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EUCEMAN – The European Center on MicroNanoReliability

EUCEMAN – The European Center for MicroNanoReliability was founded in 2005. It has become the most important European non-profit foundation in the field of reliability and lifetime promotion in the micro-nano transition region (see www.euceman.com).

EUCEMAN promotes interdisciplinary research and development as well as co-operations in designated fields of reliability of materials, components and systems with particular focus on micro- and nanotechnologies, especially in the micro-nano transition region. Special attention is given to the application in the fields of business, science and technology.

The main focus is directed towards co-operations between scientists, the industry and society in general, and in particular between research institutions and industry. Specialists from about 20 countries participate in the activities of EUCEMAN.

EUCEMAN has organized important conferences and workshops worldwide. An outstanding event was the 1st world congress on MicroNanoReliability in 2007 which was held in Berlin. About 500 participants from 41 countries gave presentations. Since then numerous conferences have been organized and supported by EUCEMAN in several countries.

EUCEMAN together with Fraunhofer Micro Materials Centers in Berlin and in Chemnitz is editor of the international publication series M&N on Micro- and Nanomaterials research which can be read in many famous libraries worldwide.

1. Aims, Purposes of EUCEMAN

- EUCEMAN supports collaboration on a voluntary, independent and non-profit basis.
- Main objective: promotion and support of co-operation between scientists, the industry and society at large, and in particular between research institutions and industry.
- EUCEMAN pays particular attention to the induction of synergies in the above-stated fields between the member states of the EU, extending to the initiation, organisation and leadership of activities, project proposals and joint projects within the EU.
- EUCEMAN acts as provider of reviews, analyses, evaluations, recommendations and support, including funding intentions which initiated the process of EUCEMAN's establishment.

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2. Further activities of EUCEMAN

- Foundation of *Eurolabs*
- Create a *European Network* of Eurolabs
- EUCEMAN will hand over Awards for MicroNanoReliability
- It will carry out and initiate Expert Opinions
- EUCEMAN will initiate National Contact Points for Reliability in the field of micro-nano-reliability.

3. Vision, Concepts, Initiation and Coordination of Projects nationally an internationally

- EU projects (IP, CRAFT, COST, …)
- International (e.g. USA-Germany, …)
- National (BMBF, AIF, DFG, Humboldt foundation etc.)
- Regional (lands, e.g. Saxony, Berlin, …).

4. Scientific Fields of EUCEMAN Activities for Micro-and Nanoreliability

- Reliability of Automotive Electronics
- Reliability in Micro- and Nanoelectronics
- Physics of Failure
- Reliability combined with Safety and Security
- Design for Reliability
- Testing and Reliability.

5. Current Activities: Selected European Joint Projects

- NanoPack EU-IP (participants: IBM, THALES, Fraunhofer, Bosch et al.)
- NanoInterface (STREP)
- Smart-LIC EU-IP (electromobility project)
- SmartPower
- COSIVU EU-IP project
- NanoTherm EU project.

6. Current activities in the field of Organisation of Conferences

- MicroMaterials conference series; Berlin

- First World Conference in the field of reliability of high tech applications MicroNanoReliability; Berlin
- MicroCar conference series on micro materials, nano materials for automotive; Leipzig
- Annual "Micro & Nano Reliability" International Symposium at the Microtech/Nanotech conference and expo series; USA
- Co-organisation or sponsoring
- Annual conference EuroSimeE; Paris, Delft, Berlin, Bordeaux, Linz, Lissabon, …
- Annual conference Smart System Integration (SSI); Barcelona, Brüssel, Como, Dresden, …
- Safety and Security Systems; Potsdam, Berlin, …
- Polytronics; Garmisch-Partenkirchen, …
- Annual conference THERMINIC; Leuven, Barcelona, Paris, Budapest, …
- Micro-Nano-Integration meetings
- Materials Science and Engineering (MSE) Workshop reliability; Darmstadt, …

7. Overview of EUCEMAN accessible reliability testing equipment

(various labs in different countries in Europe)

- X-ray Computer Tomography System „Nanotom"
- Laser Scanning Microscopy
- Universal Cycle Test Stands
  - Including humidity, vibration
  - With high-speed-camera, image processing, DIC measuring technique
- microDAC and nanoDAC measuring technique
- Micro moire technique
- FIB-based deformation and stress analysis
- Complex test stands for reliability analysis
- Mechanical, thermal, electrical, humidity, vibration loading
- With DIC-technique and lock-in impulse thermography
- AFM measuring pool (humidity sensitive AFM, AFAM AFM)
- EBSD measuring technique
- NanoRaman and Micro Raman measuring techniques
- Acousto-microscopy combined with other techniques
- Mechanical and thermal test and measuring techniques
  - DMA, TMA, Tiratest, MTS, Instron etc.
  - With additional special thermal and mechanical modules and humidity-environmental measurements

- Electrical-thermal measuring techniques / lock-in impulse thermography
- Various X-ray measuring techniques (energy-dispersive etc.).

8. Some aspects of modern reliability research

Reliability issues have become more and more important in the recent years for the development of modern micro- and nanotechnologies as well. The comprehensive application (the „break through") of nanotechnology will become possible only then, if also in the clasical disciplines as in electronics or automotive industry reliable criteria and concepts will be available which will lead to sufficient statements for reliability an lifetime estimation of components and systems. Such a knowledge is not yet available in the region of modern nanotechnologies until now. A well accepted scientific approach to the „*Nanoreliability*" field from the point of view of modern science can only be achieved by the modern methods of so-called „Physics of Failure", i.e. the physics of damage and failure modelling (in mechanics this has become well known as „damage mechanics" approach). „Physics of Failure" is the generalization of the pure mechanical approach taking into account the majority of modern laws of physics. This is far beyond the classical theory, because the complex field interactions and the micro- and nanostructures have tob e taken into account at least in the necessary approximations.

In the micro-nano transition region the reliability concepts have become most important, because they cannot be neglected for system reliability estimations at all and not only being based on a pure phenomenological description of material properties as it ist he case until now.

The overwhelming majority of experts in the field of Nanoreliability already now express the opinion that a fundamental approach to reliability analysis, reliability estimation and reliability optimization of products can only be achieved in combination of modern methods of nanoanalytics with direkt coupling to modern simulation and design methods on the basis of physics of failure concepts. This can be described by the term „Design for Reliability" taking into account the fact that experiments and theory are coupled in a very strong matter in the field of reliability of nanosystems.

The new expression „Design for Nano- and Microreliability" has already become more and more known, and it describes this new approach somewhat more accurately.

For the classical combination between Design and Experiments the expression DOE-Design for Experiment has become important. In the nano region this very general term has received a really strategic meaning, because of the strong coupling between nanoanalytics and nanosimulation leads to very important new challenges in the field of nanoreliability too.

In the nanoregion the so called crack avoidance strategies (e.g. interface cracks in MEMS and NEMS and the very complex nano-layered systems with many layers made up of quite different materials) lead to applications of modern nanoanalytics combined with advanced simulation methods. This may really mean a large step forward for modern nanotechnology.

9. Advanced fracture concepts as a strong basis for EUCEMAN to stimulate reliability research in the micro-nano regions

Modern crack avoidance concepts for components, structures and devices in the micro-nano-transition region have become very successful in those cases if they are based on the physics of failure

approach. This is true for the direct theoretical basis and also for the experiments. Physics of failure concepts are based on the physical balance relationships.

Most important in this respect is the so-called „energy balance" around the cracks, i.e. the power release balance around the crack region. In most cases this is very important-Besides this we have to consider also the complex material behavior with multi-interaction between the different fields (mechanical, thermal, elektromagnetic, diffusion-controlled fields, chemical or. physico-chemical relations, radiation effects etc.).

The energy balance around the crack zone has lead to the famous J integral concept introduced by Tscherepanow (1967) und Rice (1968), as it is based on the correct energy balance at the crack in a very simple manner taking into consideration elastic and to a certain extent also small elastic-plastic deformation fields around the crack tip.The energy potential is conservative. This leads to the path- independence of the J-Integral around the crack tip. Later this was also shown for loaded crack flank generalizations being important in the field of geological applications. The J-concept is up to now the most widely used crack concept all over the world. Of course it is not valid in many modern applications mainly in the fields of micro- and nanotechnologies, but it can be used as a first approximation very often Further generalizations of these so-called „small-scale yielding integral concepts" are the HRR-solutions (Hutchinson, Rice, Rosengreen) and then the generalized integral concepts. They can take into account nearly any kind of material behavior. Local plasticity can already be included in the case of „normal" J integral. In applications in electronics and microsystem technologies temperature fields play an important role. More than 60 % of all failure of electronic devices can be shown to come from thermal defects. This is one important reason for the fact that thermal effects in the generalized integral fracture concepts have become so important, especially also in the micro-nano-interface region. There are a lot of approximations (e.g. Gurtin et al.).

First fundamental publications were presented by Bui, Ehrlacher et al. (France), Miyamoto, Kikuchi et al. (Japan), Atluri et al. (USA). They correctly included the temperature as a field quantity into the generalized J-Integrals. In the following years step by step the concepts could be generalized for elastic-plastic and visco-plastic behaviour. The path-independency of the integrals was not longer valid, and incremental generalizations also were introduced.The path-independent integrals were very important in the beginning of modern fracture mechanics (linear elastic fracture mechanics). This property is not so important now because oft the strong development of modern computer technology which enables to calculate very complicated path-dependent integrals very fast.

Above mentioned activities have become important tasks in the projects and activities supported by EUCEMAN.

Modern fracture mechanics will further develop and will become a mayor field of reliability research for advanced micro- and nanotechnologies, and it therfore will remain an important part of reliability analysis of EUCEMAN.

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