European Commission

Community Research

# A high-temperature testing technology for micro- and nanomaterial

*In advanced microtechnology, medicine and microbiology, a large variety of nanoscaled materials are used. Product functionality depends on the reliability and performance of these materials. The determination and assurance of these performances requires the knowledge of materials behaviour parameters at nanoscale. This is dependent on the geometry of component, on surface factors, etc. Material behaviour parameters obtained from macroscopic testing cannot therefore be transferred to nanoscaled material design.*

*High temperature applications of nanoscaled materials with an operational temperature range up to 300°C are of specific interest. This gives rise to the demand for a measuring and testing technology for determination reliability parameters of nanoscaled objects.*

*Therefore, the objectives of the HiT project are to develop a device for high temperature nanoscale material tests together with a testing technique for high temperature components.*

*The technique will be integrated with surface deformation field measurement.*

## The Market

The expected development of the high-temperature electronics market was estimated by HITEN, the High Temperature Electronics Network at EUR400 million in 2003 and at EUR900 million in 2008.

The driving force for high temperature components is the elimination of expensive and bulky cooling systems. This will result in improved system architectures, increased performance and efficiency, reduced environmental emissions, and large cost-savings.

Initial applications will be those which are least price sensitive and where the use of HTE components is of sufficient benefit to justify their costs.

The largest potential application is a 200-250°C technology required to implement distributed engine control systems in the automotive and aerospace industries. Other applications in these sectors include electronic braking, exhaust sensors, and transmission control.

Thus, supplemental developing and testing technologies are required by companies, which need to optimise the reliability of high temperature systems or processes. This is true especially for energy-intensive industries, which are coming under increasing environmental and economic pressures to improve efficiencies and reduce costs.

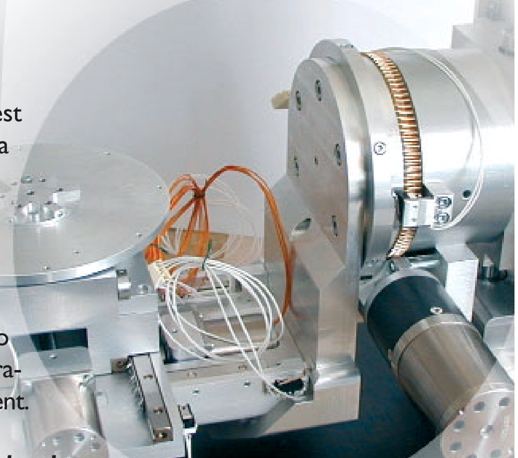
## Innovations

Thermo-mechanical reliability of materials is predicted through mathematical modelling of material behaviour and according computer simulation. For macroscale structures and down to large microscale methodologies are usually based on a finite element analysis approach. Especially in the field of electronic packaging many techniques and systems have been developed to predict the reliability of solder bonds, stress/strain behaviour of packages etc.

Further development of nanotechnologies therefore requires suitable methods for the numerical modelling, techniques for measuring accurate material parameters on which the modelling can be based and techniques for the model verification.

The project aims at developing a comprehensive testing methodology based on an electron-optical microscope with special features for hybrid micromaterial and nanomaterial testing at high temperatures.

- ***Testing Device Techniques***
  To enable high-temperature standard specimen deformation tests a special micro deformation stage (HiTest) is developed that allows to apply a wide variety of mechanical and thermal load regimes to micro-scaled and nanoscaled material specimens under investigation.

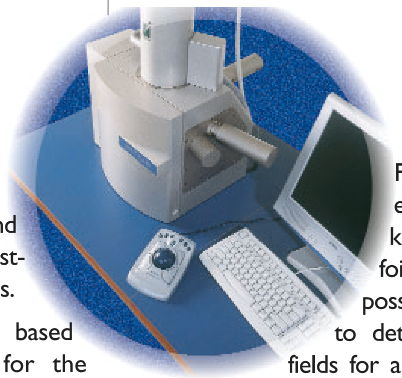


- ***Scanning Electron Microscopy***
  To operate the HiTest micro deformation stage a special scanning electron microscope (SEM) with an extra large specimen chamber and TCP/IP software interface is constructed which is able to operate in high-temperature specimen environment.

- ***Image Acquisition Technology***
  Additionally, the HiTest-SEM is equipped with a new Region-of-Interest scanmode (ROI) especially developed to record irregularly shaped surface regions such as material interfaces or thin films at a high image resolution.

- ***Digital Image Analysis***
  For surface deformation detection from SEM micrograph series, the digital image correlation method (DIC) is improved by the introduction of element-adapted kernels, a high-resolution subpixel approach and a special FE interface.

- ***Finite Element Analysis***
  An improved finite element methodology that supports a common interface with the DIC-software is developed that includes the experimentally obtained node point displacements. Thus, material parameters influencing the surface deformation measures directly or indirectly can be optimised by simulation.



## The Project Team

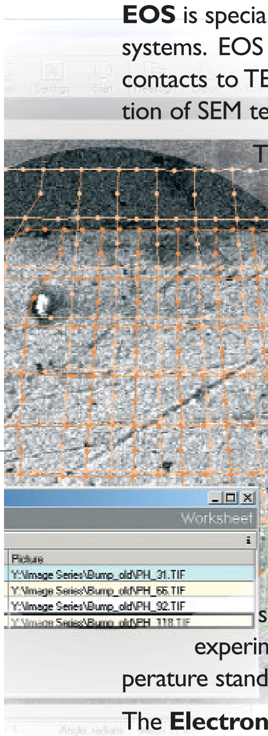
Prime proposer Image Instruments is active in developing and manufacturing image based digital measuring systems and testing equipment for microtechnology and medical applications.

The overall experience of the company with image based measuring systems makes it an excellent partner for the development of test equipment and evaluation methods as well as project co-ordination.

**TESCAN** is specialised in digital microscope imaging and offers standard products as well as tailor-made electron optic solutions. The company is contributing highly competitive SEM technology.

**SWETEST** is dedicated to development, application engineering and marketing of sophisticated equipment for methodical testing of materials and is therefore responsible for the applications of the test equipment.

**EOS** is specialised in the design and application of electron optical systems. EOS has very complementary experience and market contacts to TESCAN with special expertise in biomedical application of SEM technology.



The RTD performer **Fraunhofer IZM** is a leading research organisation in the field of advanced packaging technologies for microelectronic and microsystems applications. The department of Mechanical Reliability in Microtechnology is active in fields like thermo-mechanical reliability analysis, fracture electronics, and experimental analysis.

The **Georgia Institute of Technology** is one of the world leading research institutions in the field of Electronic Packaging, and especially on thermo-mechanical reliability. Due to the close co-operation established between IZM a GATech the consortium would have the possibility to access GATech's experimental equipment for the verification of the high-temperature standard test procedures to be developed in the project.

The **Electronic Production division of Chalmers University of Technology** deals with fundamental methods and processes in electronics packaging technology. Ongoing research concerns e.g. advanced packaging and reliability qualification methodology in combination with finite element analysis.

The **Research Centre Mittweida** represents the application research institute of the University of Technology and Economics Mittweida. FOM mainly contributes application testing.

## An application example

A main problem in flip chip bonding on FR-4 substrates is caused by the large thermal mismatch between epoxy and the silicon die. To compensate mechanical and thermal stresses between substrate and chip, underfill foils are used at the interface.

To optimise the geometric interface parameters by numerical FE-calculation the coefficients of thermal expansion components (CTE) have to be known both perpendicular and along the foil plane. Using the HiT testing device, it is possible by means of digital image correlation to detect the measure surface deformation fields for a variety of temperatures and therefore to detect the needed CTE component values versus the test temperature range.

## Glossary

***HT:*** *High Temperature, in electronic packaging the temperature range above 135°C*

***DIC:*** *Digital Image Correlation, an image matching technique that makes use of the local grey value distribution to track surface point displacements.*

***ROI-scan:*** *Region of Interest scan mode, a special scan mode of the primary electron probe in a digital scanning electron microscope in order to record irregularly shaped surface regions at a high image resolution.*

***Hybrid FEA:*** *Hybrid Finite Element Analysis, an improved finite element methodology where the experimentally obtained node displacements are considered by the solving algorithm.*

## *High Temperature Test Technology for Micromaterial and Nanomaterial*

***HiT***

***Contract number: G6ST-CT-2001-50099***

Start date: 01.08.2001 — End date: 31.07.2003
Duration: 24 months
Project cost: 1 673 826 euros — Funding: 836 913 euros

**Project co-ordinator:**
Dr Rolf Kühnert, Image Instruments
kuehnert@HiT-office.net
www.euspen.org

**Image Instruments GmbH** — *Chemnitz (D)*
*Representing EUROPRACTICE*
*www.image-instruments.de*

**Tescan s.r.o.** — *Brno (CZ)*
*Digital microscopy imaging*
*www.tescan.cz*

**Swetest Instrument AB** — *Stockholm (S)*
*Material testing technologies*
*www.swetest.se*

**Elektronen-Optik Service GmbH** — *Dortmund (D)*
*Electron optical service*
*web www.eos-do.de*

**Fraunhofer-IZM** — *Berlin (D)*
*Reliability and microintegration research*
*www.izm.fhg.de*

**Research Center Mittweida** — *Mittweida (D)*
*Testing applications*
*www.forschungszentrum-mittweida.de*

**Georgia Institute of Technology** — *Atlanta (US)*
*www.gatech.edu*

**Chalmers University of Technology** — *Göteborg (S)*
*Micro-technology research*
*www.pe.chalmers.se/org/e/prod*

### Useful links

http://www.cordis.lu/nanotechnology/home.html
http://europa.eu.int/comm/research/industrial_technologies/index_en.html
http://www.cordis.lu/fp6/nmp.htm

Thematic Area 3(NMP) infodesk: rtd-nmp@cec.eu.int

*Release december 2002*

KI-AC-02-011-EN-C