

Lectio Materia

Newsletter of the ACADEMIA NDT INTERNATIONAL Science, Technology and Diagnostics in Non-Destructive Testing

Hungary welcomes Academia for scientific meeting

It is now more than three years since the ACADEMIA NDT International was formally established and it is the first time that a meeting of the ACADEMIA is to be held in Hungary, a country with a long history of fine academic achievement and the scene of many active efforts in science.

In the time since its birth, the ACADEMIA NDT has achieved a great deal – most notably its membership has grown considerably and three memorable Special Lecture Meetings have been held, the first in Shanghai coinciding with the 17th World Conference on NDT, the second in Brescia, Italy, the official seat of the organisation, and the third alongside the 10th European Conference on NDT held in Moscow in 2010.

The idea of the ACADEMIA NDT International emerged a few years ago, reflecting a need in the NDT community to have a body that is evidence of the science in the NDT field at the highest level. A Steering Committee was formed and met for the first time on 25 May 2007 in Opatija, Croatia.

The overall objective of the ACADEMIA is to foster research, development and education in the NDT field by engaging NDT professionals in a combined effort, thus attaining the goal of always seeking progress.

The main purposes and objectives of the ACADEMIA NDT International activities are as follows:

 To promote science, research and development encouraging the application of the findings in the field of NDT at universities, R&D centres and institutions and other relevant bodies throughout the world.

- To establish and maintain a network among scientists and technologists involved in the basic sciences, research and development for NDT methods, techniques, equipment and implementation advancement.
- To highlight the work of the research and development in NDT.
- To be mindful of the contributions from scientists and distinguished professionals in the NDT field, inviting them to ACADEMIA NDT.
- To attract the attention of international authorities, government and public organisations to the importance of the benefits that NDT provides.



Giuseppe Nardoni President, ACADEMIA NDT International

The ACADEMIA is not in competition with NDT associations and institutions such as ICNDT or other regional NDT groups, nor with the national societies, but sees itself as an association complementary to all of these.

The membership of the ACADEMIA NDT comprises Full and Honorary members. At present there are 38 Full members (including 6 Council) and 7 Honorary members. For a full list of members, visit **www.academia-ndt.org**

ACADEMIA NDT International Scientific Meeting Thursday 14 April 2011 Hotel Flóra, Eger, Hungary

09:00 – 09:20 Welcome and Introduction

- 09:20 09:50 **1. Lecture: 'Non-destructiveness and nanotechnology'** Norbert Kroó (Hungary)
- 09:50 10:20 2. Lecture: 'Micromagnetic characterisation of aged steel microstructures in NDT for nuclear power applications – thermal ageing, fatigue and neutron embrittlement' Dr Gerd Dobmann (Germany)
- 10:20 10:40 Coffee break
- 10:40 11:10 3. Lecture: 'The non-linear mixing of waves: the up-and-coming method for transmission, evaluation and metrology' Serge Dos Santos (France)
- 11:10 11:40 **4. Lecture: 'X-ray methods for investigation of microstructure and damage** inhomogeneity'

Professor János Lendvai (Hungary)

11:40 – 12:10 **5. Lecture: 'Corrosion fatigue research on railway axles'** Stefano Beretta (Italy)

12:10 - 12:30 Discussion

Norbert Kroó

Biography & Abstract



Norbert Kroó is Vice President of the Hungarian Academy of Sciences and Founding Director of the Research Institute for Solid State Physics and Optics of HAS. He first used nuclear methods in condensed matter studies and later turned to laser physics and quantum optics. Surface plasmon optics is a typical field of this type. He has published about 300 scientific papers and is the owner of 40 patents. He has worked in

several countries and with outstanding scientists such as

Herbert Walter and Alexander Prokhorov. He is the former President of the European Physical Society and a member or honorary doctor of several distinguished scientific institutions, including the Scientific Council of the European Research Council, and has received awards from many states and their academies. His latest decorations are: the Wallis E Lamb Award for Laser Physics and Quantum Electronics (USA), and the Commander of the Order of the Lion (Finland).

Professor János Lendvai

Topography plasmon near-field image of a gold surface

Professor János Lendvai studied physics at the Eötvös Loránd

research interests are precipitation phenomena, mechanical properties, calorimetry, non-equilibrium materials, amorphous and

Non-destructiveness and nanotechnology

Norbert Kroó, Hungarian Academy of Sciences

N anotechnology started with Richard Feyman, but many scientists Moubted the stability of nanostructures although many examples were known, for example in life sciences to prove the stability. The birth of nanoscale imaging (for example STM, AFM etc) gave a significant momentum to the development of nanosciences and technologies.

As an example, simultaneous images created by a surface plasmon near-field scanning tunnelling microscope of the topography, local temperature distribution and the surface plasmon near-field with very

high (up to 1 nm) resolution are shown. These devices, however, can be used not only to register images but for technological purposes too, even down to atomic scales. Atoms (and molecules) can be moved on surfaces to create stable structures in bottom up way. These technologies are not yet ripe for industrial use due to their costs, but are widely used in research laboratories. Examples of structures produced this way are also shown.

Chemical self-ordering is another method to produce stable structures. This technology is promising for future applications.

Finally, some principal limits of nanotechnologies are discussed, including an example from applications in information technologies.

Biography & Abstract



University in Budapest and was awarded his PhD at this university in 1971. In 1992 he obtained his DSc title from the Hungarian Academy of Sciences after presenting his thesis on 'The mechanism of formation of precipitation microstructure and its effect on the mechanical properties of aluminium alloys'. Since 1993 he has been a Professor at the Eötvös Loránd University, Budapest. His

nanostructured metallic materials. Between 1987 and 1989 he was a visiting scientist at the Max-Planck-Institut für Metallforschung, Stuttgart, Germany. From 1995 until 2009 he was Head of the Department of Materials Physics (formerly Department of General Physics) and between 2001 and 2008 Director of the Institute of Physics at the Eötvös University, where presently he is the leader of the Solid State Physics and Materials Science PhD programme.

Professor Lendvai is a member of several national and international scientific committees and advisory boards of international journals in the field of materials science and physics. He was chair of the International Conference on the Strength of Materials, ICSMA 13, in 2001. In 2011 he was elected Vice President of the Solid State Physics Committee of the Hungarian Academy of Sciences. He has published over 200 scientific papers and received more than 1000 independent citations.

X-ray methods for investigation of microstructure and damage inhomogeneities

and

Professor János Lendvai, Department of Materials Physics, Eötvös Loránd University, Budapest

 $N_{\rm give}$ x-ray line broadening and X-ray tomography methods can give quantitative information on inhomogeneities in the defect and phase microstructure. X-ray line broadening or X-ray line profile analysis (XLPA) has become one of the most powerful methods to characterise microstructures of crystalline, especially metallic, materials during the past two decades. Diffraction line broadening is caused by different defects present in crystalline materials: small coherent domains, dislocations, other types of microstrains, twin boundaries, stacking faults, chemical inhomogeneities, grain-tograin second order internal stresses and point defects, especially vacancies. XLPA provides gualitative and guantitative information about defect types and densities at the same time. Line profiles can broaden, be asymmetric and can be shifted, and these features can be anisotropic in terms of hkl indices. In this presentation, the most important features will be summarised for the determination of dislocation densities, twinning and vacancy concentrations. With modern detectors and relatively easily accessible synchrotron sources, X-ray line profile analysis is an ideal technique to determine dislocation density, grain or subgrain distribution.

X-ray computed tomography has proved to be a powerful method for the 3-D microstructure analysis of heterogeneous materials. With conventional X-ray sources, conebeam tomography can image microstructural features down to a few micrometres if the absorption contrast between the constituents of the material is appropriate. The brilliance of synchrotron sources increases the spatial, temporal and contrast resolution. Furthermore, the coherence of the beam allows

the detection of the phase contrast, related to the different electron densities in the constituents within a material, even if the absorption contrast is poor. Holotomography exploits phase contrast to image components with similar densities at high resolution. The achievable resolution is better than \sim 1 μ m and it can be improved below 100 nm using sophisticated X-ray optics. 3-D imaging of engineering metals requires high energies and samples large enough to investigate a representative microstructure. The non-destructive nature of the

method applicable to reasonably large samples should make it possible to follow the evolution of the microstructure as a function of, for example, external load and/or thermal cycles.

Through a few selected case studies it will be demonstrated that by applying powerful numerical evaluation and simulation methods the data can be used for property and life-time predictions.



X-ray phase contrast tomography reconstruction of a cast Al-Si allov. The a-aluminium dendrites in blue, Mg2Si particles in gold, and Si particles in red. The eutectic aluminium is transparent

Gerd Dobmann



Dr Gerd Dobmann was born in Saarbrücken, home of the Fraunhofer Institute for Non-Destructive Testing (IZFP), one of the world's leading institutes engaged in research and development concerning the physical principles of NDT, materials characterisation and control and monitoring of production processes and industrial plants and components. Dr Dobmann is currently an Advisory Director of the Fraunhofer IZFP, responsible specifically for process monitoring and

control and basic research.

Dr Dobmann studied at the University of the Saar Region and conducted his thesis in applied physics and electrical engineering, theoretical electrodynamics, on the subject of 'The calculation of the electromagnetic field of a vertical electric dipole on a periodic rough earth surface', with Dr K-D Becker. At this stage, he began his research activities with the Fraunhofer IZFP in 1974. In 1975 he commenced his doctorate thesis on 'Theoretical, numerical and experimental investigations into the application of the electrical direct current potential drop techniques in NDT'.

In 1976, Dr Dobmann was appointed head of a scientific working group: 'Electrical, magnetic and thermal techniques in NDT' at Fraunhofer, and in 1978 he became head of the Electromagnetic Techniques department, a group of three scientific working groups, eight scientists, four engineers, three technicians and four PhD students. In 1979 he was awarded his PhD in Applied Physics `magna cum laude'.

Biography & Abstract

Gerd Dobmann was organiser of the 3rd International Symposium 'Materials Characterization' in 1988 and editor of the conference proceedings. As deputy to the Institute Director at Fraunhofer, he is responsible for the research plan of the IZFP and is Director of the 'Scientific Projects' division.

Dr Dobmann has published numerous technical papers and three texts in the field of theoretical electrodynamics, in co-operation with Prof K-D Becker and Dr K-J Langenberg.

He is author of four chapters in specific monographs to NDT, Editor of the 'Handbook on the Magnetic Examination of Welds' (published in 1988 by the British Welding Institute) and author of the 'IIW Handbook on the Non-Destructive Measurement and Analysis of Residual Stress in and around Welds' (published in 1993 by the US American Welding Council).

He is a member of the German Society for Non-Destructive Testing (DGZfP), Chairman of the Saarbrücken Working Group, and Deputy Chairman of the NDT in Civil Engineering Committee and Deputy Chairman of the Ultrasonics Committee. He is a Fellow of the Institution of Electrical Engineers (now IET) and a Chartered Engineer registered by the UK Engineering Council.

Gerd Dobmann is Chairman of Commission V of the IIW, 'NDT and Quality Assurance', Member of the American Society for Materials, ADSM, European Chapter, Honorary Member of the Indian Society for NDT and was Chairman of the Programme Committee for the European Conference on NDT 2006, in Berlin.

Micromagnetic characterisation of aged steel microstructures in NDT for nuclear power applications – thermal ageing, fatigue and neutron embrittlement

Gerd Dobmann, Fraunhofer-IZFP, Saarbrücken, Germany

bviously, worldwide, a renaissance of the nuclear industry is taking place and many countries are favouring nuclear power as a reliable opportunity to generate electrical energy at very low CO₂ generating rates in order to avoid the greenhouse effect in the earth's atmosphere. However, since 1986 when the Tschernobyl accident was happening, worldwide nearly no new nuclear power plants were established. The People's Republic of China, India and, in the last decade, also Finland and France are the exception. In other words, existing supply chains of manufacturers were destroyed or have changed their technical application field. Furthermore, a lot of technical expertise was lost as younger generations were influenced politically to find interest in scientific areas other than nuclear physics or nuclear engineering. Moreover, the consequences of the Tsunami accident near Sendai in Japan on the six power stations with BWR in Fukushima have to be taken into account, and different countries around the world sceptically discuss again the use of nuclear power.

So even if we can observe – independent of the actual accident – a change of mind in many countries, such as Turkey, concerning the positive acceptance of nuclear power, one question needs to be answered: Will we find enough well-skilled technicians to safely build all the planned nuclear power plants in the future?

Therefore, life extension of existing plants plays an important role. This is true as we have learnt in the last decades how much potential we have for lifetime extension. We have to take into account ageing phenomena concerning the materials, such as thermal ageing, fatigue and neutron embrittlement, when we think of steel components in the primary circuit, such as the reactor pressure vessel, heat exchangers, surge line, pressuriser vessel, main cooling pumps and pipelines. However, as in some countries life extension to an overall lifetime of 80 years is in discussion, we also have to take into account the infrastructure, *ie* the concrete components of the containment and the cooling towers, and also ageing phenomena of electric cable insulation, etc.

Within these lifetime extension strategies, the methodology of a continuously applied ageing management worldwide is seen as an important measure to guarantee nuclear safety. Besides the application of standardised non-destructive testing (NDT) technology during in-service inspection trials in order to perform a diagnosis of the material state, on-line structural health monitoring of components by enhanced and intelligent NDT sensors and sensor networks will also play a forthcoming future role.

In Germany, code-accepted procedures to perform ageing management were finally discussed and approved by the authorities. However, research and development in the last decade in the Nuclear Safety Research Programme of the German Ministry for Economy and Technology was continuously performed in order to develop and qualify NDT technology for characterisation of ageing phenomena.

The proposed contribution will describe the objectives of this research and the final results obtained. In any case, the methodology of the micromagnetic NDT procedures was especially developed. This methodology is suitable for materials characterisation of magnetisable steels in terms of determination of mechanical properties. There are many similarities between movement of dislocations under mechanical loads and pinning of this lattice defects at vacancies, participates, grain and phase boundaries, contributing to the strength of the material and the movement of magnetic domains under magnetic loads, *ie* when the material is magnetised in a hysteresis loop.

The methodology of the Micromagnetic, Multiparameter, Microstructure and Stess Analysis (3MA) is discussed which, on a wide basis of different diverse as well as redundant information, allows the sensitive materials characterisation.

In case of a Cu-rich steel alloy, precipitation hardening is discussed in combination with thermal ageing. It is shown that superimposed fatigue loads will enhance the thermal ageing effect.

Fatiguing of austenitic stainless steel can be combined with phase transformation from the cubic-face-centred lattice to cubicbody-centred martensitic phase, which is also ferromagnetic in nature. Where the carbon content is low enough to avoid the phase transformation at elevated service temperatures, other NDT techniques based on electric conductivity effects have to be applied.

3MA is also sensitive to characterise neutron embrittlement in pressure vessel materials. Material of Western pressure vessel design, as well as of Russian design, were characterised, which shows that a new NDT technology for in-service inspection of the pressure vessel wall from the id-side can be developed.

ACADEMIA NDT INTERNATIONAL

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Serge Dos Santos



Serge Dos Santos was born in Valenciennes, France, in 1971. In 1995, he received the 'Diplôme d'Etudes Approfondies' of Physics with the mention 'Molecular spectroscopy and non-linear physics' from the University of Dijon, France. He worked at the FEMTO Institute (LPMO-CNRS), Besançon, France, on the study of the origin of low-frequency fluctuations in ultrastable oscillators. He obtained a PhD degree in Engineering Science in 1998 for his contribution to understanding the

link between low-frequency noise and non-linearity in synchronised systems. Then he joined the Ultrasonic Group 'GIP Ultrasons', created by Professor Léandre Pourcelot at Tours, France, working on the development of new medical and non-destructive testing (NDT) applications of non-linear acoustics for ultrasound imaging.

In 1999, he obtained an Assistant Professor position at the LUSSI-CNRS Laboratory, directed by Professor Frédéric Patat, also devoted to fundamental research on non-linear acoustics and signal processing.

In 2005, he was an invited researcher at Artann Laboratories Inc (USA) working on the development of non-linear time-reversal acoustics methods. At 37 years old, he received his 'Habilitation à Diriger des Recherches' from the University of Tours, France.

He is now Assistant Professor at the ENI Val de Loire (ENIVL), Blois, France, where he is involved in the organisation of the international exchanges of students and researchers. Since 2007, he has given lectures related to 'Non-linear signal processing and non-destructive testing (NDT)' within the ERASMUS framework at Prague Technical University and the University of Valencia in Spain. At ENIVL, he is responsible for signal processing, advanced control and non-destructive testing lectures.

Biography J. Abstract

Since 2009, he has conducted his research at the U930 'Imaging and Brain' INSERM-CNRS-University Francois-Rabelais Research Laboratory, directed by Professor Denis Guilloteau, working on biomedical applications of the advanced signal processing methods developed for the non-linear NDT of complex materials. Since 2000, his research projects have included ultrasonic characterisation of material using non-linear acoustics (AERONEWS FP6 European project) for the aeronautic industry, advanced non-linear signal processing using Lie groups, and non-linear analysis of ultrasound contrast agent for complex imaging and therapy applications.

During the last 10 years, Serge Dos Santos conducted experimental research within invited stays at Artann Laboratories (2005 and 2007, Princeton, NJ, USA), Nottingham University (2005, UK), Exeter University (2007, UK) and VZLU Center (2006 and 2007, Prague) in order to test and validate time-reversed-based non-linear NDT systems.

His bibliography contains 115 references with 54 co-authors, including 16 reviewed contributions, 53 international conferences (8 invited) and 23 seminars or lectures, and he is a member of the Scientific Committee for the VIth International Workshop NDT in Progress Meeting of NDT Experts, 10-12 October 2011, Prague, Czech Republic.

The non-linear mixing of waves: the up-and-coming method for transmission, evaluation and metrology

Serge Dos Santos, Centre-Val de Loire Université, Blois, France

The transmission of information has been possible with the use of the modulation of electromagnetic signals. The initial objective was motivated by the need to use the optimisation of electromagnetic signals in a frequency range that allows a good propagation of waves. Engineers had to propose simple electronic set-ups in order to perform these frequency conversions from the audible band (the message) to a higher frequency band (HF). The basic electronic components need to use a non-linear set-up that produces the attachment of the low-frequency (LF) message to the HF carrier with a mixing of electromagnetic waves. These concepts constitute the keystone of the transmission of information, its improvement and the development of the associated metrology necessary for these new experimental set-ups. Metrology of the frequency stability of ultrastable oscillators exploits frequency mixing properties.

In the context of ultrasonic imaging (US), the non-linear mixing of acoustic waves constitutes a promising method for the improvement of the sensitivity of ultrasonic evaluation of complex media. Harmonic imaging has replaced all fundamental conventional techniques for new echographic US systems. These methods are presently proposed with industrial applications for the local evaluation of mechanical properties and degradation at the microstress level of complex media, such as bone, skin, tooth and other bio-mechanical media. Non-linear mixing of acoustic waves has also shown its interest for the evaluation of microdegradation properties in materials. The various Non-linear Elastic Waves Spectroscopy (NEWS) methods are, in practice, difficult in their use, but exploit the same mixing elementary key in their concept. These methods constituted a well-approved perspective in the context of non-destructive testing (NDT) of complex materials. Their interest comes from the fact that their enhancement sensitivity could also be associated to localised metrology also using advanced signal processing and new tomography processes in the time domain.

Image quality, qualitative evaluation and reliability of the transmitted information are linked to metrology aspects of the propagation medium. The quality of transmission is enhanced with the modulation process induced by frequency mixing. Nevertheless, the demodulation process needed for extracting the information is, in counterpart, affected by the low-frequency noise induced by non-linearity. The understanding of the origin of this low-frequency

noise in non-linear mixing processes is also limited to the improvement of the experimental set-up metrology. Metrology of the frequency stability of ultrastable oscillators exploits frequency mixing properties. The fact that the frequency is the physical parameter known with the best accuracy has something in common with the mixing method that is experimentally used for its evaluation.

The non-linear effects induced by mixing processes of electromagnetic, optic and acoustic waves need to be clearly studied for understanding and improving the properties of the medium that induces these effects. Signal processing associated to this evaluation should be adapted to the intrinsic properties of non-linear mixing: the performance of





the associate engineering systems being highly dependent on the invariance of their properties in terms of the associate metrology.