  - Micro-nano Electrical Contact
  - Electromigration
  - Dielectric charging
  - Multi-layers material properties
- **Magnetic MEMS devices**
  - Kerr Effect
- Packaging hermeticity
  - Residual Gas Analysis
- Morphological characterisation
  - FIB, SEM, TEM…
- **200 mm compatible vacuum probe station** with home-made software for statistical data treatment
- **Standard accelerated ageing tests**
  - accelerated electrical cycling test bench
  - thermal cycling, thermal shock, moisture
  - combined pressure (250 b) and temperature tests

CEA-LETI: examples

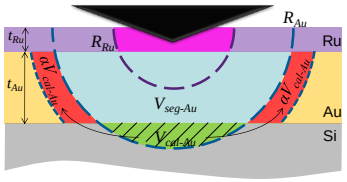
• Residual Gas Analysis for packaging reliability assessment

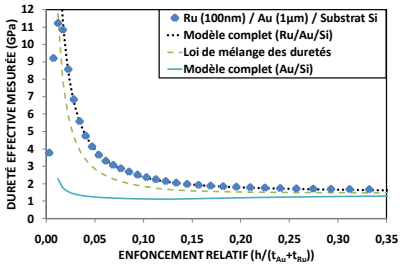


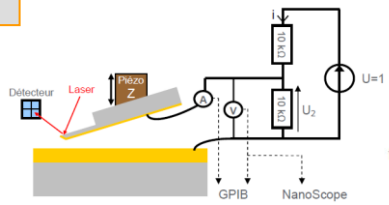


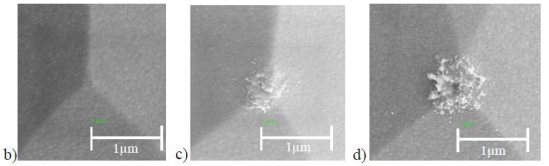
Resolution 10^{-14} moles ⇔ 10^{-3} mbar in a 0.1 mm^3 mems cavity

• Electrical contact reliability



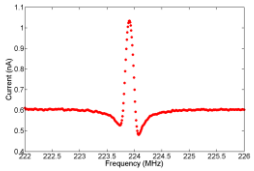




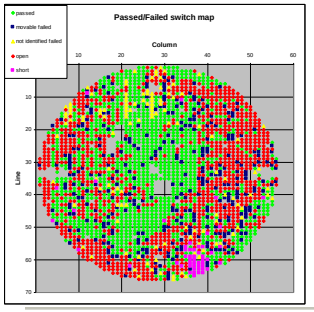


RF Switch long term reliability

• M & NEMS characterisation

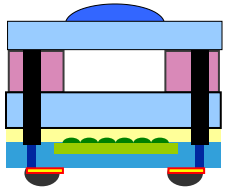


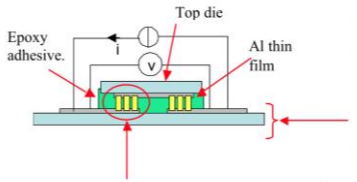
Dynamic characterisation of NEMS devices

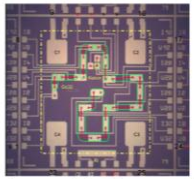


Statistical Analysis of tests results

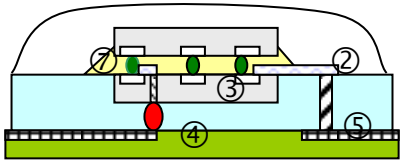
• 3D Integration reliability

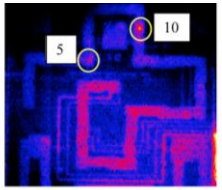






Base substrate and the 32 contacts daisy chain (green).





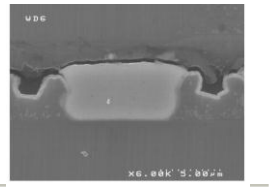


Fig. 8. Chip B7 Lockin thermography imaging (0.5 Hz / 20min / 1V; Phase image)

VTT Contribution to Reliability Platform

Competitive edge

- Long-term experience in reliability for MEMS and packaging applications
- Experienced, well-trained personnel

- **Advanced equipment for mm-wave electrical measurements (incl. cryogenic meas.)**

- **Accelerated testing**

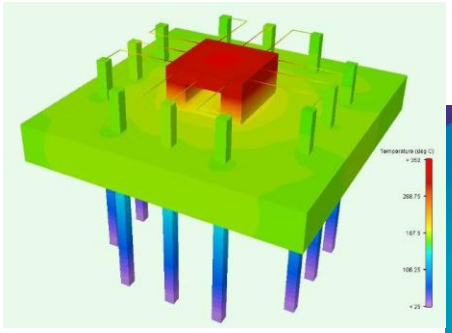
- Broad network of companies, from large end-users to SME's
- Small scale production of certain technologies (e.g. MEMS and LTCC)
- Characterization with the aid of VTT Expert Services

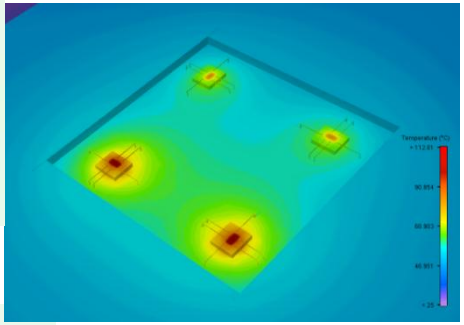
Technical description

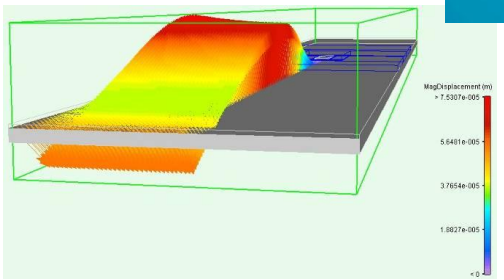
- **Finite Element Analysis**
  - Comsol, ANSYS, MATLAB, CATIA, IRON CAD
- Failure analysis and characterization
  - X-ray and infrared spectroscopy
  - SEM and SAM characterization
- **Thermal management**
  - CFD design and analysis (FloTherm)
  - Measurements with sensors, thermographic camera, semiconductor junction temperature (T3Ster)
  - Thermal resistance (structure function) of devices with semiconductor heat source (T3Ster).
- **Mechanical testing**
  - Thermal cycling and humidity
  - Hermeticity testing (gross leak and He fine-leak testing)
  - Peel testing
  - Vibration, shock,
- **Electrical testing**
  - Scattering parameters and noise figures (on-wafer)
  - Cryogenic characterization (from 20 K to room temperature, incl. vacuum measurements)
  - Electrical overstress, electrical discharge, etc.

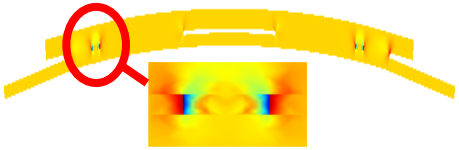
VTT Examples

FEM and CFD simulations



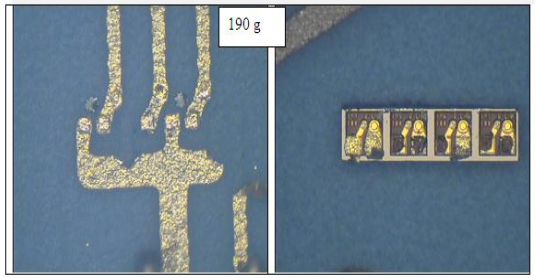




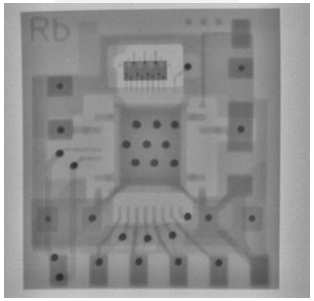


Cryogenic characterization

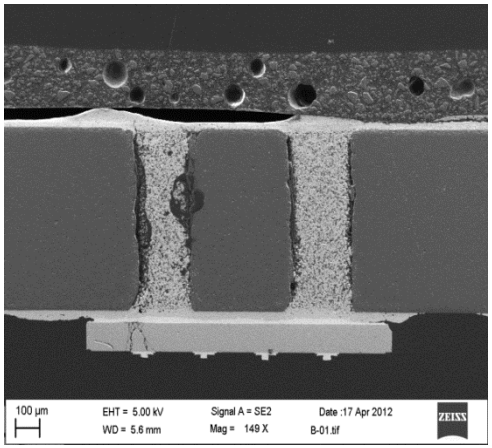
Peel testing



X-ray



Failure analysis with cross-sections and SEM



FhG Contribution to Reliability Platform

Competitive edge

- More than 25 years experience in reliability driven R&D for semiconductor devices, MEMS and packaging applications
- **Advanced simulation and failure mechanics capabilities**
- Extended equipment for material and device characterization
- In-house developments of unique tools and techniques
- Experienced, well-trained personnel
- **JEDEC and MIL STD based accelerated testing, combined testing**
- R&D contract experience with major semiconductor and MEMS manufacturer in Europe, as well as SME's
- Small scale production and medium-large scale production support
- World-class partners through HTA and EU projects

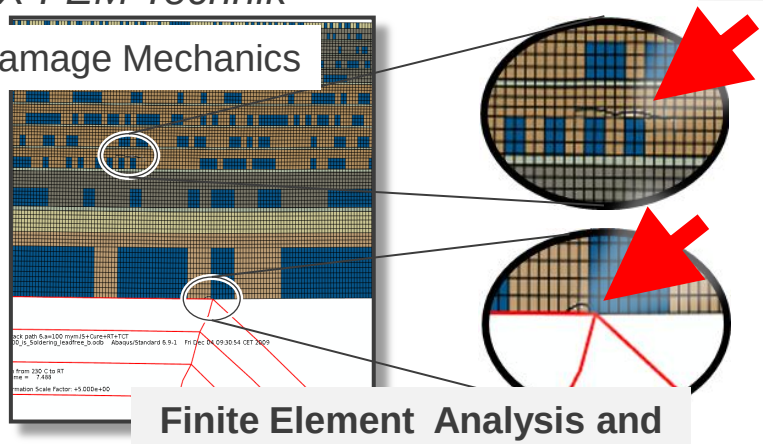
Technical description

- **Finite Element Analysis** (ANSYS, ABAQUS, optiSlang)
- **Failure mode modeling**
  - by fracture mechanics (VCCT, CZM, etc.)
  - optimization for failure behavior by Design of Experiment (DoE) approaches
  - fatigue analysis
  - damage models
- Advanced determination of thermo-mechanical material properties
  - DMA, TMA, tensile testing, TGA, DSC
  - nanoindentation
  - surface wave dispersion
- **Stress measurement techniques**
  - **fibDAC stress relief**
  - Raman stress measurement
  - EBSD based stress measurement
  - local & global bow measurement
- **Defect detection**
  - **high resolution X-ray tomography**
  - **Scanning Acoustic Microscopy**
  - Focused Ion Beam (FIB) cross sectioning
- Standard accelerated and combined load testing
  - thermal cycling, thermal shock
  - vibration loading
  - active power cycling

FhG Examples

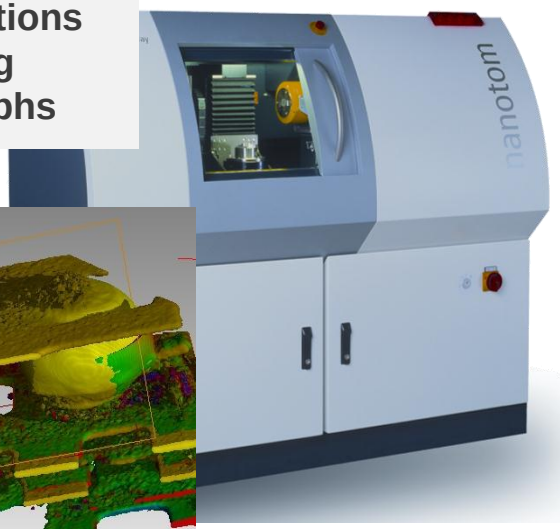
X-FEM Technik

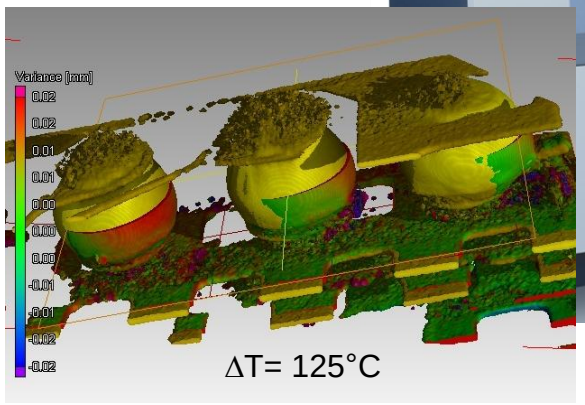
Damage Mechanics



Finite Element Analysis and Failure Modeling on BEoL structures

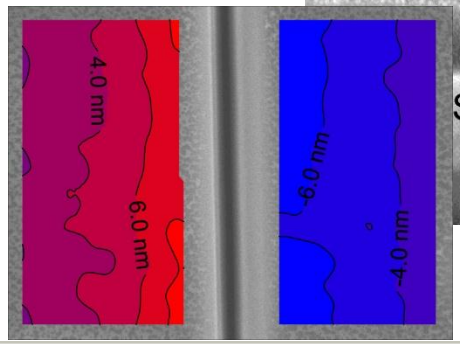
3D measurement of deformations due to thermal loading from X-ray CT micrographs

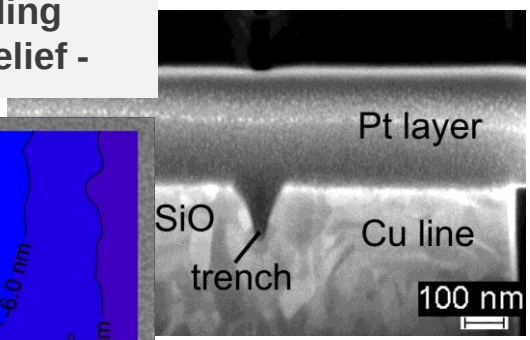




ΔT= 125°C

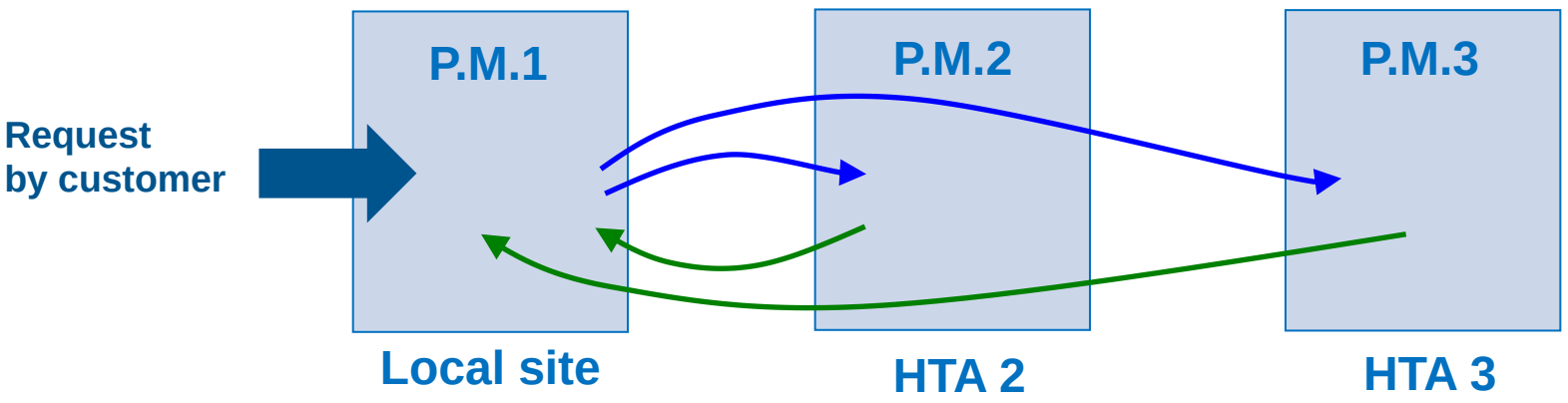
Local stress measurement by FIB ion milling - fibDAC stress relief -





Accelerated Testing with combined loads (thermal, vibration, moisture)

Operation of the Platform



HTA Expertise is: - treated in a complete confidential process
- handled in a framework of a (simple) standard contract

Key principles of operation

- **One-stop shop**
- In case of multiple offers the partner who supplies the best offer from customer point of view will be used (delivery time, experience, cost, suitability of processing equipment)
- **Information is also directly transferred between the specialists** (platform managers are kept informed).

Platform Manager's (P.M.) role

- Acts as a one-stop shop for the customer
- Contact person and coordinator
- **Acts as a matchmaker between the specialists**
- Know-how of design rules
- Know-how of processing capabilities and limitations
- Pricing, scheduling, and resourcing

Generic Reliability Challenges of MEMS application in space

- ***Complexity of MEMS devices*** (interaction between failure sites, multiple failure risk)
  - ☞ need to optimize devices for multiple loads and failure mechanisms
- ***Variety of materials*** (new materials, complex material laws, time dependent and long term material behavior, material properties under extreme conditions, size dependent material properties)
  - ☞ new testing approaches
- ***Harsh environmental conditions*** in space for whole devices
- Demands of ***long term reliability*** over mission load profile
  - ☞ advanced concepts of accelerated testing
- ***New devices*** and approaches for their microfabrication
  - ☞ advanced modeling of failure behavior
- ***Specific load*** exposure for space applications (radiation, hermeticity)

Access to Platform services

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