Yearbook

2007

Research Institute for Technical Physics and Materials Science

Hungarian Academy of Sciences

http://www.mfa.kfki.hu

Research Institute for Technical Physics and Materials Science
Hungarian Academy of Sciences

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MTA MFA Yearbook 2007

Editors: György Zoltán Radnóczi, Zsolt Zolnai
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DIRECTOR'S FOREWORD

Further in the footsteps of the great predecessors… was the motto of the celebrations of the 50th anniversary of our institute in 2007. The Research Institute for Technical Physics of the Hungarian Academy of Sciences - MTA MFKI, was founded according to a decision of the minister's council of the Hungarian People's Republic in 1956, and started its operation in 1958. The formation of the successor institution, the present Research Institute for Technical Physics and Materials Science, was the result of a merger according to the decision of the General Assembly of the Hungarian Academy of Sciences in 1997. Both parent institutes, the MTA MFKI and the KFKI Research Institute for Materials Science, exist under the name of MTA MFA since January 1, 1998, i.e. for just ten years.

This double jubilee deserved a series of commemorative events, which focussed a considerable attention to the activities and achievements of the institute. Just to name a few, we hosted the meeting of the Department for Physical Sciences and the Department of Technical Sciences of the Hungarian Academy of Sciences (HAS). The institute was visited by the president of HAS, Szilveszter E. Vízi, and the acting Vice President of the National Office for Research and Technology of Hungary, Ms. Ilona Vass. The Hungarian scientific periodicals, *Fizikai Szemle* and *Híradástechnika* both dedicated their October 2008 issue to the commemoration of the 50 years jubilee, each publishing several papers of the co-workers of the institute reviewing past and present research activities. We gave several interviews for TV and the press. With the help of the National Technology Information Centre and Library (OMIKK BME) an audio-visual documentary, a commemorative DVD was compiled (edited by Dr. Judit Árvay-Kucsera) introducing many written, photographic and film documents from the proposal of the establishment of the institute by the HAS member Prof. György Szigeti until the present achievements.

The main events of the celebrations were scheduled for the 3rd and 4th October 2007 with a number of international celebrities attending. In the entrance hall of the main building of the institute an exhibition, featuring the relics of the past was inaugurated. After arranging a guided tour of the laboratories for our international guests and former colleagues of the predecessor institutes, the day was crowned by a boat trip on the Danube. Thanks to the generosity of our sponsors, colleagues and foreign guest could enjoy besides the reunion the illuminated panorama of Buda and Pest while tasting a number of selected Hungarian wines from the historical wineregions of the country along with folkmusic performed by our coworker Zoltán Juhász.

On the 4th October the Celebration took place at the main building of HAS (see attached programme). The morning programme in English was dedicated to the greeting addresses of the elected officials of our academy, and invited guests who paved the way for international contacts, long lasting collaborations and exchanges during the past decades. The Celebration was attended by prominent members of the foreign legations in Budapest. During the Celebration we signed a contract of R&D co-operation with Mr. Soichiro Mizuguchi, the president of the Japanese company Tateyama Kagaku, Toyama.

The afternoon programme received a special attention from a wide audience. It was moderated by the past directors of the predecessor institutes Prof. László Bartha and HAS member Prof. József Gyulai and devoted to reviews by our former and present colleagues. This overview gave a brief summary of the far reaching consequences of the foresight of the founding scientists and allowed anyone an individual assessment of the results of the past five decades.

In 2007 the Research Institute for Technical Physics and Materials Science was invited to become a member of the newly established World Materials Research Institute Forum. This international initiative, coming from the President of the National Institute for Materials Science, Tsukuba, Japan, is aimed at intensification of the scientific contacts between the meanwhile 42 member institutions by allowing access to facilities, fostering joint projects and exchange of young researchers.

In June the first – albeit extended by 6 months – period of duty of the present director expired. From July 2007 the president of HAS appointed him for a new period of five years to again head the institute. This came in a period of worsening economic slow-down in Hungary, a continuing depression not favouring the development of scientific research as such. The decline was obvious from the radically decreasing domestic R&D support, especially in the applied field, and the lack of resources for investments in scientific infrastructure. The record high turnaround of 2006 of ca. € 6M was reduced by ca. 15% in 2007.

Despite this generally unfavourable climate, the MFA management tried to continue the policy of small improvements in the laboratory reconstruction and reshuffling from own resources. This coincided with the need for a reorganisation of the management structure, which finally took effect from January 2008. In order to decrease expenditure the institute was forced to reduce the occupied laboratory and office floor-space by 400 m^2, by more concentrated rearrangement of the processing equipment. We also invested in closed-loop cooling for most of the laboratory apparatus. In the framework of these rearrangements four laboratories and seven offices were renovated.

The spin-off company ANTE Innovative Technologies Ltd. of MFA moved to Székesfehérvár, in order to be eligible to access EU regional structural development funds. Early in 2007 another spin-off, TactoLogic Ltd. was founded with the pharmaceutical company Gedeon Richter SHC and the Péter Pázmány Catholic University (PPKE). This company completed successful product development based upon the integrated tactile sensor jointly developed by PPKE and MFA using the patented CMOS-compatible bulk micromachining process of our institute. MFA is also one of the stakeholders in AlbaNano Ltd, a company of the HAS for the support of applications of nanotechnology in the industry of the Middel-Transdanubia Region.

"Dum spiro spero" … wrote the president of HAS in the guest book of the 50 years old institute. This ancient wisdom can give us guidance for the years to come, and the hope that all the invested efforts, energy and enthusiasm of half a century will finally bear fruit and lead to the appreciation and acknowledgement of this research field also in Hungary, which it long deserves.

Budapest, January 2008.

István Bársony

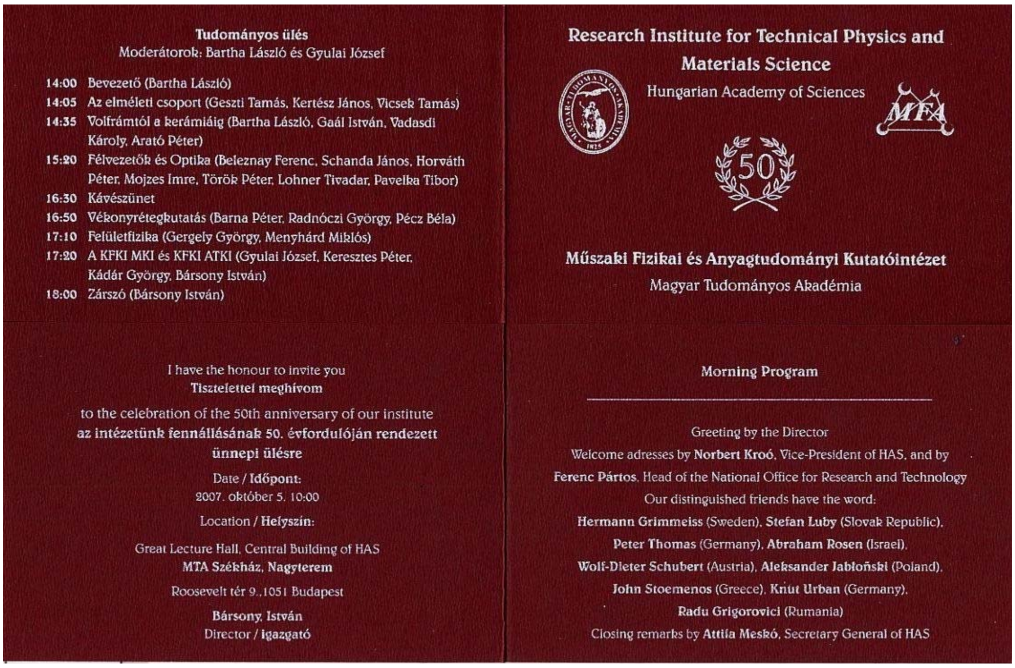
NOTABLE EVENTS IN YEAR 2007

Celebration of the 50th anniversary of the Institute

To honour this anniversary an exhibition featuring relics of the main activities of the institute and its predecessors was established in the main building of MFA. The memorial collection was inaugurated by Prof. István Bársony, the Director of the Institute.

The official 50th anniversary ceremony was organized in the Great Lecture Hall of the central building of the Hungarian Academy of Sciences. A number of distinguished guest, friends, colleagues and R&D partners were invited to this from all over the world. Memorial and scientific speeches were given about the most important and memorable moments of the Institute and its predecessors.

As special highlight of the anniversary ceremony, present and former MFA members as well as collaboration partners of the institute enjoyed a get together party – a boat trip with vine tasting on river Danube.



Tudományos ülés
Moderátorok: Bartha László és Gyulai József

14:00 Bevezető (Bartha László)
14:05 Az elméleti csoport (Geszti Tamás, Kertész János, Vicsek Tamás)
14:35 Volfrámtól a kerámiáig (Bartha László, Gaál István, Vadasdi Károly, Arató Péter)
15:20 Félvezetők és Optika (Beleznay Ferenc, Schanda János, Horváth Péter, Mojzes Imre, Török Péter, Lohner Tivadar, Pavelka Tibor)
16:30 Kávészünet
16:50 Vékonyrétegkutatás (Barna Péter, Radnóczi György, Pécz Béla)
17:10 Felületfizika (Gergely György, Menyhárd Miklós)
17:20 A KFKI MKI és KFKI ATKI (Gyulai József, Keresztes Péter, Kádár György, Bársony István)
18:00 Zárszó (Bársony István)

I have the honour to invite you
Tisztelettel meghívom
to the celebration of the 50th anniversary of our institute
az intézetünk fennállásának 50. évfordulóján rendezett ünnepi ülésre
Date / **Időpont:**
2007. október 5. 10:00
Location / **Helyszín:**
Great Lecture Hall, Central Building of HAS
MTA Székház, Nagyterem
Roosevelt tér 9., 1051 Budapest
Bársony István
Director / **igazgató**

Research Institute for Technical Physics and Materials Science
Hungarian Academy of Sciences
Műszaki Fizikai és Anyagtudományi Kutatóintézet
Magyar Tudományos Akadémia

Morning Program

Greeting by the Director
Welcome adresses by **Norbert Kroó**, Vice-President of HAS, and by **Ferenc Pártos**, Head of the National Office for Research and Technology
Our distinguished friends have the word:
Hermann Grimmeiss (Sweden), **Stefan Luby** (Slovak Republic), **Peter Thomas** (Germany), **Abraham Rosen** (Israel), **Wolf-Dieter Schubert** (Austria), **Aleksander Jabłoński** (Poland), **John Stoemenos** (Greece), **Knut Urban** (Germany), **Radu Grigorovici** (Rumania)
Closing remarks by **Attila Meskó**, Secretary General of HAS

Official invitation to and program of the 50th anniversary ceremony of the institute at the main building of the Hungarian Academy of Sciences in Budapest.

Past director of MFA, Prof. József Gyulai with Dr. Ilona Vass, Vice President of the National Office for Research and Technology of Hungary, and the director of MFA at the anniversary celebration.

Ceremony in the Great Lecture Hall of the Hungarian Academy of Sciences.

Celebrating the 50th anniversary in the main building of MFA. The exhibition was inaugurated by the director of the Institute.

Boat trip on river Danube – get together.

Mr. Soichiro Mizuguchi, president of the Japanese company Tateyama Kagaku, Toyama, and Prof. István Bársony, the Director of MFA signing the contract of R&D co-operation.

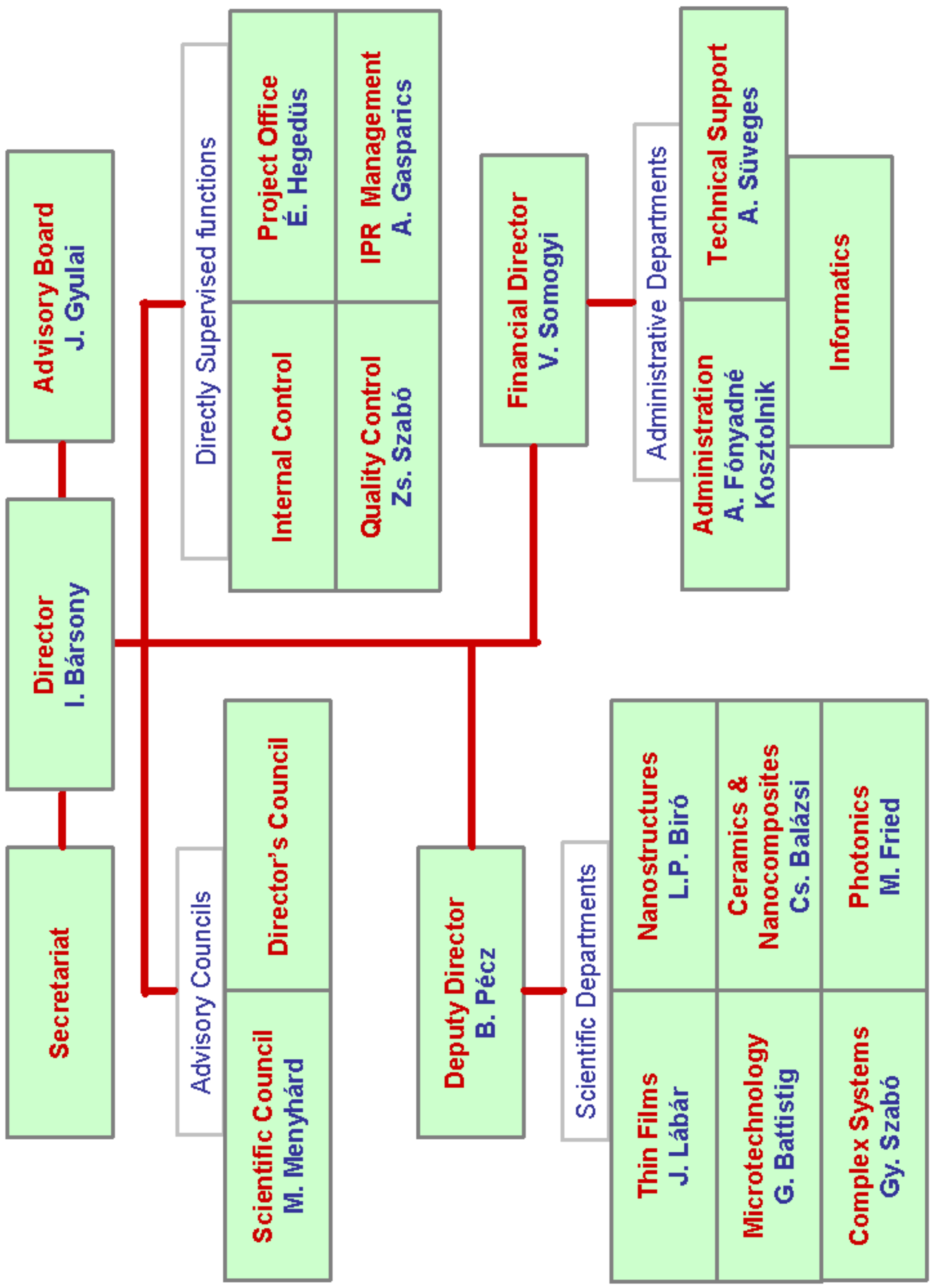
MFA became a founding member of WMRIF

In 2007 MTA MFA was invited to become one of the 31 founding members of the World Materials Research Institute Forum (WMRIF). The kick-off meeting was organized by the Bundesanstalt für Messtechnik (BAM) in Berlin, Germany.

Representatives of member institutions at the founding meeting of the World Materials Research Institute Forum (WMRIF) *in Berlin, Germany.*

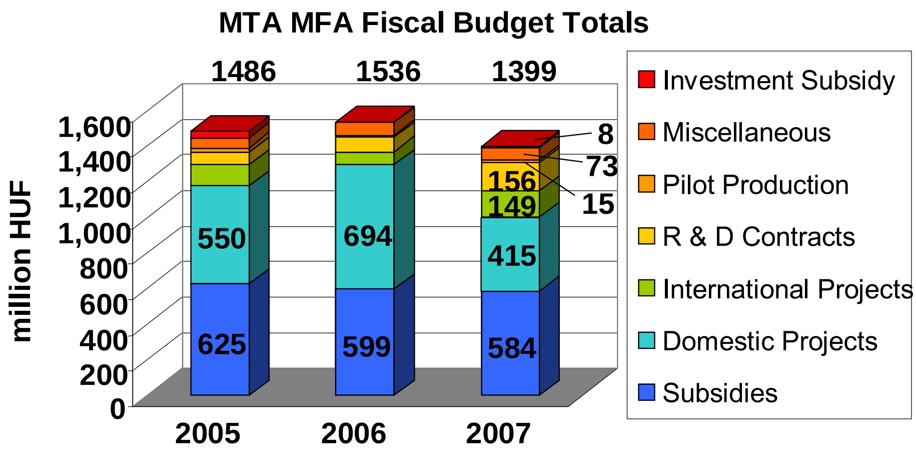
GENERAL INFORMATION

Organisation

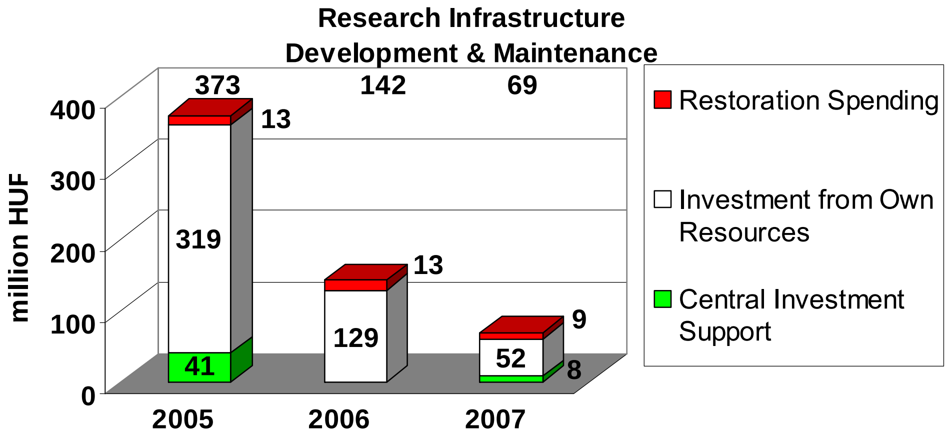


Key Financial Figures

The total budget of MFA has grown continuously in the last couple of years, but in 2007 the turnover reached only ca. 90% of the previous years' budget (ca. €5.6 million*). The intensive participation of MFA in domestic projects and the substantial increase of the share of successful R&D contracts as well as international projects could not compensate for the continuously decreasing subsidies and reduced domestic innovation financing.



Despite the marginal central investment support, the Institute managed to develop the research infrastructure every year substantially.



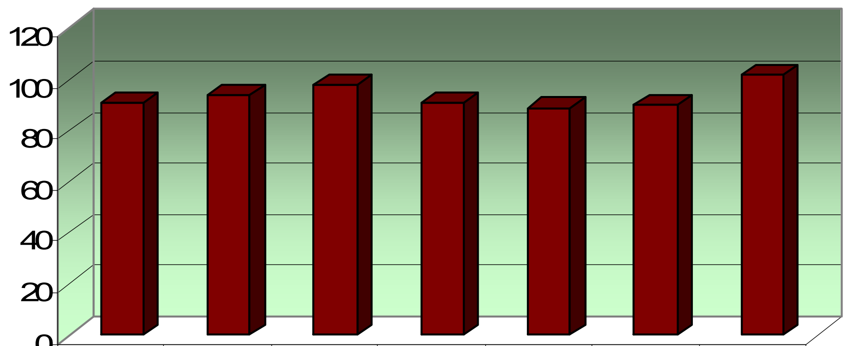
*Note, the budget items above are shown in millions of Hungarian Forints (HUF). For comparison: 1 million HUF ≈ 4000 €

Scientometry (International Impact)

The number of MFA publications listed in the database ISI Web of Science (http://www.isiknowledge.com) shows a stable average of about 95 papers/year.

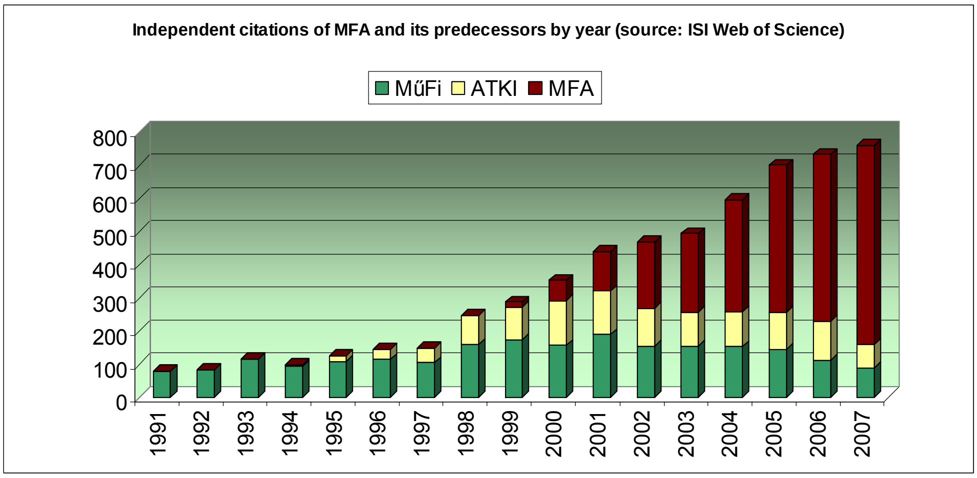
The detailed list of all the 196 MFA publications reported in 2007 (including also the regular journal papers and conference presentations which are not listed in the ISI database) can be found at the end of this yearbook.

MFA Publications (source: ISI Web of Science)



	2001	2002	2003	2004	2005	2006	2007
publications	91	94	98	91	89	90	102

The number of independent citations to the publications of MFA and its predecessors' in the last fifteen years follows an intensively growing tendency confirming the significant international interest in the research activity of the Institute.



Nanoscience highlights

Engineering graphene nanostructures for nano-scale electronics applications

(OTKA-NKTH grants K-67793 & NI-67851)

Levente Tapasztó, MFA Nanostructures Laboratory

The practical realization of nano-scale electronics faces two major challenges. The precise engineering of the nanometer-size building blocks is necessary to obtain the required functionality, and then the assembly of these components into complex functional architectures (circuits) has to be solved. Carbon nanotube (CNT) based electronics provides an eloquent example. In spite of their exceptional electronic properties and the intense research activity for the last fifteen years only basic demonstration-devices could be realized by time-consuming processes. This is mainly due to the lack of reliable selective growth and assembly processes for nanotubes.

However, a recently discovered carbon material, a two dimensional, one atom thick layer of carbon atoms arranged in a hexagonal lattice, called ***graphene***, might offer the solution. Graphene retains the exceptional electronic properties of carbon nanotubes, and also offers the possibility to lithographically pattern its structure.

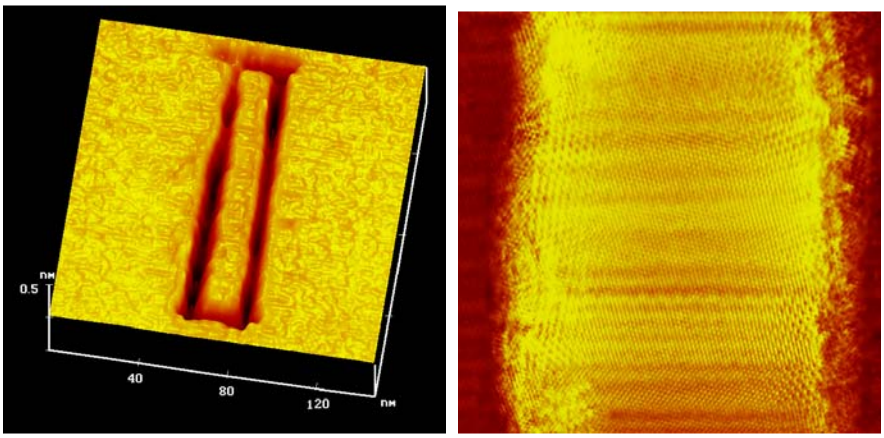


Figure 1.

A major setback in the development of graphene based field-effect transistors is the inability to electrostatically confine electrons in graphene, since a single layer of graphite remains metallic even at the charge neutrality point. In order to overcome this problem, a way to open a gap in the electronic structure of graphene has to be found. A straightforward solution is to pattern the graphene sheet into narrow ribbons, which can be viewed as unrolled single wall nanotubes. Due to the quantum mechanical constriction of electronic wave functions in the direction perpendicular to the axis of the ribbon, a confinement-induced gap can open. Theoretical works predicted the strong dependence of the gap on width and crystallographic orientation of the ribbon. This dependence offers us the opportunity to tailor the electronic structure of the graphene nanoribbons (GNRs), on the other hand it also imposes strict requirements for the fabrication of GNR-based devices, since in order to provide sufficient reproducibility, the accurate control of their structure down to the atomic scale is imperative.

With standard e-beam lithographic (EBL) methods, GNRs down to a few tens of nanometers in width could be realized recently, which seems to be the limit of this technique. Moreover, EBL has difficulties in controlling the crystallographic orientation of the ribbons.

We have developed an STM lithography based method, which is able to prepare graphene nanostructures with predetermined atomic structure, enabling us to fully engineer their electronic properties In our work we combine the ability of STM to locally modify the surface with atomic resolution imaging in order to engineer nanostructures with almost atomically precise structure and predetermined electronic properties – a task considered as a great challenge in nanotechnology. Cutting was done by applying a constant bias potential (significantly higher than the one used for imaging) and simultaneously moving the STM tip with a constant speed in order to etch the desired geometry fitted to the crystallographic structure known from previous STM imaging of the sample.

In Fig. 1 we show a 10 nm wide and 120 nm long graphene nanoribbon etched by STM lithography. After the patterning process, atomic resolution STM images could be achieved revealing the atomic structure of the GNRs. When imaging a 10 nm wide armchair GNR at low bias voltage, oscillations in the electron density distribution parallel to the axis of the ribbon were observed as shown in Fig. 2 below. The periodicity of the observed oscillations was about 0.4 nm, which clearly differs from the period of the underlying atomic structure (0.246 nm), and corresponds to the Fermi wavelength of electrons in graphene.

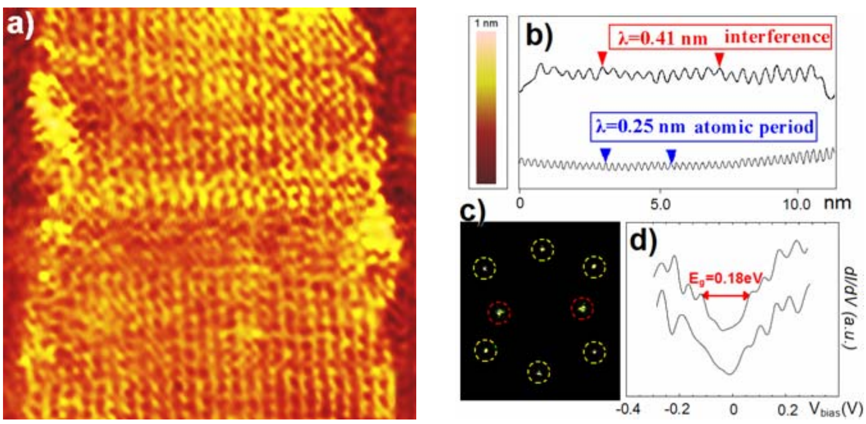


Figure 2.

In order to investigate the band structure of GNRs Scanning Tunneling Spectroscopy (STS) measurements have been preformed (Fig. 2). For the 10 nm wide armchair GNR, a 0.18 eV gap value was found in good agreement with the theoretical predictions.

A great advantage of our STM lithography based method as compared to e-beam lithography is the ability for downscaling. With our method, ribbons down to a few nm in width can be achieved, corresponding to gap values which allow room temperature operation of graphene nanoribbon based electronic devices. Furthermore, STM lithography offers us the opportunity for patterning more complicated architectures, even complete integrated circuits from networks of GNRs. One can imagine the feasibility of a variety of electronic devices based on our technique, which could open up new directions in the experimental realization of graphene-based electronics.

Electromagnetic Reading System of Laser Marked Logistic Bar Codes

(GVOP-3.1.1-2004 – 05-0452/3.0)

Antal Gasparics, Gábor Vértesy, MFA Laboratory of Non-Destructive Testing

The importance of identification of vehicles (and a lot of other objects) becomes more and more significant. The mechanically imprinted car identification numbers can be removed and rewritten. This is the fact which indicated the research and development of steel marking system. The developed system can be used also for logistic purposes during the manufacturing process, since it provides writing of the identification codes as well as their reliable readouts without any contact even if the marked components are treated mechanically or thermally, or got painted layer coverings.

In case of the developed novel technology laser device is applied to produce lines on the ferromagnetic specimen surface by the help of CO_2 laser irradiation. This type of marking is considered to apply as barcode for identification in car industry and production logistics. The physical basis of the marker evolution is a local phase transformation in the vicinity of the surface in low and high carbon steel occurring as a consequence of rapid heating and cooling process. The induced local phase transformations result changes of the local magnetic properties. A special probe was developed and applied for the electromagnetic reading out of the written code. The codes can be successfully detected by this device, even beneath the 1 mm painted layer. The markings have been proven thermally stable enough to use them as barcodes even when the temperature of painting process is relatively high. Furthermore, no drawbacks the barcodes have been discovered could result corrosion or mechanical weakness.

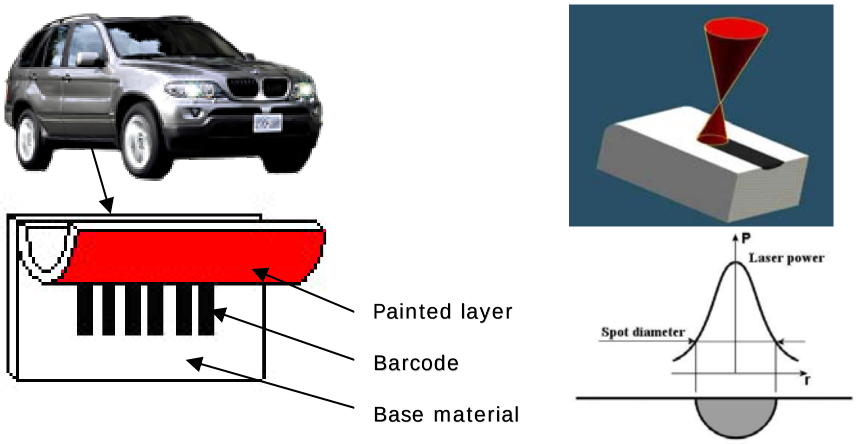


Figure 1 *Laser marking. Invisible car identification and process of laser scribing*

The electromagnetic reading out of bar codes is based upon the local phase transformations and the local modifications in the stress field around the individual markers. It is caused by the rapid heating and cooling processes during the laser-metal interaction. The device, which was developed for reading out is a special type eddy current measuring head. Eddy currents are generated in the metallic objects, and the magnetic field of eddy currents are measured by a high sensitivity magnetic field sensor (Fluxset sensor) built in the probe. Due to the local changes of electric conductivity and magnetic permeability at the barcodes, the eddy currents are distorted, which is detected by the probe. It was found, that marker lines produced by laser beam in the range of 100-300 W power were detectable in reliable way by using this sensor. It was found also, that these markings were thermally stable enough to use them as barcodes on the car body sheets.

Fig. 2 shows the measuring probe, which is suitable for reading of bar codes. All electronics, which is necessary for the operation of the device is built in the device. It is controlled by a laptop computer. The signals of the probe from the laser scribed lines are seen on the screen. A software was also developed for this device, which makes possible the proper reconstruction of the original code from the measured signals (decoding). The obtained binary code (after detecting and decoding of the bar codes, written is a specimen) is also seen on the screen of the computer.

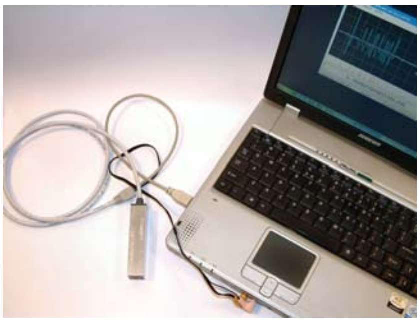


Figure 2 *Fluxset measuring probe connected with laptop for reading out of logistic bars. Signals from the barcodes and result of decoding are seen on the screen.*

Prizes and Honours

Honours to the institute MFA

The Research Institute for Technical Physics and Materials Science of the Hungarian Academy of Sciences (MTA MFA) has been invited from Hungary as one of the 31 foundation members of the World Materials Research Institute Forum (WMRIF) established in 2007. The foundation meeting has been organized by the Bundesanstalt für Messtechnik (BAM) in Berlin, Germany between 13-15 June, 2007.

Honours to MFA members

Dr. László Bartha, Professor Emeritus
Order of Merit of the Hungarian Republic - Officer's Cross
For his internationally appreciated results achieved in tungsten research and for his outstanding activity presented as the director of the predecessor of MTA MFA.

Dr. György Gergely
First Prize in Physics*, awarded by the* ***Hungarian Academy of Sciences***

Dr. György Szabó
Prize in Physic, *awarded by the* ***Hungarian Academy of Sciences***
For his prominent role in the extension of methods used in statistical physics to investigate evolutionary games in order to understand the macroscopic processes in economic and ecological systems based on the analysis of microscopic interactions between different individuals, species, or strategies.

Dr. Béla Pécz
Bolyai plaquette*, awarded by the* ***János Bolyai Research Grant Advisory Board of the Hungarian Academy of Sciences***

Dr. Péter Petrik
Paul Drude Award*, at the* ***4th International Conference for Spectroscopic Ellipsometry in Stockholm, Sweden***
For his unique contributions with strong focus on ion-implanted single-crystal semiconductor materials and the damage that these materials sustain through the implantation process.

Dr. Csaba Balázsi
János Bolyai Postdoctoral Grant

Zsolt Szabó
Appreciation by the ***Secretary-General of the Hungarian Academy of Sciences***
In recognition of his prominent work attached to the Hungarian Academy of Sciences

Dr. Gábor Vásárhelyi
Junior Prima prize in the category of „Hungarian Science"

Dr. Antal Adolf Koós
Junior Scientists' Award of the Hungarian Academy of Sciences
For his work: Preparation and investigation of carbon nanotubes

Dr. Csaba Balázsi, Dr. György Molnár, Dr. Zsolt Zolnai
József Öveges Research Grant

Dr. Miklós Serényi and his co-workers
Plaquette of the Mediterranian Microwave Symposium MMS 2007 held in Budapest, Hungary
For presenting: Hámori A, Serényi M, Dér A, Kökényesi S, Ferencz K: All-optical switching possibilities for optical packet switching

Enikő Horváth
Best Presentation Award, 2007 Conference of the Hungarian Microscopy Society
For presenting: Horváth E, Tóth AL, Neumann PL: Materials processing using focused beams - experiment and prospects

MFA prizes and honours in 2007

Dr. Gábor Pető
Professor Emeritus Instituti

Dr. Imre Eördögh
MFA Prize
In recognition of his decade long successful work in the development of multidisciplinary applications of quantitative microscopy methods as well as for the realization of patented real time time-coding image processing techniques.

Dr. Andrea Edit Pap
MFA Prize
For her internationally recognized results presented on the deuterium-assisted passivation of large area Si wafers and for successful developments in MEMS technology.

Dr. Levente Tapasztó
MFA Junior Prize
For his outstanding results on the realistic mapping of carbon nanotubes and for his prominent supervisor activity at the Roland Eötvös University.

Visitors

Miklós Adamik
SAVCOR Komárom Ltd., Komárom, Hungary

Prof. György Amsel
Université Pierre et Marie Curie and French National Research Center, Paris, France

Martin Andritschky
SAVCOR Komárom Ltd., Komárom, Hungary

László Balázs
GE Hungary, Budapest, Hungary

dr. Balázs Bernáth
HAS Plant Protection Institute, Dept. of Zoology Budapest, Hungary

Prof. Gary Bernstein
University of Notre Dame, Indiana,USA

Prof. Serge Berthier
UPMC-P6 Université Pierre et Marie Curie, Paris, France

Magdalena Bieda-Niemiec
Institute of Metallurgy and Materials Science, Polish Acad. Sci., Krakow, Poland

Prof. Dr. Hynek Biederman
Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Sergiy Bilichuk
Yuri Fedkovych Chernivtsi State University, Kiev, Ukraine

Domokos Biró
Petru Maior University, Targu Mures, Romania

Prof. Gerry Burnstien
University of Notre Dame, Indiana,USA

Prof. Leonid A. Chernozatonskii
Institute of Biochemical Physics, Moscow, Russia

Prof. Robert W. Collins
Department of Physics and Astronomy, The University of Toledo, Ohio, USA

Prof. Árpád Csurgay
University of Notre Dame, Indiana, USA

Prof. Alexandru Darabont
Babes-Bolyai University, Cluj, Romania

Dr. Olivier Deparis
Facultés Universitaires Notre-Dame de la Paix, Namur, Belgium

Dr. Catherine Deville
Institute de NanoSciences de Paris, Université Paris 6, Paris, France

Prof. Nikolay Gennadevich Galkin
Institute for Automation and Control Processes, Russian Acad. Sci, Vladivostok, Russia

Dr. Eva Heblakova
Institute of Measurement Science, Slovak Acad. Sci., Bratislava, Slovak Republic

dr. Zoltán Hlavathy
Institute of Isotopes, Hungarian Acad. Sci., Budapest, Hungary

Petro Horley
Yuri Fedkovych Chernivtsi State University, Kiev, Ukraine

Khalid Hoummada
L2MP, University Paul Cézanne, Marseille, France

Dr. Pavel Hubik
Institute of Physics, Czech Acad. Sci., Prague, Czech Republic

Michael Idelchik
GE Global Research, USA

Prof. Yoshiaki Itoh
The Institute of Statistical Mathematics and the Graduate University of Advanced Studies, Tokio, Japan

Dr. László Jakab-Farkas
Sapientia Hungarian University of Transylvania, Targu-Mures, Romania

Dr. Guang-Way Jang
Industrial Technology Research Institute (ITRI), Taiwan

William Jang
Industrial Technology Research Institute (ITRI), Taiwan

Prof. István Jenei
Babes-Bolyai University, Cluj, Romania

Fahdel El Kamel
Grenoble Electric Engineering Laboratory, CNRS, Grenoble, Franc

Takashi Kato
Ministry of Education, Culture, Sports, Science and Technology, Tokyo, Japan

dr. Annamária Kertész
Department of Botany, Hungarian Natural History Museum, Budapest, Hungary

Dr. Hak Min Kim
Korea Institute of Materials Science, Republic of Korea

Dr. Sung You Kim
Korea Institute of Materials Science, Republic of Korea

dr. János Kis
Szent István University, Budapest, Hungary

Dr. Wolfram Knabl
Plansee AG, Reutte/Tirol, Austria

Bc. Matej Kovalcik
Institute of Physics, Slovak Acad. Sci., Bratislava, Slovak Republic

Zuzana Krizanova
Institute of Electrical Engineering, Slovak Acad. Sci., Bratislava, Slovak Republic

Andreas Krueger
SUSS MicroTec Lithography GmbH, Germany

Toyokazu Kubota
Embassy of Japan in Hungary

Prof. Jacques Lafait
UPMC-P6 Université Pierre et Marie Curie, Paris, France

Lydia Lee
Industrial Technology Research Institute (ITRI), Taiwan

Prof. Kwan-Tai Leung
Institute of Physics, Academia Sinica, Taiwan

Dr. Welkin Ling, Dr. Man-Yin Lo
Industrial Technology Research Institute (ITRI), Taiwan

Dr. F. Javier Garcia López
Centro Nacional de Aceleradores, Sevilla, Spain

Prof. Amand A. Lucas
Facultés Universitaires Notre-Dame de la Paix, Namur, Belgium

Prof. Stjepan Lugomer
Materials Science Department "Ruđer Bošković" Institute, Zagreb, Croatia

dr. György Makranczy
Department of Zoology, Hungarian Natural History Museum, Budapest, Hungary

Prof. Boguslaw Major
Institute of Metallurgy and Materials Science, Polish Acad. Sci., Krakow, Poland

Dr. Dominique Mangelinck
L2MP, University Paul Cézanne, Marseille, France

Dr. Roman Maniewski
Institute of Biocybernetics And Biomedical Engineering, Polish Acad. Sci., Warsaw, Poland

Prof. Isaac P. Mayer
The Hebrew University of Jerusalem, Jerusalem, Israel

Tomonori Mohri
Ministry of Economy, Trade and Industry, Tokyo, Japan

Dr. Yolanda Morilla Garcia
Centro Nacional de Aceleradores, Sevilla, Spain

Tsuneo Morita
Tateyama Laboratory Hungary Ltd.

Prof. Zoltán Néda
Babes-Bolyai University, Cluj, Romania

Dr. János Neugebauer
Plansee AG, Reutte/Tirol, Austria

Dr. Andreas Nutsch
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SCIENTIFIC REPORTS

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Main Activities

Research and development of physical, chemical/biochemical sensors and integrated systems:

- MEMS and MEMS related technology, with special emphasis on development of Si MOS embedding circuits.
- Development and applications of near IR light emitting diodes and detectors.
- Solar cells and their competitive technology.
- Acoustic wave devices and their application.

Fundamental research on:

- sensing principles
- novel materials and nanostructures
- novel 3D fabrication techniques
- ion-solid interaction for supporting MEMS development.

Device and material characterization.

Facilities

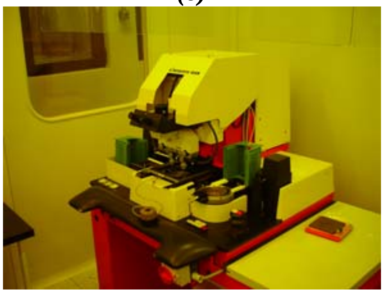
- 300 m^2 clean room (class 10 - 10000) with complete Si wafer processing line. Actually set for 3 and 4 inch diameter. See the Figures 1(a) - 1(h) below.
- 50 m^2 mask laboratory (class 100) for chromium masks up to 5 inch, Fig. 1(i).
- Mask processing with resolution of 1 μm.
- Alkaline and porous Si bulk micromachining.
- Mounting and encapsulation.
- Device testing and electrical characterization.

(a) *(b)*

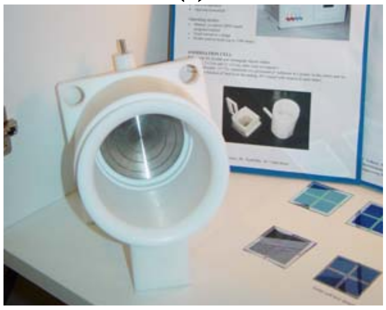
Figure 1

(c)

(d)



(e)



(f)

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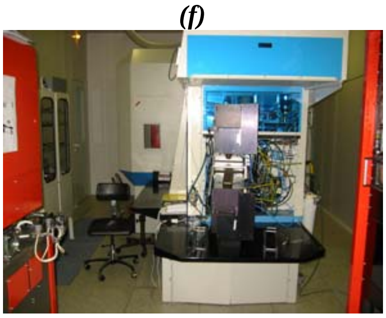

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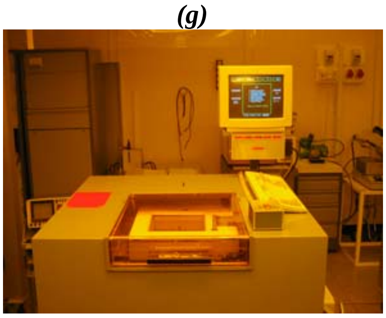
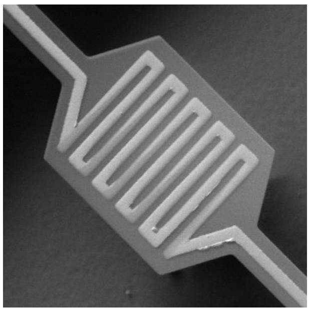


(i)

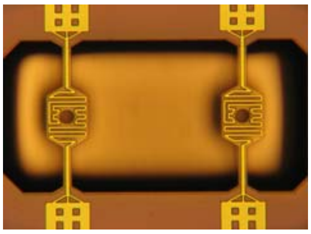
Figure 1 *continuation*

Production

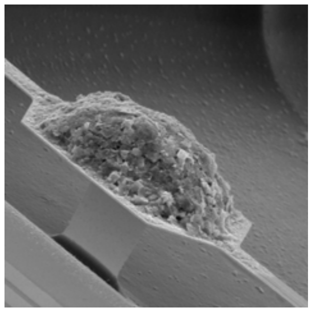
Calorimetric gas sensors with microfilament structure – Figs. 2(a), (b), and sensitive coatings – Figs. 2(c), (e), custom design and packaging – Figs. 2(d), (f); the hotplate dimensions: 100×100×1 μm^3



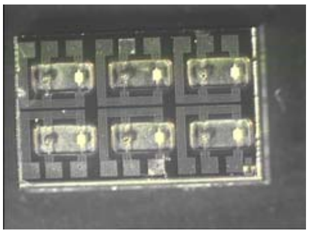
(a)



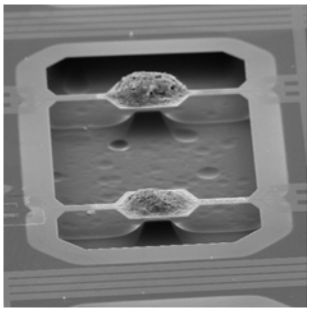
(b)



(c)



(d)



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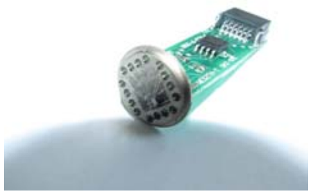
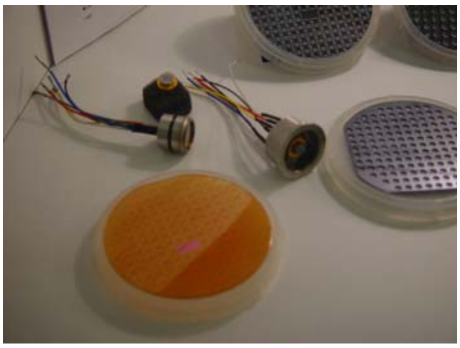


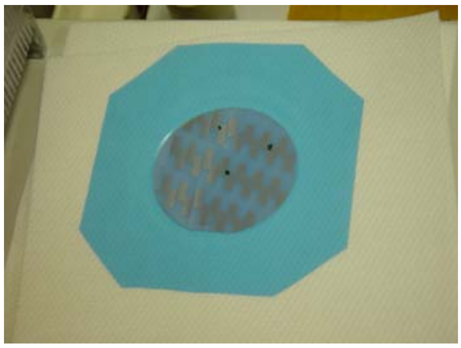
(f)

Figure 2

Development, custom design and small scale production of Si piezoresistive and capacitive pressure sensors – Fig. 3(a) and SAW filters – Fig. 3(b) (center frequency 10-250MHz).



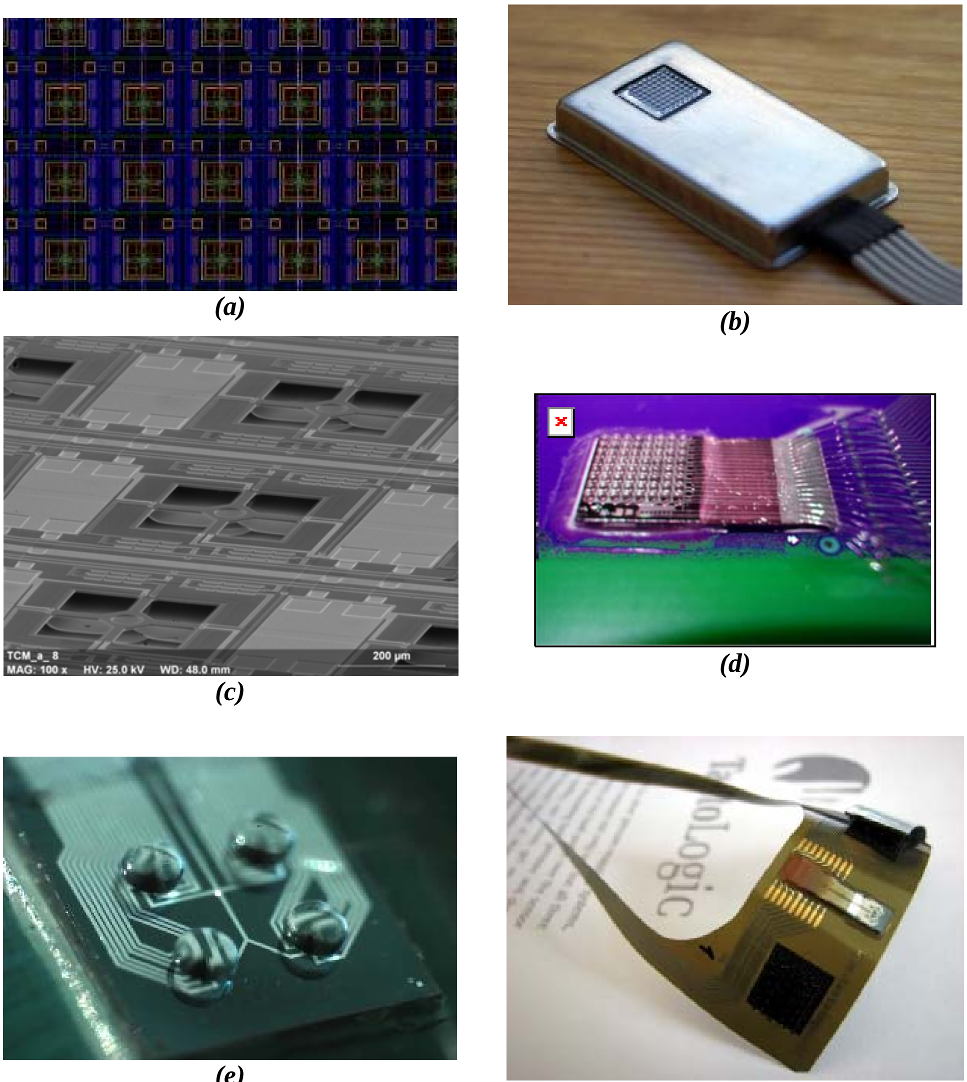
(a)



(b)

Figure 3

Development and small scale production of tactile sensor and sensor array fabricated by piezoresistive bulk micromachining technology: TactoPad is the 8×8 three-axial taxels array Fig. 4(c), and (d), the layout design – Fig. 4(a) and the packed device – Fig. 4(b). TactoFlex 2×2 is a small three-axial sensor array – Fig. 4(e) on a flexible support, designed for finger-mounted application – see Fig. 4(f). A spin-off company, **TactoLogic** (www.tactologic.com) has been launched for the further development and for the commercialization of the tactile sensors.



(a) *(b)*

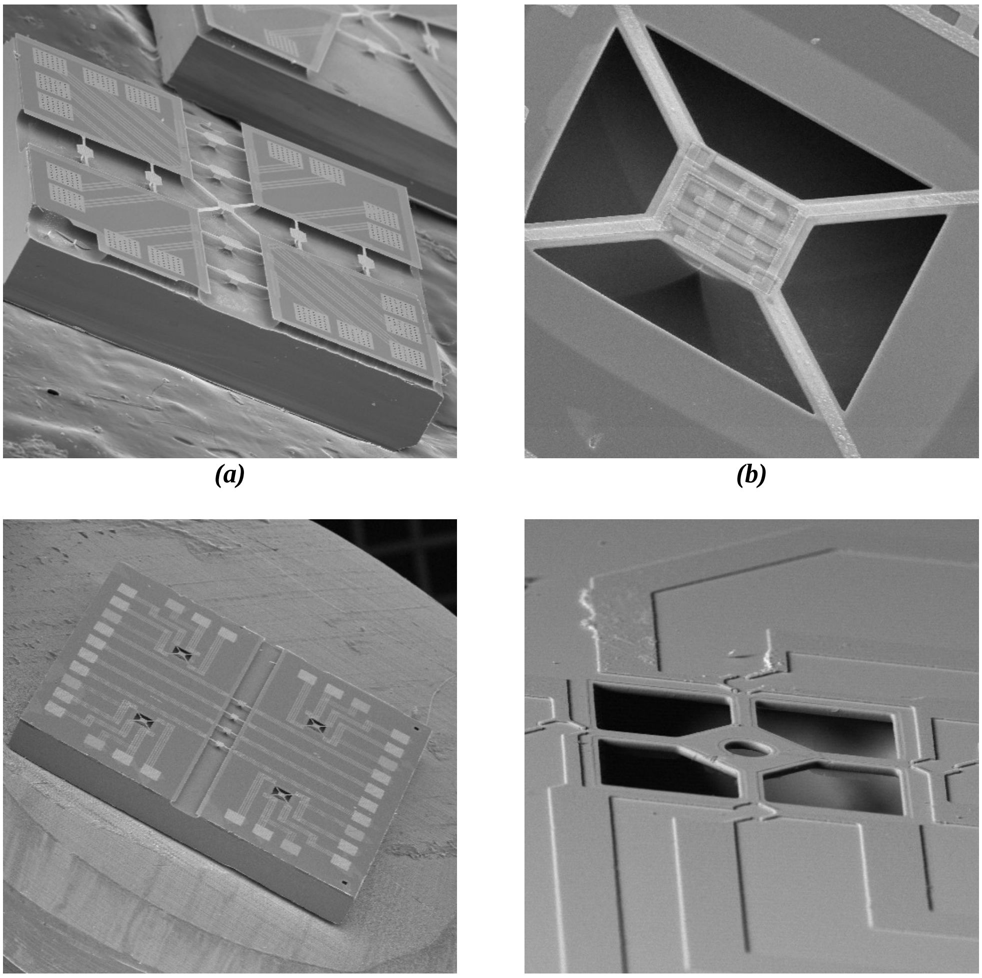
(c) *(d)*

(e) *(f)*

Figure 4

Fundamental research on:

- sensing principles
- novel materials and nanostructures, cantilever and bridge structures, Si and dielectric membranes
- novel 3D fabrication techniques – porous Si based Si micromachining, see Fig. 5(a), (b), (c), and (d) below.
- ion-solid interaction for supporting MEMS development.



(a) *(b)* *(c)* *(d)*

Figure 5

Design and realization of cantilever microphones for photo-acoustic gas detector system

(NKFP3-00021/2005 project, "Development and Field Application of Complex Photoacoustic Systems for Monitoring Environmental Conditions", 2005-2008)

P. Fürjes, Cs. Dücső

An extremely sensitive photo-acoustic gas detector system is developed to analyse the methane circulation of living forests. The method is based on the detection of the pressure wave generated by the selective energy absorption of the interested gas component which is excited by an adequate laser-pulse in the test chamber. The MFA was working to realize a micro cantilever microphone which is capable to detect the methane gas content in the ppm range through the deformation of the suspended reflective micro-membranes. The circumspect geometric and materials design of the suspending multilayer microstructures is a crucial object of the research.

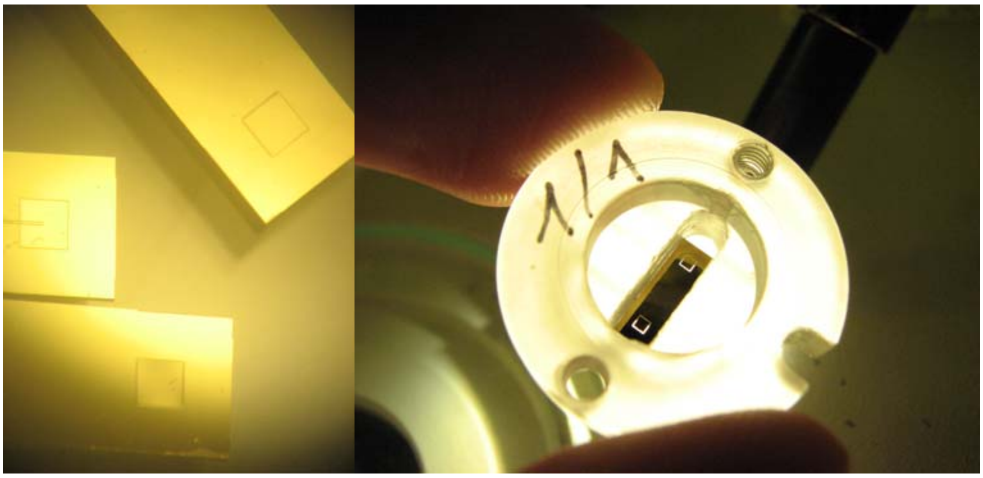


Figure 6 *The manufactured micro-cantilever structures (left) and a packaged device (right).*

3D MEMS structures including two optical microphones were designed, developed, and manufactured applying reliable realization technology, fitting these structures to the active and reference flow chambers of the opto-acoustic measuring system. The adequate structures were manufactured by two side bulk micromachining silicon technology achieving remarkable improvement of the former membrane formation techniques. For the formation of these structured thin layers (reflective membranes suspended by flexible arms) which forms the moving part of the sensor structure, a special structuring process has been developed combining the selective lateral doping with Electrochemical Etch Stop and Reactive Ion Etching processes. The

ElectroChemical Etch Stop process was significantly improved using the anisotropic alkaline etching to form 2-4 μm thick compact silicon membranes applying the ProTEK polymer (Brewer Science) for selective protection of the active area of the sensor structure.

Si MEMS by Proton Beam Writing and porous Silicon micromachining

(Hungarian Scientific Research Fund under Grant No. T O47002)

Cs. Dücső, P. Fürjes, I. Rajta

3D microfluidic Si devices characterized by vertical walls of high aspect ratio were formed by combination of proton beam writing (PBW) technique and subsequent selective porous Si (PS) etching. Crystal damage generated by the implanted protons results in increased resistivity, that limits or even cease the current flow through the implanted area during electrochemical etching. Characteristic feature of the proposed process is that the shape of the MEMS components are defined by two implantation energies, i.e. higher energy is applied to define the frame of the device while lower energy is used to write the moving components. The implantation energies were selected such as to result appropriate difference between the two projection ranges, taking into consideration the thickness of the walls of the moving component and the isotropic etching profile of the electrochemical PS formation. The electrochemical etching is stopped when the sacrificial PS layer completely underetches the moving components but the etching front does not yet reach the bottom of the frame. Therefore, the dissolution of PS results in a ready-to-operation device with a released moving component embedded. The feasibility of the process is demonstrated by the fabrication of micro turbines and non return valves.

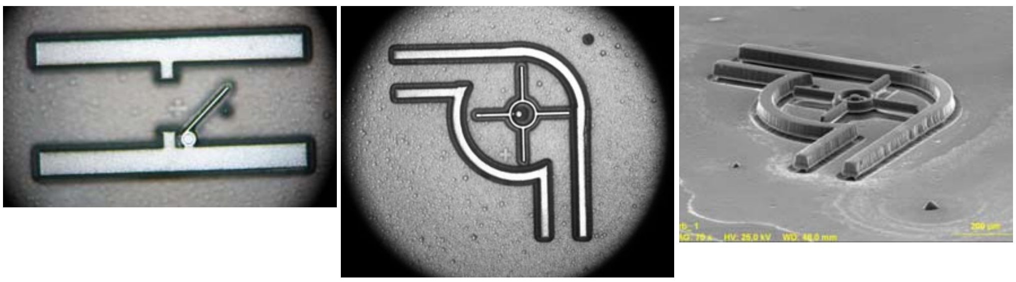


Figure 7 *Microfluidic valve (left) and turbine (middle & right) realized by proton direct writing and porous Si etching*

Fluidic applications for corrosive environments

P Fürjes, Cs. Dücső, P. Csíkvári

Protective coating of microsystems used in harsh environment is essential for reliable device operation. Due to their well-known superior chemical and abrasion resistance, deposited diamond or diamond like carbon (DLC) layers are among the most attractive candidates for this purpose, providing that the layers prove pinhole-free in the given environment.

In present work we describe and characterize micro-hotplate structures formed by front side porous silicon micromachining process in combination with a three-step multilayer deposition (diamond/polycrystalline-Si/diamond), doping and appropriate patterning. The material of the filament is preferably polycrystalline silicon, however, Pt can also be considered. Selective area deposition (SAD) technique allows patterning of the diamond layers. Although the extremely high thermal conductivity of the deposited polycrystalline diamond layers (260 – 900 W/mK) does not favour the addressed task, our preliminary calculations show that temperature of 100^{o}C can be reached by less than 100 mW input power on the surface of the two-arm suspended hotplate. Beside the thermal and thermo-mechanical properties of the hotplates, the chemo-protective effect of the diamond layer was investigated.

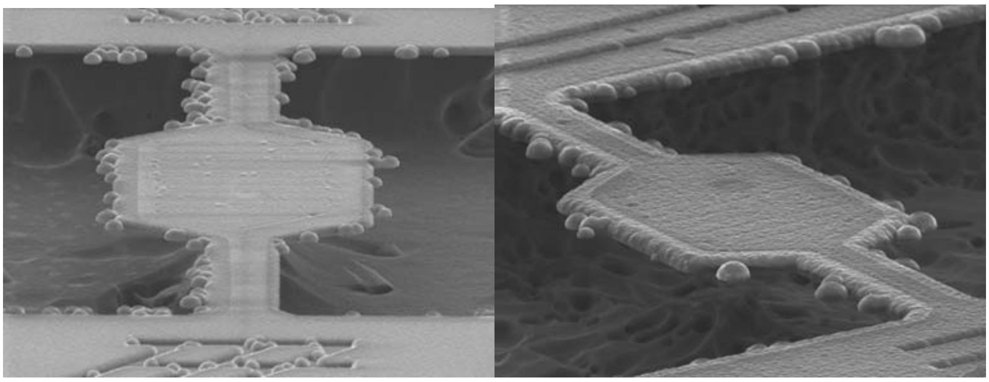


Figure 8 *Poly-silicon micro-heater formed by diamond SAD technique.*

Investigation of actuation phenomena and controllable moving microstructures

(Hungarian Scientific Research Fund under Grant No. F 61583)

P. Fürjes

The research of the realization and application of controllable moving microstructures was started at the MEMS Laboratory of MFA near the development of sensor structures. The practicability of the actuation phenomena (electrostatic, magnetic, thermal) and prognosticable functional parameters of the designed structures (deformation, driving frequency, residual stresses of the layer structures) were analyzed by Finite Element Modeling. Test structures were manufactured by the development and application of adequate MEMS techniques, and they were analyzed considering the functional aspects.

Thermo-mechanical analysis of functional layers in MEMS structures

P. Fürjes

Micro-hotplates are basic components of sensors and lab on a chip devices, e.g. as sensors of calorimetric principle, or heaters in chemical micro-reactors. The most frequently used structural materials are silicon-nitride, non-stoichiometric silicon-nitride, silicon-oxinitride, silicon-dioxide and multilayered combination of these materials. Beyond the frequently applied structural materials, protective coating of MEMS elements used in harsh environment is essential for their reliable operation. The best candidates for such application are diamond, diamond-like-carbon (DLC) or SiC because of their superior chemical and abrasion resistance in aggressive chemicals.

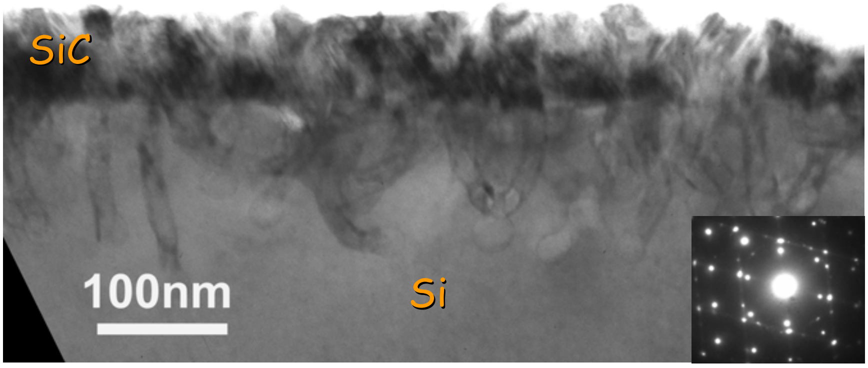
In the micro-hotplate design the most important parameters to be considered are the thermal conductivity, the thermal capacitance and the residual stress in the applied layers in order to select the optimum functionality of the device. While appropriate data are available for the widely used materials (SiO_2, Si_3N_4) this is far not being the case for the non-stoichiometric materials or deposited diamond and DLC layers. Their properties are process dependent, i.e. both their composition and structure are determined by the given individual process. Therefore, relatively simple methods for determination of thermo-mechanical properties are essential in functional design.

We describe alternative techniques for the formation of micro-filaments encapsulated in CVD non-stoichiometric silicon-nitride or multi-crystalline CVD diamond layers and present how the thermal properties of the structural materials can be determined by measuring static and dynamic temperature responses of the micro-hotplate.

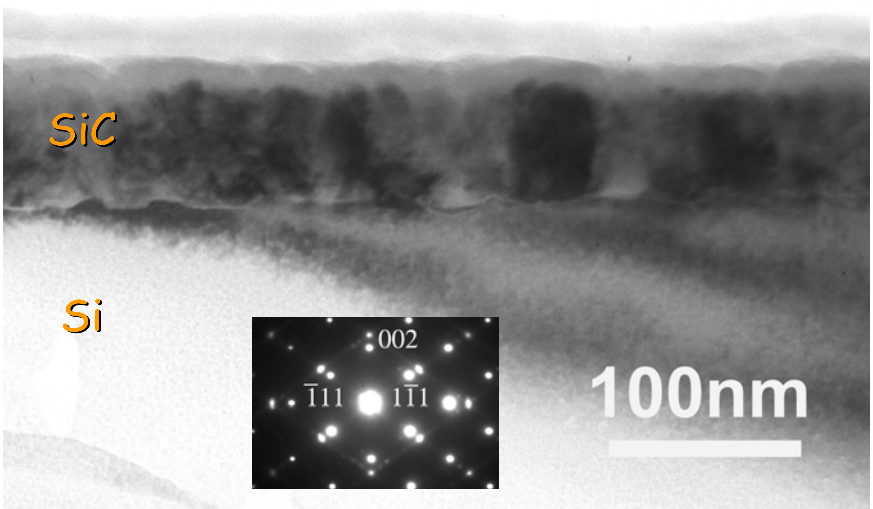
Fabrication of SiC nanocrystalline structures

A. Pongrácz, Z. Zolnai, G. Battistig

Epitaxial SiC nanocrystals at the Si side of SiO_2/Si interface made by reactive annealing in CO may be used as templates for heteroepitaxial growth of polycrystalline or even for single crystal SiC layers. We have shown that on Si substrate covered with SiC nanocrystals polycrystalline 3C-SiC layer can be formed without wormholes (Fig. 9) .



(a)



(b)

Figure 9 *Cross sectional transmission electron microscopy image of CVD deposited 3C-SiC layers on (100) Si, (a) conventional method with carbonization step, wormholes are formed during the CVD deposition, (b) SiC nanocrystals formed by CO reactive annealing were used before the CVD step, no void or wormhole formation is present.*

As part of an academic research exchange program Zsolt Zolnai took part in the characterization of 3C-SiC layers made by CVD on Si substrates and Ge(Ga)/Ge(As), GaAs/Ge(As) layers made by MOCVD. New sample set was fabricated for a systematic structure and composition measurement. The characterization methods: XRD, TEM, RBS/C (MFA, Budapest), SIMS/SNMS (ATOMKI, Elektronspectroscopy Department, Debrecen, partners: K. Vad, Z. Berényi, G. Katona). Optimization of growth parameters and growth of epitaxial SiC layers for micromechanical systems, investigation of As diffusion in Ga layers are the main goals of this cooperation.

Fabrication of radiation hard resistive bolometer for ITER

(Contract work for Max Planck Institut für Plasmaphysik)

M. Ádám, É. Vázsonyi, Cs. Dücső

Our goal was the reproduction of a radiation hard resistive bolometer, which is reliable in an environment with high neutron fluxes expected in ITER. Following device specifications made the technology development challenging: ±1,5% resistivity variation of Pt calorimeters on SiN_x membrane, 4-10µm thick W absorber on the backside of the membrane. The most critical part is the sputtering of the thick tungsten absorber layer. Structures have been delivered but we are still developing our technology to reduce the residual stress in the tungsten layer and to control the size of the sputtered area.

Physics and Technology of Elemental, Alloy and Compound Semiconductor Nanocrystals

(EU FP6 project SEMINANO No. 505285, and Hungarian Scientific Research Fund under Grant No. T048696)

Zs. J. Horváth, M. Ádám, J. Balázs, P. Basa, L. Dobos, L. Dózsa, T. Lohner, G. Molnár, P. Petrik, B. Pődör, P. Szöllősi, Z. Zolnai

Semiconductor nanocrystals (NCs) embedded in insulators are usually studied for light emitting and memory purposes. In our group this activity is aimed mainly for memory applications and has been connected with two projects, namely the "Physics and Technology of Elemental, Alloy and Compound Semiconductor Nanocrystals - Materials and Devices" (SEMINANO) EU FP6 project No. 505285 and the "Nanodots and nanolayers in semiconductor structures - electrical and photoelectrical properties" Hungarian Scientific Research Fund (OTKA) under Grant No. T048696.

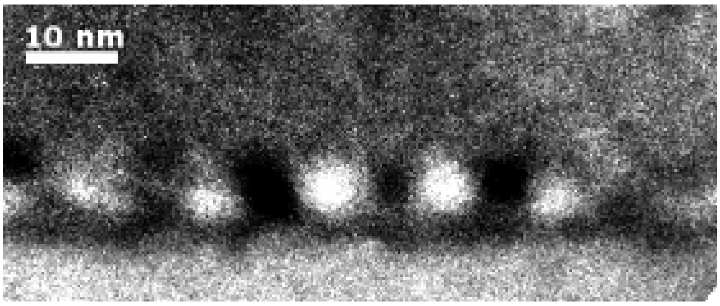


Figure 10 *Energy-filtered XTEM image of sample No. 1 with white dots corresponding to silicon atoms – spherical objects in the middle of the figure are corresponding to the Si NCs embedded between two Si_3N_4 layers.*

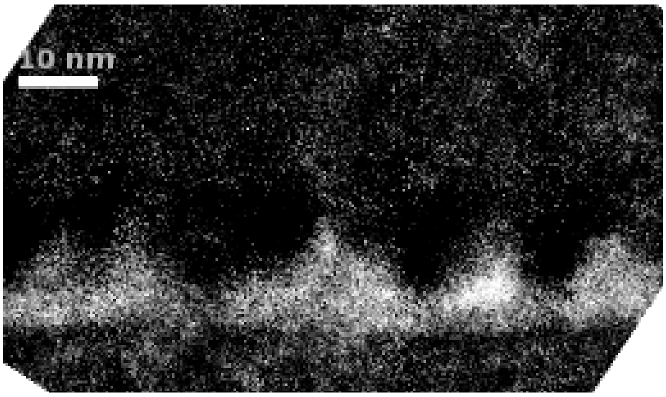


Figure 11 *Energy-filtered XTEM image of sample No. 2 with white dots corresponding to oxygen atoms – image indicates SiO2 pyramids between the Si NCs.*

$Si/SiO_2/Si_3N_4/Si$ NC/Si_3N_4 (No. 1) and $Si/SiO_2/Si_3N_4/Si$ $NC/SiO_2/Si_3N_4$ (No. 2) multilayer structures with embedded Si NCs were formed, the SiO_2 layers were grown by chemical oxidation of silicon by nitric acid. These samples exhibited good charge injection properties: charging voltage pulses with ±8 V, ±10 V, ±12 V and ±15 V amplitudes and 10 ms width yielded 7.8 V, 10.3 V, 13.1 V and 16.5 V wide memory window width (flat-band voltage difference between the "written" and "erased" state). The extrapolated memory window width for 10 years were expected to be 0.3 V after charge injection with ±12 V, 10 ms pulses. These structures are useful for those applications where small writing/erasing voltage pulse amplitudes are needed, but where information storage for several years is not a requirement.

Optical, electrical and memory properties of MIS structures containing sputtered SiO_x or Al_2O_3 layers with embedded CdSe NCs were characterized in the frame of co-operation with University of Minho, Portugal. Some of the samples exhibited good charge injection properties, yielding the first known observation of such phenomena with CdSe NCs.

Pulsed laser annealing of implantation-amorphized SiC layers

(József Öveges Research Program Under Grant No. SiC_impl.)

Z. Zolnai, A. Karacs, J. Balázs, A. L. Tóth

Nowadays the investigation of single crystalline silicon carbide (SiC) as a candidate for high power, high frequency device industry is an intensive research area. Nevertheless, in this case the problem of selective doping can be solved only by ion implantation. The post-implantation annealing of irradiation-induced lattice damage using either furnace or pulsed laser treatment is not yet solved, however, this obstacle should be overcomed before SiC is applied in semiconductor processing. The aim of this project is to investigate the effect of pulsed laser annealing on both (0001) and (11-20) oriented SiC wafers after ion implantation. On the double side polished (0001) cutted wafers the experiments were done for both front side and back side illumination. The damaged (amorphized) surface SiC layers were produced by Ar^+, P^+, and Ni^+ implantation and the annealing was performed with a Q-switched pulsed Nd:YAG laser operating at wavelengths of λ=1064, 532, and 355 nm.

The single crystal, as-implanted, and post-implantation annealed samples were investigated by Rutherford Backscattering Spectrometry combined with Channeling technique (RBS/C) and with Scanning Electron Microscopy combined with Energy Dispersive X-ray Spectroscopy (SEM/EDS). As the RBS/C results in Fig. 12 show during pulsed laser treatment the annealing and diffusion of crystal defects occurs at the crystalline/amorphous interface of the implanted SiC sample, therefore recrystallization process starts from the bulk side. The significant difference in the SEM/EDX spectra confirms the oxydation of the implanted surface during laser beam annealing which process can stop recrystallization close to the sample surface.

Optical transmission measurements were performed on the implantation-damaged samples, post-annealed by laser pulses with different wavelegths of light and at different geometrical arrangements, i.e. front side or back side (through the transparent substrate) illumination. The measurements were performed to see the changes vs. wavelength in the visible region λ= 360-700 nm, i.e. mainly for below bandgap excitation. As Fig. 12 shows the transparency of the single crystalline SiC sample reduces a lot after implantation. For the as-implanted stage the degree of transmission at λ= 355 nm and λ= 532 nm is similar and the wavelength dependence is weak. This feature is due to the presence of crystal damage and the distortion of the band structure. The annealing process leads to the increase in intensity transfer by reducing the thickness of the amorphous layer and by annihilating the defects. The difference in transparency between unimplanted virgin (v) and post-implantation annealed samples is more significant for wavelengths close to the edge of the bandgap. For pulsed laser annealing at λ= 532 nm the absorption of the sample decreases step by step during the subsequent laser pulses. Consequently, the structural and optical changes due to the annealing process may be saturated for high number of pulses. The similarity in the end stages after several hundreds of laser pulses shown in Fig. 13 can be explained by this saturation phenomena.

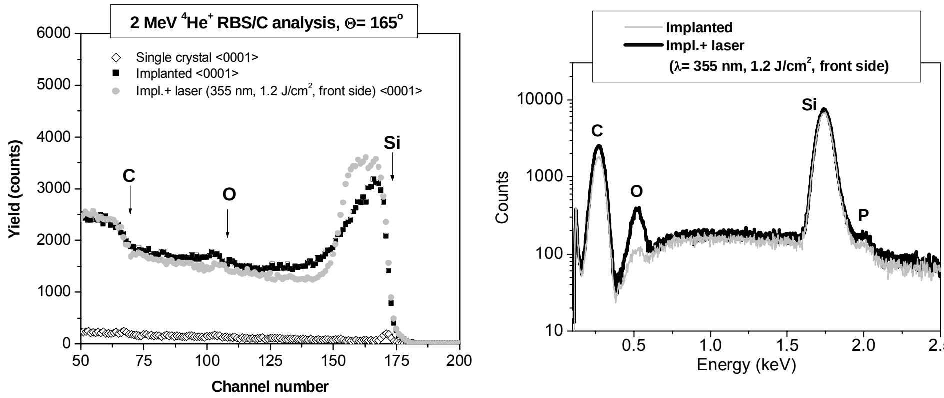


Figure 12 *To the left: The effect of front side pulsed laser annealing on (0001) 4H-SiC amorphized with 120 keV* P^+ *ion implantation (fluence:* 5×10^{15} cm^{-2}*) Results of RBS/C measurements, To the right: Energy dispersive X-ray spectrometry (EDX) spectra of the implanted unannealed and the implanted and pulsed laser annealed sample. Parameters of the laser treatment:* λ*= 355 nm, pulse energy density: J= 1.2 J/cm*^{2}*, pulse duration: t= 5 ns ,number of pulses: 200, respectively.*

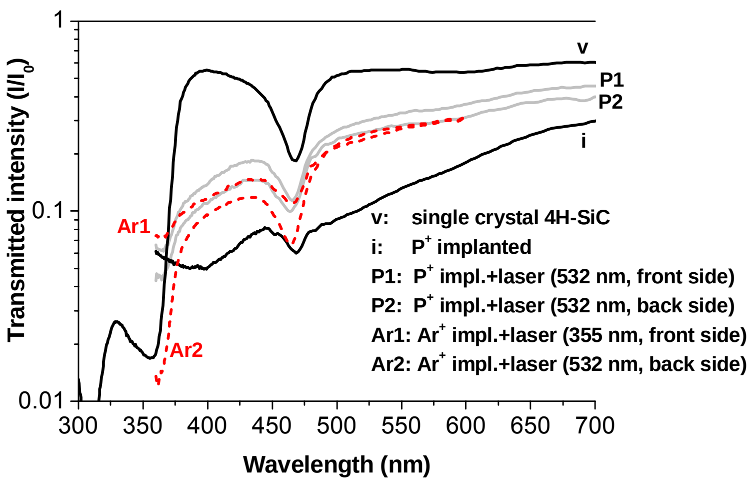


Figure 13 *Optical transmission measured on double side polished 4H-SiC samples with thickness of 400* μ*m. Data for single crystalline, as-implanted, and post-implantation laser annealed samples are also shown.*

Design of MEMS tactile sensors and their measurement setup

(Joint development with TactoLogic Ltd.)

M. Ádám, I. Bársony, Cs. Dücső, T. Mohácsy, G. Vásárhelyi, É. Vázsonyi

Although the "Telesense" Sensing Computers and Telepresence Project, granted by the Széchenyi-NKFP has formally ended in 2004, we continued this work with the aim of developing integrated tactile sensor arrays, capable of measuring pressure and force maps. Our sensory unit is a three-dimensional micro force meter. In each array many of these sensors are arranged on a surface. Previously, we have had developed and functionally tested the first smart sensor of the institute: a 64 element three-axial force sensor array, in which we demonstrated – first time worldwide – that the sensors produced by front side porous Si etching can be integrated into standard CMOS circuits in a monolith form. On the prototype chip the MEMS sensors are neighbored by an n-well CMOS decoder, a current generator made of p-channel transistors and transfer gate switches. We also have patents pending on our novel technology.

We integrate this and other similar sensor arrays into evaluation kits for educational and research purposes through a spin-off company founded together with PPKE and SZTAKI. The two other institutes developed the HW and SW parts of the whole sensory system.

This year's results can be divided into two main parts. On the scientific front the only real advance is a new Ph.D. degree for Gábor Vásárhelyi. On the commercial front we founded our spin-off, TactoLogic Ltd., where Gábor Vásárhelyi (CTO) coordinates the development and system level integration or the tactile sensors. The main results are the following:

- Coordinator work that integrates the product development from the first steps of the MEMS technology through the design of the read-out circuitry to the final design issues
- Final design and product development of the 2×2 tactile chips (TactoPad 2×2 and TactoFlex 2×2)
- Development of 8x8 chips (TactoPad 8×8), connecting the design and the technology
- Integration of the sensor arrays with the read-out device (MasterBoard), design of the communication protocol, connectors, etc.
- Software development with detailed documentation for the first products
- Final design issues of the first real products, including logos, vignettes, connectors, covers, outlook, etc.
- Home page development
- Detailed measurements for qualifying the sensors and their parameters
- General documentation for the products (User's Manual, Sensor DataSheets, Software Guide, Installation Notes)
- Ads, leaflets, posters, pictures, demo videos, etc.

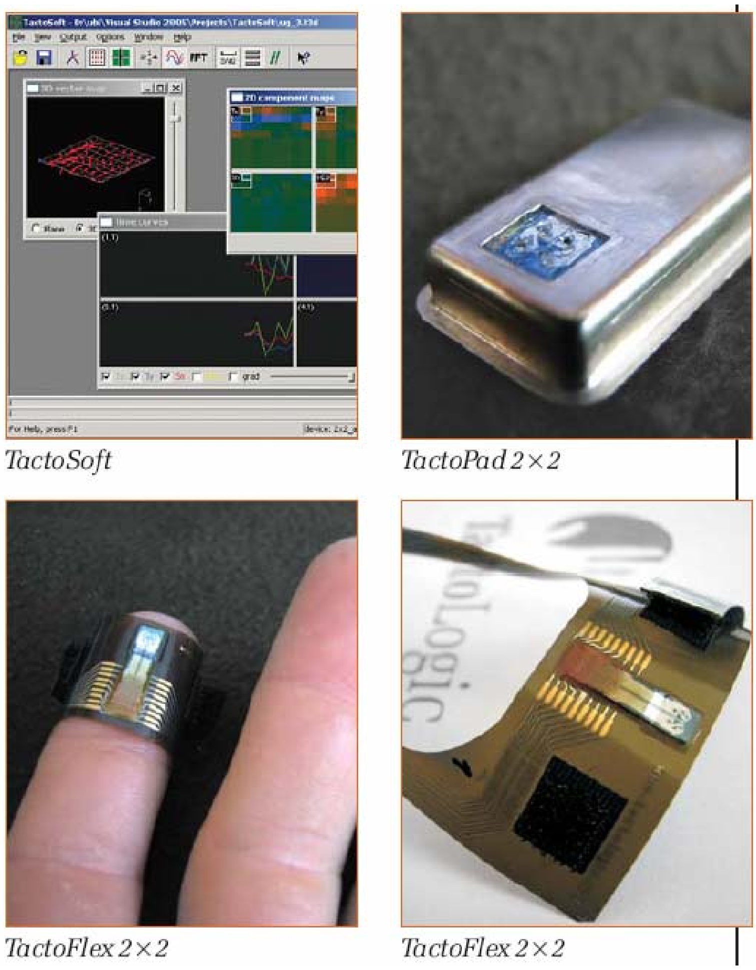


Figure 14
Product versions of the 2×2 (4) element tactile chip

The development of indoor solar cells

B. Szentpáli, I. Pintér, E. Kuthi, Cs. Dücső, M. Ádám, Z. Lábadi, Á. Németh, V. Rakovics, T. Mohácsy

In the course of cooperation with Tateyama Kagaku Ltd. the coworkers of our department developed a single crystal Silicon indoor solar cell with shallow emitter made by plasma immersion ion implantation (PIII). Optimizing the heat treatment of the screen printed contacting paste we were able to make good contacts to shallow PIII emitters of the solar cells that were intended for indoor environment.

The efficiency of indoor solar cells was recorded at four different mixed illumination circumstances. Two different solar light illuminations were applied (one measured indoor in the room with light scattered from the wall in front of the window, while the other light was 1% AM1.5 solar light). These light sources were mixed with indoor fluorescent light of 150 lx, and 700 lx intensity.

The efficiency of the reference a-Si solar cell (made in Japan) is slowly increasing up to 600 lx light intensity, but beyond this intensity the efficiency is gradually decreasing. The efficiency of this cell, however, remains higher than the newly developed c-Si PIII cells up to 1000 lx.

Using fluorescent light at very high illumination, however, the PIII cells have higher efficiency than that of the reference a-Si cell. Even higher is the difference at the advance of PIII cells at mixed illumination measured not far from the window of the room.

We produced ultra shallow emitters for PIII solar cells using low temperature diffusion process. The purpose of this work was to achieve blue sensitivity as high as possible. These cells have efficiencies in the range of 11-13 % at 700 lx indoor fluorescent light.

Figure 15 *The photograph of ultra shallow emitter solar cells with different metallization grids on 5×5 cm² Si wafer. In order to obtain optimal serial resistance for the PIII cells, 4 different metal grids were tested. These metal grids are applicable in a wide range of emitter resistance (90-300 Ohm/sq).*

Output power saturation in InGaAsP/InP surface emitting LEDs

V. Rakovics, S. Püspöki, I. Réti

InGaAsP/InP LED’s are widely used for optical telecommunication, and for selective spectroscopy in the near infrared range. Observations regarding the temperature sensitivity and power saturation of InGaAsP lasers and light emitting diodes (LED's) have led to extensive studies to find the responsible mechanisms. At high current densities the efficiencies of the diodes drop quickly. The light-current curves are not linear even in short pulse operation.

We prepared and investigated nine different wavelength InGaAsP/InP surface emitting double heterostructure LEDs. Optical power and spectral characteristics of the diodes were investigated as a function of driving current and case temperature. At fixed emitting wavelength, the maximum power is proportional to the volume of the active layer. Short wavelength diodes perform better at high current densities. The output power saturation (Fig. 16) and the temperature sensitivity of the diodes depend on the composition of the active layer.

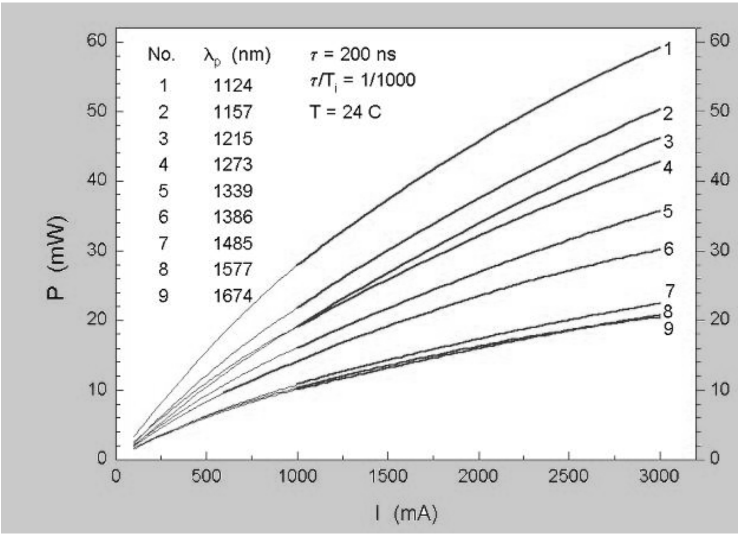


Figure 16 *Output power of the different wavelength LED's as a function of pulse current*

E-field probe for closed space EMC measurements

(GVOP-3.1.1.-2004-05-0354/3.0.)

B. Szentpáli, I. Réti, F. B. Molnár, J. Farkasvölgyi, K. Kazi, Z. Mirk, A. Sonkoly, and Z. Horváth

The generation and measurement of defined electromagnetic fields for radiated immunity test on open area test site is rather expensive. Further the environmental, meteorological conditions strongly influence the measurements. Therefore there is a real need for performing the investigations in closed measuring chambers built in laboratory rooms. Different methods have been proposed in the literature as anechoic chambers, reverberation boxes or TEM cells. In all cases there is a chance for the resonance in the chamber and/or the appearance of spurious modes and therefore the exposed electric field can differ from the expected one. The purpose of this project was the development of an E-field probe for the independent control of the actual value of the microwave field. The probe is an accessory of the measuring chamber, it is connected by a long flexible cable therefore can be placed to a large variety devices under test. It is important that the probe and its cable should not disturb significantly the field distribution; the sensitivity of the probe should be isotropic, because the test is made at all degrees of polarization.

The traditional isotropic E-field probe construction, with three mutually orthogonal short dipole antenna was applied. The detector diodes are mounted in the gap of the dipoles. The connections between the sensors and the amplifier are 2 m long flexible resistive transmission lines fabricated by screen printing from resistive carbon paste on 0,125 mm thick polyester foil. There is a low-pass filter between the diode and the resistive line. The other end of the resistive line is mounted in a DS type connector; it fits into the socket mounted on the inner wall of the measuring chamber. Facing to it on the outer wall of the chamber there is the equivalent socket for the amplifier.

The effect of the resistive transmission lines on the field distribution were checked first in the GTEM cell. A monopole antenna was fabricated from a semi-rigid cable by removing the outer conductor at the 12 mm long end part. This antenna was fixed in the GTEM cell and the transmission was measured and saved between the feed point of the cell and this antenna in the case when the cell was empty. Then the resistive transmission line was placed into the GTEM cell and the transmission measurement was performed again. The difference of the first and the second transmission spectra was registered. The measurements were made by placing the sensing monopole in 5 measuring points within a 0.5 x 0.5 m^2 square and orienting it to 3 mutually orthogonal directions in each measuring position (IEC 61000-4-20) Fig. 17 shows the measuring set-up. Beyond the field scattering effect of the resistive transmission lines the same investigatins were performed for objects used for fixing, holding the equipments under test. These objects are made from plexiglass, polystyrene foam, wood, etc.

Figure 17 *The measuring set-up for the field scattering effect. In the photo the field distribution of the plexiglass sheet is investigated in the GTEM cell.*

The conclusion of the numerous investigations was that the difference in the transmission was always less than 1 dB in the case of the resistive lines, even when they were arranged very different ways. On the other hand any other conductive wires, or coaxial cables resulted in significantly greater effects, at least at one frequency the difference exceed the 6 dB. It happened also in the case of the thinnest available coaxial cable having only an outer diameter of 1.8 mm. Objects having not too long dimensions, as small metal boxes or coaxial adapters, etc. showed also small effect on the field, except when they were placed in the immediate vicinity of the monopole.

The resistive line is a low pass filter. The cut-off frequency is about 800 Hz. This is the reason for the application of the simple envelop detector only, having direct DC output. This is the price for the not disturbing character of the probe.

Figure 18 *The calibration of the probe in anechoic chamber with the calibrated horn antenna.*

Figure 19 *The isotropic E-field probe with the flexible leads.*

The sensitivity of the probe was calibrated in free space in an anechoic chamber with the help of calibrated antennas. The calibration set-up is shown in Fig. 18.

The DC output voltage of the individual sensor is amplified and digitalised with a resolution of 12 bit. The bit values of the voltage (LSBs) are feed to a personal computer via the serial port. The measured data are shown in real time on the monitor of the computer and the observer can save the actual data by mouse click in dedicated .dat files under Windows environment. The data can be imported into the Excel, where the further processing, as multiplication by the correction factors due to the frequency and field strength, etc. is possible.

At low levels the output of the detectors are proportional to the square of the electric field. Therefore the sum of the three signals will be the correct vectorial sum of the square of the total field strength, its square root is the effective value of the field, independent from the polarization.

This calibration is made for each detector individually at each measuring frequency. This calibration function is feed in the Excel program, for computing the corrected value of the field from the output of the detector. In this way the dynamic range can be extended up to 20 dB. The directional sensitivity can be characterised by the ratio of the outputs at parallel and perpendicular polarizations. It is better, than1:100. Fig. 19 shows the probe.

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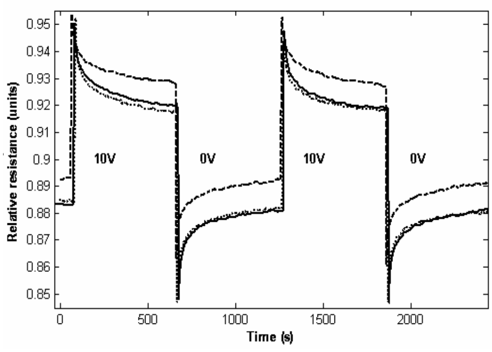
The Nanostructures Department has an almost two decade expertise in the investigation and production of various nanostructures. In recent years in the focus of the research at the Nanostructures Department were various carbon based nanostructures and their potential applications in nanotechnology, nanoelectronics, sensorics, and environmental protection, as well as bioinspired materials, like photonic nanoarchitectures in butterfly scales. In 2007 the most important progress has been achieved in:

Nanotube-based gas sensors

(OTKA T049182, T049131 and OTKA-NKTH-K-67793)

Z. E. Horváth, M. C. Bein, E. Horváth, Z. Mészáros, K. Kertész, and L. P. Biró

Carbon nanotube (CNT) based gas sensors were prepared by spraying suspensions of different CNT samples on Si/SiO_2 substrates patterned with separate gold stripes. After the evaporation of the ethanol solvent, the resulted CNT layer connects metallic stripes, making it possible to test the electrical resistance of the CNT layer under various gas ambients. This sample structure enables the investigation of the effect of temperature change and of the gate voltage. We found that the sudden change of the gate voltage induces a transient of the measured resistance, the parameters of which depend on the concentration and the kind of the vapors present.



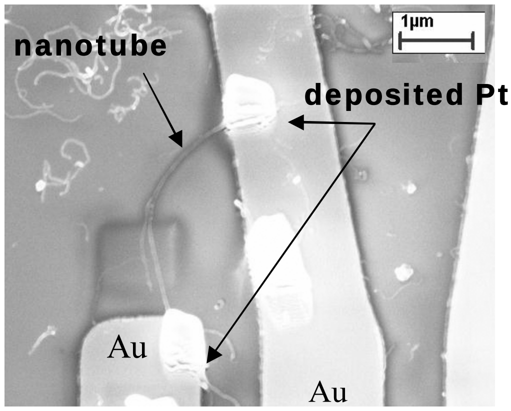


***Figure 1**. Relative resistance versus time plot of a mat of CNTs with 0.6% ethanol (continuous), 3% ethanol (dashed), and 2.4% acetone (dotted line) v/v in air concentration, changing the gate voltage (value displayed in the middle)*

***Figure 2** Individual CNT contacted to gold electrodes by electron beam assisted Pt deposition*

Improving the method we applied during the last year for the contacting of individual CNTs (in cooperation with Spanish coworkers), we contacted functionalized and as prepared multiwall CNTs on prepatterned gold microelectrodes. CNTs directly lying across two separate microelectrodes were identified and electron beam assisted platinum deposition (EBAD) in the LEO 1540 Crossbeam system of our institute was used to fix them to the substrate and to achieve good electrical contact. In this way, single tube sensors were manufactured in the full sense of the word. The samples are suitable for testing their gas sensing properties with the same setup used for the CNT layers. Comparative study of individual and layered CNTs is in progress.

Removal of low concentration oil pollution from water

(GVOP 3.1.1.-2004-05-0295/3.0)

Z. E. Horváth, P. Nemes Incze, Z. Vértesy, E. Horváth, K. Kertész, L. P. Biró

In cooperation with Hungarian industrial and academic partners, we developed a method for the manufacturing of a filter composite based on a porous absorber immobilized by polymeric bonding. The filter is capable to decrease the oil concentration of the waste water from 2000 µg/l (which can be achieved by conventional methods) down to 100 µg/l at acceptable filter resistance. Patenting is in progress.

Preparation of graphene by thermal oxidation of exfoliated graphite plates

(OTKA-NKTH grants K-67793 & NI-67851 K-67793 & NI-67851)

Z. Osváth, P. Nemes-Incze, E. Horváth , Z. E. Horváth, and L. P. Biró

Commercial exfoliated graphite (1 mg material in 20 ml benzene) was treated ultrasonically for 3 h. Droplets from the suspension were dispersed on a Si wafer. Graphite platelets of 1–5 μm in diameter were observed by tapping mode atomic force microscopy (AFM) using a Nanoscope IIIa instrument operating in air.

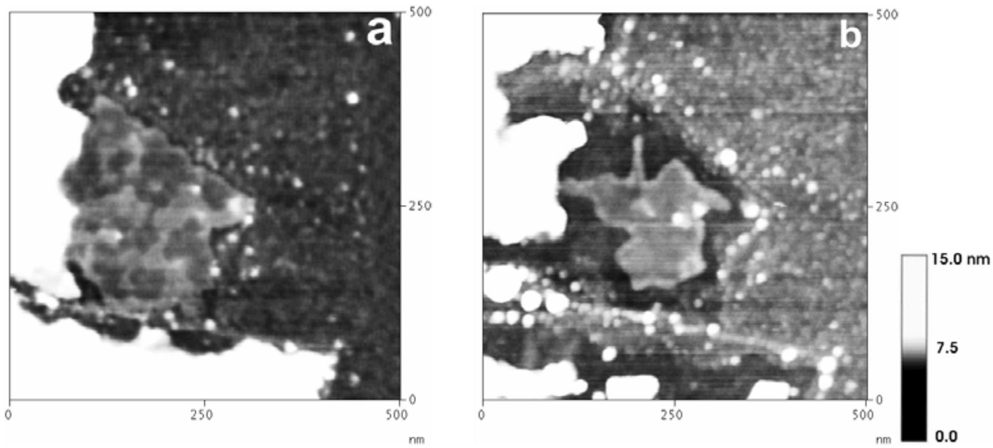


Figure 3 *Tapping mode AFM images (500 x 500 nm^2) showing the effect of oxidation. The images were recorded after oxidation step II (a) and after oxidation step III (b). A lacy, incomplete top layer can be observed in (a), whereas a single atomic layer was left behind in (b).*

After the AFM investigation, the sample was introduced into a quartz reactor of 18 mm inner diameter and oxidized in an electric furnace with an effective heating length of 200 mm. The oxidation process was carried out in three steps. In the first step the sample was oxidized at 450 ^{o}C for 10 min (step I). In the second and the third steps the sample was heated at 550 ^{o}C for 10 min (step II) and 20 min (step III), respectively. AFM measurements were performed after each oxidation step and the effect of oxidation was observed on the same graphite platelet.

The portion of the platelet shown in Fig. 3(a) has a non-uniform thickness, which is caused by monolayer deep pits which start to appear during the first oxidation step. An incomplete, lacy top layer forms during the second oxidation step, due to the overlapping of these oxidation pits. The third oxidation step removes completely the lacy top layer (see Fig. 3b), and a single graphene sheet is left behind. The horizontal dimensions of the platelet are also decreased.

Measurement of the correct height of SiO_2 supported graphene crystals by tapping mode AFM

(OTKA-NKTH grants K-67793 & NI-67851 K-67793 & NI-67851)

P. Nemes-Incze, Z. Osváth, Z. E. Horváth, and L. P. Biró

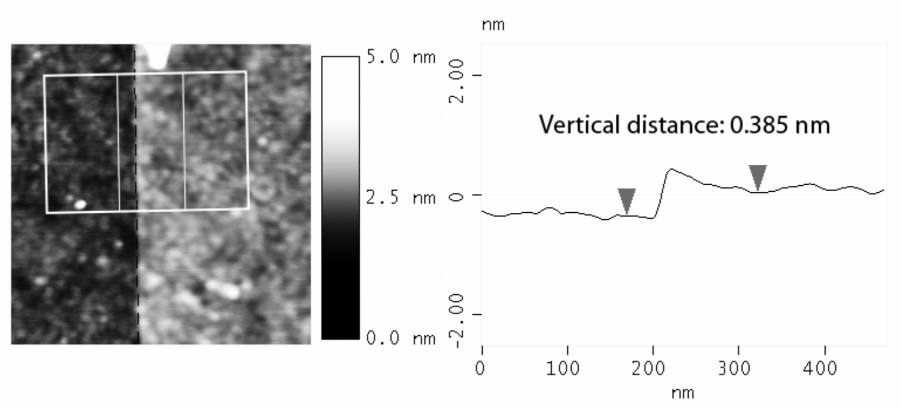
Graphene as a single layer hexagonal *sp*^{2} carbon lattice has attracted the interest of theoreticians since the 1940s. It was believed that a two dimensional crystal, like graphene, could not exist in practice until K.S. Novoselov (2004) et al. prepared the material, in a simple tabletop experiment. After the successful preparation of graphene and few layer graphite (FLG), many research groups working in the field of carbon nano-architectures and materials science have started to explore this exiting new material. Today research into graphene is one of the fastest growing fields in materials science, however most of the publications in the field are of theoretical nature.

The practical importance of graphene is due to its properties, which are in many respects similar to those of carbon nanotubes (CNTs). At the same time, as a large sheet, graphene can be patterned nanoscopically in a planned way, to create complex networks of nanoelectronic devices, without the major difficulties encountered in the case of CNTs. Difficulties arise mostly from the problem of separating nanotubes with different chirality and the problems with the precise manipulation (or growth) at the nanometer level, in order to build CNT devices at a predetermined location.

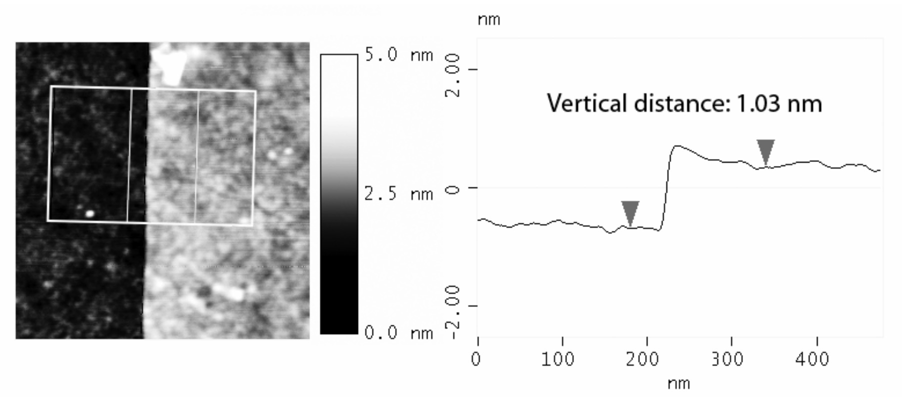
In any practical application or experiment it is of paramount importance to precisely determine if the nanoobject is graphene or FLG, and if FLG, how many layers it has? AFM, if properly used, is one of the best suited methods for FLG thickness measurement.

Tapping mode AFM (TAFM) is a widely used tool to check the thickness of selected FLG crystals on SiO_2 substrates. It is well known that TAFM images are not purely topographic and can depend very strongly on the nature of the tip – sample interaction. Reports from literature of the thickness of graphene crystals on SiO_2 vary a great deal (from 0.35 nm to ~1 nm for single layers). Our research has shed light on one possible mechanism for this large deviation. We have shown, that the apparent thickness of supported FGL films, as measured by TAFM, depends strongly on the free amplitude of the AFM cantilever. By changing the free amplitude we can deliberately introduce a nearly 0.6 nm increase in the thickness of a graphene crystal (see Fig. 4).

By carefully selecting the free amplitude we can obtain a more precise thickness. To prove this, we have correlated the thicknesses of selected FLG crystals (1, 2, 3, 5, 10 layer) with their Raman spectra. The data show good agreement.



(a)



(b)

Figure 4**. Two consecutive measurements* **on the same graphene layer, with differing free amplitude of the cantilever. a.) 150 mV, b.) 65 mV At the higher free amplitude setting the measured thickness increases significantly. (see linecut)*

Complexity and evolution of photonic nanostructures in bio-organisms: templates for material sciences

(EU6 BIOPHOT NEST-Pathfinder, STREP INCO-12915/2005)

K. Kertész, Z. Véretesy, G.. I. Márk, L. Tapasztó, G. Molnár, L. P. Biró

Visual communication is crucially important in the living world, both for avoiding dangers (like predators) and observing opportunities (like noticing sexual partners, food or prey, etc.). Natural evolution has created many ingenious ways both to avoid dangers (cryptic behavior, mimicry) and to realize opportunities (sexual communication by color, both attractive and repellant). In the *BioPhot* project we are interested in those devices often intricately structured both on micro- and nano-scale into complex nanoarchitectures, where structure, material composition, pigment and fluorescence may interact in a complex manner to create visual effects which enhance the chances of survival and reproduction in various species of butterflies and beetles.

In the year 2007 we achieved several breakthroughs in the investigation of photonic nanorchitectures of biologic origin, here only a few will be enumerated.

We showed that the nanoarchitectures occurring in the blue and green scales of the butterfly *Albulina metallica* both have quasiorderd character and the color difference is associated with the different first neighbor distances in the differently colored scales.

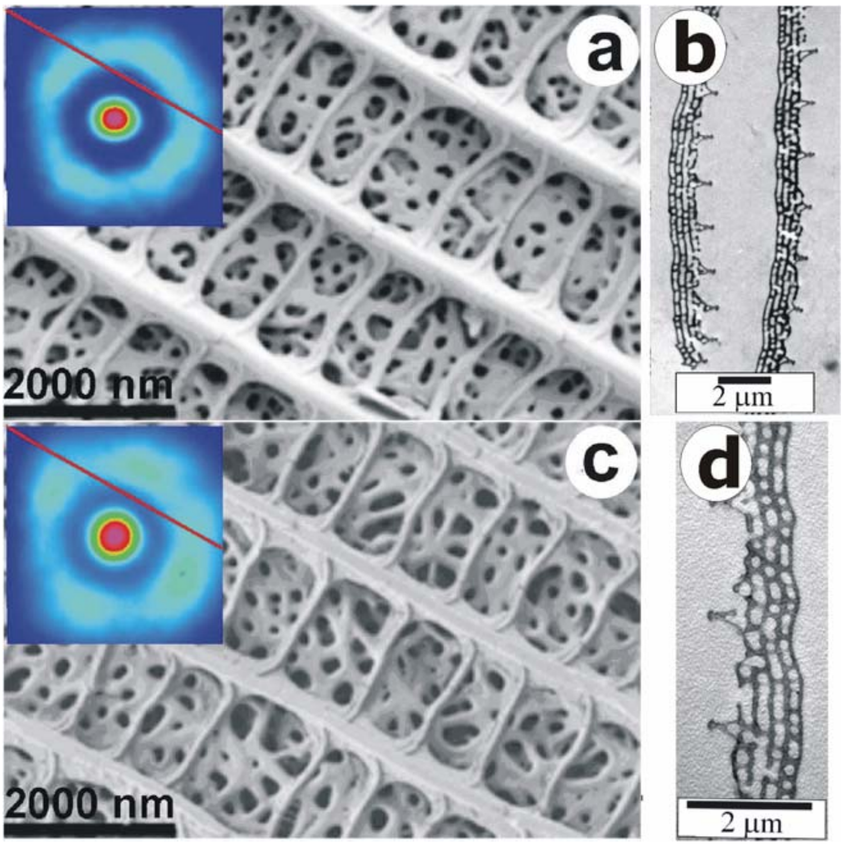


Figure 5 *Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) images of the scales of Albulina metallica. (a) SEM and (b) TEM of blue dorsal scales; (c) SEM and (d) TEM of ventral scales. The insets in the upper left corner of SEM images show statistical arrangement of holes in the SEM images calculated with the BioPhot Analyzer software (http://www.softadmin.ro/biophot)*

Similar nanoarchitectures were reproduced using standard thin film deposition methods to produce nanoarchitectures of In@SiO/SiO/In@SiO sandwich structures. We showed that by tailoring the size of In grains in the composite it is possible to shift the position of the experimental reflectance maximum. This is a further experimental proof that indeed, quasiordered photonic nanoarchitectures may yield different colors depending on the distance of the first neighbors.

We elucidated the structure and the optical properties of the scales of the *Troides magellanus* butterfly. The scales are characterized by well developed ridges of triangular shape which run parallel the longer axis of the scales. Spectro-goniometric, SEM, TEM, optical microscopy characterization and modeling revealed that there is a complex interaction between a fluorescent yellow pigment, diffraction gratings and blazed diffraction grating occurring in the wing scales that are responsible for the characteristic "blue-white flash" emitted by this butterfly when viewed from its hindwing at angles shallower than 70^{o}.

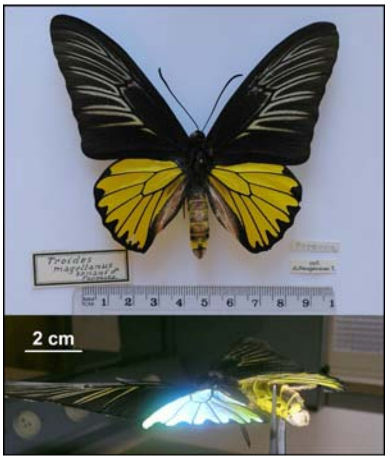


Figure 6 *The male butterfly Troides magellanus is a large insect bearing black forewings and mostly yellow hindwings. The upper view shows the dorsal side of the butterfly, seen under near-normal incidence. The lower image shows the backscattered flash of white light seen when moving the butterfly plane close to the observation axis, in a grazing backscattering geometry.*

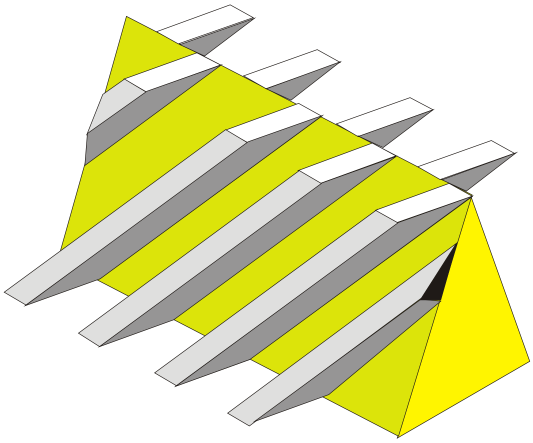


Figure 7 *Idealized ridge structure: the triangular cross-section yellow ridge contains the papilliochrome II pigment, the transparent lamellae on the ridge act as a diffraction grating responsible for the blue coloration and enhance the coupling of UV and blue light in the ridge yielding enhanced fluorescence at* $\lambda = 530$ *nm.*

WEB Schrödinger: an interactive program for the wave packet dynamical solution of the 2D Schrödinger equation and for the visualization of the results

(OTKA-NKTH grants K-67793 & NI-67851 K-67793 & NI-67851)

G. I. Márk, P. Lambin, L. P. Biró

At the Nanostructures Laboratory of the Research Institute for Technical Physics and Materials Science a quantum mechanical simulation package was developed during the last decade for the investigation of electron tunneling- and transport through nanosystems. This software is based on the wave packet dynamical solution of the time dependent two- and three dimensional (2D, 3D) Schrödinger equation. The program proved to be a considerable help at the interpretation of the STM images of carbon nanotubes. Wave packet dynamical simulations have also been used efficiently as a demonstration tool for the basic processes of quantum transport.

Present day computers and modern algorithms make it possible to numerically solve the two dimensional (2D) time dependent Schrödinger equation for realistic systems in a couple of minutes. Utilizing this fact, during the year 2007, we prepared an interactive program for the wave packet dynamical solution of the 2D Schrödinger equation and for the visualization of the results. In order to make the simulation package the easiest to use, we implemented it in such a way that it is not necessary to install any programs on the client computer, the program can be accessed through a simple Web browser. The Internet address is as follows:

http://www.nanotechnology.hu/online/web-schroedinger/index.html

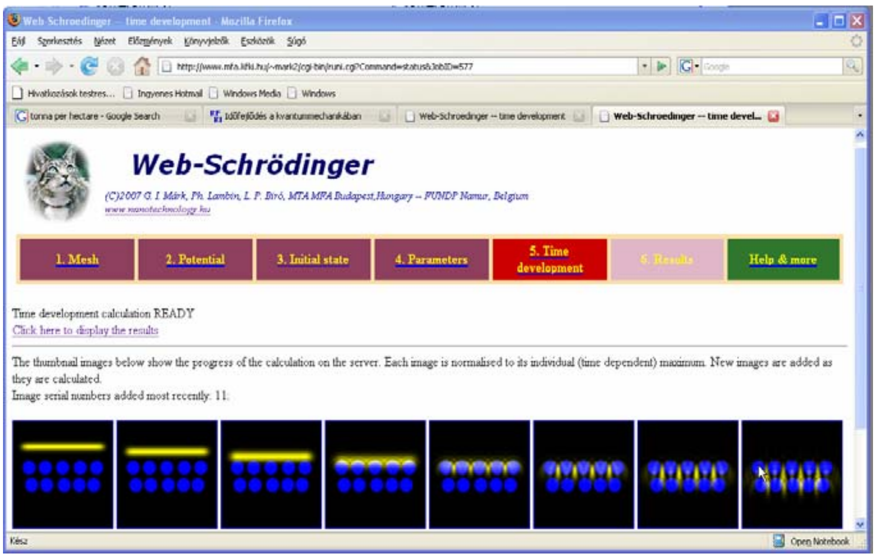


Figure 8 *Interactive wave packet dynamical simulation of the transport of an electronic wave packet through a quasi ordered nanosystem*

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Electron diffraction based analysis of phase fractions and texture in nano-crystalline thin films

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X-ray diffraction (XRD) based determination of phase fractions from powder samples has been common since the introduction of the Rietveld-method. Similar method did not exist for electron diffraction (ED), mainly due to the dynamic nature of ED. The last decade saw a boom in nano-technology and most of the transmission electron microscopy (TEM) laboratories frequently deal with nanocrystalline thin films. For these samples the kinematic approximation is acceptable. A method, based on selected area electron diffraction (SAED) was developed to extract quantitative phase information form SAED ring-patterns, recorded from such nano-crystalline thin films in the TEM. An XRD-like one-dimensional (1D) distribution is deduced first from the ring pattern, by averaging the intensity circularly. The original rings appear as peaks in this 1D distribution. Intensities of the peaks are extracted by fitting pre-definied functional shapes to both the background and the peaks (see Fig. 1).

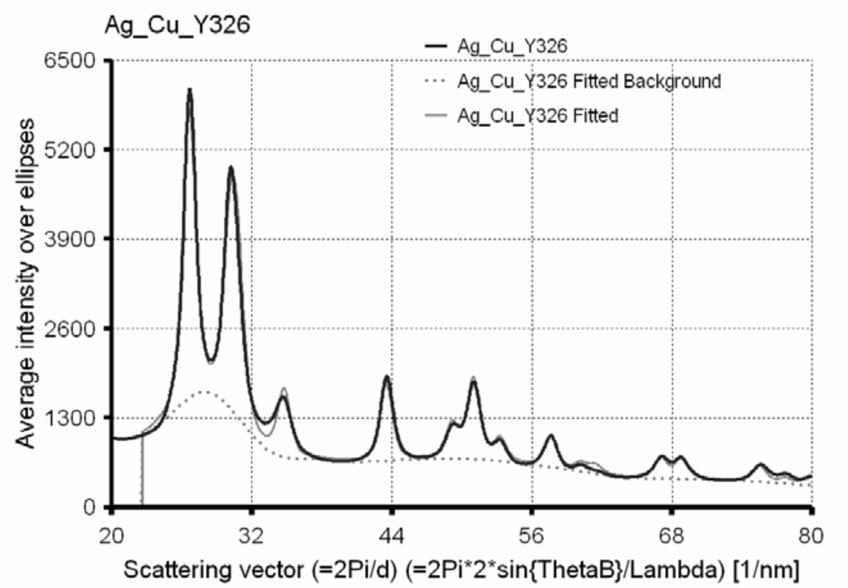


***Figure 1**: Example of the measured and the fitted distributions. Sample: sequentially evaporated 10 nm Ag and 10 nm Cu on a self-supporting substrate of 5 nm a(morphous)-Carbon. Analysis result is 51 vol% Ag / 49 vol% Cu*

The optimum parameters of the curves are determined from best fitting of the model curve to the experimental distribution. The experimental intensities, obtained by the fitting procedre, are compared to the theoretical intensities, calculated from the kinematic approximation. Volume fractions of the individual nano-crystalline phases are given as the result. Examination of several samples proved that introduction of two additonal corrections was necessary. On the one hand, the Blackman-correction was introduced to modify the calculated intensities due to dynamic effects. On the other hand, truly random orientation distribution proved to be rare in thin films, so analysis of texture was also incorporated into the method. At the moment, fiber-texture, observed from the direction of the texture axis can only be quantified in the present version. However, this seems to be the most frequent texture form in thin films.

FOREMOST (FP6): „Fullerene-based Opportunities for Robust Engineering: Making Optimised Surfaces for Tribology" (2005-2009)

G. Radnóczi, K. Sedlacková, G. Kovács, Z. Czigány, A. Jakab

The project deals with mainly non carbon based inorganic fullerene like materials (IFLM) (e.g. WS_2, NbS_2, TiS_2, BCN, TiN/MoS_2 nanocomposites, MoS_xO_y) effect on tribological coatings for machine industry. MFA is responsible for TEM characterisation of the coatings and providing structural and growth information on structure properties-deposition parameter relations. The close co-operating partners are CEA Grenoble, Ion Bond UK and Switzerland, Milan University, Forschungszentrum Dresden-Rossendorf (FZD), Linköping University Sweden in materials production and CNRS Toulouse France in TEM characterisation.

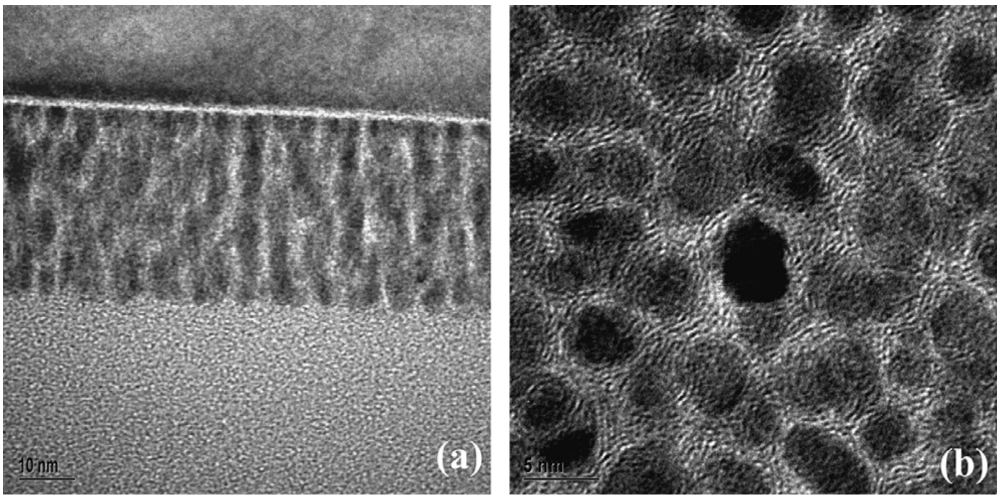


Figure 2 *Cross-sectional (a) and plan-view (b) high-resolution TEM images of the C:Ni composite thin film grown at 300 °C.*

Growth regimes of C:Ni (30 at.%) composite thin films grown by ion beam co-sputtering (FZD)in the temperature range of RT-500 °C are investigated. The combination of elastic recoil detection analysis, X-ray diffraction, transmission electron microscopy and Raman spectroscopy was used to characterize the composite structure. Three growth regimes are identified characterized by different Ni nanoparticle shape (granular, columnar, Fig. 2) and crystal structure (Ni_3C or fcc Ni). The comparison of the Raman spectroscopy results from carbon reference and C:Ni (30 at.%) thin films shows that the presence of Ni enhances significantly the 6-fold ring clustering at RT, while at higher temperatures it favors ordering into 6-fold ring clusters [1].

Experiments (Milano University) suggest that the pulsed microplasma cluster source can efficiently produce IFLN-MoS_2 and that supersonic cluster beam deposition is a suitable tool for the dispersion of nanoparticles in solid matrices (Fig. 3) [C. Piazzoni, M. Blomqvist, A. Podesti, G. Bardizza, M. Bonati, P. Piseri, P. Milani, C. Davies, P. Hatto, C. Ducati, K. Sedlácková, G.Radnóczi: Nanocomposite TiN films with embedded MoS_2 inorganic fullerenes produced by combining supersonic cluster beam deposition with cathodic arc reactive evaporation Appl. Phys. A, 90(1) 101-104 (2008)] with a good compatibility with standard PVD coating technologies without requiring the use of an hazardous chemical precursor. Optimization of this approach is underway in order to improve the tribomechanical properties of the nanocomposite films and to explore the possibility of scale up for the production of self-lubricating coatings.

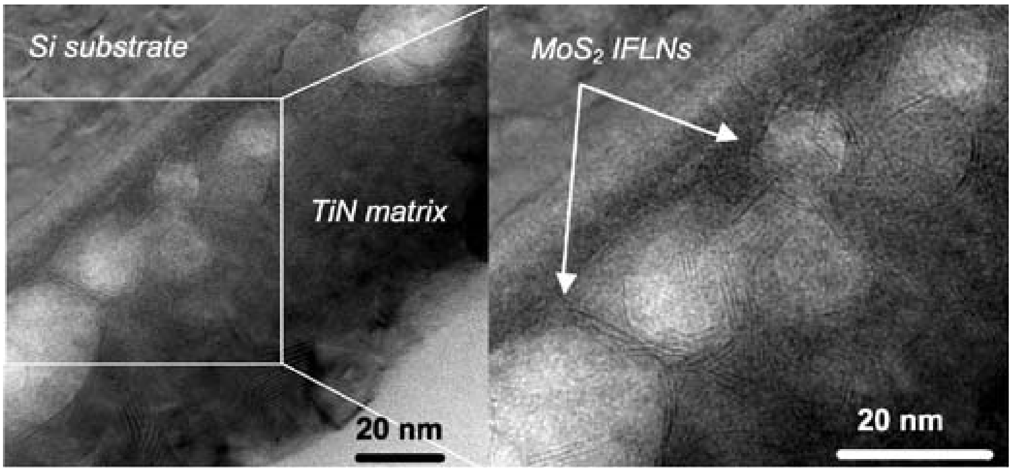


Figure 3 *(Left) Cross section TEM micrograph of a MoS_2/TiN nanocomposite film produced using the multilayer deposition mode. 10–50 nm size IFLN-MoS_2 are dispersed in the TiN matrix. The silicon substrate and TiN matrix can be clearly recognized. (Right) higher magnification view of the same region showing the structure of MoS_2 nanoparticles.*

A novel kinetic Monte Carlo method for epitaxial growth

(OTKA T048699, EU FP6 Project INNOVATIAL IP 515844-21, Romanian CEEX Nanobiospec grant)

Z. Néda, R. Deák, P. B. Barna

A fast and realistic kinetic Monte Carlo method, aimed to reproduce pattern formation mechanism in epitaxial growth is developed. The method has the great advantage that incorporates many degrees of freedom for the surface diffusion of the atoms and works with hopping barriers calculated from realistic pair-potentials. By several simple examples the applicability of the method is illustrated: simulation and statistics of island growth and coalescence, impurity segregation and stacking fault dynamics. The method offers new perspectives to study hetero-epitaxial growth as well and formation of several deposited layers in reasonable computational time using normal PC type computers.

Triangular lattice ((111) plane of fcc structure) is used as substrate (filled circles in Fig. 4) Considering a bulk fcc substrate, stacking fault develops at the interface of the substrate and a growing hcp monolayer island (Fig. 5). By this manner phase boundaries will also appear between growing islands of fcc (C) and hcp (B) types.

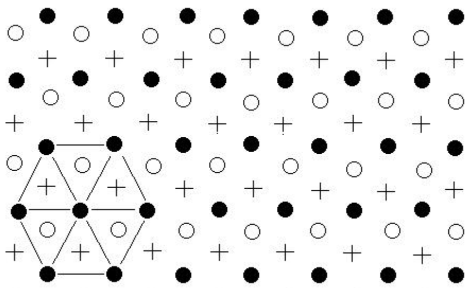


Figure 4 *Geometry of the considered lattice. Filled circles represent the sites of the substrate, empty circles and crosses represent the fcc and hcp lattice sites, respectively, on which the new layer can grow*

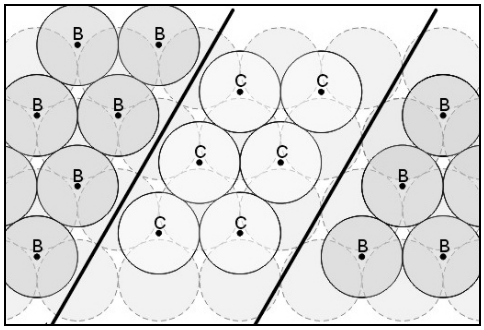


Figure 5 *Phase-boundaries that can be formed on the triangular fcc surface.*

For computing the potential-barrier that governs the surface diffusion of the atoms phenomenological pair-potentials are used. The hopping barrier for the diffusion process is calculated from the binding energies of the atoms in the initial and final states. As a first trial Lenard–Jones type pair-potentials were considered, although other accepted forms would probably lead to qualitatively similar results. The following simple linear form for calculating the hopping barrier of an atom has been proposed:

$$\Delta E_{X \to Y} = -\alpha E_n^X + (1-\alpha)(E_n^Y - E_n^X)$$

Where E_n^X (E_n^Y) is the total interaction energy (binding energy) of the atom at sites X (Y), respectively, and α is a parameter with a value of 0.35. Some examples are demonstrated in the following. Some movies are also given on the home-page dedicated to this study: http://phys.ubbcluj.ro/~zneda/kmc.htm

Evolution and annihilation of stacking-faults and phase-boundaries on an fcc (1,1,1) surface

The case when atoms are deposited with a fixed deposition rate (F=10ML/s) on a planar fcc (1,1,1) surface formed by the same type of atoms is considered. Monolayer domains of the two equivalent orientations but with different, fcc and hcp, sequences are nucleated and grown. Formation, motion and annihilation of stacking faults related phase-boundaries are followed during simulation (Fig. 6).

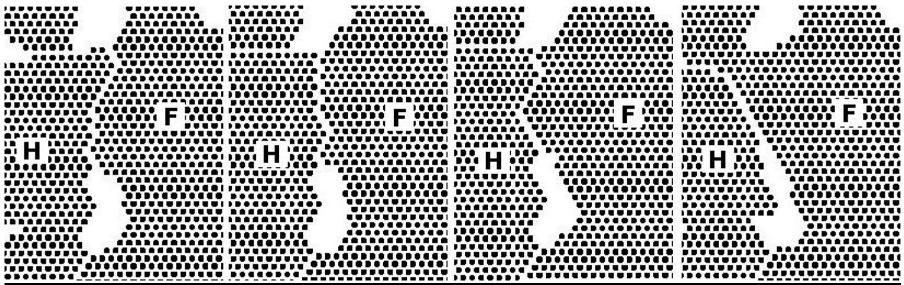


Figure 6 *Characteristic time evolution and annihilation of stacking faults related phase-boundaries for the case when only A type of atoms are deposited. The pictures from left to right represent some steps in the time-evolution. The F and H islands correspond to fcc and hcp stacking, respectively. Simulation parameters are: E_{AA} =0.15eV, T=650K, F=10ML/s and $f_0=10^{12}$ Hz.*

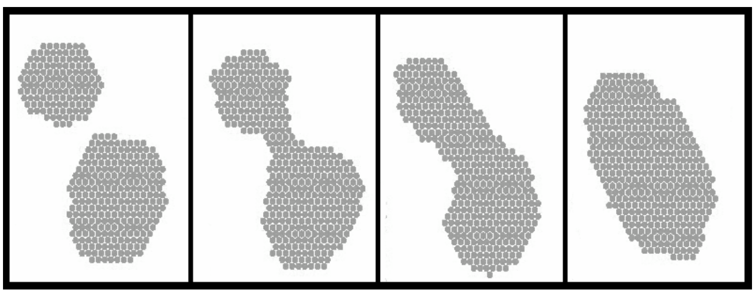


Figure 7 *Observed island coalescence scenario in simulations. Simulation parameters are: T=450 K and F=0.1 ML/s.*

Island coalescence

The scenario of island coalescence is in qualitative agreement with the one observed in experiments. In simulations one can observe the realistic formation of the neck and the fast rounding of the resulting islands. A simulation sequence in this sense is illustrated in Fig. 7. Movies made from simulation results are presented again on the home-page dedicated to this study.

Formation of impurity decorated islands in case of two-component deposition.

Simulation with the co-deposition of the **A (•)** and **B (+)** type of atoms leads to the expected structures. For the fixed parameters ($f_0=10^{12}$ *Hz*, E_{AA} =0.15eV, E_{BB} =0.0001 eV) and as a function of the E_{AB} parameter two main type of structures are observable: island containing intermixed **A** and **B** type of atoms, and islands decorated by **B** impurities. As expected, for low E_{AB} values the impurity decorated islands are stable, while for higher E_{AB} values the islands containing intermixed **A** and **B** type of atoms are observable (fig. 8). Increasing or decreasing the temperature will only shift the boundary between these two type of structures and favour larger or smaller islands of lower or higher number density (nucleation density) respectively, for the same number of deposited atoms.

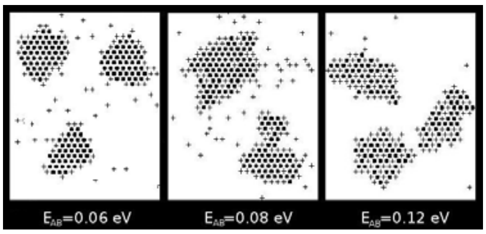


Figure 8 *Island structures obtained as a function of the E_{AB} parameter. Simulations with E_{AA}=0.15eV, E_{BB}=0.0001 eV, T=650K, F_A=F_B=10ML/s and $f_0=10^{12}$ Hz. The structures from left to right are obtained for $t=1.25\cdot10^{-2}$ s (60000 MCS), $t=2.73\cdot10^{-2}$ s (20000 MCS) and $t=1.87\cdot10^{-2}$ s (1500 MCS) simulation time, respectively. A central part of a much larger simulation area is presented. For E_{AB}<0.08 eV impurity decorated islands are formed.*

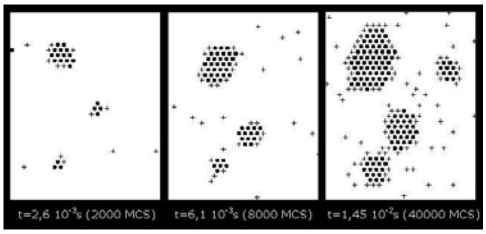


Figure 9 *Snapshots from the time evolution of the system. Simulation parameters are E_{AA}=0.15eV, E_{BB}=0.0001 eV, E_{AB}=0.06 eV, T=650K, F_A=F_B=10ML/s and $f_0=10^{12}$ Hz. A central part of a much larger simulation area is presented.*

The time evolution of the structures for the case of impurity decorated islands is illustrated in Fig. 9. Some movies showing a more complete dynamics are available on the home-page dedicated to this study.

Metal-metal nanocomposites

(OTKA T048699)

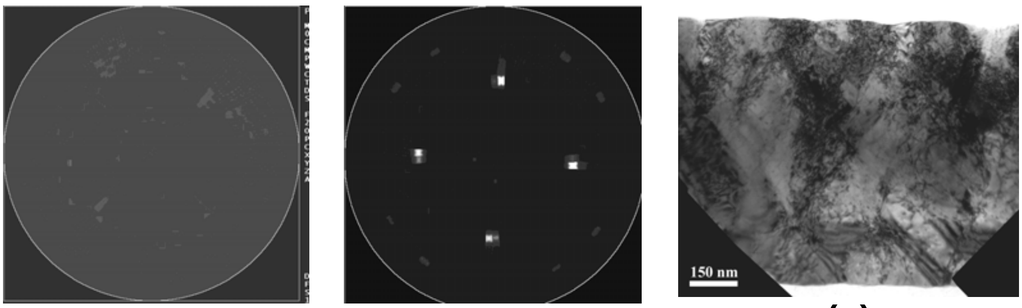
G. Radnóczi, F. Misják, P. B. Barna

The formation and morphological development of two phase composite films still has a number of open questions. E.g. metal–metal (nano)composites are posing many unsolved growth problems. Especially the basic processes of morphological and texture development in them needs to be further clarified.

The Cu-Ag system can be a suitable model for the investigation of texture and morphology development in metal-metal nanocomposites. Films of 50 and 400 nm thickness were prepared by co-deposition of thermally evaporated Cu and Ag in vacuum of 10^{-5}-10^{-6} mbar onto cleaned (100)Si wafers. The composition of the films corresponded to Cu, Cu_9Ag_1, Cu_4Ag_6(eutectic) and Ag in agreement with the physical and morphological properties of these films.

Thin (20 nm) Cu films grow on amorphous C substrates without any measurable texture according to electron diffraction investigations. In that case oxide formation on the growing Cu crystallites has been considered to be the reason for blocking the selection processes like coalescence, crystal growth and grain growth, supposing that nucleation occurs in random orientation on amorphous substrate.

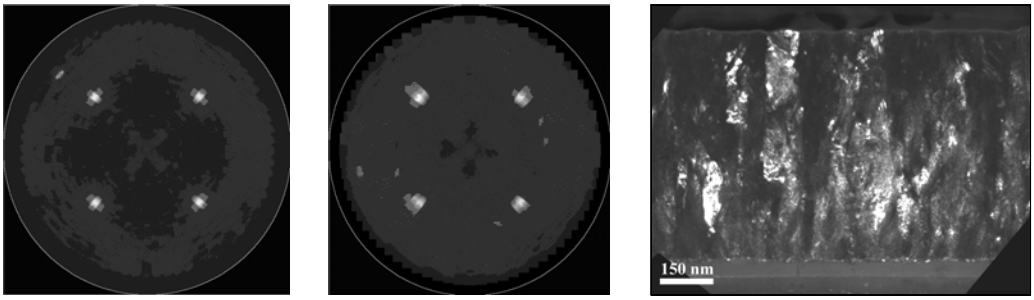
A thin film of Cu grown on (100) Si displays very faint or practically no texture as long as the thickness is 50 nm (Fig. 10(a)). The 50 nm thick film shows columnar morphology with a grain size nearly equal to the film thickness. This must be due to the effect of substrate, providing much less oxygen or water species in the starting stage of the growth process compared to carbon substrate.



(a) (b) (c)

Figure 10 *<111> pole figures of Cu films of 50 nm thickness (a), 400 nm thickness (b) and TEM bright field cross section image of the 400 nm thick film (c).*

In Cu/(100)Si films grown to 400 nm thickness a strong {100}Cu||(100)Si and <100>Cu||[011]Si biaxial texture appears (Fig. 10(b)). This texture is the result of the selection processes leading to the strengthening of the weak <100> texture detected in the thin sample (Fig. 10(a)). The selection takes place due to the interaction of the growing grains with oxygen and copper-oxide formation. The selection processes occur during crystal growth resulting in grain size of a few µm (Fig. 10(c)). An important role in this sense can be attributed to the native oxide forming on the Si surface during exposure to air after cleaning and before evacuation. The possibility of epitaxy involves the breaking up of this oxide layer on Si surface by Cu at room temperature as could be evidenced by TEM investigations.



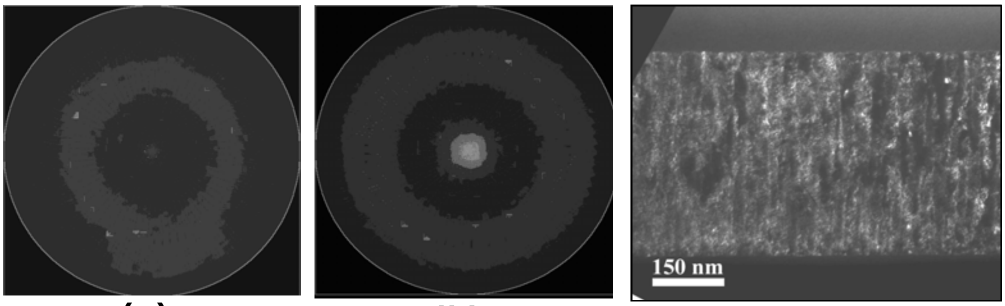
(a) (b) (c)

Figure 11 *<111> pole figures of Cu 10 at%Ag films of 50 nm thickness (a), 400 nm thickness (b) and TEM dark field cross section image of the 400 nm thick film (c).*

Co-deposition of 10 at% of Ag to Cu results in changes of texture development compared to Cu film. The pole figure recorded in Cu{111} reflections (Fig. 11(a)) shows relatively strong two axis <100> texture for the 50 nm thick Cu-Ag film. Simultaneously a weak <111> wire texture is observed. Comparison to Cu films (Figure 1a) tells, that Ag co-deposition with Cu enhances the texture formation in Cu film. However, the additional <111> wire component was not observed in Cu/[100]Si films. Thin Ag films have <111> wire texture on (100)Si in our experiments. Based on these two experiments we can propose that Ag enhances both the epitaxial growth of Cu on (100)Si and the <111> wire texture in thin (50 nm) films.

Increasing the thickness to 400 nm (Fig. 11(b)) preserves the biaxial <100> texture obtained in thin Cu_9Ag_1 films (Figure 2a). The one axis <111> texture is suppressed by growing crystals and grains in the Cu_9Ag_1 film (Fig. 11(a) and (b)). Morphologically the result is a composite in which the grain size of both components is smaller than the thickness of the film both in lateral and in film normal directions (Figure 11c).

Only wire textures were observed in the eutectic (60 at% Ag) films, characterised also by very small grain size. Both the thin (50 nm) and thick (400 nm) films have a pronounced <111> wire texture which is observed for both Ag and Cu. (Fig. 12(a) and 12(b)). In the case of this composition no evidence of the breaking of the natural SiO_x layer was observed, i.e. Ag is reducing the activity of Cu to oxygen.



(a) (b) (c)

***Figure 12**. <111> pole figures of Cu-Ag films of eutectic composition of 50 nm thickness (a), 400 nm thickness (b) and TEM dark field cross section image of the 400 nm thick film (c).*

Carbon-metal nanocomposites

(OTKA T048699)

G. Radnóczi, K. Sedlacková, R. Grasin, G. Kovács, M. Rédeine Szerencsi

For the investigation of two phase thin films the carbon-metal nanocomposites represent scientific interest both from the point of view of their growth mechanism and nanostructure as well as their physical properties. Varying the metal (Ni, Ti) and matrix components (C, CN_x) a wide range of processes, solid phase reactions chemical bonding types can be scanned and so structure-property relations can be effectively studied and tested. The practical application of carbon metal nanocomposites is also very promising due to the possibility of multifunctional applications.

C-metal (Ni, Ti) nanocomposite thin films were deposited by dc magnetron sputtering in argon between 25°C and 800°C onto SiO_2 (300 nm) covered Si substrates in order to compare the structure- mechanical property relations in these films.

A comparison between structure and mechanical properties of dc sputtered C-Ni and C-Ti nanocomposite thin films has been made in the growth temperature range of 25-800^{o}C. C-Ni films undergo morphological and phase change at 400^{o}C deposition temperature, while the C-Ti films possess the same phase state and morphological character in the whole range of deposition temperatures. Despite the structural differences the dependence of hardness (H) and elastic modulus (E) on the deposition temperature shows very similar behaviour. The same character of the hardness and modulus curves is mostly influenced by the structure and the morphology of the carbon matrix. The difference in absolute value between the H and E curves of C-Ni and C-Ti could be related to the C-metal bonds, chemical stability and mechanical properties of the corresponding carbide phase.

In Fig.13 we show the comparison between the C-Ti and C-Ni nanocomposite films grown at 200 °C. The same comparison at 800 °C deposition temperature is presented in Fig. 14.

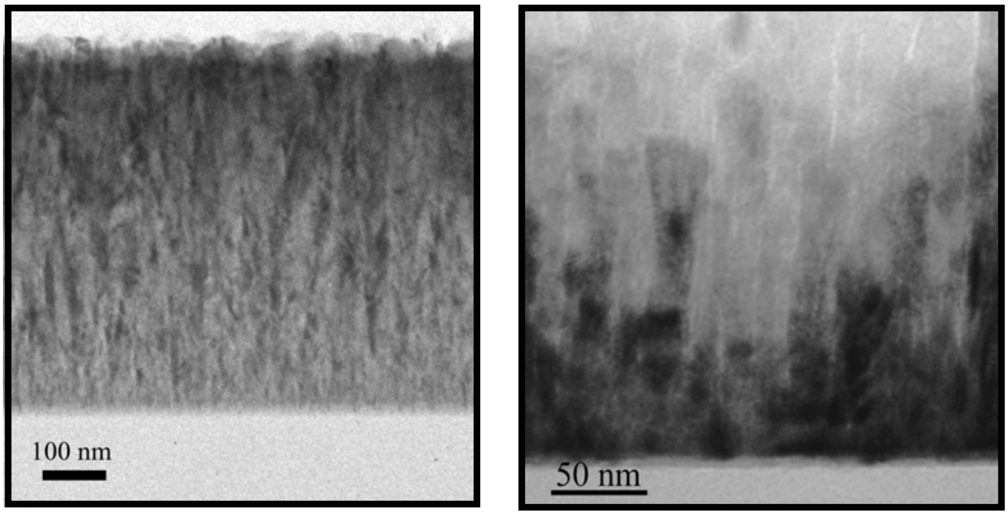


Figure 13 *The structure of C-Ti (right) and C-Ni (left) samples prepared at 200 °C*

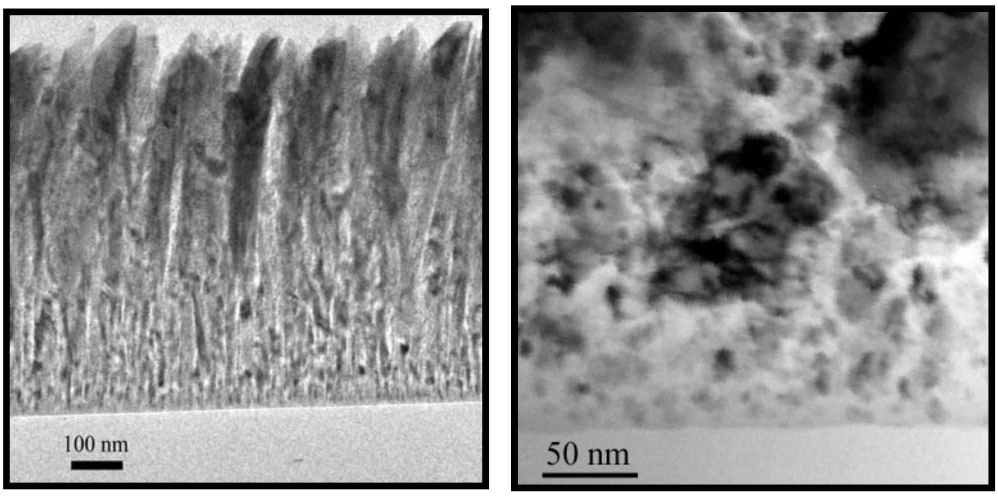


Figure 14 *The structure of C-Ti (right) and C-Ni (left) samples prepared at 800 °C.*

According to nanoindentation tests, the mechanical properties (hardness Fig.15, and reduced modulus of elasticity, Fig. 16) of the films showed the same behaviour for the two metals as the function of the deposition temperature. The maximum hardness of the C-Ni and C-Ti films is achieved for films grown at 200^{o}C and is around 14 and 18 GPa, correspondingly.

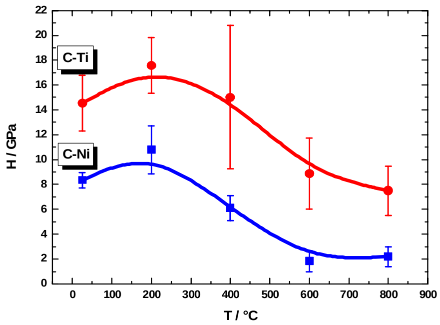


Figure 15 *The hardness of the nanocomposite thin films as the function of deposition temperature*

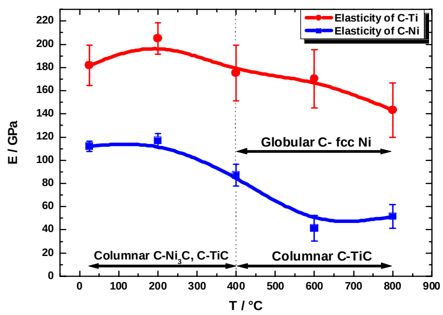


Figure 16 *The modulus of elasticity of the nanocomposite thin films as the function of deposition temperature*

Formation of Phases and Textures in Co-Sputtered ($Cr_{1-X}Al_X$)N Thin films

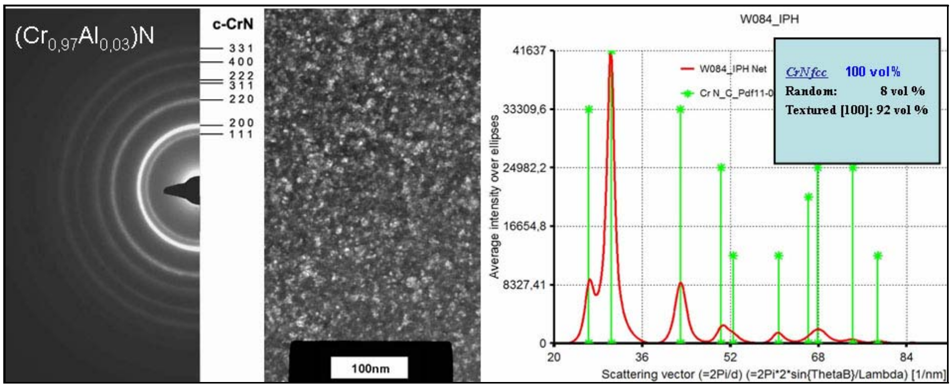
(EU FP/ Project INNOVATIAL IP 515844-21)

P. B. Barna, O. Geszti, G. Lestyán, L. Székely, G. Sáfrán, G. Radnóczi

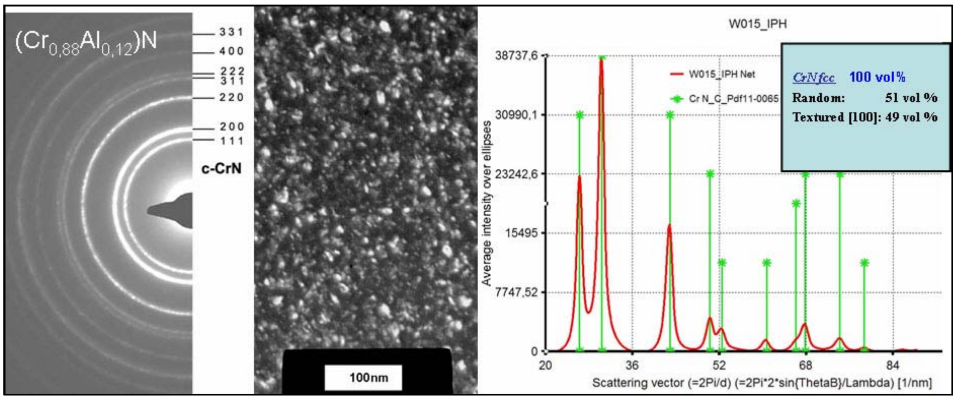
The c-($Cr_{1-x}Al_x$)N films have particularly high potential as wear- and corrosion-resistant functional coatings. These coatings have high oxidation resistance with Al content lower than 63 at%. The properties are deteriorated at higher Al concentration. This is attributed to the formation of h-Al(Cr)N phase *[O. Knotek, et.al, Surf. Coat Technol 163-164 (2003) 57-61]*. According to the XRD investigations the transition of c-Cr(Al)N to h-Al(Cr)N takes place in a narrow (0,6<x<0,75) composition range. The theoretical solubility limit of Al in CrN is 77 at%. *[T. Li, et.al, Surf. Coat. Technol. 201 (2007) 7692-7698]*. The growth of monophase single-crystal c-($Cr_{0,32}$, $Al_{0,68}$)N films indicated the highest solubility of Al in the c-CrN phase *[H. Willmann, et.al, Scripta Mat. 57 (2007) 1089]*.

In the present project formation of the cubic and hexagonal phases as well as the texture conditions were investigated in the 0<x<1 composition range in thin (d < 60 nm) ($Cr_{1-x}Al_x$)N films prepared by micro-combinatorial method. Beside the identification of the phases and textures also their volume fractions have been determined by the improved version of the ProcessDiffraction program [*J.L. Lábár, to be published*].

The CrN film is small crystalline with nearly complete [100] texture. In case of 3 at% Al additive a grain size decreased and the volume fraction of randomly oriented crystals is increased (Fig. 17(a)). At 12 at% the Al grain size is increased and the degree of texture is drammatically decreased (Fig. 17(b)). Nearly 50 vol % of the crystals are randomly oriented.



(a)



(b)

Figure. 17 *SAED patterns, DF TEM images and the ProcessDiffraction evaluation of the SAED patterns. The volume fraction of the fcc and hcp phases as well as the textures are given*

At 54 at% Al the hexagonal phase is well detected, small crystalline and textured, while the crystals of the fcc phase are larger and randomly oriented (Fig. 18). The grain size increases with decreasing Cr concentration. The volume fraction of hcp phase also increases. At 71 at% Al the hcp phase is the majority and completely textured, while at 83 at% Al the random fraction is remarkable. In pure AlN the crystals are only partly oriented. The fcc phase exists up to 83 at% Al and is randomly oriented in each samples.

The results proved that the formation of h-AlN phase starts at remarkably lower Al concentration ($x \sim 0{,}5$) than the solubility limit of Al in the fcc-CrN ($x \sim 0.7$). This can be attributed to the probability of the simultaneous nucleation of the fcc and hcp phases beyond 50 at% of Al. When AlN is doped with Cr, the fcc phase characterizing the CrN structure shows up already at 15 -17 at% Cr. This could be indicative of the lower solubility of Cr in the growing h-AlN.

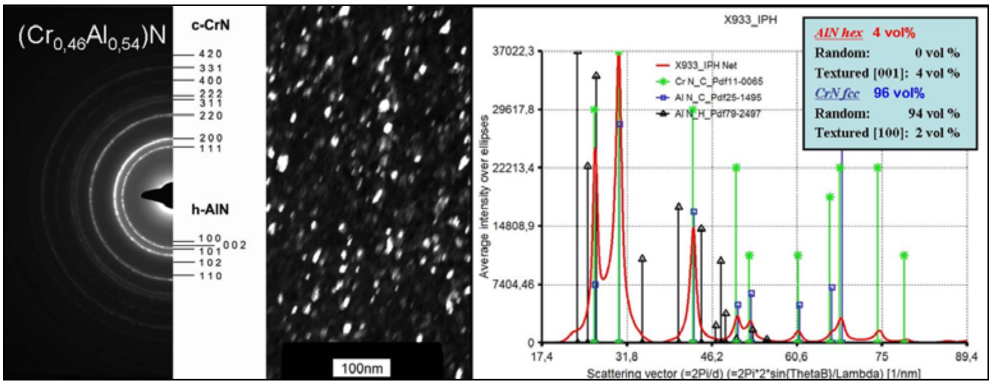


Figure 18 *At 54 at% Al the hexagonal phase is well detected*

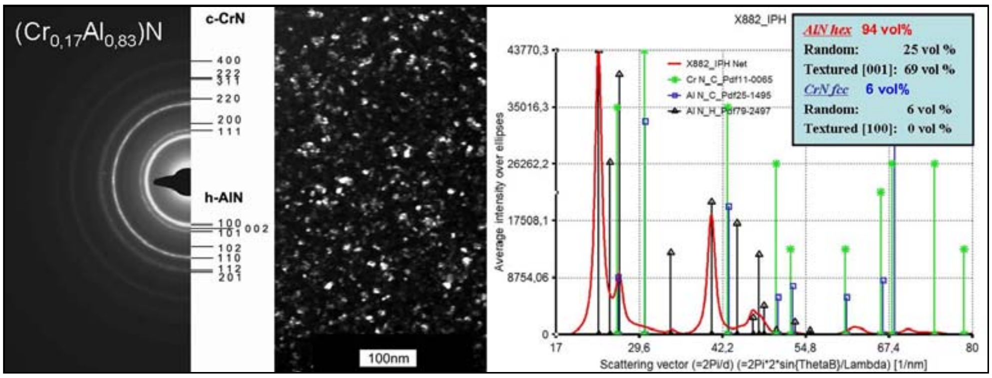


Figure 19 *At 83 at% Al largest part of hcp phase is textured, while the fcc phase is random*

Growth, synthesis and microscopy of wide bandgap semiconductors

(OTKA 47141 (2004-2007))

B. Pécz, Á. Barna, G. Radnóczi, J. Lábár, L. Tóth, L. Dobos, Z. Makkai, G. Z. Radnóczi, B. Veisz

During the project wide bandgap semiconductors (like SiC, GaN, ZnO) and contacts to them have been investigated. The characteristic defects and dislocation density values have been determined. An explanation was given for the matching of diamond and SiC. Investigating ZnO layers grown on sapphire with a MgO buffer it was found that the MgO can transform to a $MgOAl_2O_3$ spinel, which decreases the misfit.

Different nanostructures have been prepared from the SiC nanocrystals formed in CO annealing of oxide covered silicon wafers seprating them from the silicon by further oxidization.

Metal contacts have been prepared both to SiC and GaN, which have been investigated in details.

On the Al/Ti contacts (used as ohmic contacts to p-type SiC) we have concluded, that Ti_3SiC_2 phase (responsible for the ohmic behavior) is formed on the silicon polar side of SiC, only.

Hybrid Substrates for Mass Production of High Frequency Electronics

(HYPHEN - FP6 IST 027455)

B. Pécz, L. Tóth, L. Dobos, F. Riesz, G. Z. Radnóczi

The goal of the project is the development of hybrid substrates for growth of GaN layers. The starting material is polycrystalline SiC. About 500 nm thick single crystalline Si or SiC layer is transferred onto the starting wafer by smart-cut and wafer bonding methods at PICOGIGA. MFA performs characterization of the wafers and layers grown both by molecular beam epitaxy (MBE) and chemical vapour deposition (CVD). The non-destructive Makyoh topography is used to determine the bow of whole wafers. Transmission electron microscopy (TEM) is used for the characterization of layers, interfaces and for the determination of dislocation density.

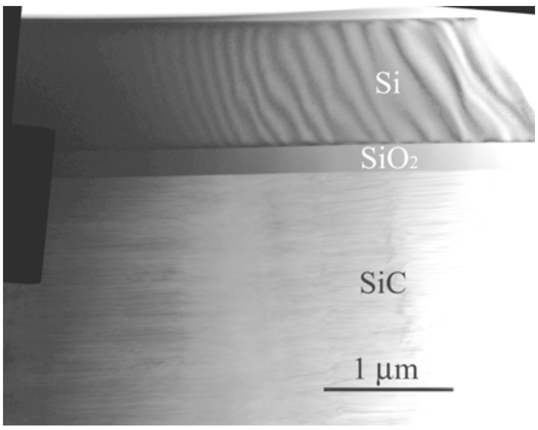


Figure 20 *Thin Si layers transferred onto polycrystalline SiC substrate by smart-cut technique with a surface roughness of rms < 1 nm.*

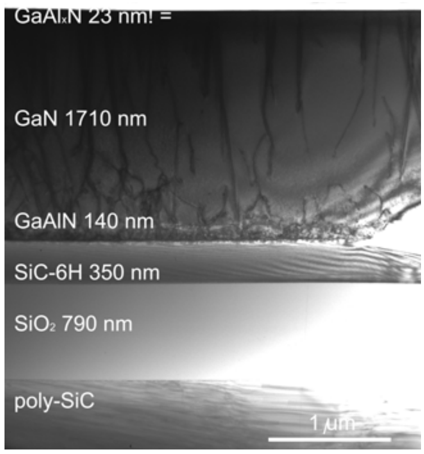


Figure 21 *Typical nitride layers grown onto the thin hexagonal SiC strip of the hybrid substrate. Threading dislocations are well visible.*

The achieved results are the following: We have determined that the polycrystalline wafer has a columnar structure and the characteristic sizes were also measured. The smart-cut transferred Si and SiC single crystalline layers are free of defects, but the top surface of the composite template is a little bit wavy. The surface roughness in the case of Si can reach about rms = 5 nm, but it was demonstrated in this project, that the rms can be decreased below 1 nm by special methods (Fig. 20). On SiC surfaces (smart cut transferred) typically rms = 3 nm values were measured.

The top surface of the nitride layers grown on both hybrid substrates (with single crystalline Si, or SiC on SiO2/polyicrystalline SiC) is flat (Fig. 21). Orientational relationships are the same as in the case of GaN grown on classical, thick Si, or SiC wafers. The dislocation density in layers grown by MOCVD close to the surface is 1-1.4 × 109 cm-2, which is the same as in layers grown on thick SiC wafers.

Nanocomposites for Piston/Liner Systems

(EU-FP6 NMP3-CT-2003-505622)

B. Pécz, L. Tóth, É. Hegedűs, I. Kovács

Nanocomoposite coatings are extensively investigated in the last couple of years for their advantageous mechanical and tribological properties. The goal of the project was to develop a coating, which is relatively hard (10-20GPa), but same time exhibits low friction (<0.2 on steel at non-lubricated condition). Further requirements are the low wear and good thermal stability to a few hundred ^{o}C.

MFA was responsible for the structural characterization of these new coatings in the NAPILIS project, which was mainly done by transmission electron microscopy. Analytical measurements as well as very intensive high resolution microscopy were carried out.

Analysis and detailed investigation of several coatings in the frame of the project finally led to the selection of two different CrC/carbon coatings on piston rings.

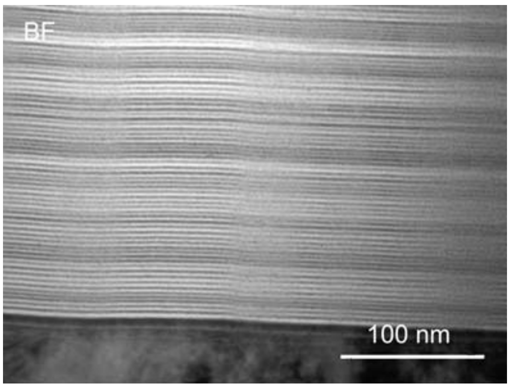


Figure 22. *Cross sectional electron micrograph of the multilayer coating CrC/graphite*

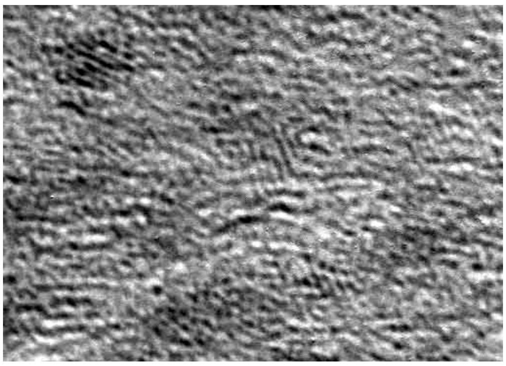


Figure 23. *Both (111) and (002) lattice planes of the fcc CrC phase as well as the (0002) spacing of the randomly oriented graphite phase were observed on the high resolution electron micrograph.*

The first type of coating was prepared by reactive sputtering of Cr target in a gas mixture of methane/Ar, which resulted in the formation of fcc CrC grains in amorphous carbon matrix. The average grain size was found to be 2 - 5 nm depending on the bias voltage. The grains were randomly distributed in the amorphous matrix, but a quasi-periodic structure formed by a self-organizing process during the deposition was also observed. The amorphous carbon matrix contains hydrogen, therefore it can be considered as a DLC (diamond-like carbon) material. Composite layers were prepared with a friction coefficient lower than 0.1 and the coatings exhibited sufficiently low wear (10^{-15} m^3/Nm).

The other selected type was a hybrid method combining sputtering and arc deposition as well and a superlattice like multilayer coating was produced by the rotation of the sample holder. One of the layers in the superlattice was nanocrystalline CrC, while the other one was graphite (Fig. 22). The periodicity of the superlattice (i.e. the thickness of a bilayer) was about 3-5 nm. Although the graphite layers could not be oriented in the ideal direction, even CrC/graphite superlattices containing random graphite fulfilled the required parameters (Fig. 23) and the microstructure was preserved in an engine test.

Comparison of the effects of Ga^+, Ar^+ and CF_4^+ ion irradiation

(NKFP 3A/071/2004)

Á. Barna, L. Kotis, S. Gurbán, M. Menyhárd, A. L. Tóth,

Medium energy (some tens of keV) ion irradiation is frequently used to cut specimens for transmission electron microscopy (TEM) studies. It is well known that during this cutting serious changes are introduced to the material. We are studying Si/Cr multilayer samples which are irradiated by various ions (Ga^+, Ar^+, CF_4^+) of 20 keV applying angle of incidences of 5° (Ga^+), 65 ° (Ga^+), and 75 ° (Ar^+, CF_4^+) by means of AES depth profiling. The ion beam induced mixing at the Si/Cr interface (the broadening of the interface) is measured as a function of the removed layer thickness.

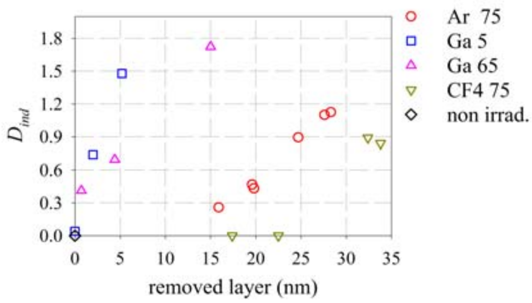


Figure 24 *The broadening of the interface vs removed layer thickness due to ion irradiation of various projectiles of 20 keV. 5 and 65 in the caption stands for irradiation applying angles of 5 and 65°. D_{ind} is the parameter of the logistic function fitting the transition.*

The weakest and strongest ion mixing (belonging to a given removed layer thickness) were found for CF_4^+ and Ga^+ 5° irradiations. For Ga^+ irradiation the larger the angle of incidence the weaker the ion mixing is. The extent of mixing does not correlate with the corresponding projected range. Comparison of the experimentally measured ion mixed profiles with those given by dynamic TRIM simulations gives poor agreement for Ar^+ and fails for Ga^+ irradiation, respectively.

Surface excitation correction of the inelastic mean free path (IMFP); PL-15.

G Gergely, S Gurban, M Menyhard and A Jablonski

The IMFP is an important material parameter determining electron transport processes in electron spectroscopy (AES, XPS, EPES, REELS). The IMFP was determined on Si, Ni, Cu, Ag and Au samples, used for reference samples in quantitative surface and thin film analysis. Goto's database in absolute units (%) was evaluated applying the EPESWIN software of Jablonski. Surface excitation (SEP) correction was made. The material parameters were determined by best fitting of the IMFPs measured using elastic peak electron spectroscopy (EPES) to calculated NIST TPP-2M data. Testing the models and material parameters of Chen, Nagatomi, Kwei, Ding and Werner resulted in best approach with models of Chen and Werner.

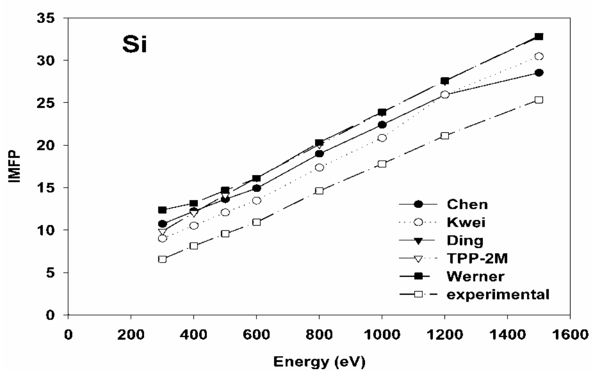


__Figure 25__ Comparison of the uncorrected IMFPs with the SEP corrected curves of Si. Best approach was achieved with material parameters of Chen (improved) and Werner

Ion mixing by Focused Ion Beam (FIB)

(NKFP 3A/071/2004, SLO 7/05)

Á. Barna, L. Kotis, J. Lábár, A. Sulyok, M. Menyhárd, Z. Osvath, A. L. Tóth, A. Zalar, P. Panjan

Previously we have reported on the ion mixing experiments by FIB (Ga^+ 30 keV) on Si amorphous (41 nm) /Cr polycrystalline (46nm) multilayer structure [20]. The main message of the study was that thickness of the mixed region depended on the Ga^+ fluence, and it was joined to the pure Cr matrix with an unusual sharp interface. The experiment has been continued on C/Ni and Ni/C structures. In the case of C/Ni system similar behavior is observed. Again a well defined carbide layer forms due to the ion irradiation.

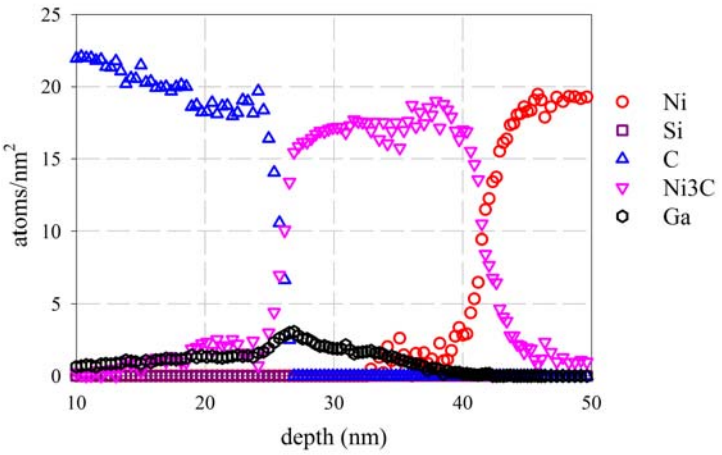


Figure 26

On the other hand if we apply the same procedure to the Ni/C layer (the thickness of the layers are the same) then the interface broadening is a usual one. Thus we could show that the ion mixing is asymmetric as it was reported by us for low energy ion irradiation.

Atomistic simulations: ultrafast atomic transports

(NKFP 3A/071/2004.)

P. Süle, M. Menyhárd

Atomistic simulations became a versatile tool in nanophysics in the last decades. Recent progress in the field reveals that approaching the nanoscale dimension of materials the rules known in the continuum often break down. Experimental probes in the nanoscale often fail to establish the mechanism of various atomistic processes. However, in combination with atomistic simulations the understanding of materials properties could help in developing new materials with promising technological applications.

In the recent year we studied using classical molecular dynamics simulations the anomalous interfacial broadening of multilayer metals. In particular, in Pt/Ti we pointed out a peculiar mechanism which could be relevant for other materials with anisotropic interface [156]. We find that the intermixing heavy atoms move across the interface with Lévy flight (superdiffusion). At best of our knowledge this is the first report of *Lévy intermixing* in the solid state .

A second topic is the *ultrafast burrowing metallic clusters* into various substrates. Briefly, we reveal that e.g. a Pt nanocluster burrows into Al within few ps keeping its integrity. This is an unprecedented dynamic phenomenon which has not been previously anticipated. The process could allow the fabrication of metallic inclusions without the damage of the substrate and even the deposited cluster remains intact. Hence the explored process is technologically promising.

The *transient faciliated surface alloying* of Pt in Al(111) has also been explored and an interesting mechanism has been revealed. We find that the intermixing of Pt atoms into Al(111) takes place via an ultrafast (athermal) exchange process. This is a non-Arrhenius atomic transport process which works even at very low temperatures. The deposited Pt atom (soft landed) induces the coherent transient movement of few surface Al atoms. These highly excited atoms promote the inter-layer transport of Pt into Al(111) in a self-organized manner. The process does not require energy load: the system self-organizes itself without external stimulus even at ~0 K external temperature (P. Süle, J. Chem. Phys. (2008) in press).

Constraction of medium energy ion gun

(NKFP 3A/071/2004)

Á. Barna, M. Menyhárd, Technooorg Linda Ltd.

A new ion gun has been developed for medium energy (10-20 keV) ion energy range. The basic of the construction agrees with the low energy ion gun, but the technical solutions are vastly different because of the high voltage requirements.

The parameters of the new ion gun: energy: 2-20 keV, projectile: any, beam diameter 0.1mm (10 mm working distance). The milling rate was measured to be 150 μm/h in Si at 20 keV and angle of incidence 75 °. The new ion gun is successfully used for ion mixing experiments (see topic entitled *Comparison of the effects of* Ga^+*,* Ar^+ *and* CF_4^+ *ion irradiation* in this volume), and sample fabrication. The test chamber with the gun is shown in the figure.

Figure 27 *Test chamber with the 20 keV ion gun.*

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Development of optical models for ellipsometric study of multicomponent materials

(Hungarian Scientific Research Fund under Grant No. T 047011)

M. Fried, T. Lohner, N. Q. Khánh, P. Petrik, O. Polgár

Amorphous silicon and silicon nitride multilayer samples were prepared and investigated by spectroscopic ellipsometry and cross sectional transmission electron microscopy. The complex refractive index of reactively sputtered amorphous silicon was determined using the Tauc-Lorentz oscillator model. It was shown that spectroscopic ellipsometry provides quantitative information on the in-depth structure of the multilayer system [150].

Solid phase epitaxial regrowth and ion beam induced epitaxial crystallization of ion implanted silicon was investigated using Rutherford backscattering spectroscopy and spectroscopic ellipsometry. The Czochralski-grown silicon wafers were amorphized with 100 keV Zn^+ or Pb^+ ions at liquid nitrogen temperature. The ion beam induced epitaxial crystallization was stimulated by irradiation with 3 MeV Si^+ ions while the temperature of the samples was stabilized at 400 ^oC. Evaluation of spectroscopic ellipsometry data yielded the thickness of the native oxide layer and of the amorphized and recrystallized silicon layer [4].

Ellipsometric modelling of nanograin structures and thin films for biological and (opto)electronic applications

(Hungarian Scientific Research Fund under Grant No. K61725)

P. Petrik, N. Q. Khánh, S. Kurunczi, O. Polgár

Silicon nanocrystals formed in non-stoichiometric silicon nitride were investigated using spectroellipsometry, for the evaluation of the spectra parametric semiconductor models were selected [27, 190].

The quality of flagellin films in terms of thickness and homogeneity was investigated by spectroscopic ellipsometry. Flagellin films were prepared in three steps: silanization, glutaraldehyde activation and finally the coating with proteins. The process of film preparation was optimized by varying the duration of the silanization and by testing sticking on different substrates including Si wafer covered with different thickness of silicon-oxide and also covered with a thin film of tantallum pentaoxide. Spectroscopic ellipsometry was applied to gain in-depth information on the film properties for the optimization of the immobilization. The thickness of the immobilized protein (FliC) layer as a function of duration of silanization can be seen in Figure 1.

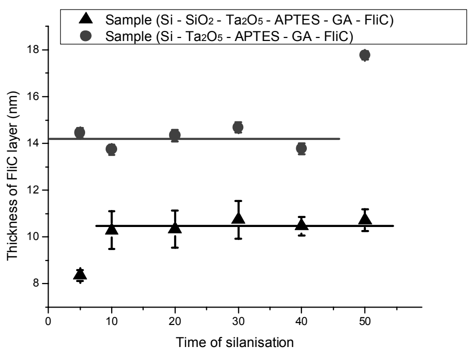


Figure 1 *Thickness of FliC (immobilized protein) layer as the function of silanization time. Average thickness is shown by the thick lines (excluding the two outliers). Samples with the native oxide (●) and with the thermal oxide (▲) are presented.*

We contributed to the determination of the refractive index in bulk PMMA as a function of bombarding proton penetration depth [137].

Fabrication of diffractive optical elements using ion implantation

(Hungarian Scientific Research Fund under Grant No. K68688)

T. Lohner, I. Bányász, M. Fried, C. Major, F. Pászti, A. Watterich

Erbium-doped tellurite glasses are of great interest for the fabrication of active integrated optical circuits because of their unique properties in terms of bandwidth and rare earth solubility. Multimode channel waveguides in a glass of this family, namely, a sodium-tungsten-tellurite glass, has been realised with high-energy ion irradiation technique, where one dimension of the ion beam size was reduced to micro-scale by the silicon mask (Figure 2). This approach makes possible the fast fabrication of waveguides with high aspect ratio (~ 10^3). The 24 μm wide and 10 mm long waveguide stripes achieved by 1.5 MeV N^+ irradiation with doses between 5 x 10^{15} and 4.0 x 10^{16} ions/cm^2 were studied using interference phase contrast microscopy, atomic force microscopy and surface profilometry. The waveguiding effect was investigated by the end-fire coupling technique. Multimode light propagation has indeed been observed in these channels, confirming the effectiveness of this method [30].

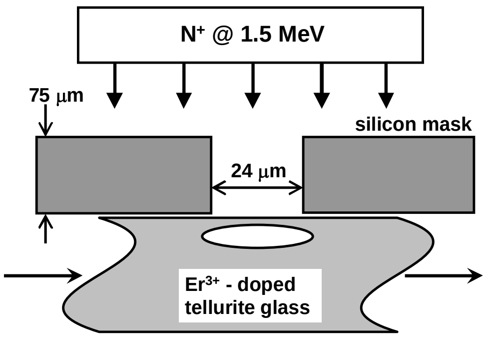


Figure 2 *Sketch of the setup used to fabricate channel waveguides in* Er^{3+}*-doped tellurite glass by ion irradiation. A silicon mask, with an opening of about 24 μm, is placed in front of the sample before each exposure in order to define a channel waveguide.*

Wide-angle ellipsometry

(GVOP-3.1.1-2004-05-0435/3.0 AKF project [2005-2007])

M. Fried, G. Juhász, C. Major, P. Petrik, O. Polgár, Z. Gy. Horváth

Two different versions of the “point source – pin hole camera” type wide-angle ellipsometer setup were completed and tested: the multiwavelength setup and the spectroscopic setup.

With the help of a DAAD-MÖB support the adaption of the new version of the apparatus (equipped with a spherical mirror) to a vacuum system was implemented in the Fraunhofer Institute of Integrated Systems and Device Technology (IISB) in Erlangen, Germany (Figure 3).

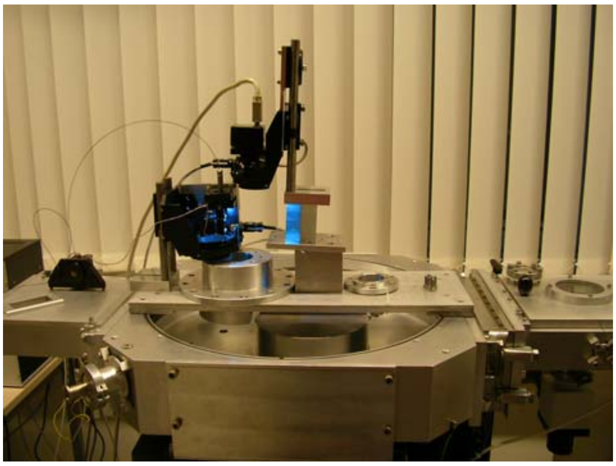


Figure 3 *Photograph of the new version of the wide-angle ellipsometer (equipped with a spherical mirror) mounted to the diagnostic chamber of a metal organic chemical vapor deposition system.*

European Integrated Activity of Excellence and Networking for Nano and Micro-Electronics Analysis

(EU I3, ANNA Projekt No. 026134 (2007-10)

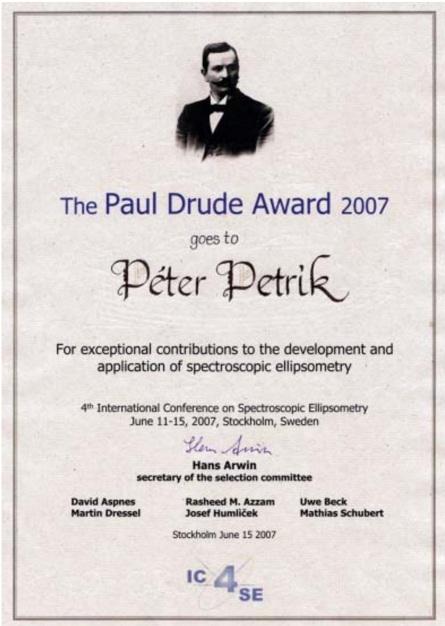
P. Petrik

The ANNA project aims to offer European universities, research institutes, large companies and small and medium-sized enterprises a joint laboratory that addresses threats to the growth of their nanotechnology and microelectronic sector. The companies and researchers involved will benefit from the efforts to solve the challenges they face when using new technology.

The accreditation of the ellipsometric laboratory of the MFA is in progress. Research groups from different European universities, research institutes submitted proposals in order to perform spectroellipsometric investigations in cooperation with MFA. Besides this activity research tasks involving investigation of shallow implanted profiles, nanocrystals and ultrathin layers were initiated.

Paul Drude Award 2007

Péter PETRIK, PhD, senior researcher at the Research Institute for Technical Physics and Materials Science at the Hungarian Academy of Science, Budapest, received the 2007 Paul Drude Award for his unique contributions with strong focus on ion-implanted single-crystal semiconductor materials and the damage that these materials sustain through the implantation process. The Paul Drude Award is given to a young scientist for exceptional contributions to the development and application of spectroscopic ellipsometry. The investiture ceremony is organized at each International Conference of Spectroscopic Ellipsometry (ICSE). The fourth ICSE conference in 2007 is held in Stockholm. The ICSE4 Paul Drude Award is sponsored by the J. A. Woollam Co., Inc., and includes a monetary prize of €1000.



Makyoh topography

(Hungarian Scientific Research Fund under Grant No.K68534)

F. Riesz, J. P. Makai, I. E. Lukács

Makyoh topography is an optical tool for the flatness testing of specular surfaces, based on the defocused detection of a collimated beam reflected from the tested surface. The main development in 2007 from methodological point of view was the installation of a Digital Micromirror Device (DMD) into the setup (Figure 4). The DMD allows the structuring of the illuminating beam with an arbitrary pattern. Comparison with interferometry yielded good agreement using square grid and a spot matrix patterns.

The accuracy of the correlation method used for the evaluation was studied using computer simulations; typically, 0.1 to 0.2 pixel accuracy was demonstrated.

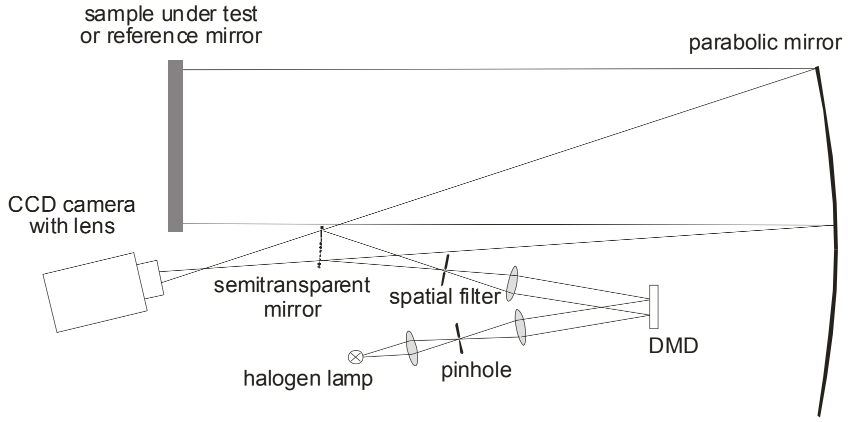


Figure 4 *Layout of the Makyoh-topography set-up with the DMD*

On the application side, we studied the 'swirl' defect in *p*-type Si wafers using the qualitative version of Makyoh (Figure 5). (Swirl defects are typically observed in heavily *p*-doped Si wafers after preferential etching. They have spiral feature generated by the agglomeration of point defects while the crystal cools down after pulling. Swirl defects are shown to have a detrimental effect on device quality.) The observed image contrast was compared to our previous model of image formation for a periodic surface relief, and a good agreement was found, considering the simplicity of the model. By comparison to surface stylus profiling the detection sensitivity was better than 30 nm height amplitude over a 1.5 mm spatial period.

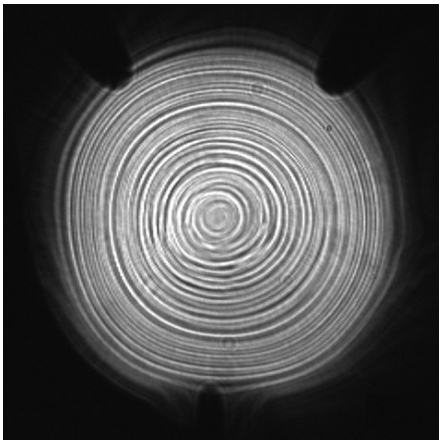


Figure 5 *Makyoh-topography image of a p-type Si wafer having swirl defect*

Makyoh topography also served as a tool for various testing tasks (both in-house and within collaborations), namely: assessment of the deformation in MEMS membranes and solar cell structures, studying the surface morphology of PbI_2 crystals for nuclear detector applications (in collaboration with Institute of Photonics and Electronics, Prague), strain and morphology measurements on SiC/Si heterostructures for growth optimisation (with IMEM–CNR, Parma), morphological studies of various substrates for hydroxyapatite growth (with the Institute of Solid State Physics, Sofia) and deformation measurements on Si/SiC-based hybrid substrates for GaN growth (within the HYPHEN project).

AQUANAL Local Analysis of the Natural Water and Geological Medium by micro- and nano- character investigations

(NKFP 3A/079/2004)

A. Hámori, S. Kurunczi, J. Makai, M. Rácz, A. Sebestyén, M. Serényi

The trace of the oil pollution on the surface of the natural water was a part of the AQUANAL project. During the research and development period we have investigated the optical reflection property of the water surface coated by oil with different layer thicknesses. Two solutions were developed to observe the evolution of an oil layer with thickness of several hundred nanometers. The first equipment detects the reflection change of the water surface caused by oil film or drop using image converter system (Fig. 6). The second one measures the reflection change of a polycarbonate surface influenced by the clambered oil layer. The sensor detects a small amount of pollution immediately, therefore it can be efficiently applied in environment monitoring.

The other goal of the project *AQUANAL* is to design a sensor for contamination measurement of heavy metal pollution (Ni, As) of natural water. A computer controlled measurement method was developed to detect the heavy metal contamination by optical method using optical waveguide covered by protein receptors. The quality of the layers was tested by spectroscopic ellipsometry.

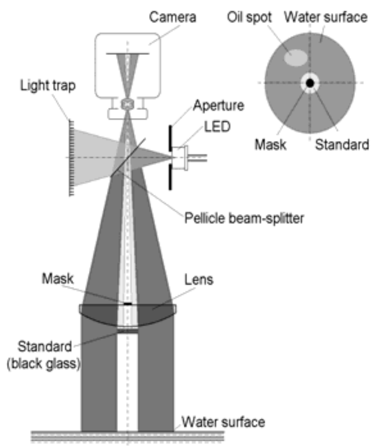


Figure. 6 *Equipment to observe the oil pollution.*

Opto-electronic devices based on the protein Bacteriorhodopsin

(NATO Project No. SfP974262)

A. Deák, A. Hámori, N. Nagy, M. Serényi

In addition to organic and inorganic crystals, biological molecules have also been considered for use in optoelectronics, among which the chromoprotein bacteriorhodopsin (bR) has generated the most interest. Illumination of the bR film results in changes in the absorption spectra accompanying changes in the index of refraction. This opens the way to a highly interesting use of the nonlinear characteristics of bR, namely for the modulation of the coupling of light into and out of integrated devices controlled by the light-induced transitions of bR. Optical switch based on Mach-Zender interferometer was fabricated using sputtered silicon-oxi-nitride (SiON) layer on quartz substrate. The pattern of the interferometer was developed from the 4 μm thick waveguide by excimer laser ablation. The new technological process makes it possible to take shape the dielectric layers having thickness of several micrometers. Fig. 7 illustrates the capability of the process. The figure shows a small fragment of the USAF 1951 Resolution Test Chart fabricated from 4 μm SiON on fused silica substrate.

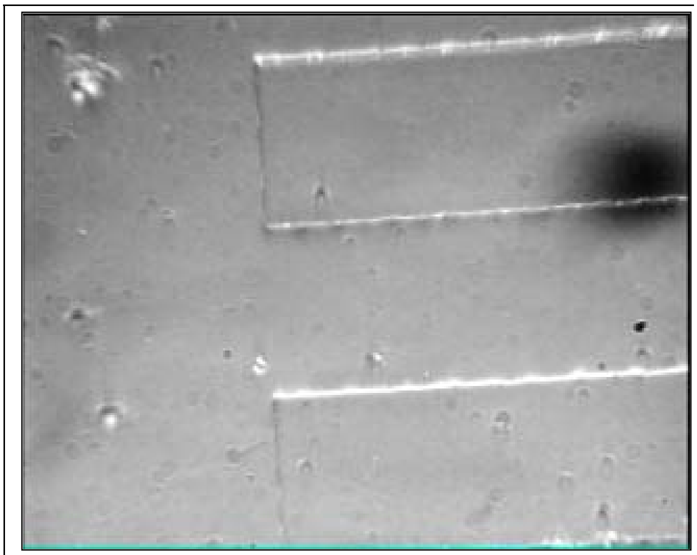


Figure 7 *The pattern of a 4 μm thick SiON layer.*

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Silicon Nitride-Based Ceramics and Nanocomposites

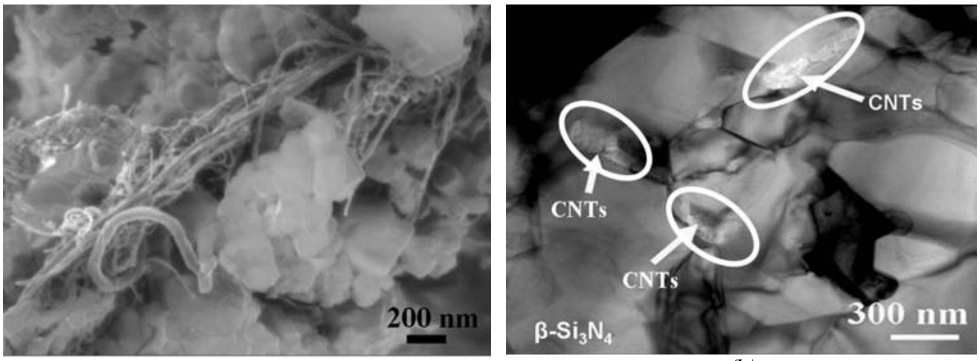
(SVEDNANO, OTKA K63609 and János Bolyai Postdoctoral Grant)

P. Arató, C. Balázsi, B. Fényi, O. Koszor, J. Pfeifer, F. Wéber

The intensive study of ceramic nanocomposites started in this laboratory six years ago.

The long-range aim is to develop new materials with a high level of synergism. Composites with silicon nitride matrix and carbon nanotube (CNT) reinforcement have been in the focus of our interest. It is known that CNTs are characterised by exceptional mechanical and physical properties, however their incorporation into ceramic matrices gave only modest improvements. This discrepancy is caused by two facts, firstly, it is difficult to produce a homogenous distribution of CNTs in the ceramic matrix and secondly, their degradation at the temperature of sintering had to be prevented. First our team succeeded to find processing parameters providing the maintenance of carbon nanotubes in a silicon nitride based matrix.

In year 2007 we continued the investigation of CNT/silicon nitride composites. Samples were prepared with different compositions, sintering techniques (HIP, hot isostatic press, HP, hot pressing and SPS, spark plasma sintering) and processing parameters. Their micro and nanostructure were examined by scanning electron microscopy (SEM), X-ray diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FTIR), mechanical and electrical properties were measured. We attempted to reach a better understanding the relationships between processing parameters, structure and properties.



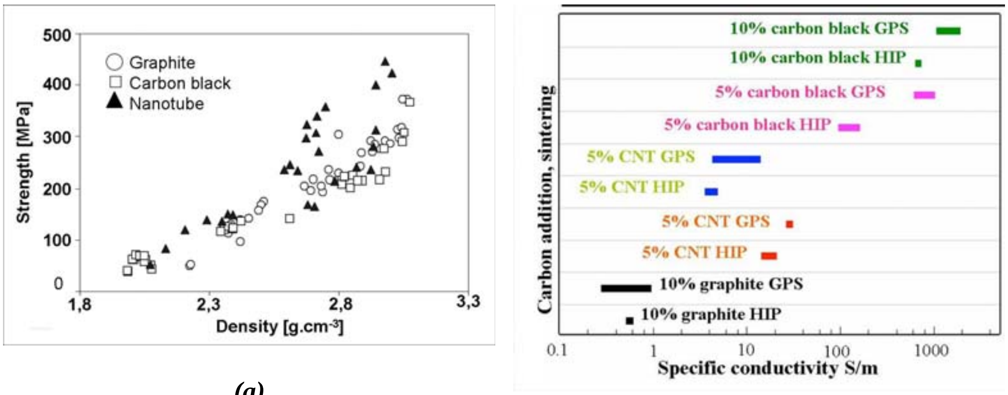
(a) (b)

Figure 1 *Structure of Si_3N_4 based nanocomposite with carbon nanotube addition. (a) SEM image of starting powder mixture before sintering, (b) TEM image of sintered nanocomposite [12].*

Image obtained by direct examination of structure can be supplemented by the information gained from results of measurements.

The density – four point bending strength curve for samples made with carbon nanotube additives is shown in Fig. 2. It is clear that the rate of densification decreased with increasing additive content as in the case of carbon black, graphite and CNT additions. The linear tendency of density-strength relation suggested that the mechanism of densification did not change during sintering because the bond between ceramic phases and CNTs was strong. It is worth to mention that these averaged four point strength values have been obtained for samples realised by gas pressure sintering (GPS).

Several temperature-time GPS runs were executed, the goal was to cover a wide porosity range. It is possible, considering the density-strength lines, to distinguish between two ranges of density. The value of density below 2.5 g cm^{-3} depends on the density but does not depend on the type of additive. At higher density the addition of CNT gives larger strength than the addition of graphite or carbon black.



(a) *(b)*

Figure 2 *Mechanical (a) and electrical (b) properties of Si_3N_4 based nanocomposites with different carbon addition.*

In addition to the mechanical properties physical characteristics were also measured. The DC specific conductivity was determined in co-operation with Miskolc University. It was found that 3 wt% CNT is sufficient to alter the transport properties of the HIPed composites. The order of magnitude of electrical conductivity of silicon nitride ceramics is 10^{-11} - 10^{-12} Sm^{-1} while its value in the composite realized by GPS and HIP was as high as 18 Sm^{-1} in the case of CNT additions [7, 8, 51], at the same time the difference between mechanical properties of ceramic and composite was less than 50%. These data mean that the percolation trough the CNTs network providing the conductivity, while the ceramics are bonded each to the neighbouring particles providing the mechanical strength. In the case of carbon black addition electrical conductivity of 1000 Sm^{-1} have been obtained (Fig. 2b). It is sure that a composite which is wear resistant, refractory and conductive will be used in a wide region.

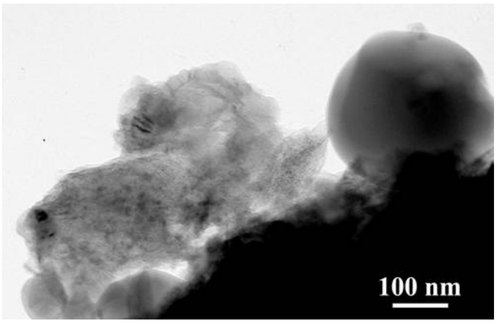
Hydroxyapatite and Polimer Based Bio-Compatible Nanocomposites

(MTA-OTKA-NSF, MTA 91, OTKA 049953 and József Öveges program)

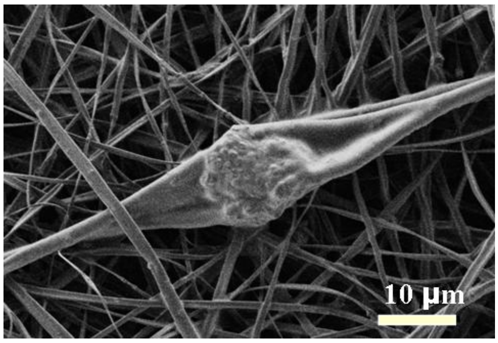
C. Balázsi, F. Wéber

The significant increase of the number of old people results in new aims for the materials of human implants. One of possible answers is to develop a material which does not damage the tissue at the surface of the implant and keeps an appropriate strength throughout decades of years. Another material imagined bears the mechanical load at the beginning, then promotes the formation of bone tissue and dissolves when its work becomes unnecessary. Experiments to work out processing technology for production materials with the mentioned characteristics are in progress in several research centres of the world.

Hydroxyapatite (HAP) is one of the ceramic materials often used in making implants. Its bio-compatibility is fine, its strength, however, is not high. We developed a processing technology starting from natural raw materials for preparing bio-compatible hydroxyapatite based composites. The procedure is advantageous from the point of view of environmental protection of environments and energy saving, too. Steps of processing include techniques of soft chemistry and high temperature sintering, the size of particles is in the micrometer and nanometer ranges.



(a)



(b)

Figure 3 *Nanocystalline bi-modal hydroxyapatite from eggshell (a) and fibrous structure of hydroxyapatite-polymer composite (b) [15].*

Our laboratory began to study various kind of ceramic- polymer composites this year in co-operation with State University of New York at Stony Brook. Electrospinning gave a three dimensional arrangement of polymer micro and nano fibres. This structure has high porosity and large specific surface, consequently provides good conditions for biodegradation. In composites prepared in our laboratories hydroxiapatite nanoparticles were dispersed in a polymer matrix. It is thought that the nanograins may be particular places for the regeneration of bone tissue. Our experiments on the interaction between composite and tissues are continued.

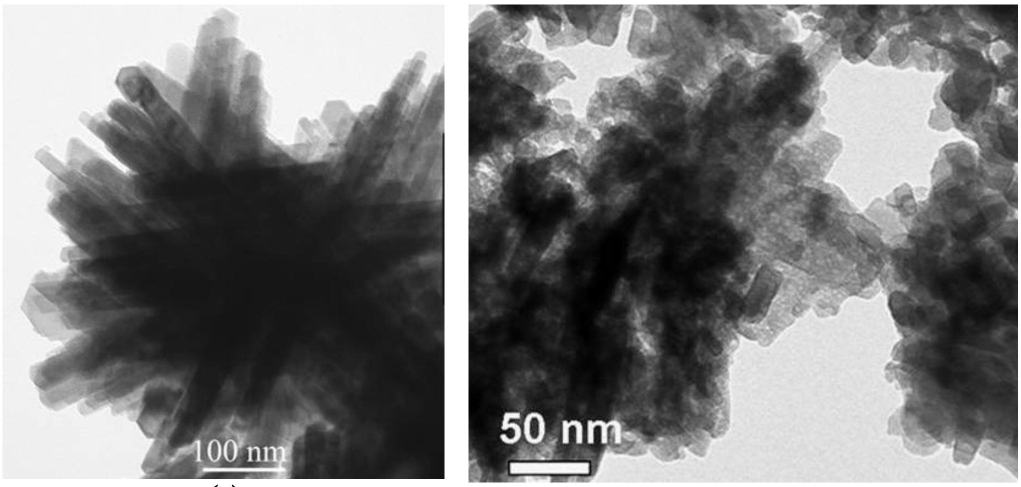
Tungsten Oxide Functional Ceramics

(MTA-OTKA-NSF, MTA 91, OTKA 049953)

C. Balázsi, J. Pfeifer

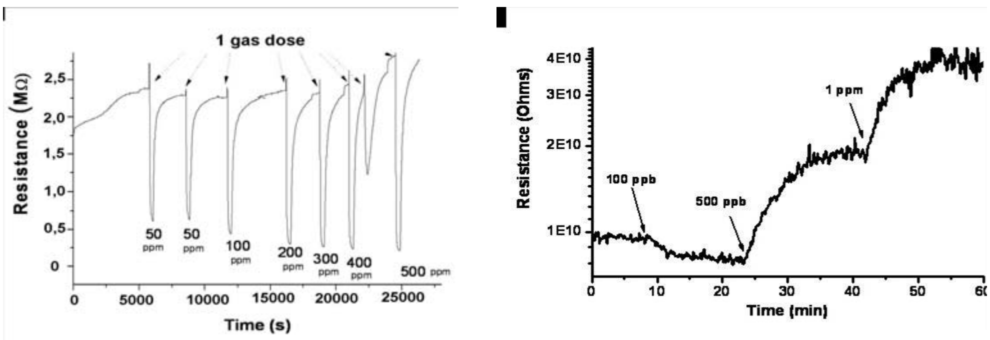
Tungsten oxide compounds, promising at sensing dangerous gases in the ambient have been prepared in order to use them as thin layers of functional ceramics. The synthesis was based on soft chemical methods: acidic precipitation and hydrothermal dehydration of potassium and sodium tungstate derivatives. The potassium tungstate precursor resulted in tungsten bronze structures with nanosize morphology. The same preparation method using sodium tungstate precursor resulted in metastable open structure derivatives, $WO_3.1/3H_2O$ and h-WO_3 with nanosize morphology as well (Fig. 4). Powders of h-WO_3, c-WO_3 and m-WO_3 were used to deposit sensing layers at the Department of Materials Science & Engineering SUNY, Stony Brook. Responses of the sensors to NH_3 and NO_2 gases are shown in Figure 5. The films showed a decrease in resistance on exposure to NH_3 and increase in resistance to NO_2 as is characteristic of an n-type semiconductor. The layers were found to be sensitive in the concentration range of 50-500 ppm to NH_3 [16].

The detected concentration level (as low as 100 ppb) is very close to the ambient air quality standard for nitrogen dioxide established by the Department of Environment and Natural Resources, USA (i.e. 53 ppb, http://daq.state.nc.us/rules/rules/D0407.pdf), which demonstrates the high potential of our new gas sensors.



(a) **(b)**

Figure 4 *TEM images of tungsten oxide nanopowder. (a) orthorombic „mother" phase of $WO_3.1/3H_2O$, (b) hexagonal WO_3.*



(a) *(b)*

Figure 5 *Sensing properties of h-WO_3 to NH_3 at 300°C (a) and NO_2 at 150°C (b).*

Materials for Light Sources with Improved Properties

L. Bartha, I. Gaál

Thoriated tungsten electrodes are often used in high intensity discharge lamps since thermionic emission of tungsten is markedly increased by the presence of Th atoms on the surface. The evolution of the surface composition of thoriated tungsten has been followed up by means of Auger electron spectroscopy after various heat treatment performed below 2300 K. It turned out that the evolution depends dramatically on the current density of the electron beam exciting the Auger electrons, and no Th adatom enrichment has been observed without electron beam irradiation in this temperature region. It has been shown that the sources of Th adatoms are thoria particles attached to the free surface of the wire. It is expected that the electron induced oxygen depletion of the thoria particles is the main reason for thorium release onto the free surface.

Complex Systems Department

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Ph.D. students/Diploma workers

Jeromos VUKOV, Ph.D. student

Evolutionary games

(Hungarian Scientific Research Fund under Grant No T43007)

G. Szabó, A. Szolnoki, I. Borsos, J. Vukov

The investigation of evolutionary games is based on the application of numerical and analytical methods developed previously to study non-equilibrium many-particle systems. Instead of particles in the present models players (representing group of people, human individuals, biological species, or bacteria) are distributed on the sites of a lattice or any other network. As a combination of the traditional game theory and Darwinian selection rule the players play games with their neighbors and sometimes they are allowed to adopt one of the neighboring strategies with a probability depending on the payoff difference. Many interesting questions arise when the players' income comes from the Prisoner's Dilemma games representing the conflict between the individual and common interest. In these cases the selfish individuals are forced to choose „defection" yielding the lowest total income. Conversely, the choice of mutual cooperation would result in the highest total score. The main purpose of these investigations is to explore conditions (evolutionary rules including noise, connectivity structures, set of strategies, payoffs, and individual features) providing the highest average income for the individuals of a society.

We have studied, for example, what happens if two types of players (A and B) are distinguished in a way that players A are capable more effectively to convince their neighbors to follow their own strategies during the strategy adoption process. Initially players of type A and B are distributed randomly on the sites of a two-dimensional lattice and both types of players can choose either cooperation (strategy C) or defection (strategy D). The different efficiency in the strategy adoption process supports the cooperative behavior for the players of type A because followers of a cooperative master increase their master's income while the income of an exploting master (player of type A with a strategy D) is reduced by his/her follower. Consequently, after a short transient time the cooperative behavior (strategy C) of the masters (players A) becomes the best strategy (example) for others to follow. The maintenance of cooperative behavior can be characterized by two threshold values of temptation to choose defection. If the income b of the exploiting strategy D exceeds the second threshold value then the cooperative strategy dies out and the individuals receive the lowest average income. If b is less than the first threshold value then the cooperative behavior will conquer the whole system, and within the intermediate region the C and D strategies coexist. The threshold values of the temptation depend on the noise level K as shown in Fig. 1.

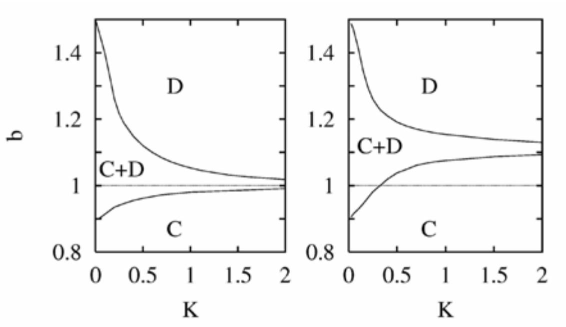


***Figure 1**: Temptation-noise phase diagram for an evolutionary Prisoner's Dilemma game on the kagome lattice in the absence (left) and presence (right) of players capable to convince their neighbors more efficiently.*

Recently our investigations are focused on those models where the above mechanism results in a more relevant improvement in the maintenance of cooperative behavior.

Besides the evolutionary Prisoner's Dilemma games we study models with many strategies (biological species) where a portion of strategies form associations (with proper spatio-temporal structures) and the final state of the evolutionary process is determined by the competition of some privileged associations.

A review paper entitled „Evolutionary games on graphs" by György Szabó and Gábor Fáth was published in the Physics Reports 446 (2007) 97-216. (See ref. [157])

The above research is made in collaboration with Matjaz Perc (University of Maribor), Michel Droz (University of Geneva) and biologists (Tamás Czárán and Péter Szabó) at the Eötvös University of Budapest.

Nonequilibrium statistical physics

(Hungarian Scientific Research Fund under Grant No T046129)

G. Ódor

Universal scaling behavior is an attractive feature in statistical physics because a wide range of models can be classified purely in terms of their collective behavior due to a diverging correlation length. Scaling phenomenon has been observed in many branches of physics, chemistry, biology, economy etc., most frequently by critical phase transitions and surface growth. This is a basic science topic, the results can be used in applied sciences. Diverging correlation length, necessary to change the global symmetry at a second order phase transition point, and scaling may also occur away from the critical phase transition point. Naturally in a fully ordered state (at zero temperature) the correlation length is infinite. If the interactions of the system is so that reaching this state requires diverging time one finds dynamical scaling near that point. This happens usually in case of multi-particle, reaction-diffusion systems in the inactive phase (experimentally observed). For the request of the publisher World Sientific I have completed a 300 page book titled „Universality in nonequilibrium systems", which summarizes our knowledge about nonequlibrium classes as an extension of a former review by Géza Ódor published in Rev. Mod. Phys. (Vol. 76 (2004) pp. 663-724)

A question of theoretical and experimental interest is whether and how the critical behavior is changed by introducing a small amount of uncorrelated impurity leading to models with quenched disorder. Realistic systems may contain a certain amount of quenched disorder. This disorder can take the form of vacancies or impurity atoms in a crystal lattice, or it can consist of extended defects such as dislocations or grain boundaries.

In collaboration with Dr. Nóra Menyhárd (OTKA partner) we have continued the investigation of the disordered parity conserving reacion-diffusion model. We performed large-scale Monte Carlo simulations to explore the effect of quenched disorder on one dimensional non-equilibrium kinetic Ising models with locally broken spin symmetry at zero temperature (the spin-flip rates are allowed to favour differently the '+' and '-' spins). Absorbing-type critical behavior is studied (zero branching rate of kinks), the critical spreading of '+' and '-' spins and of the density of kinks.

It is found only for a particular choice of the parameters of our model (corresponding to the strongly spin-anisotropic kinetic Ising model by Majumdar et al.) that spatial impurities exert strong effect on the critical behavior. Typically, however, changes start to set in only for impurity strengths near the limit of their blocking a diffusion process. In the vicinity of this point the critical behavior becomes similar to that showing up e.g. in the one-dimensional impure contact process with power law type Griffiths-like behavior for the kink density and with varying cluster exponents obeying the hyperscaling law similar to those reported by Cafiero et al.

We have shown that the isotropic two-component $AB\to 0$ model is insensitive to the reaction-disorder and only logarithmic corrections arise induced by strong disorder in the diffusion rate.

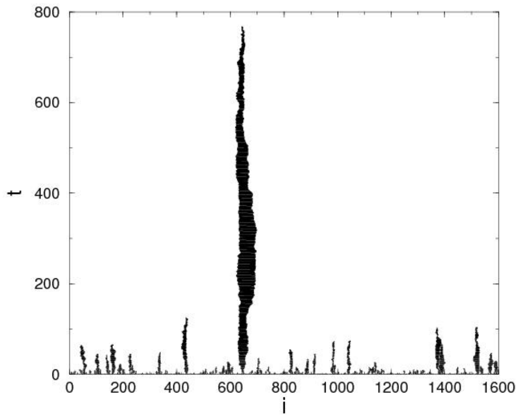


Figure. 2 *Space-time evolution in the disordered Majumdar-Dean-Grassberger model from the random initial configuration („i" on the horizontal axis denotes lattice site location). The + (black) and - (white) spin clusters are separated by kinks. From ref. N. Menyhárd and G. Ódor, One-dimensional spin-anisotropic kinetic Ising model subject to quenched disorder, Phys. Rev. E 76, 021103 (2007), see Ref. [109]*

Another current topic of interest is the possibility of first order transitions in reacion-diffusion systems in low dimensions. We have started a research in collaboration with Prof. R. Dickman (Brazil) to explore a debated question in case of triplet creation systems.

As an application of the knowledge of nonequilibrium models we have also investigated a social related model as a proposal of Prof. D. Stauffer (Cologne). A two-temperature Ising-Schelling model is introduced and studied for describing human segregation. The self-organized Ising model with Glauber kinetics simulated by Müller et al. exhibits a phase transition between segregated and mixed phases mimicking the change of tolerance (local temperature) of individuals. The effect of external noise is considered here as a second temperature added to the decision of individuals who consider change of accommodation. A numerical evidence is presented for a discontinuous phase transition of the magnetization.

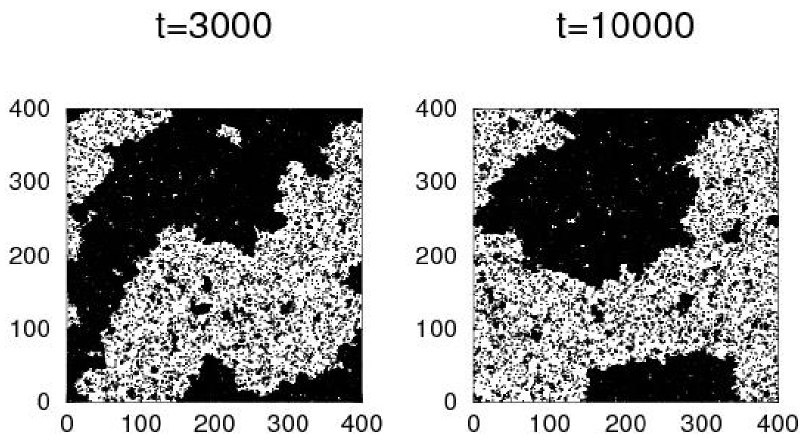


Figure 3 *Clusters survive small external noise in 2d simulations (numbers on the axes denote lattice location), hence the inclusion of a small second temperature does not change the composition of neighbors in the steady state. From ref. G. Ódor, Self-organizing, two-temperature Ising model describing human segregation, arXiv:0710.1496 Int. J. Mod. Phys C 19 (2008) in press.*

An ongoing collaboration with Dr. Karl-Heinz Heinig at FZD (Dresden) aims to apply the kinetic Monte-Carlo method to the 3 dimensional diffusive pair contact process to explore its dynamical (ageing) properties. We proposed and obtained a new collaborative grant from DAAD-MÖB to explore scaling of self-organizing surface structures of nanomaterilals.

Analysis of folk music using self learning systems

(Hungarian Scientific Research Fund under Grant No K 63312)

Z. Juhász, J. Sipos

A comparative study of different oral musical traditions requires a uniform and unbiased description of the national folk music cultures. To do this, we developed a method mapping the contour of each melody to a point of a multidimensional metric space. In this model, the characteristics of a given musical culture are attributed to spatial characteristics of a point system which is built up by the melodies of a representative collection. The spatial characteristics are determined using principal component analysis.

Another tool of uniform description of different musical traditions is a system that determines the typical melody contours in a given set of melodies automatically, using a special form of artificial intelligences: the so-called Kohonen's self organising map. In general, this method is able to classify melody collections from many points of view: interval and rhythm distributions can be classified, and typical motives inside the melodies can also be identified.

Based on the above techniques, a comparative study of different musical cultures can be accomplished as follows:

- The analysis of the overlapping of the point systems corresponding to different musical cultures is able to determine common, as well as separate areas of the musical space. Thus, common and special musical principles can be distinguished using this analysis.
- The cross-classification of the melodies using "national" self organising maps detects those melody types that have variants also in the foreign culture, as well as special melody types that have no relationship "abroad".
- The results show an extended system of relations between different musical traditions, and propose the theory of certain primitive musical languages. Using the above-mentioned techniques, the archetypes of these primitive languages can also be reconstructed.

In the current state of the research, we can study 15 different musical cultures in Eurasia. Our Chinese, Mongolian, Anatolian, Karachay, Mari-Chuvash-Tatar, Bulgarian, Sicilian, Hungarian, Slovak, Finnish, Polish, German, Luxemburgish, French and Appalachean (Scotish-Irish) data bases consist of 1100-2500 melodies per nation (region).

A further, cross-cultural comparison of the similar melody classes in the 15 different national cultures allows us to decide if the correlations should be attributed to real cultural interactions or occasional events of an independent musical evolution. The results are illustrated by a graph indicating those cross-cultural contacts where the probability of occasional coincidences is less than 1%. The system shows two main musical primitive languages, one of them including Bulgarian, Anatolian, Sicilian, Mongolian, Karachay, Chinese, Volga, Hungarian and Slovak, while the other consisting of Finnish, German, Polish, Luxemburgish, French and Appalachean cultures. The two systems are connected by the strong relations of Hungarian and Slovak folk music to Finnish, Appalachean, and German traditions.

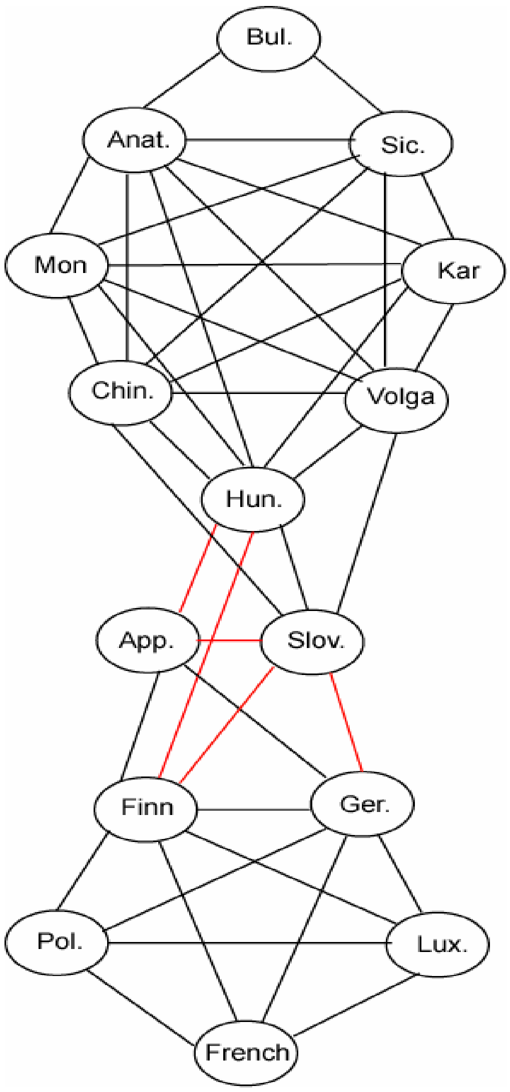


Figure 4 *Genetic connections of 15 musical cultures in Eurasia*

Developing high-resolution brain electro-mapping (BEM)

(NKFP 2/004/2004, Members of consortium: University of Pannonia, MFA HAS, ISH Ltd., The National Institute of Psychiatry and Neurology)

G. Kozmann, K. Szakolczai, K. Haraszti

Our group started a research on Brain Electro Mapping (BEM) in 2004. The essential feature of BEM is to grasp surface (scalp level) manifestation of brain bioelectrical phenomena associated to physiological or pathological activity. The EEG recordings based on 128 channel low noise measurement, and the volume conductor is calculated by series of MRI/fMRI or CT images. The final goal was to provide a new electro-imaging technology; a source level representation by different approaches of inverse computations for high spatio-temporal resolution brain plasticity research Based on these two sorts of information, the system is capable to provide detailed bioelectrical source distribution on cortical level or even in deep layers. The broadening of the spectra of structural and functional brain imaging modalities is expected to improve the quality of diagnosis and therapy of stroke, dementia, and learning disabilities etc. patients. The major strength is in the high temporal resolution (in our case 0.5 ms), while it's spatial resolution is in the range of 3-5 mm. The spatial resolution could be improved if more exact data on volume conductor conductivity values were available. High temporal resolution seems to be an important feature when studying the connectivity of different regions within the brain. As a result of R&D work an international cooperation started in 2007, within the framework of FP7 called NEUROMATH.

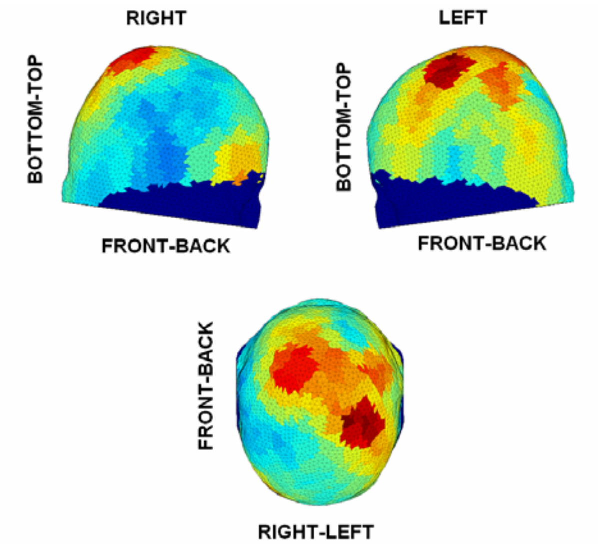


Figure 5 *Visualization of the brain electrical activity on the scalp*

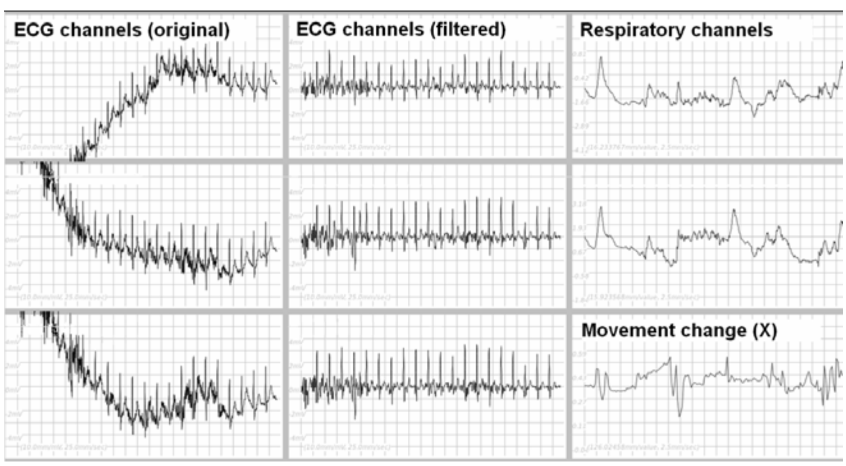
Intelligent physiological telemonitoring system

(GVOP AKF 0196/2004, Members of Consortium: MFA HAS, Ministry of Defense, Meditech Ltd.)

G. Kozmann, K. Szakolczai, K. Haraszti, A. Csalótzky Bolgár

The aim of the project is to develop an intelligent measuring and supervising system for monitoring and transmitting of physical, circulatory and emotional status, work load and environmental load. The major components of the system comprise robust wearable sensors and signal conditioners with connection to the local portable data acquisition module. Data processing will be carried out in two steps, locally and in a centralized surveillance system. Data transmission is using radio frequency carrier. The location of the patient is also monitored with GPS. We have developed and tested ECG, O_2 saturation, pulse, skin resistance, skin temperature sensors and also accelerators for estimating physical activity and body position. All of those have been integrated to a special dress, capable of holding all the sensors without significantly influencing the everyday life of the user. 5-5 prototypes of all hardware elements have been produced.

Figure 6 *The data gathering hardware (left) and the screenshot of the monitoring software(bottom).*



In 2007 the testing of all hardware has been completed, and the monitoring software has been modified. New algorithms have been added to the data filtering, acquisition, and to the decision support system, which can be personalized with limits gained from the patient's reference measurement. The monitoring system as a complete set has been tested in rest, and exercise phase and also in extreme situations provided and controlled by the special training centre of the police. The results will be used in new contracts signed with 2 of the major Hungarian telecommunication companies.

Evaluating prerequisites of sudden cardiac death with QRS and QT integral maps

G. Kozmann, K. Szakolczai, K. Haraszti, A. Csalótzky Bolgár

In our approach body surface mapping (BSPM) was used to access the whole bioelectrical information available on the body surface. Beat-to-beat QRS and QRST integral maps, Karhunen-Loeve coefficient time-series (KL_i, $i=1\text{-}12$), RR and nondipolarity index (NDI) time-series were computed. The increased variability of NDIs and KL parameters may imply to elevated arrhythmia vulnerability therefore might give a warning for sudden cardiac death using only noninvasive techniques. This method separates the causal and random effect of cardiovascular regulatory system, and quantitatively describes the changes in spatio-temporal depolarization and repolarization inhomogeneity.

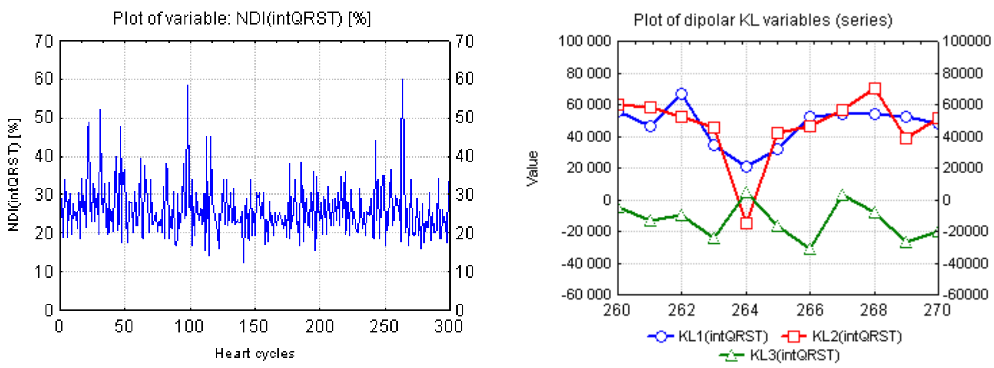


Figure 7 *High spikes in NDI parameters result in sudden changes in KL values which suggest increased risk for sudden cardiac death*

Development of an integrated monitoring system for time encoded telecommunication system

(NKFP2-00016/2005)

I. Eördögh, C. Hegedűs., K. Szász, E. Tunyogi, L. Moldvai, T. Mohácsy

In year 2007 the team has developed a CMOS integrated sensor chip for the realization of the time encoding principle, evaluated its operation with SPICE simulation, designed detailed circuits, and started the layout design. We also started the development of platform independent image processing software modules, for biomedical application utilizing the IMAGEJ Java software modules. Further experimental development has been done for real time target detection, using the SONY smart camera equipment under embedded Linux operation system. We set up a mathematical model for the approximation of contour data for digitized objects using hat functions represented by a 3rd order spline. Now, we are working on the software simulation.

Detailed description of patented CMOS sensor chip

We designed a CMOS smart sensor chip comprising not only the CMOS pressure sensitive depletion type transistors, but the signal sensor operational amplifier and a patented time encoder circuitry. This circuitry converts directly the non electric signals (in this case pressure) into time encoded signal, i.e. time intervals. This signal then can be post processed very simply.

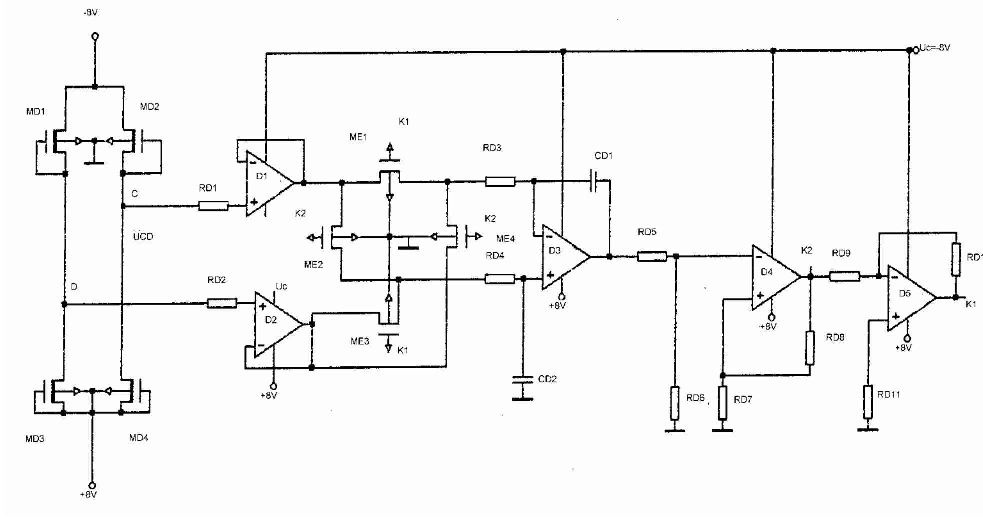


Figure 8 *The design of the CMOS circuitry.*

The operation of the designed circuitry is analyzed with SPICE simulation program. The design is based on our CMOS technology. According to our solution the pressure sensors are not resistors but depletion type CMOS transistors operating similarly as a Wheatstone bridge. The power supply is symmetrical. The sensor bridge operates like a differential amplifier with current generator supply, therefore the output voltage of the bridge amplifier (UAB) is in principle independent of the power supply, and depends only on channel hole mobility (μ) which in turn depends on the mechanical tension produced by pressure.

Hiba! Érvénytelen beágyazott objektum.

Figure 9 *Simulation diagram: output frequency versus mobility of holes in CMOS sensor channel.The accuracy is better than 0.1 % concerning both the linearity and the sensitivity of power supply voltage.*

Development of Q-Fish program module

(Quantitative analysis of Fluorescence In Situ Hybridization microscopic images)

I. Eördögh, Z. Szentirmay, E. Szikszay, K. Szász

Image processing for biological applications. Analysis of microscopic images for scanning the inside morphological parameters of cell nuclei, software modules for DNA densitometry, FISH (Fluorescence In Situ Hybridization) sample analysis, data evaluation for estimation of number of genetic copies of malignant tumor cells.

We developed an evaluation procedure and image processing software for screening of the inside structure of tumor cell nuclei, DNA densitometry also have been improved. We developed FISH (Fluorescence In Situ Hybridization) sample analysis software including data evaluation modules to estimate the number of genetic copies of malignant tumor cells, in order to contribute to determine the grade of malignancy. These modules are suitable for images of optical microscopy. We have proved that IOD (Integrated Optical Density) data calculated by our method weakly depend on illumination light strength, position, and the 3D rotation angle of the cell nuclei. The Q-FISH program module has been built into our previously developed IMAN 2.0 IMage ANalysing program suit. One of the main tasks was to find the number of copies for partly occluded FISH replicas. We measured several morphologic parameters for every replica, and then we trained the single ones into a reference class. After this procedure the conglomerates were separated according the parameters of the reference class.

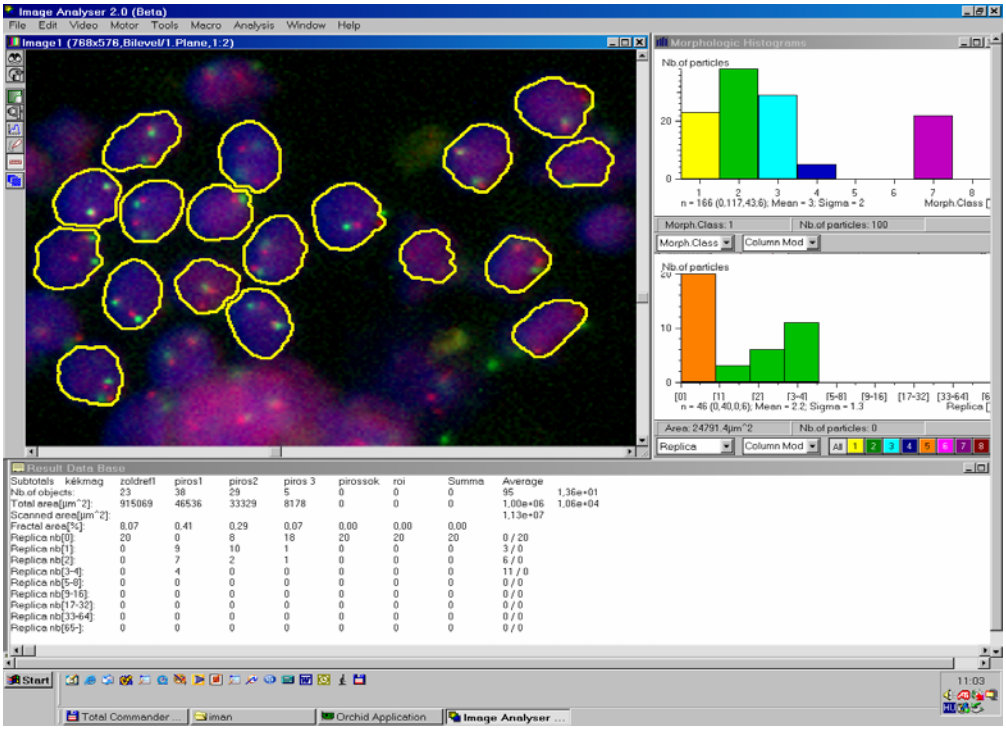


Figure 10 *Typical FISH microscopic image of neuroblastoma.*

ACTIVITIES

Scientific Promotions

Dr. György Szabó
Evolutionary Games on Networks
Doctor of Scince (D.Sc.) of the Hungarian Academy of Sciences

Dr. György Kádár
Secretary General of the Roland Eötvös Physical Society

Dr. György Szabó
Chair of Statistical Physics Division of the Roland Eötvös Physical Society

György Zoltán Radnóczi
Growth Modes of III-Nitride Epitaxial Films Revealed by Transmission Electron Microscopy
Ph.D., Roland Eötvös University, Budapest, Hungary

Levente Tapasztó
STM Investigation of Carbon Nanotubes: Modeling and Interpretation of Measurements
Ph.D., Roland Eötvös University, Budapest, Hungary

Gábor Vásárhelyi
Design of Tactile Sensors and Their Elastic Cover
Ph.D., Pázmány Péter Catholic University, Budapest, Hungary

MFA patents in 2007

Patent No. P0700366
Inventors: Miklós Fried, György Juhász, Péter Petrik, Csaba Major, Zoltán Horváth
Optical equipment using pinhole camera for imaging (reflectometer, polarimeter, ellipsometer).

Patent No. P0700781
Inventors: Tibor Mohácsy, Imre Eördögh, Ernő Simonyi, László Tóth, Istvánné Somogyi
Time encoder CMOS integrated circuit balanced bridge type for non electric signal sensor.

Patent pending
Inventors: Antalné Ádám, István Bársony, Csaba Dücső, Magdolna Erős, Tibor Mohácsy, Károlyné Payer, Éva Vázsonyi
A method for fabrication of single crystalline Si elements and micro-mechanical elements supporting single crystalline Si structures integrated into CMOS technology using microstructuring process for porous silicon.

Conferences and Symposia organized with MFA contribution

10th European Workshop on Modern Developments and Applications in Microbeam Analysis. EMAS 2007, 06-10 May 2007 Antwerpen Belgium

Annual Conference of the Hungarian Microscopy Society, 24-27 May 2007 Balatonalmádi, Hungary

The 4th International Conference on Spectroscopic Ellipsometry (ICSE-4), June 11-15, 2007, Stockholm, Sweden

Fall Meeting of the E-MRS 2007 Conference, Symposium H: Current Trends in Optical and X-ray Metrology of Advanced Materials and Devices II, , September 17-21, 2007, Warsaw, Poland

BioPhot Workshop 2007: Complexity and evolution of photonic nanostructures in bioorganism: templates for material sciences, September 24-25, 2007, Budapest, Hungary

Evolution and Game Theory, Satellite conference to the Europen Conference on Complex Systems (ECCS 2007), October 4-5, 2007, Dresden, Germany

MFA Seminar Talks

23 January 2007
25 January 2007
Éva Hegedűs
(MTA MFA, Budapest, Hungary)
The EU FP7 framework program and its financial regulations

24 January 2007
The Lego Rockers team
(János Batsányi Secondary School, Csongrád, Hungary)
NANOTICS as an example for the popularization of nanotechnology at school

07 February 2007
József Kadlecsik
(KFKI RMKI Computer Networking Center, Budapest, Hungary)
What can we do against „spam”

14 February 2007
Tamás Horányi
(MTA MFA, Budapest, Hungary)
The formation of titanium-oxide implants and investigation of their bioactivity

07 March 2007
György János Kovács
(MTA MFA, Budapest, Hungary)
Structure and mechanical properties of CN_x-Ni thin films

19 March 2007
Prof. Robert W. Collins
(The University of Toledo, Ohio, USA)
Real-time polarization spectroscopies: applications in thin film growth and surfaces for photovoltaics

21 March 2007
Dr. József Margitfalvi
(MTA Chemical Research Center, Budapest, Hungary)
Applications of high-throughput and combinatorial methods in materials research

28 March 2007
Dr. Péter Domokos
(MTA Research Institute for Solid State Physics and Optics, Budapest, Hungary)
Taming atoms in quantum optics

4 April 2007
Dr. Attila Lajos Tóth
(MTA MFA, Budapest, Hungary)
Scanning electron microscopy on the nanometer scale – experience and prospects

11 April 2007
Dr. András Kovács
(Osaka University, Osaka, Japan)
L10 ordered nanoparticles with perpendicular magnetic anisotropy

18 April 2007	**Dr. György Szabó** (MTA MFA, Budapest, Hungary) *Competing associations*
16 May 2007	**András Czövek, and Dr. Imre Derényi** (Roland Eötvös University, Budapest, Hungary) *Rectification of ionic conduction in nanopores*
17 May 2007	**Vo Van Tuyen** (The University of Manchester, Manchester, UK) *About recent research activities at the University of Manchester*
20 June 2007	**Róbert Deák** (Babes-Bolyai University, Cluj, Romania / Roland Eötvös University, Budapest, Hungary) *Computer simulation of the growth process of multi-component, ultra-thin layers*
29 August 2007	**Prof. N.G. Galkin** (Institute for Automation and Control Processes of FEB RAS, Vladivostok, Russia) *Semiconductor silicide nanocrystallites in silicon matrix: growth and optical properties*
3 October 2007	**Dr. Yutaka Wakayama** (National Institute for Materials Science, Tsukuba, Japan) *Molecular electronics with Si technology*
11 October 2007	**Dr. Zsolt Gercsi** (National Institute for Materials Science, Tsukuba, Japan) *Electron spin polarization of magnetic Heusler alloys*
19 October 2007	**Dr. Patrick G. Soukiassian** ("SIMA" Laboratory Commissariat á l'Energie Atomique, Saclay and Université Paris-Sud, Orsay, France) *Amazing nanochemistry at SiC surfaces and interfaces*
31 October 2007	**Dr. Rolandas Tomasiunas** (Institute of Materials Science and Applied Research, Vilnius University, Lithuania) *Nanostructures at Vilnius University: technology, investigation and application*
07 November 2007	**Dr. György Papp** (University of Szeged, Szeged, Hungary) *Giant magnetic resistance in 2D electron gas*
28 November 2007	**Prof. Leonid A. Chernozatonskii** (Institute of Biochemical Physics, Russian Academy of Sciences, Moscow, Russia) *Electronics based on graphene structures*

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