



Institute of Electrical Engineering Slovak Academy of Sciences



Results achieved in period 2012-15

www.elu.sav.sk



11. November 2016

Presented at IEE SAS by: V. Cambel, director

Outline

- *IEE SAS – general info*
- *IEE SAS research – highlights and their continuity*
- *IEE SAS strategy and future development*

Outline

- *IEE SAS – general info*
- *IEE SAS research – highlights and their continuity*
- *IEE SAS strategy and future development*

IEE SAS: basic and applied research

4 Departments, each with own *material research, modeling, experiments*

Applied superconductivity

Electrical engineering

HTS, MgB₂

III-V semiconductors

Electronics

GaN, GaAs devices

Microel. sensors & detectors

Electronics

MEMS, x-ray & THz detectors

Physics & techn. at nanoscale

Solid-state physics

2D materials, magnetism, transport

50 scientists - 3 Top teams identified by ARRA - Scientist of the year 2014

CUB

*Physics of Condensed
Matter and Acoustics*

PhD study

~ 13 st.

STU

*Electronics and Photonics
Physical Engineering*

*Freedom
Shared labs
Internationalization*

Research at IEE:

Rules

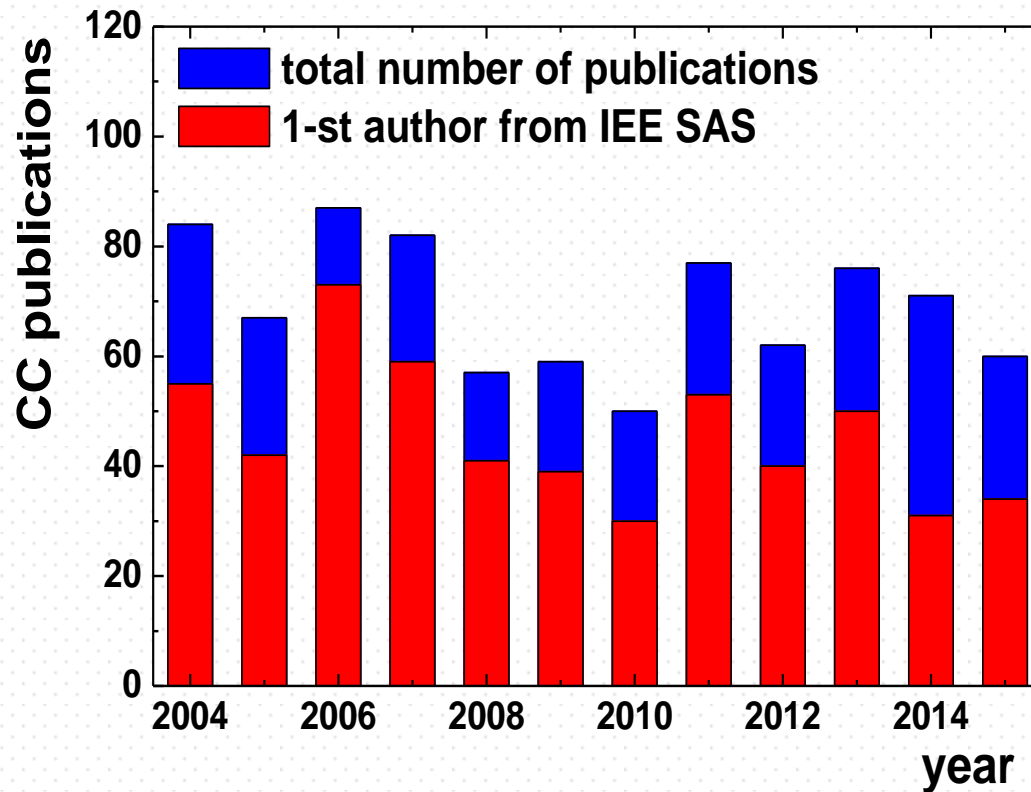
*Internal competition
Annual evaluation
Bonus to active*

Publications

~ 70/y ~ 1.3 pub/FTE

average *IF* > 2.2 (2015)

60% – international collaboration



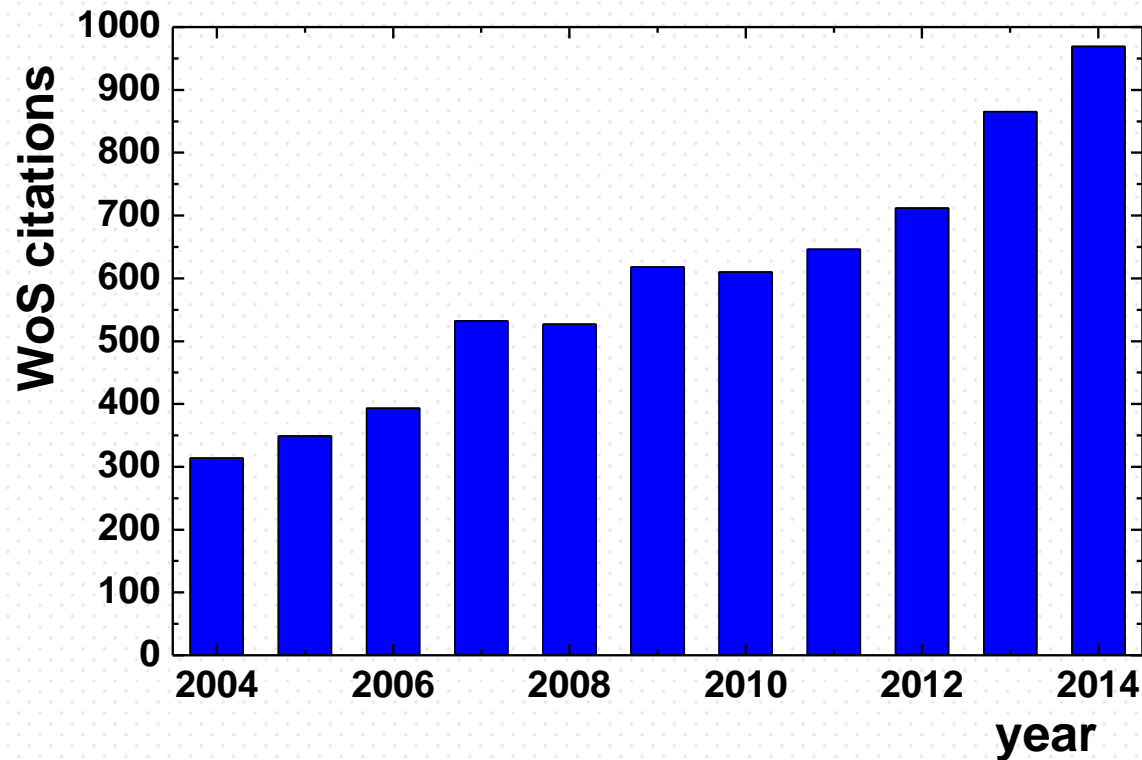
IEE high-ranking publications

		<i>IF</i>
Science		33
Nat. Commun.		11
Nanotoxicol.	2 x	7.9
Carbon		6.2
Sci. Rep. (Nat.)		5.2
Sens Act B	3 x	4.1
Phys.Rev.B.	8 x	3.7
Nanotechnol.	2 x	3.6
Appl. Phys. Lett.	12 x	3.1
Appl. Surf. Sci.	22 x	3.1
Supercon. Sci.Tech	29 x	2.7
IEEE El. Dev. L.	3 x	2.5

Motivation: equation for bonus, $X = 250 * IF (\text{€})$

Citations

~ 13 cit/FTE



Most-cited authors

J. Kuzmík	590
F. Gömöry	415
K. Fröhlich	289
J. Šouc	287
D. Gregušová	283
P. Kováč	264
I. Vávra	236
E. Pardo	228

1. Kuzmík, J., *IEEE Electron Devices Letters* 22 (2001) 510 (SCI 164, SCOPUS 19) GaN
2. Gömöry, F. et. al, *Science* 335 (2012) 1466. (SCI 69, SCOPUS 4) SC

Positive trend – stress on quality (high IF), international research, new equipment

International /national status



- 1. HiPoSwitch** – GaN based normally-off high power switching transistor for efficient power converters
- 2. EUROTAPES** – EU development of SC tapes: Integrating novel materials and architectures into cost effective processes for power applications and magnets
- 3. SupraPower** – Superconducting, reliable, lightweight, and more powerful offshore wind turbine
- 4. Fusion** Theor. and exp. study & techn. of sensors for plasma, R&D of HTS cables for fusion magnets
- 5. ECCOFLOW** – Development and field testing of an efficient YBCO coated conductor based fault limiter for operation in electricity networks

10 multilateral projects (7 x COST,...), invited talks - conferences, universities - 33

Structural funds (ERDF) – 9 projects, ~ 13 mil. € IEE SAS – new labs.

Stays at IEE – from China, Turkey, US, Bulgaria, Greece, Japan, Estonia, Spain,...

APVV (SRDA) projects 31 (22 coordinated by IEE), 22 VEGA

SASPRO – 4 projects, 2x from 2015, 2x from 2016, two from aboard



H2020 – applied for 5 projects, success – 2 accepted (start next year)

1 prolonged, 1 in second round

List of International partners

Company

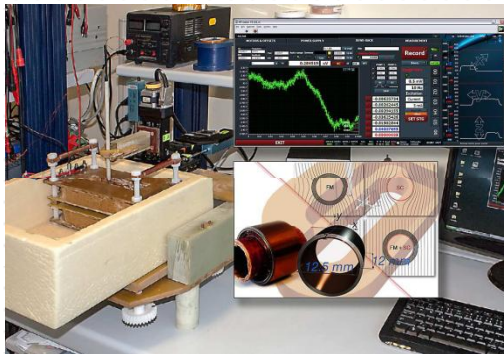
Nexans ,France/Germany
Bruker, Germany
E.on Energie, Germany
Alcatel-Thales, France
Endesa, Spain
RWE (now Westnetz), Germany
Air Liquide, France
COLUMBUS SUPERCOND., Italy
ACCIONA WINDPOWER SA, Spain
ACCIONA ENERGIA S.A, Spain
Oerlicon Leybold Vacuum,
Germany
Infineon Villach, Austria
Visic Ltd., Israel

University/scientific institute

CERN, Switzerland
NASA, USA
Univ. Cambridge, GB
Univ. Oxford, GB
EPFL Lausanne, Switzerland
ENEA Frascati, Italy
Argonne Nat. Lab., USA
Univ. Bath, GB
KIT Karlsruhe, Germany
IHP-Microelectronics, Germany
Un. Autonoma Barcelona, Spain
Drexel Univ., USA
Temple Univ., USA
JINR Dubna, Russia



Cryolaboratory



Characterization of SC



Characterization of devices

Characterization Laboratories - nanotechnology

Lithography



SEM laboratory



Clean room facility

Thin film growth



MOCVD – GaN, GaAs



PLD – SC, oxides



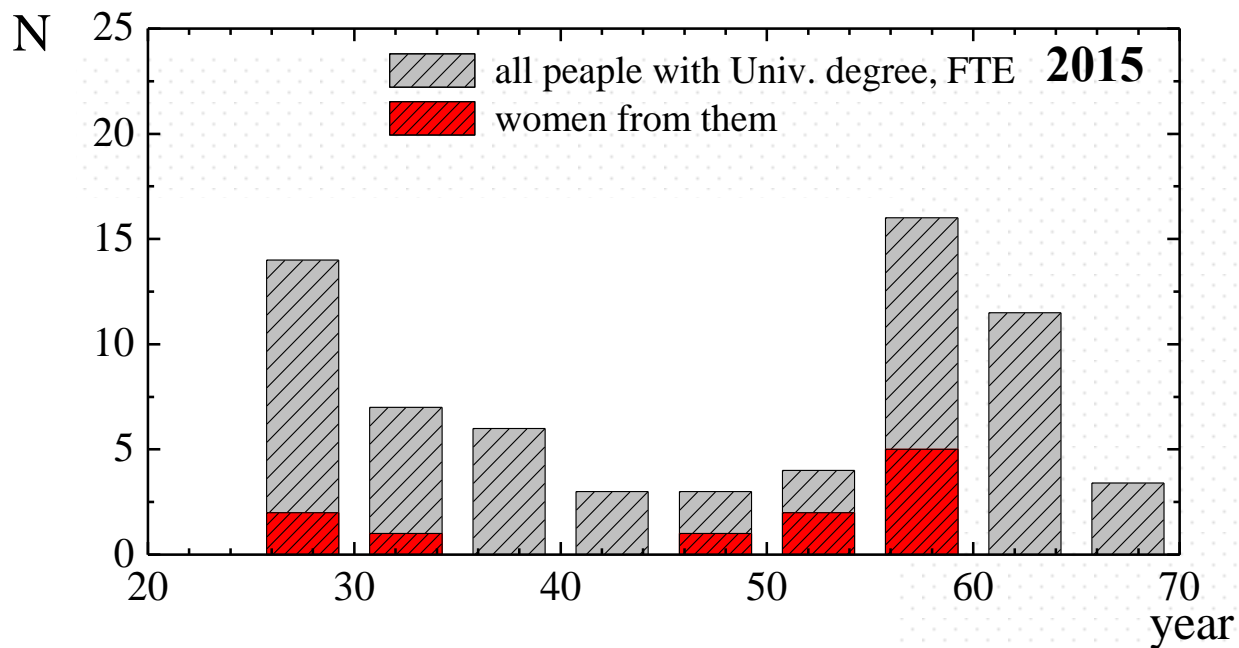
ALD for oxides

Background & management: human resources

Average age - 49 y. (Univ. deg., 2015)

Graph – gap due to system changes after 1989

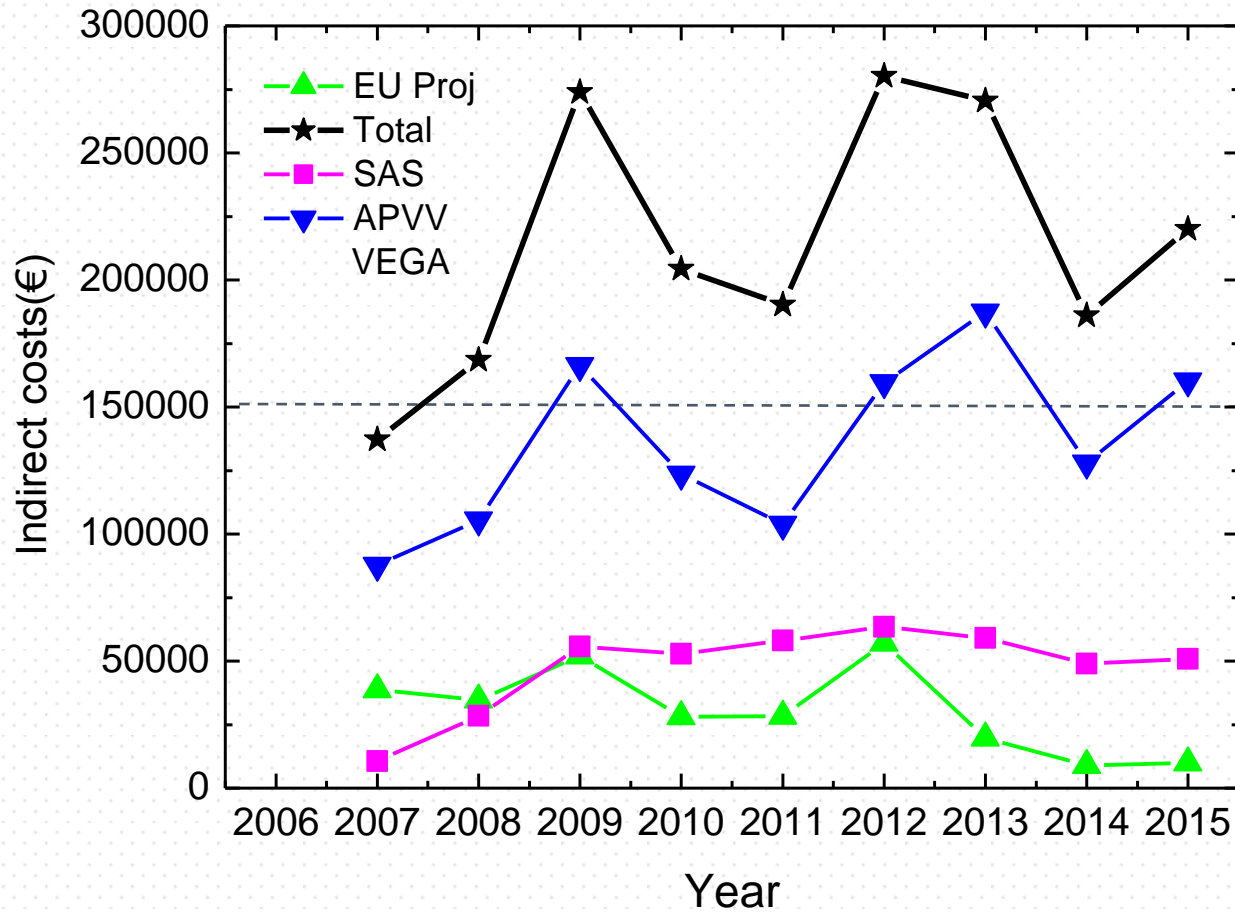
- less women reflects number of graduated students in the field



Breakthrough in 2016: average age ~ 42 years ! 8 new post-docs - 4 x SASPRO + 4

IEE indirect costs

Indirect cost – from SAS and 20% project overheads



Overall fluctuations due to APVV instability (missing calls) – getting better now

Popularization – increased activity

Night of the researchers - thousands of visitors – GaN transistors, levitation

Open day - in 2015 - 439 visitors - Booklet „Modern technologies“



Several excursions in labs, other actions (TV, radio, journals, etc...)

Best popularization is if the research has high-quality – our experience with Science

Management

Main role – improve quality of the research and its outputs for a long time. Within the period the management:

- *Applied for and managed SF projects – extra funds for research*
- *Rebuilt Labs -Lines for semiconductor / superconductor devices*
 - *List of equipment carefully selected (scientists, management, Sci. Board)*
- *Increased effectiveness - reduced number of Dept. from 8 to 4*
- *Annually evaluated activities of scientists (Departments)*
 - *Evaluation system applied for 12 (20) years, systematically improved*
- *Supported young researchers/ 8 new positions (SF + SASPRO)*

On 15th June 2016, the Scientific Board accepted research topics of the IEE for the next period.

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IEE SAS research

Dept. of Superconductivity

Energy



SC power devices
Thermonuclear fusion

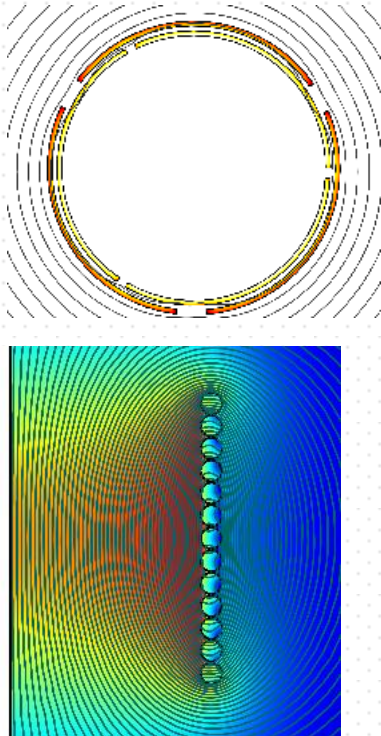
Medicine



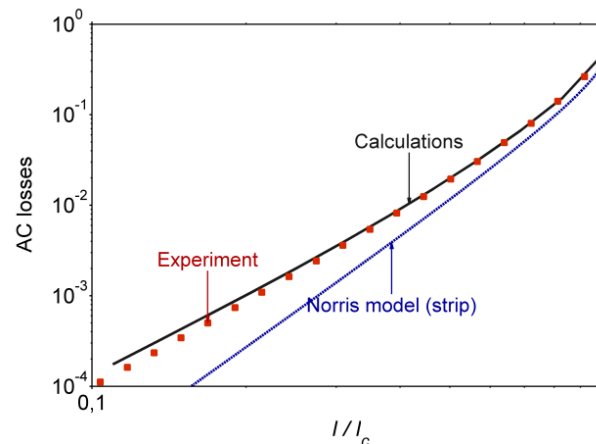
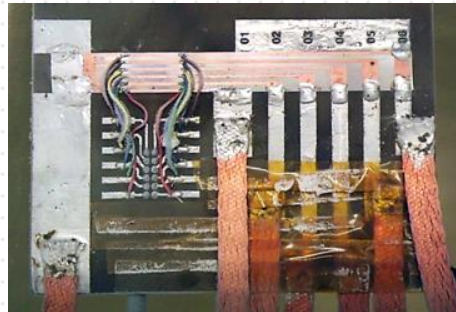
SC windings for MRI ?

HTS superconductors for electric power devices

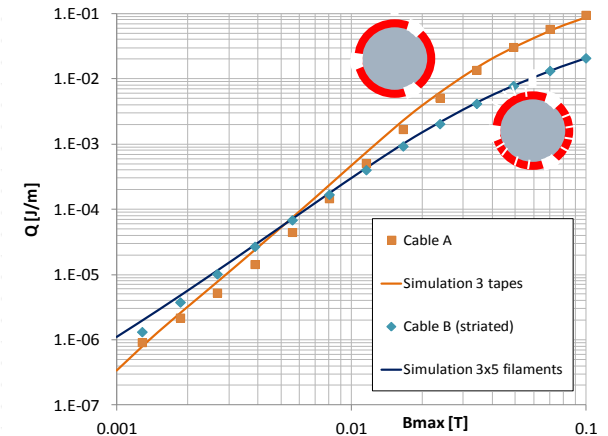
CORT cabling concept



Tape nonuniformity



AC losses in HTS tapes, cables



Outputs/papers:

5 x *Supercond. Sci. Technol.*
4 x *IEEE TAS*

IEEE Van Duzer Price 2014
for best article in IEEE TAS

Projects:

FP7 - EUROTAPES

Next: EUROFUSION
H2020 – FASTGRID
ARIES

Collaborations:

KIT Karlsruhe (stay)
Shanghai Jiao Tang
University Cambridge
DTU Lyngby

Visits at IEE:

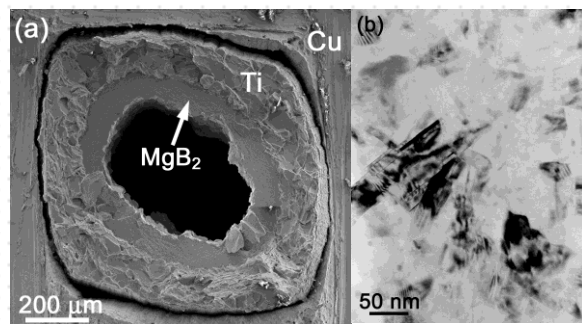
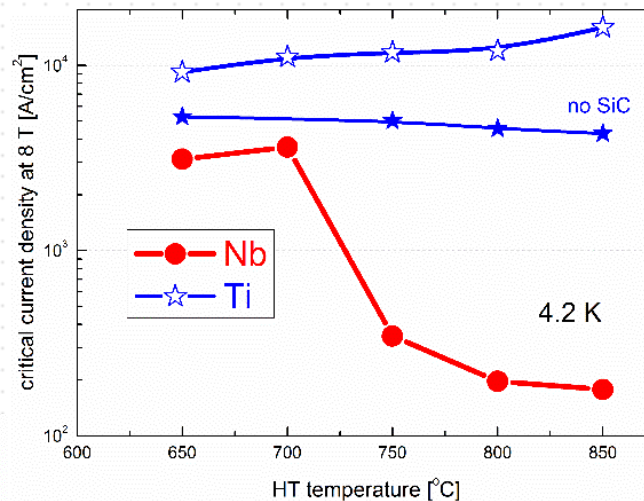
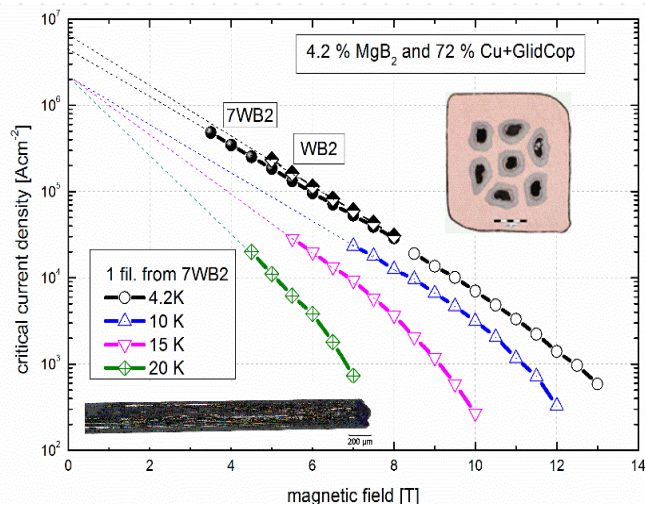
A. Kario (2 x 1 month)
N. Amaro (3 months)
J. Sheng (1 year)
R. Terzioglu (11 months)
2x4 months hosting of PhD

Progressive superconducting MgB_2 wires

MgB_2 with Ti barrier



Internal Mg Diffusion process



Outputs/papers:

J. of Alloys Comp. 2013

Sup. Sci. Technol. 2013

J. Sup. Nov. Magn. 2013

J of Alloys Comp. 2014

Sup. Sci. Technol. 2015

Sup. Sci. Technol. 2014

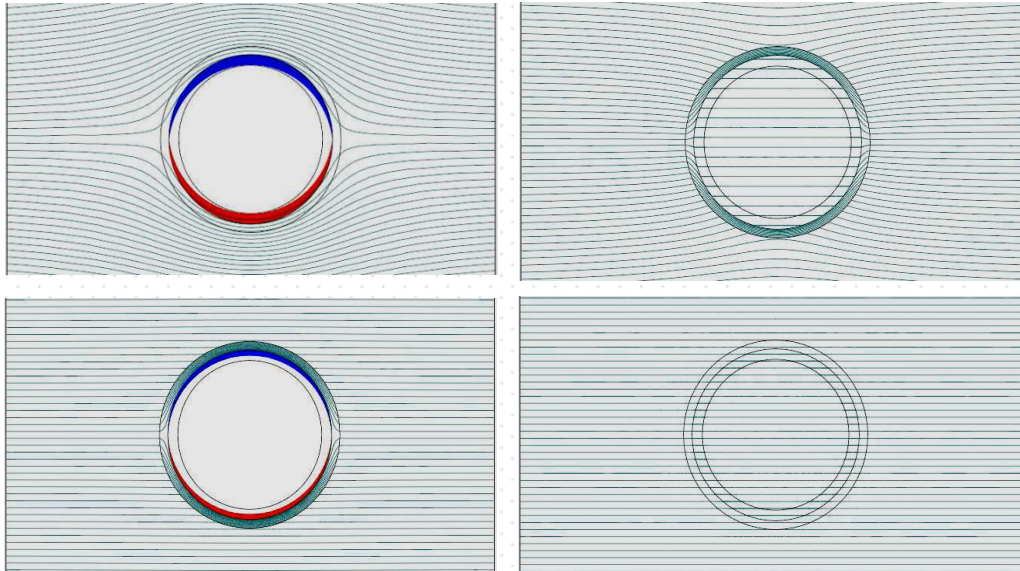
Projects: FP7 Suprapower
APVV, VEGA

Next: ULAKOS

Collaboration: Unipress Warsaw
Columbus Sup., I
IFW Dresden

Topics: Ultralight composite superconductor based on Mg, B, Ti and Al

Magnetic cloak (Science 2012)



Outputs/papers:

Science 2012

APL 2016

New J. of Physics 2015

SUST 2015

New J. of Physics 2013

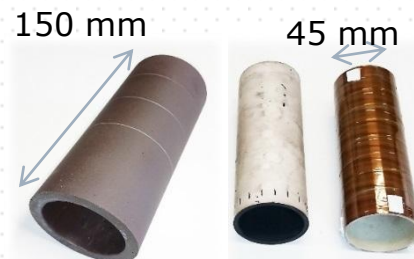
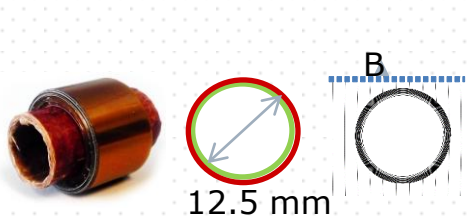
Awards:

Min. of Edu. Award 2012

SAS Prize for Popular. 2013

Scientist of the Year 2014

(F. Gömöry)



*How cells reproduce in
zero magnetic field ?*

Projects:

APVV

APVV

Collaborations:

Univ. Autonoma Barcelona

University of Ankara

NASA Ames Research Center

Visits at IEE:

Y. Nagasaki (NASA, 3m + 1y)

Next:

IEE SAS research

Dept. of III-V semiconductors

Energy



GaN switch

Safety



GaN THz source

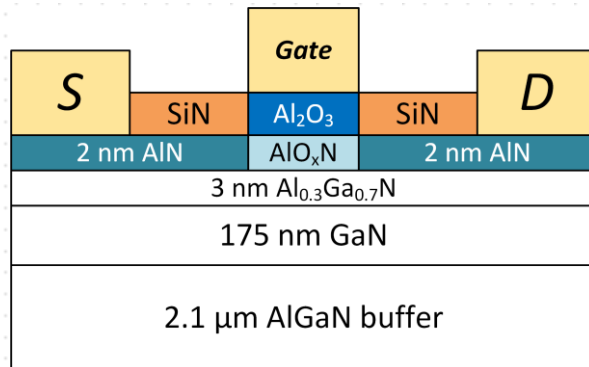
Mobility



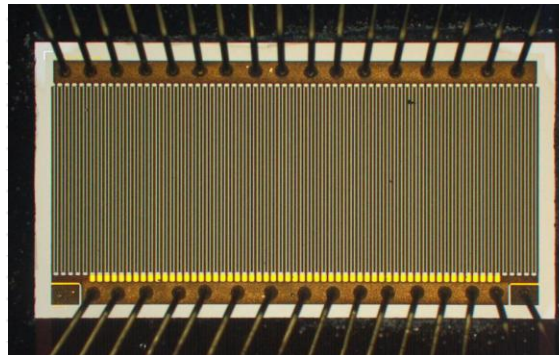
GaN electronics

GaN-based high-power normally-off switch

Energy savings



GaN heterostructure



Normally-off power transistor

Outputs/papers:

Techn. transfer to FBH Berlin
APL 2012, 2013, 2014, 2015
JAP 2013, 2014, 2015
Semicond. Sci. Tech. 2014
IEEE TED 2014...

IEEE EDL 2016

Projects:

FP7 
V4-Japan 

Next APVV, JST (?)

Topics: Vertical GaN switch

Collaboration:

Ferdinand Braun Inst. Berlin
Un. of Hokkaido (Inv. 2 pers.)
Uni. Vienna, Silezian Uni.

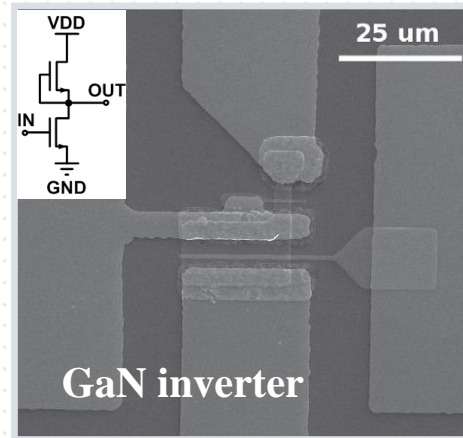
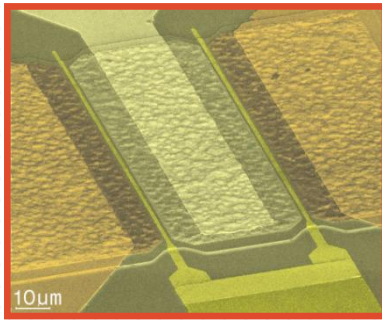
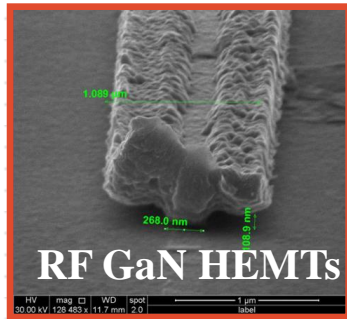
Visits at IEE:

Dr. Palankovski

Mixed-signal (logic/RF) GaN-based ICs



Monolithic integration of RF and E/D-mode switching GaN devices



Outputs/papers:

APL 2013, 2014, 2015

JapJAP 2012, 2013

Semicond. Sci. Tech. 2014

IEEE EDL 2013

IEEE TED 2011, 2014

APEX 2012...

Phys. Stat. Sol. 2015



RESEARCH REVIEW

Simplifying mixed-signal circuits in GaN

Selective plasma etching integrates E-mode and D-mode HEMTs for mixed-signal electronics

Journal for industrial community

Projects:

*Continuation of FP7
3xAPVV*

Next InN-channel HEMT

Collaboration:

*Alcatel-Thales (2y stay)
EPFL, Un. Fukui, Crete, Vienna*

*EU ECSEL project MICROTHERM
(2nd round)*

Visit:

*Dr. Kodama (Uni. Fukui)
Dr. E. Brytavskyi*

P. Chauhan, PhD study

IEE SAS research

Dept of Physics and Technology at Nanoscale

ICT



Memories:

- resistive
- magnetic

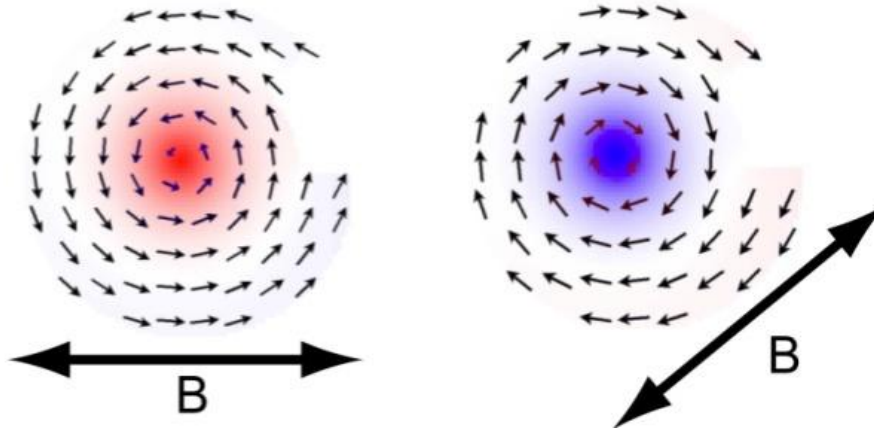
Mobility



Supercapacitors

Nanomagnetism in asymmetric nanoobjects

Vortex dynamics – simulation, experiments, MFM



Outputs/papers:

Sci. Rep. 2015

PRB 2013

JMMM 2013

AIP Adv. 2015

APL 2013

Nanotechn. 2015

2 x PRB 2016

Projects:

APVV, VEGA

Next: SASPRO

Collaboration:

Drexel Un., 2 visits

Univ. Poznań

Univ. San Sebastian

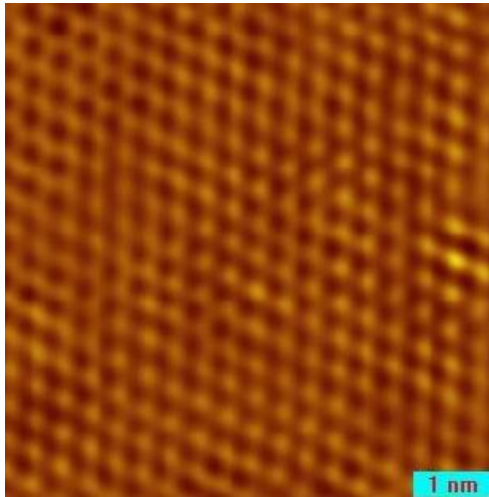
Visit:

M. Mruczkiewicz, PL

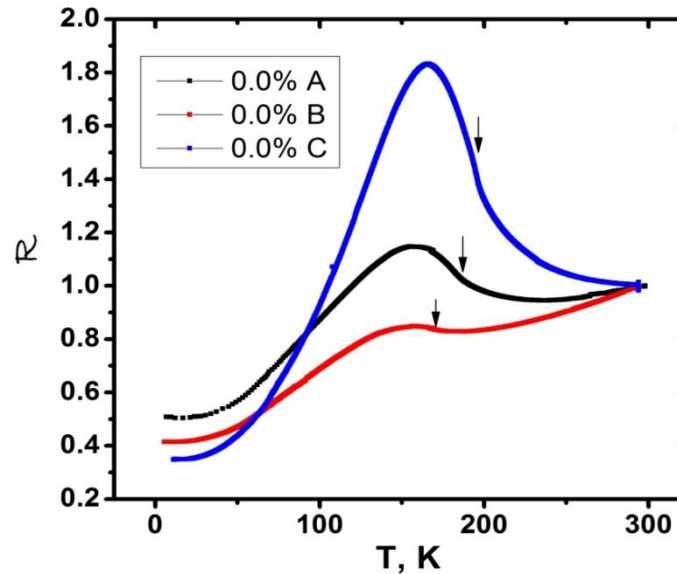
Topics: *Skyrmions and spin waves in ferromagnetic nanoobjects*

2D materials – CDW in TiSe_2 ; graphene, GO

LT AFM image of TiSe_2



CDW state in TiSe_2



Outputs/papers:

TiSe2

PRB 2016

2 x PRB 2013

Solit State Comm.

Graphene

J. Raman Spectr. 2016

J. Colloid In. Sci. 2015

Carbon 2014

Phys. Stat. Sol. B 2014

Phys. Stat. Sol. B 2014

Projects:

APVV, VEGA

Collaboration:

Temple Un., US, 2 visits

Drexel Un., US, 2 visits

ETH Zurich, Uni. Vienna

Visit:

G. Karapetrov, US

Next: Struct. Funds ?

Topics: *Technology of 2D mat. using novel methods (PLD,...); supercapacitor*

IEE SAS research

Dept. of Sensors and Detectors

Safety



THz detector

Medicine



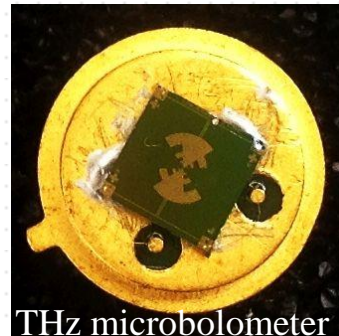
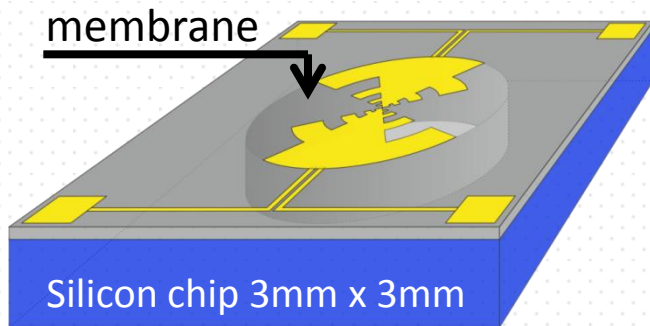
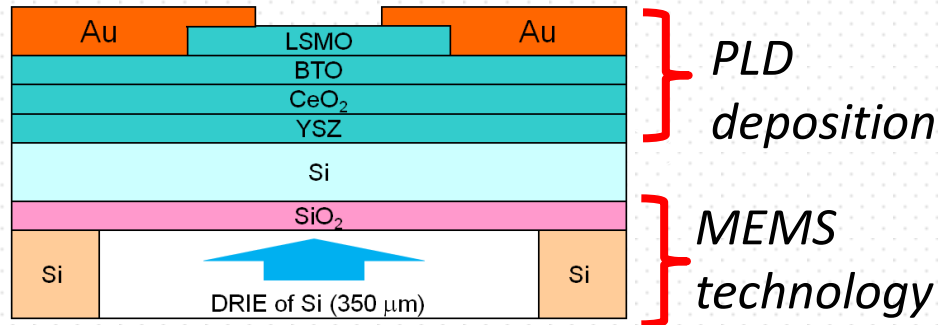
X-ray detectors

Mobility



MEMS sensors

Room temperature THz detector - bolometer



Outputs/papers:

Progress in App.Surf. 2015

Thin Solid Films 2015

Appl. Surf. Sci. 2014

Appl. Surf. Sci. 2013

Successful tests in PTB

Berlin at $f = 1,4$ THz

Application potential !

Projects:

APVV, VEGA

Next: SASPRO

Struct. Funds/NP ?

Collaboration:

PTB Berlin

Ben Gurion Uni., Izrael

NIST (stay)

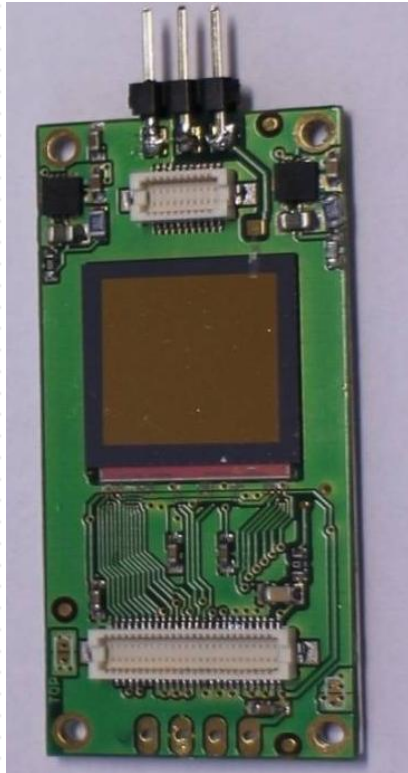
Colosseo (SK) ?

Visit:

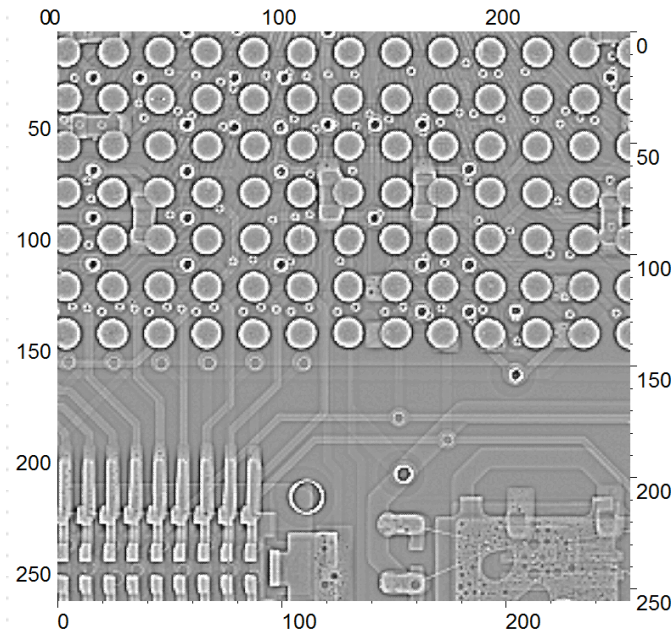
O. Babchenko (MEMS)

Topics: *Linear THz detector for safety systems*

Sensitive x-ray array detector (GaAs, InP)



GaAs matrix detector 256 x 256



4-layer PCB

Outputs/papers:

J. Instrumen. 2016

J. Instrumen. 2015

Rad. Eff. Def. in Solid 2015

J. Instrumen. 2014

NIM in Phys. Res. 2013

Application potential !

Sensitivity comparison:

GaAs 10 x more than Si

InP 30 x more than Si

Projects:

APVV, VEGA

Next: Structural Funds/NP ?

Collaboration:

IEAP CTU in Prague

Advacam CZ

Hospital Svätej Alžbety?

Visit:

Topics: Sensitive matrix x-ray detector for body screening

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IEE SAS strategy in research: Summary

Energy



SC power devices, GaN
switch, termonuclear fusion

ICT



Memories:
- rezistive
- magnetic

Safety



Hydrogen detector
THz source/detector

Medicine



SC windings for MRI
X-ray detectors

Mobility



Supercapacitors, MEMS sensors
GaN electronics

IEE SAS strategy for the future

*Is coherent with the **Development strategy SAS 2020** and with key strategic EU and Slovak documents (Europe 2020, Horizon 2020, RIS3, National Reform Progr. 2015).*

1. Research

- a) Improve its quality – better papers, more citations
- b) Internationalization - more people from abroad working at IEE (now ~ 15%)
- c) Support for presented topics– agreed by Scientific Board (May 2016)

2. Human resources

- a) Stabilize young researchers – in 2016 management increased their salaries
- b) Create new post-doc positions – EU, APVV, and SF projects
- c) Support for ERC grants

3. Contacts with Industry

- a) Increase activity towards Slovak companies
- b) Develop and test GaAs/InP body scanner with the Hospital Svätej Alžbety
- c) Base spin-off companies (new legislation needed that transforms the SAS organizations into public research institutions)

4. Public relations

- a) Widen activities towards attracting PhD students (Slovakia & 3rd countries)
- b) Intensify IEE branding towards general public (Soc. networks,...)

Thank you for your attention !

