EUROTRAINING

Nanotechnology for Electronics

26-27 March 2015, Warsaw, Poland
Warsaw University of Technology, Faculty of Mechatronics
Institute of Metrology and Biomedical Engineering
Course Chair: Prof. Małgorzata Jakubowska

1st Day Program: 26th March, 2015

Course site: Warsaw University of Technology, Faculty of Mechatronics
ul. Św. Andrzeja Boboli 8, 02-525 Warsaw, Poland

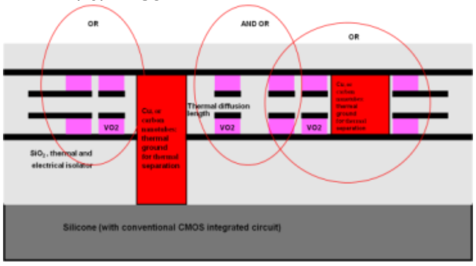
8.30-8.40 **Introduction**

8.40-9.40 **Prof. János Mizsei:**
Electronics, microelectronics, nanoelectronics: applications and trends
Presentation of invited renowned scientists

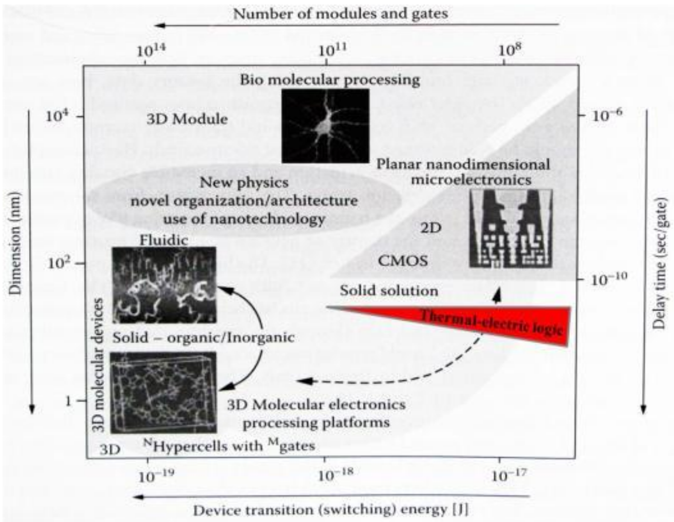
János Mizsei
CSc, PhD, DSc
Professor
Head of the Semi-conductor Laboratory
Department of Electron Devices
Budapest University of Technology and Economics
www.eet.bme.hu/staff/run/en/id/mizsei

Abstract:

Until now, the continuous development of electronics has been characterized by Moore's law. The scale down resulted in the nanosized CMOS integrated circuits, pushing the "red brick wall" towards the lower dimensions. On the other hand, there are many new ideas for building atomic or molecular scale devices for the information technology. However, there is still a gap between the up-to-date "top-down" CMOS technology and the "bottom-up" devices, i.e. molecular electronics, nanotubes, single electron transistors.
The new thermal-electric device, the phonsistor and the CMOS compatible thermal-electric logic circuit (TELC) may help to fill this gap.



Realization: a vertical (3D) thermal IC



Thermal electric logic circuit in the „gap"

EuroTraining (GA No.: 316526) – Funded by the European Union

9.40-10.40 **dr inż. Marcin Słoma:**

Nanoscale materials for large-scale electronics

Presentation of invited renowned scientist

dr inż. Marcin Słoma, PhD
Assistant Professor

Institute of Metrology and Biomedical Engineering

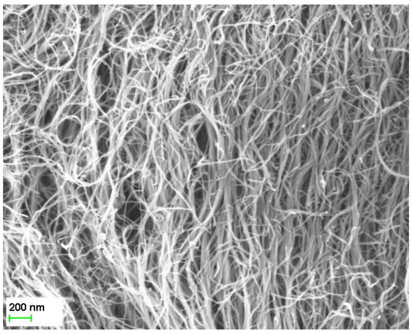
Faculty of Mechatronics

Warsaw University of Technology

http://repo.bg.pw.edu.pl/index.php/pl/r#/info/author/WUT59081/

Abstract:

Printed Electronics is one of the fastest developing electronics technologies these days. This emerging need for new type of electronics devices has motivated researchers to implement a new class of materials - nanomaterials. The interest to develop new type of consumer goods, media, energy devices, healthcare, architecture or personal electronics is pushing further the limitations in technology process by introducing cheaper, more robust and higher performance components. New possibilities are enabled by the unique electrical, optical, mechanical and thermal properties of nanomaterials. Consequently, significant effort has been devoted to the mass production of large-scale assemblies of nanomaterials into devices with controlled parameters in the field of consumer electronic, optoelectronic, photovoltaic, energy applications and sensors. This presentation is intended to present recent development in the field of large-scale electronics with the use of nanomaterials and maybe to provide guidance to future application and research challenges in this field.



Carbon nanotubes
(Author: Marcin Słoma)

Large-scale printed photovoltaics
Creative Commons license (author: Ken Fields)

10.40-11.00 **Coffee break**

11.00-12.00 **Martin Kirchner:**

Electron beam lithography – instrumentation and processing

Presentation of an industrial expert from Raith, Germany

Martin Kirchner
Sales Director New Markets

Raith GmbH
Dortmund/Germany

Abstract:

Electron and ion beam lithography are enabling technologies for research and development in many fields of nano technology. The presentation reviews the basics of both technologies. Emphasis is given on instrumentation and processing which is useful in academic or industrial research and in small batch production. Application results from recent years are presented stemming from various disciplines including Electronics and Photonics.

The presenter is with Raith, a high tech company headquartered in Dortmund, Germany. Since two decades Raith instruments are extensively used within the nano fabrication and nano engineering community. Raith made conventional electron beam lithography accessible to a broad research community worldwide. In February 2013 Raith acquired Vistec Lithography who is known for more than 40 years of experience in the field of electron beam lithography under the brands of Philips, Cambridge Instruments and Leica.

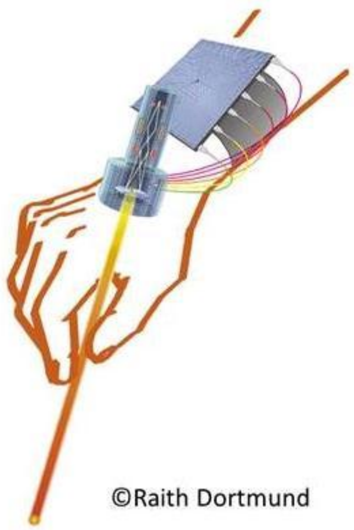


Figure symbolizes a focused charged particle beam structuring substrates at nano scale.

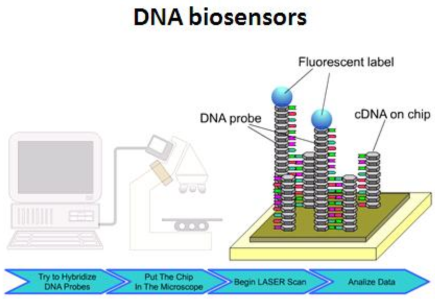
12.00-12.40 **Attila Bonyár, Ph.D.:**
Enhancing Biosensors with Nanotechnology
Presentation of a young East-European scientist

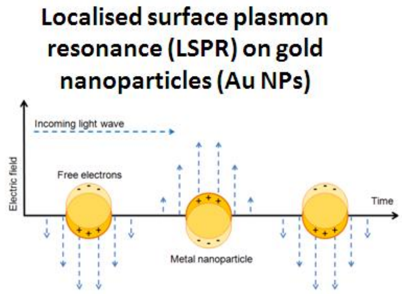
Abstract: Biosensors applying nanoscale biomaterials such as DNA molecules as sensing elements possess great potential in the fields of disease diagnostics, environment monitoring or in pathogen detection. The optimization of sensor properties (such as sensitivity or limit of detection) is a constant challenge in this multi-disciplinary field. Signal amplification methods, including the application of nano-materials or nano-patterned surfaces for surface plasmon resonance imaging (SPRi); and novel atomic force microscopy (AFM) based nanotechnology tools and investigation methods are in the focus of this presentation.

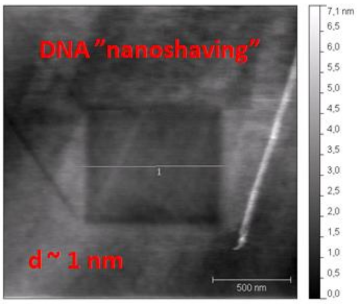
Attila Bonyár, Ph.D.
Assistant Professor

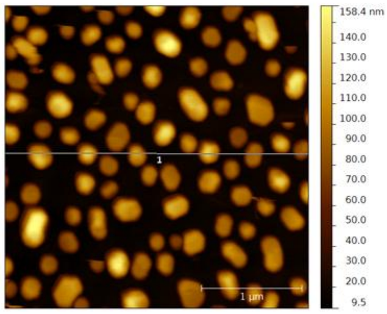
Department of Electronics Technology

Budapest University of Technology and Economics









12.40-13.40 **Lunch break**

13.40-14.40 **Grzegorz Wróblewski:**
Carbon nanomaterials in flexible and transparent applications
Presentation of a young local scientist

Grzegorz Wróblewski, MSc
PhD Student

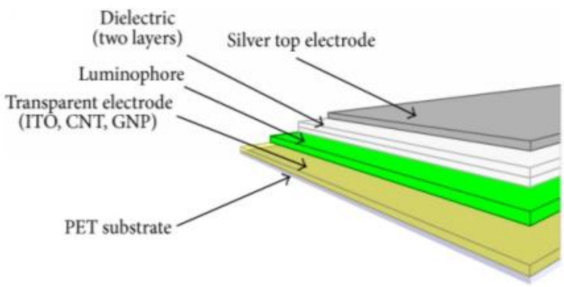
Institute of Metrology and Biomedical Engineering

Faculty of Mechatronics

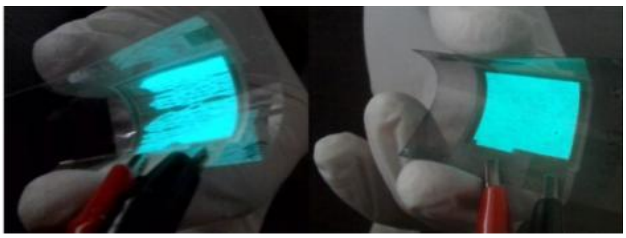
Warsaw University of Technology, Poland

Abstract: Transparent electrodes are used in a variety of applications in modern electronic systems. This includes touch screens, transparent cathodes for photovoltaics, window heaters, electromagnetic shielding, or even speakers. The most common application is front electrode for almost all types of displays: LCDs, OLEDs, and thick film electroluminescent structures (TFELs). Commonly used materials are transparent conductive oxides (TCO). In many cases there is an additional need to provide the elasticity of an electrode, where TCOs cannot be implemented because of their low mechanical strength.

The fabrication of TFEL structures with the use of elaborated transparent electrodes with oligo walled carbon nanotubes (OWCNTs) and graphene nanoplatelets (GNPs) have been investigated and are presented. Structures were subjected to series of experiments: transmittance measurements of electrodes and bending tests for evaluation of resistivity stability, irradiance comparison of structures with different colors of luminophores and different types of electrodes (ITO, OWCNT, and GNP-CNT), and accelerated aging to demonstrate the influence on the mechanical properties.



Visualization of printed TFEL



TFEL structures on ITO (left) and OWCNTs (right) after thermal shock cycles

14.40-15.20 **Konrad Kiełbasiński, Ph.D.:**
Nanosilver Sintered Joints on Rigid and Flexible Substrates
Presentation of a local senior scientist

Konrad Kiełbasiński, PhD
Senior Researcher

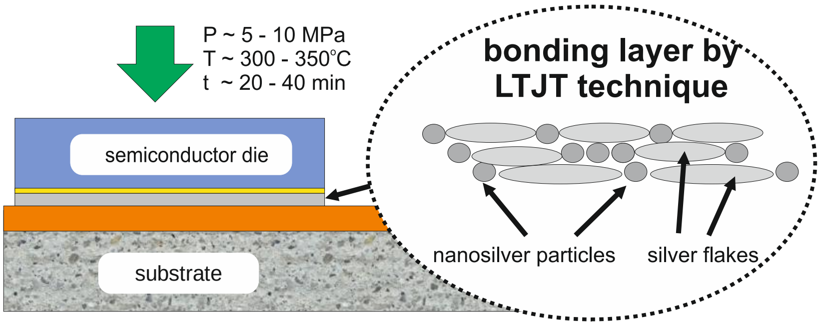
Department of Thick-Film Materials

Institute of Electronic Materials Technology

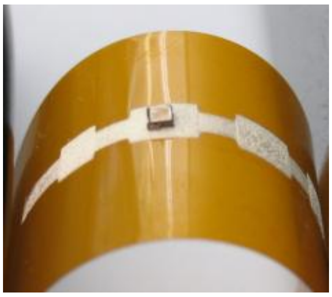
Warsaw, Poland

Abstract:

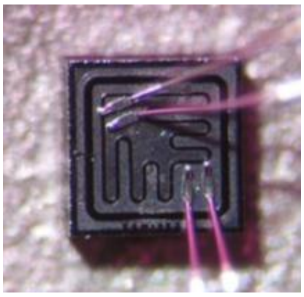
The need to replace Pb-Sn solder has led to research for new, alternative joining methods maintaining comparable, or even better, properties. One of the methods is known as Low Temperature Joining Technique (LTJT) which is an alternative to soldering and adhesive joining. With the development of nanotechnology, usage of silver nanoparticles has been considered. Silver pastes with nanoparticles exhibit the lowest sintering temperatures due to their high surface energy. They are able to sinter at temperatures below 300°C resulting in low resistance layers (2 mΩ). No other thick film paste is capable of achieving this resistance in such a low curing temperature. Low exposure to heat allows depositing and curing on wide variety of substrates including rigid metal and glass substrates as well as elastic Kapton foil or paper.



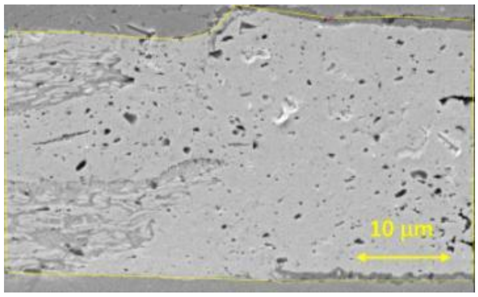
Schematic of a joining procedure.



Bonded component on elastic substrate



Bonded transistor on rigid substrate



Cross section of sintered joint

15.20-15.30 **Problem solving discussion**

2nd Day Program: 27th March, 2015

Course site: Institute of Electron Technology (ITE)
Al. Lotników 32/46, 02-668 Warsaw, Poland

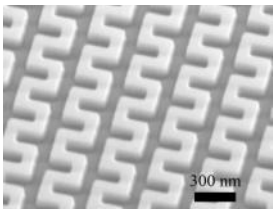
9.00-9.30 **Marek Ekielski, M.Sc.:**
Nanoimprint lithography
Presentation of a young local scientist

Marek Ekielski, M.Sc.
PhD student

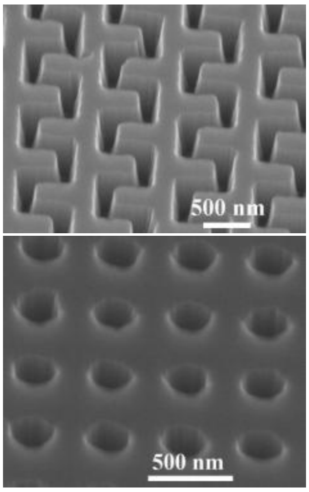
Department of Micro- and Nanotechnology of Wide Bandgap Semiconductors, Institute of Electron Technology

Warsaw, Poland

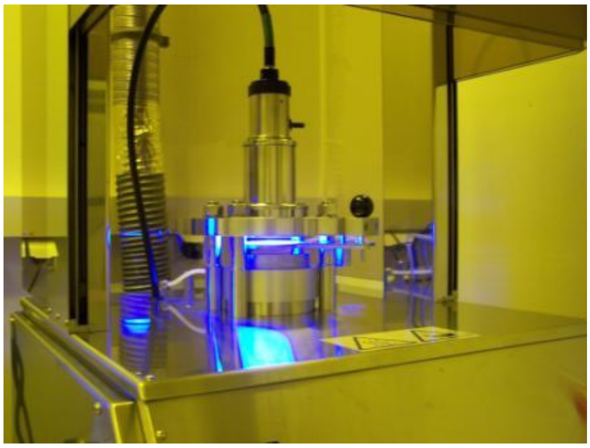
Abstract: Nanoimprint lithography (NIL) with high resolution, high throughput and low cost is powerful technique for nanoscale patterns fabrication. Technique is based on mechanical pressing of a stamp with nanopattern into a polymer film called imprint resist. In result negative impression of the stamp is achieved. Depending on application, obtained pattern can be final or (more frequently) is transferred to the substrate. NIL has two basic modes of work: thermal Th-NIL and UV-NIL. Nevertheless, since it was presented for the first time many variants of NIL have been developed.
The purpose of the talk will be the presentation of principles of NIL and its application to sub-micrometers pattern generation. Special attention will be paid to stamp fabrication using different techniques and pattern transfer to GaN.



SEM picture of stamp made of quartz

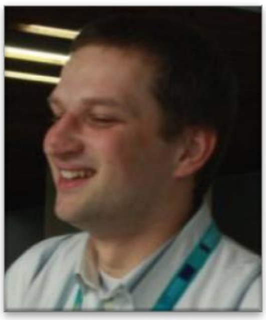


SEM pictures of NIL fabricated pattern transfered into GaN



Eitre3 Nanoimprint Lithography System

9.30-10.00 **Marcin Juchniewicz, M.Sc.:**
Current research results – introduction to the laboratory visit
Presentation of local scientist



Marcin Juchniewicz, M.Sc.
Senior Researcher

Department of Micro- and Nanotechnology of Wide Bandgap Semiconductors

Institute of Electron Technology

Warsaw, Poland

Abstract: The strength of the Department of Micro- and Nanotechnology of Wide Bandgap Semiconductors is derived from its multidisciplinary team and excellent facilities. A coordinated research group of scientists, engineers, and technicians representing such disciplines as electronics, physics, chemistry, and material science provides particular expertise in fabrication of semiconductor devices based on III-V semiconductors, namely GaAs, InP, GaSb, GaN and related ternaries and quaternaries as well as on processing of II-VI and IV-VI materials and Transparent Conducting Oxides (TCOs).

The research programmes carried out at the Department combine focused, application led research with fundamental studies on materials, processes and fabrication techniques in the field of optoelectronics, high-speed electronics and nanostructures. The research area covers:

- Development and testing of single technological processes for III-V, II-VI & IV-VI semiconductors;
- Development of process modules and complete processes for manufacturing of semiconductor devices;
- Prototypes and customer specific series.

The research groups contribute on the one hand to the departmental main topics as described above but also follow their own line of research. Recent projects focus on

- Conducting oxides for photonics and transparent electronics;
- Refractory material-based antidifussion barriers for advanced metallization systems;
- Semiconductors for spintronics;
- III-V, II-VI, and IV-VI quantum nanostructures.

10.00-12.00 **Visit to the Nanotechnology Laboratory of the Institute of Electron Technology**
Practical demonstration and laboratory visit

The Department has world-class purpose-built laboratories offering researchers an extensive array of modern equipment and other facilities enabling state-of-the art R&D in the area of new process technologies and device architectures for optoelectronic and microwave components. At the centre of these facilities is the fabrication suite totalling over 600 square meters and comprising ISO 5, ISO 6 and ISO 7 areas encompassing the full spectrum of techniques required for fabrication of compound semiconductor-based devices.

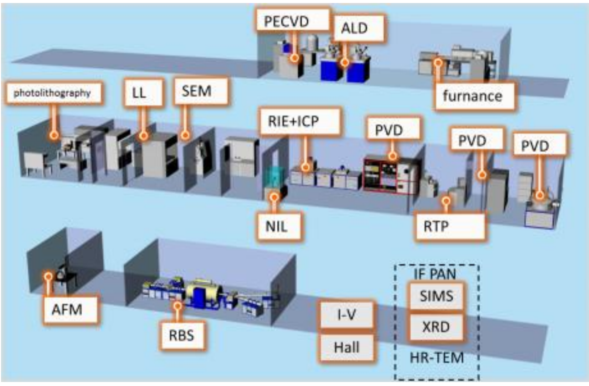
The **Laboratory of Vacuum Deposition of Thin Films** has a large thin film deposition facility based around dc/rf magnetron sputtering, ALD, thermal evaporation and e-beam deposition. The runs a number of specific thin film research projects, as follows:
- Reactive deposition of oxides and nitrides
- Metallic multilayers including antidiffusion barriers
- Ohmic contacts to wide bandgap semiconductors

The following techniques are available in the **Laboratory of Chemical and Thermal Processing**:
- chemo-mechanical polishing of semiconductor substrates
- wet and dry (ICP/RIE) etching
- conventional furnace annealing
- RTA under O2, H2, Ar, N2 and N2O atmosphere

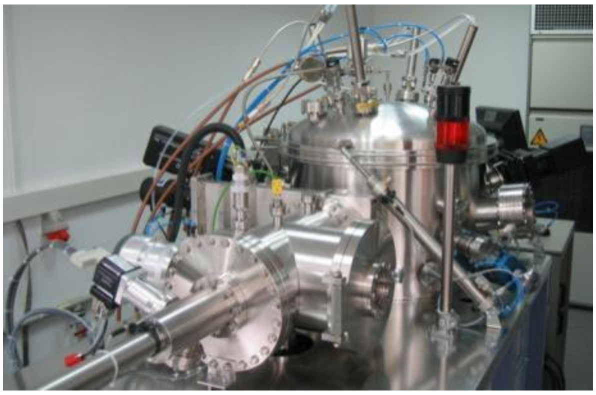
The **Laboratory of Photolithography** has a class 100 clean room equipped with two Karl Suss MJB aligners, Heidelberg Instruments laser lithography and Odbucat nanoimprint system. Being the part of inter-institutional Laboratory of Nanostructures it has access to direct-write electron beam lithography using JEOL 6400 equipped with Raith Elphy Plus software.

In the **Laboratory of Inspection and Testing** specialized instrumentation and systems are available for the characterization of thin structures fabricated in the Department. These include:
- Mechanical profiler
- Thin film stress measurement system
- Microscopy: HRTEM (+FIB), SEM, AFM, optical
- Ellipsometer
- A set-up for measurements of I-V-T and rC-T characteristics of metal/semiconductor contacts

The Department is a part of Centre of Excellence CELDIS (Centre of Physics and Technology of Low-Dimensional Structures) at the IPPAS and thus benefits from access to additional facilities for material characterisation such as Photoluminescence Spectroscopy, X-ray diffraction, EPMA, and Hall measurements in wide range of temperatures and magnetic fields.



Layout of laboratories



Gamma 1000c Thin Film Sputtering Tool

Laboratory of Photolithography

Oxford Instruments PlasmaLab100

12.00 **Collection of course evaluation sheets and disperse**

Further information / contact persons:

Dr. Olivér Krammer (krammer@ett.bme.hu tel: +36 1 4632755)
Dr. Zsolt Illyefalvi-Vitez (illye@ett.bme.hu tel: +36 1 4632753)
Budapest University of Technology and Economics,
Department of Electronics Technology, Hungary

Prof. Małgorzata Jakubowska (m.jakubowska@mchtr.pw.edu.pl tel: +48 22 234 8139)
Warsaw University of Technology, Faculty of Mechatronics,
Institute of Metrology and Biomedical Engineering, Warsaw, Poland