Microelectronics Structures and Devices

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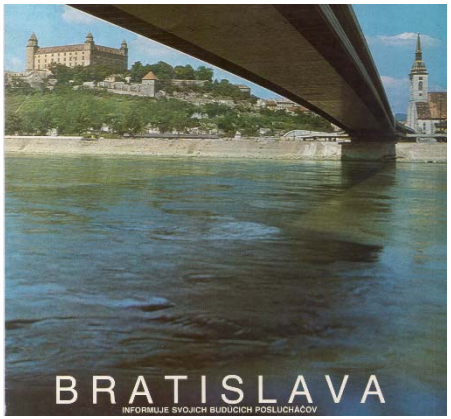
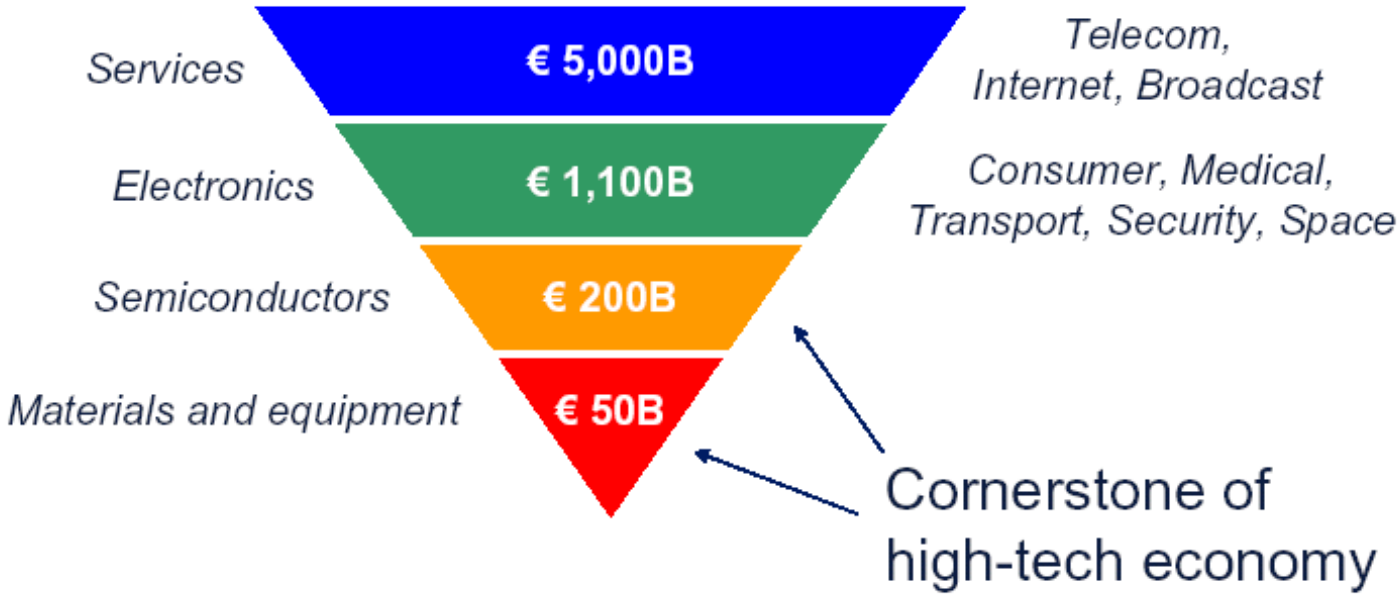
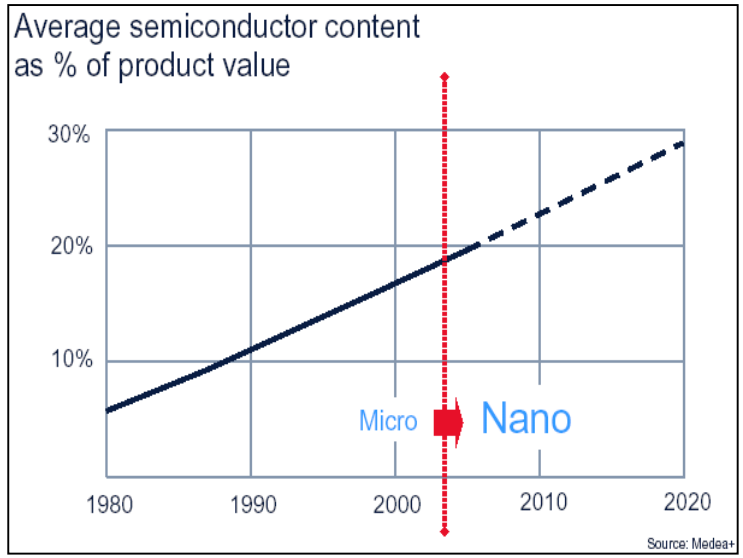


- **Introduction**
- Micro - Nanoelectronics and Photonics driving force
- New materials and technologies
- Nano-dimensions – new physical properties
- Examples of applications
- Potential and Selected Activities of Slovak University of Technology in Key Enabling Technologies
- Summary

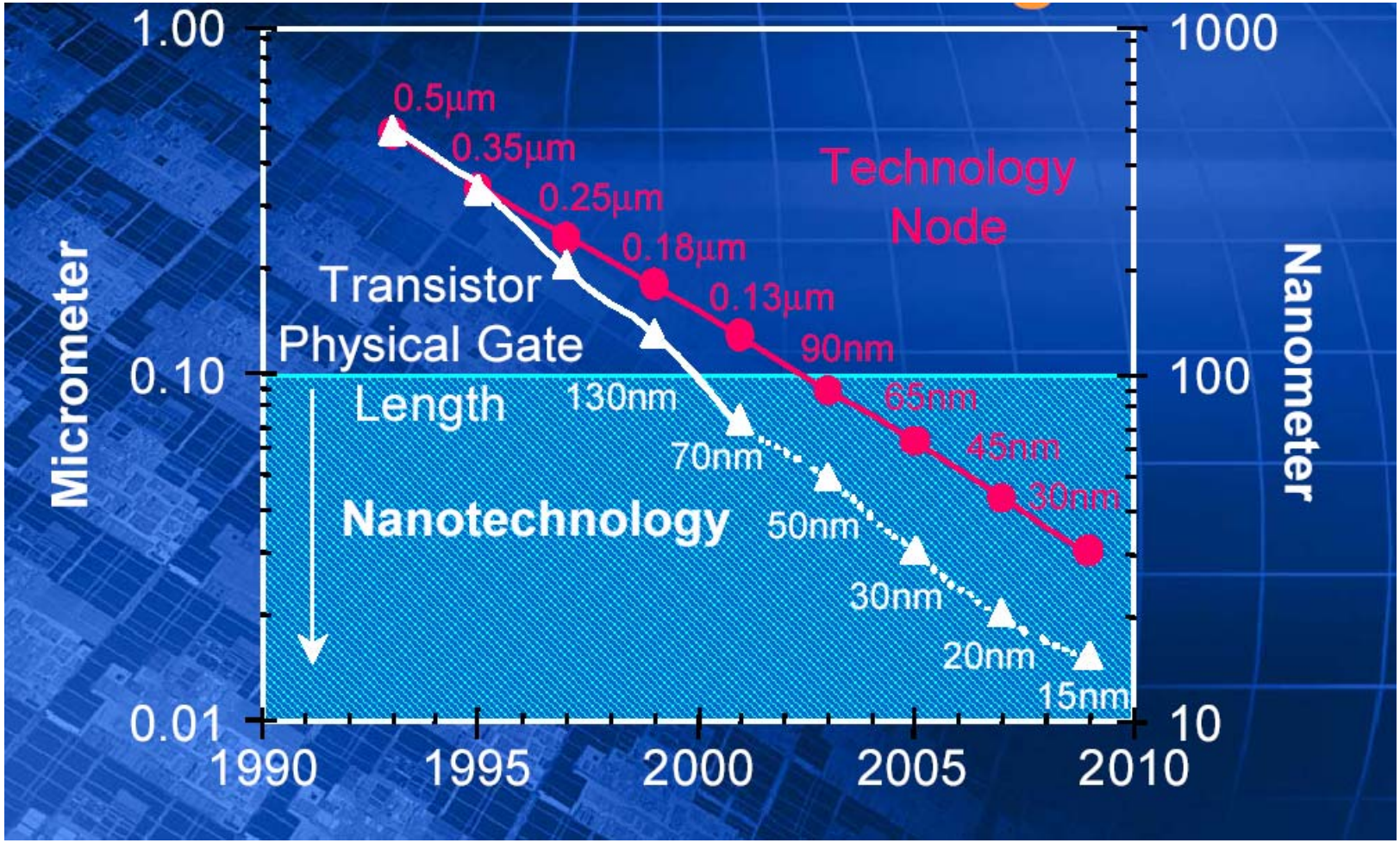
High Tech – Economic Impact



Micro and Nanotechnology penetrates to all industrial branches

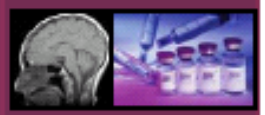
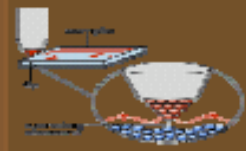


Transistor scaling

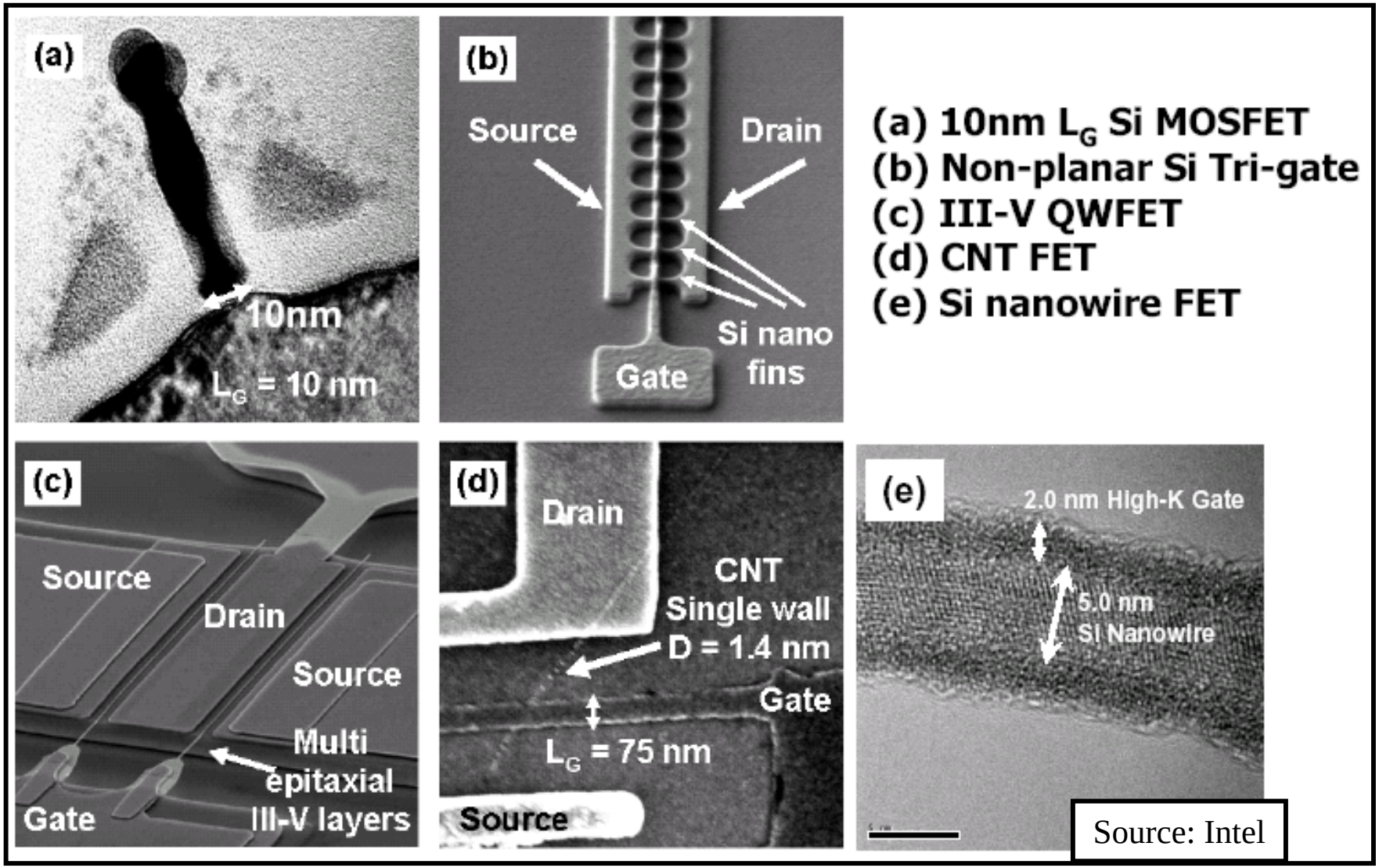


Miniaturization under 100 nm → NANOELECTRONICS

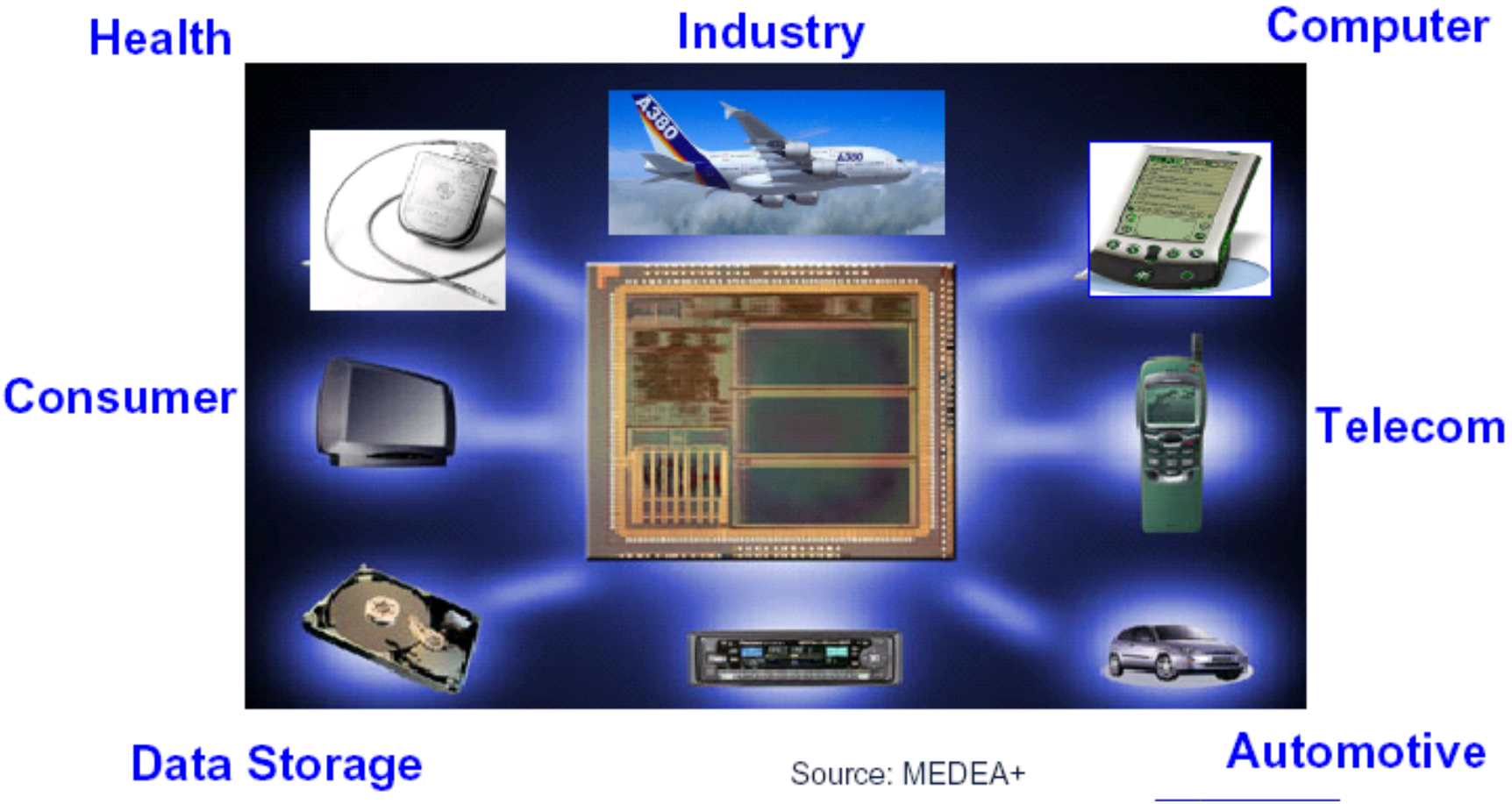
Nanotechnology (Nanoelectronics, Nanophotonics) Application Sectors

Medicine and Health	Information Technology	Energy Production / Storage	Materials Science	Food, Water and the Environment	Instruments
 Drug delivery	 GMR Hard Disk	 Hydrogen Fuel Cells	 Lightweight and strong	 Remediation methods	 Tunneling microscopy

Emerging Nanoelectronic Devices

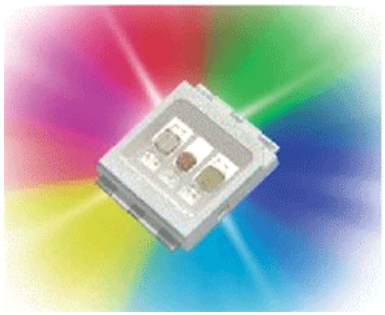


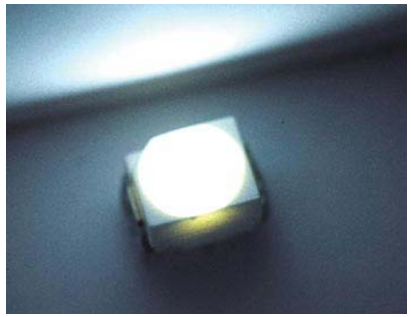
Diversity of Microelectronics

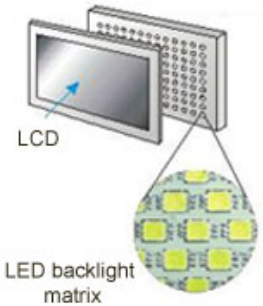


More complex, faster, cheaper, higher reliability, lower consumption

Diversity of Photonics







Diversity of Photonics

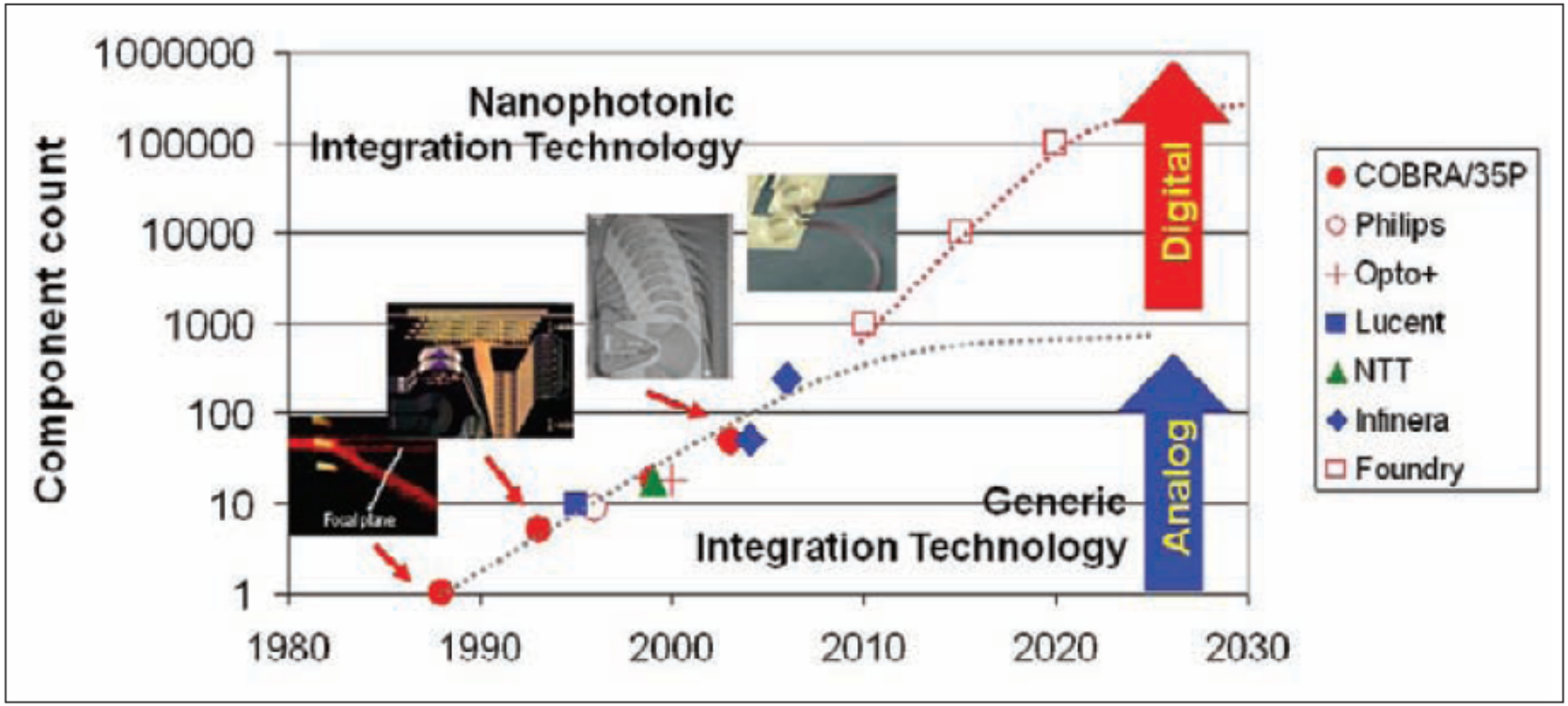
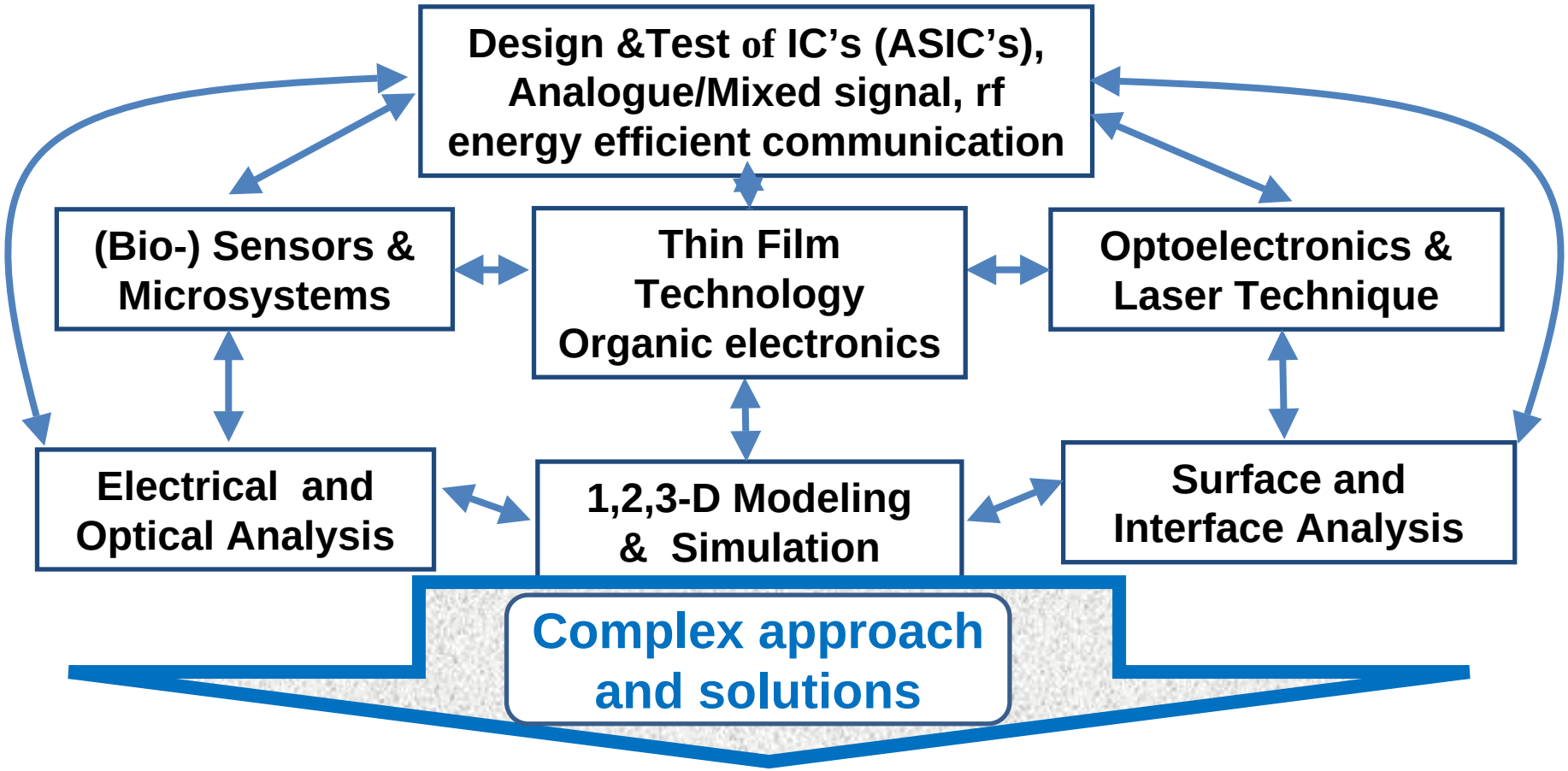


Figure 1: Roadmap shows component count versus year and rise of digitization over analog photonic integration solutions (Meint Smit, TU/e, OIDA Photonic Integration Forum, Oct 2008)

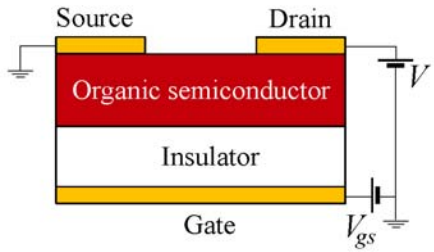
Potential and Selected Activities of Slovak University of Technology in Key Enabling Technologies

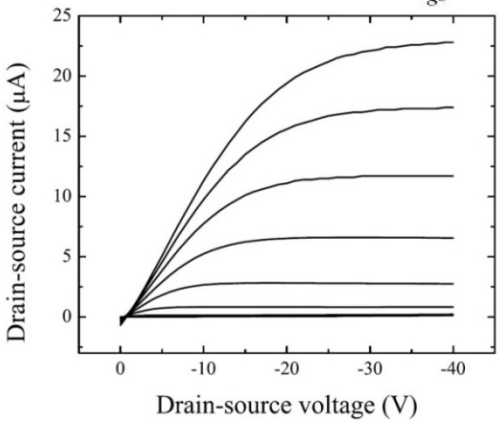


Applications: Signal processing, smart sensors, medical electronics, health, organic electronics, carbon nanotubes, graphen, photovoltaics, photonics

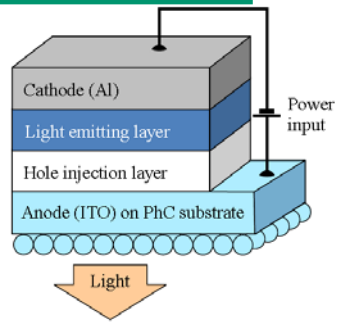
Organic electronics

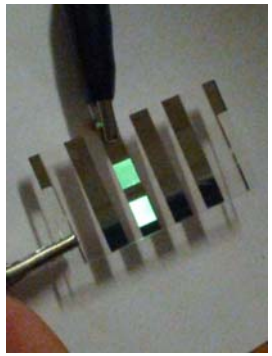
Organic FET:



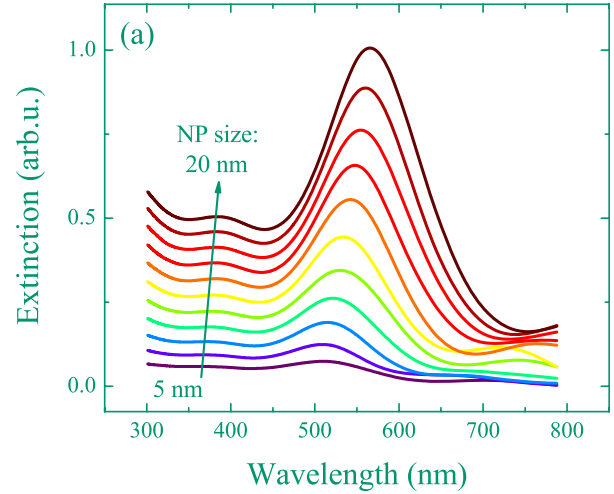


Organic LED:

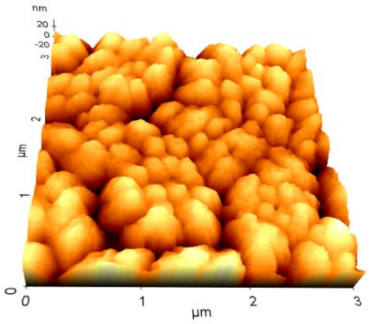




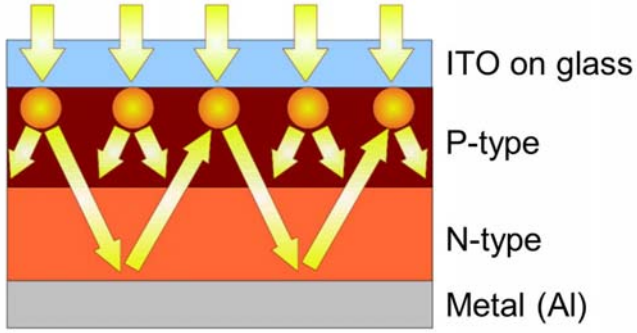
Extinction of Plasmonic NP Monolayer



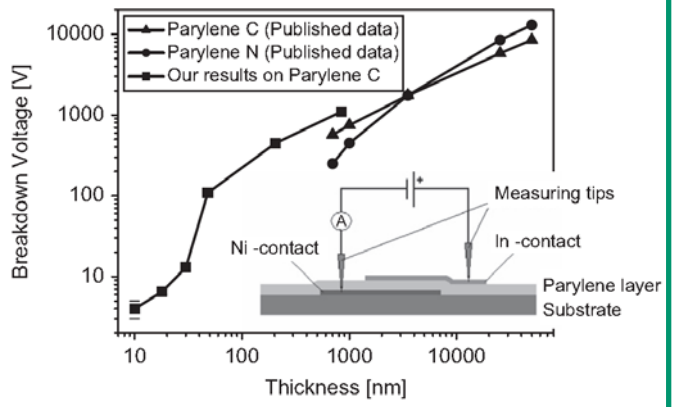
Film structure study:



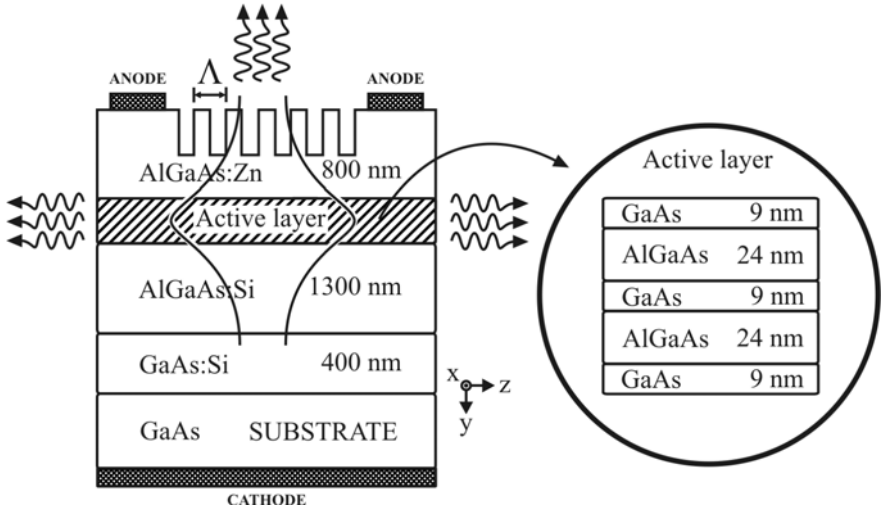
Bare glass & NP modified surface

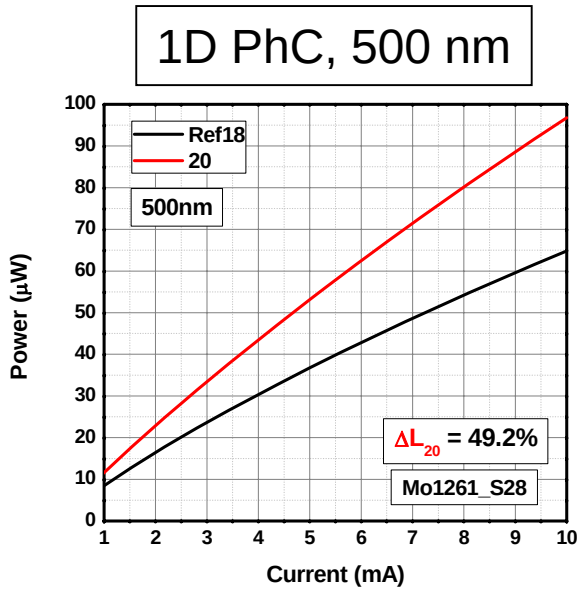


Organic Encapsulation and Insulating Films:

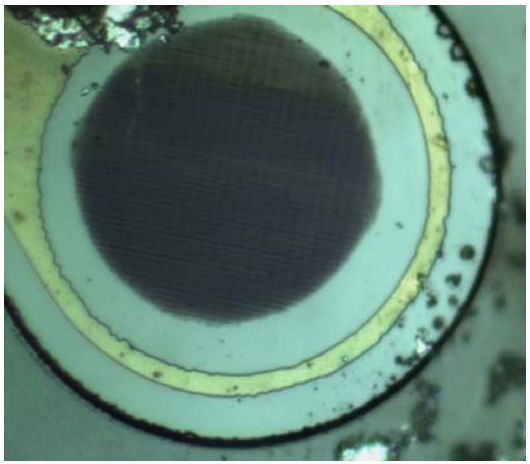


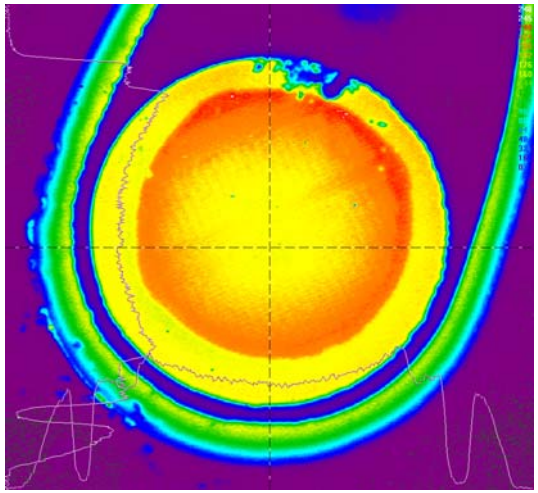
AlGaAs/GaAs LEDs with Photonic structures patterned by EBDW lithography

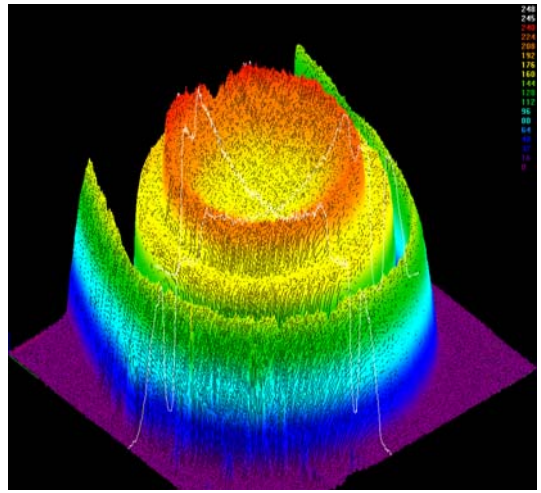




Spiricon - 1mA

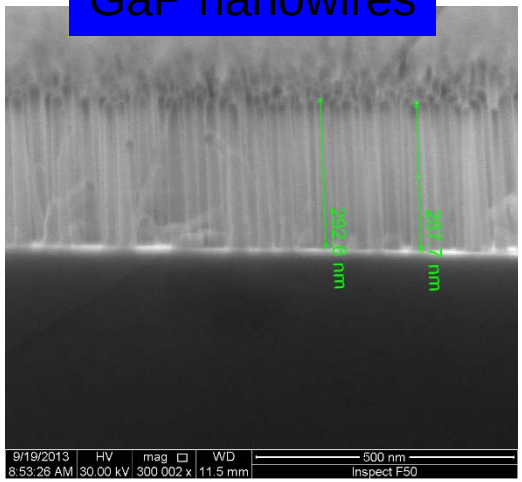






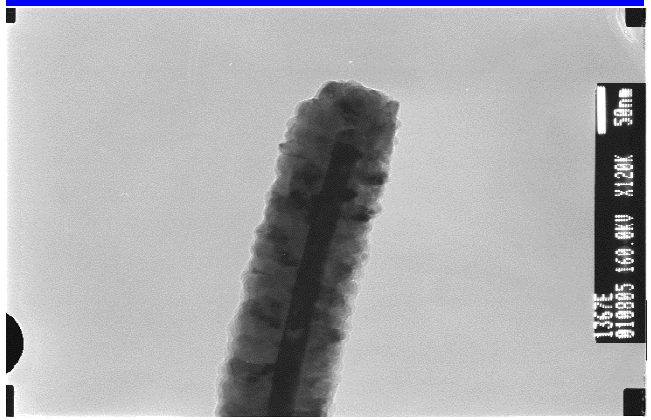
GaP/ZnO core-shell nanowire technology

GaP nanowires



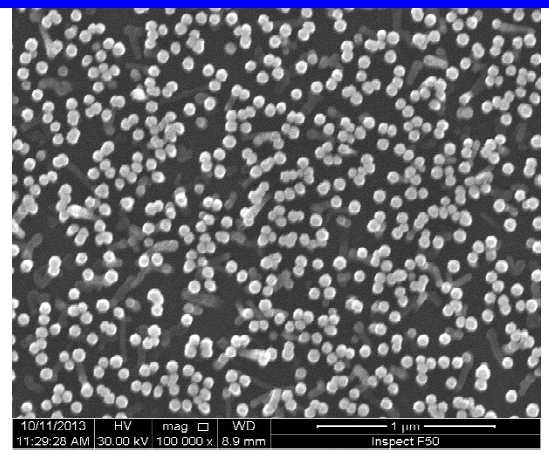
GaP-MOVPE

GaP nanowire + 50 nm ZnO

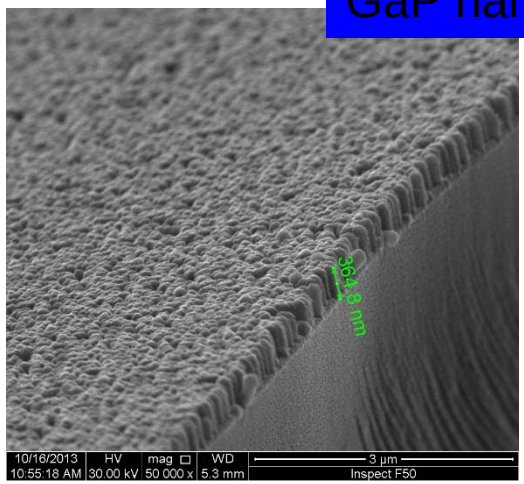


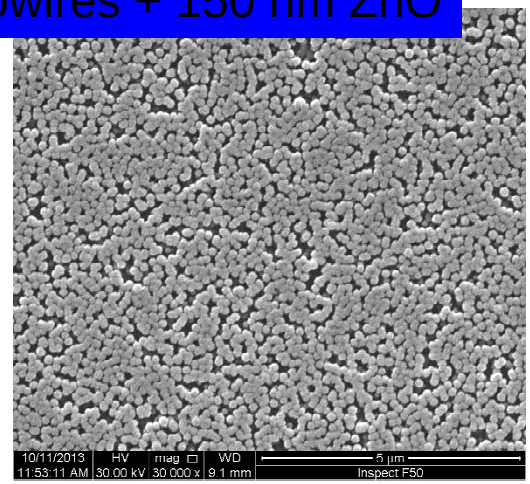
ZnO-magnetron sputtering

GaP nanowires + 50 nm ZnO



GaP nanowires + 150 nm ZnO





- **Original approach was used to prepare ZnO-GaP core-shell nanowires by combination of MOVPE epitaxial technology (IEE SAS) and subsequent ZnO thin layer deposition by magnetron sputtering deposition technique (FEI IEP)**

Photovoltaics & Energy Harvesting

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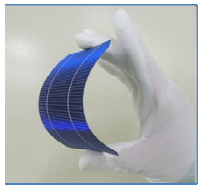
Advanced PV technologies

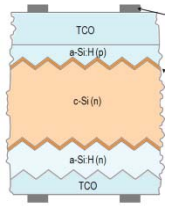
1. Gen.: crystalline silicon

High performance

Cell efficiency ~25%

3. Gen.: amorphous/crystalline heterostructure





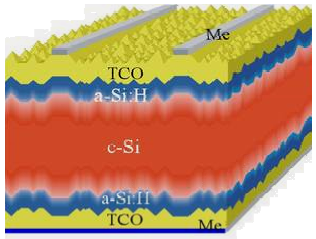
2. Gen.: amorphous silicon

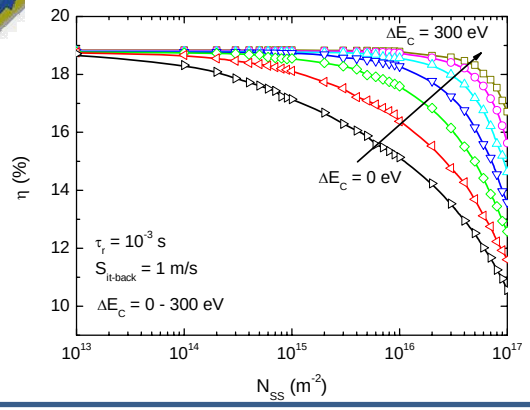
Low cost

Cell efficiency ~ 13%

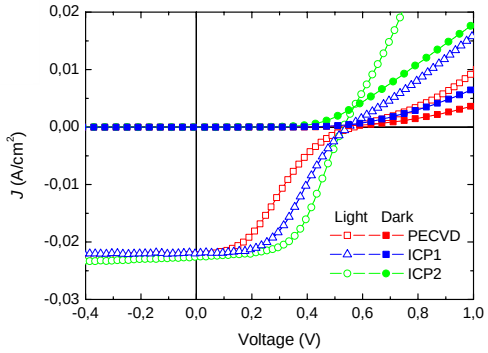
Low cost + High performance (~ 23%)

Simulations (TCAD, Optic, Electric)





Diagnostics (I-V, C-V-F...)



SMART Electronic systems for wireless biomonitoring

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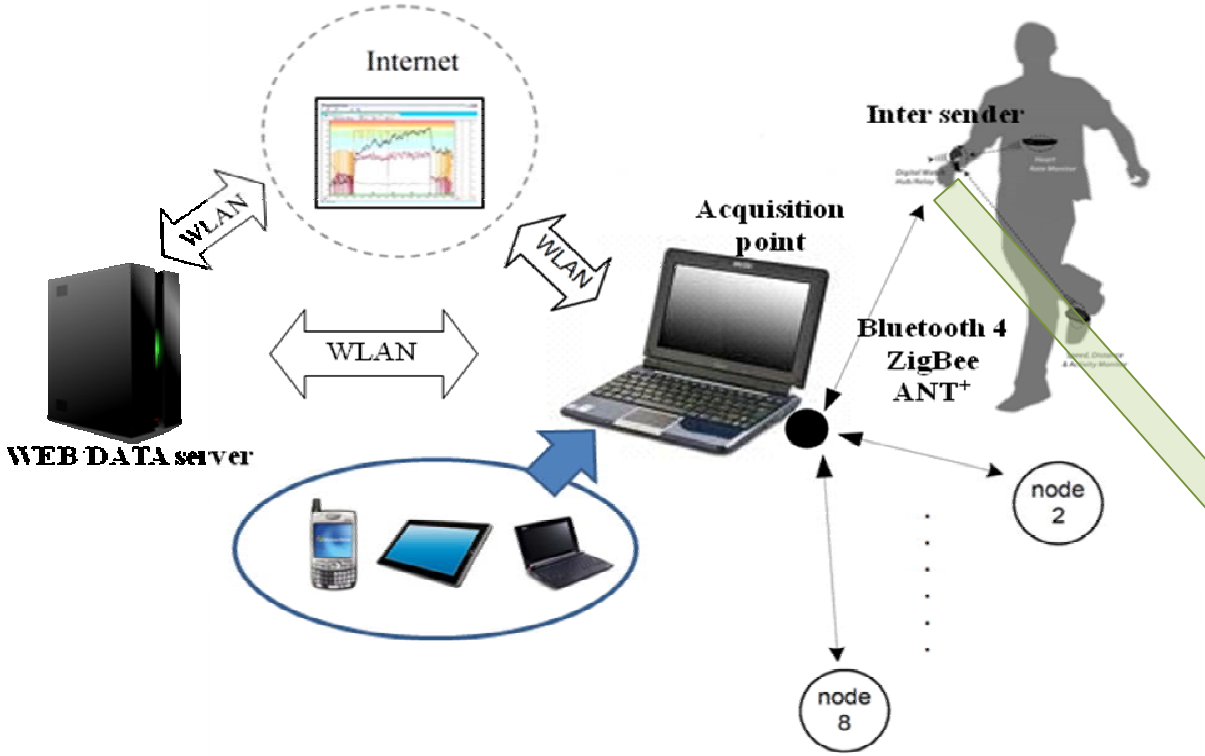
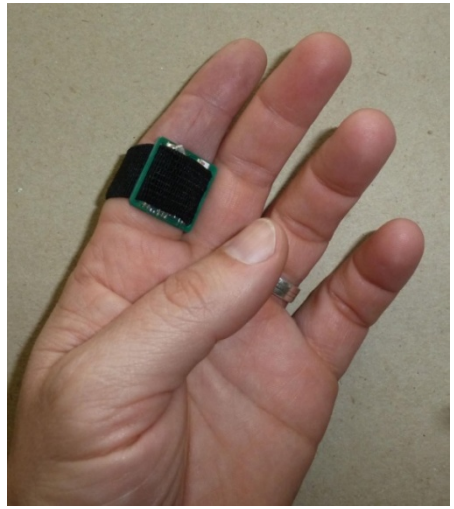
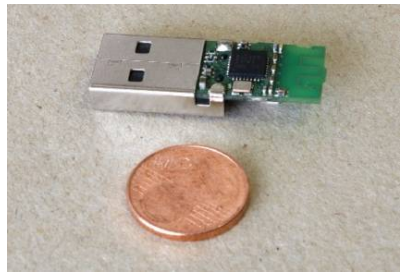
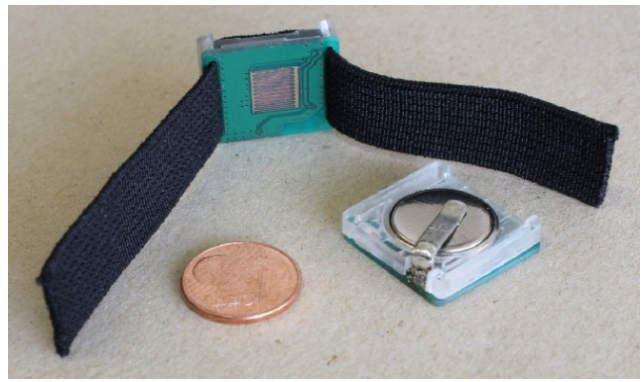




IDA microelectrode





Wireless on-body sensor (stress)

- attached to a finger
- IDA microelectrodes, special surface treatment
- USB dongle communicator
- rf energy effective communication

SMART Electronic systems for health and fitness applications

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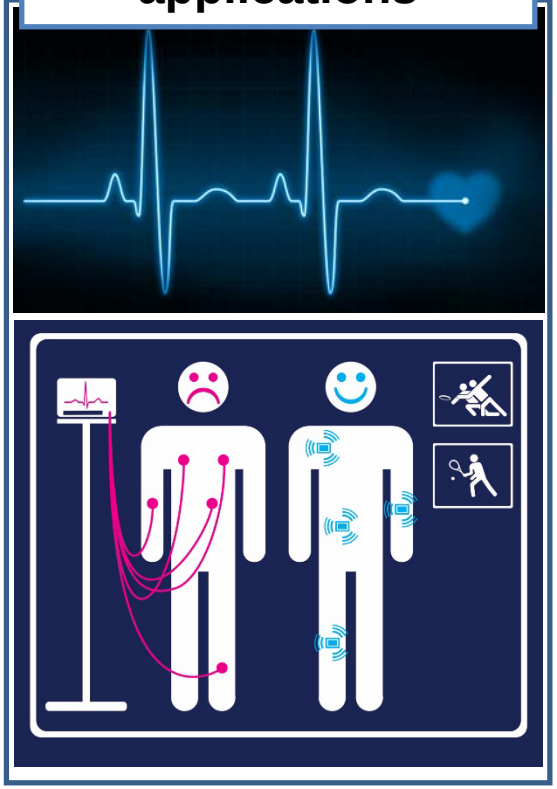
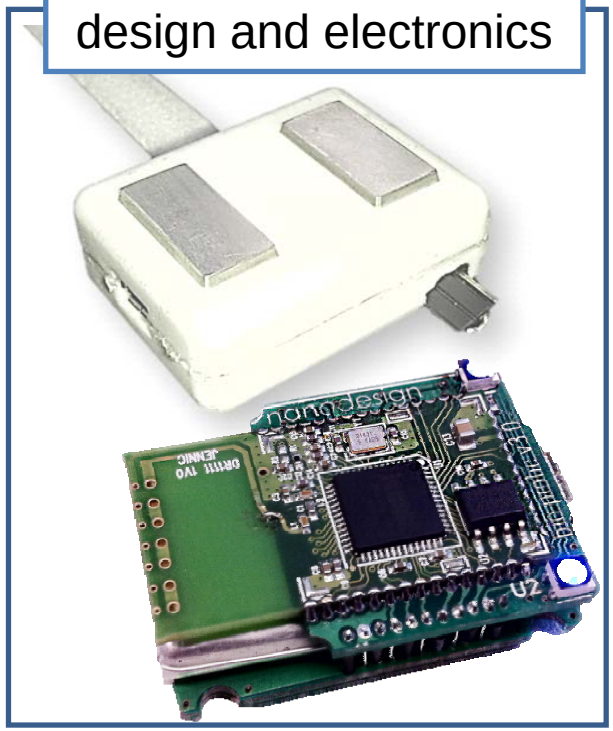
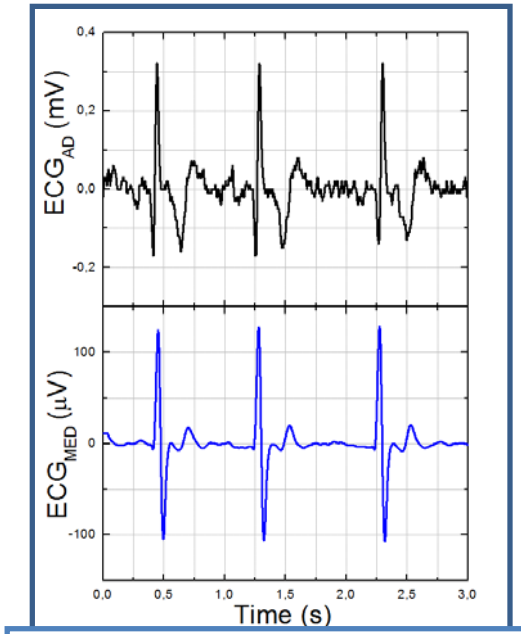
Wireless biosensing applications

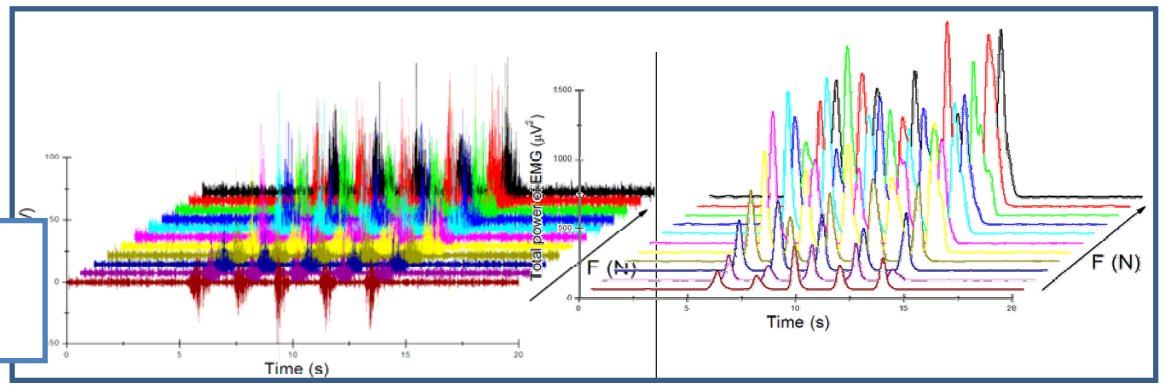


ECG sensing probe design and electronics





Raw and filtered heart-rate signal measured by wireless system



Total power of muscles EMG during fitness

SMART Electronic systems for health and fitness applications

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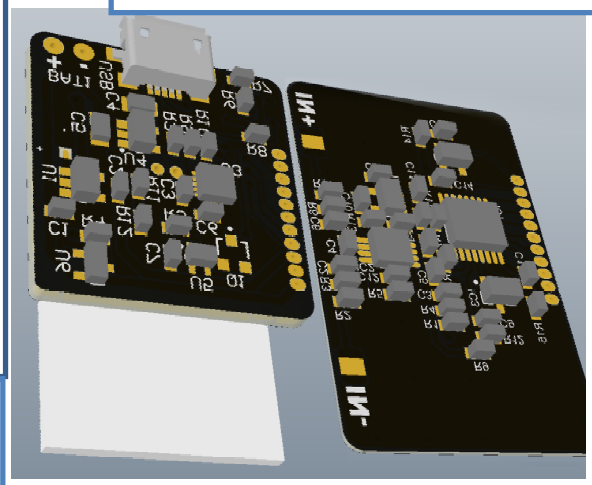
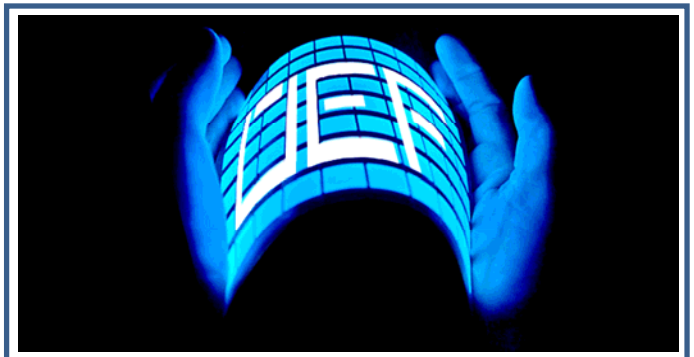
Forceplate “seven” for rehab- and diagnostic purposes developed in our labs

SMART devices serve the research in field of assisted healthcare

Intensive miniaturization of developed devices by each 6 months



Flexible clothing with flexible probes covered by organic semiconductor film for better performance



Organic semiconductor research in field of health bio-applications

SMART module for gas detection

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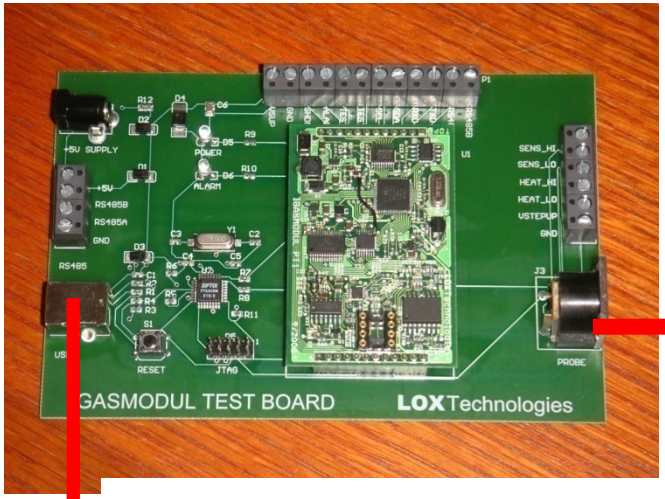
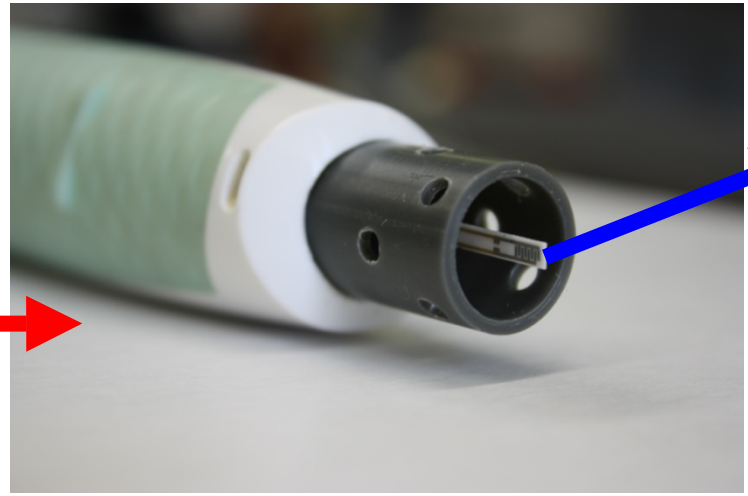
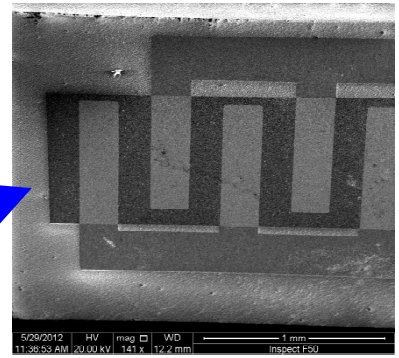
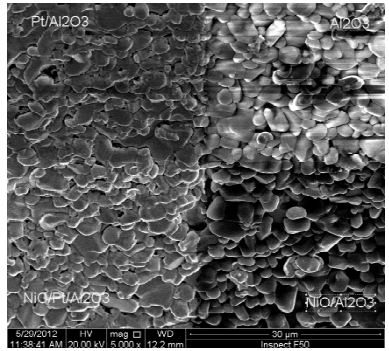


Control and measuring system



Gas sensing system

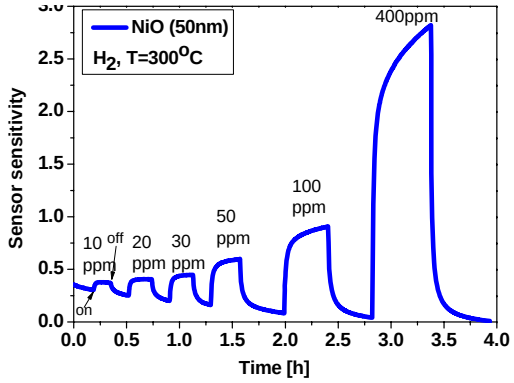




Nanostructured surface

PC

Gas calibration system



Hydrogen testing

Detection of gases:

NO_2	10 ppm
CO	150 ppm
NH_3	100 ppm
H_2	500 ppm
CH_4, ethanol, acetone	

Nanostructured boron doped diamond for sensing heavy metals

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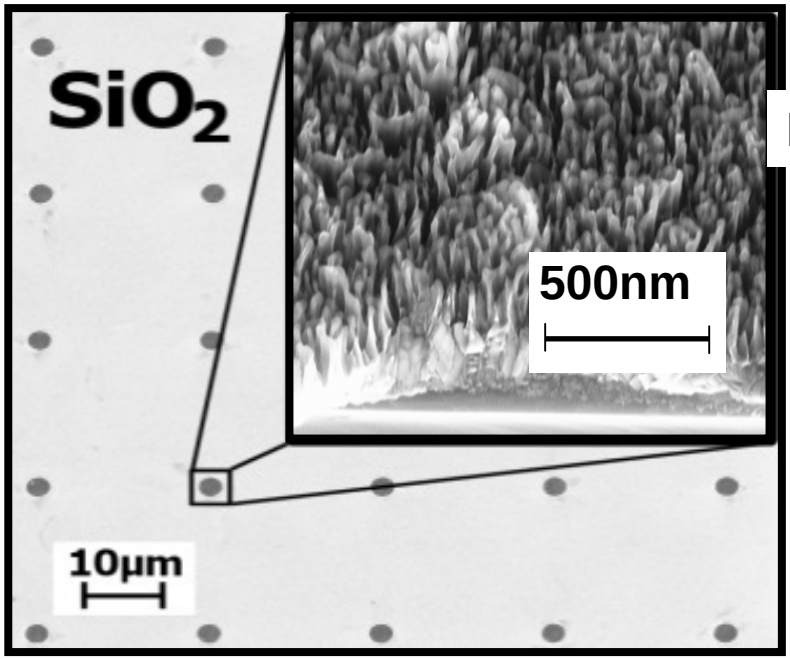
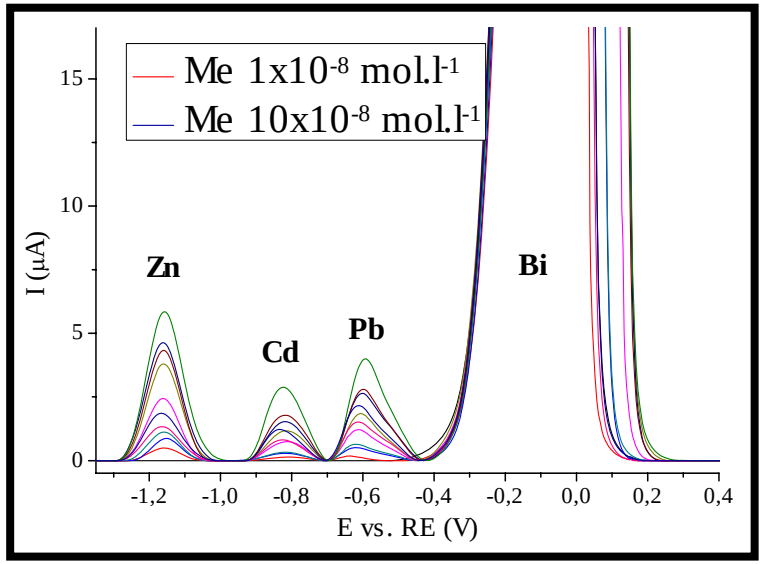
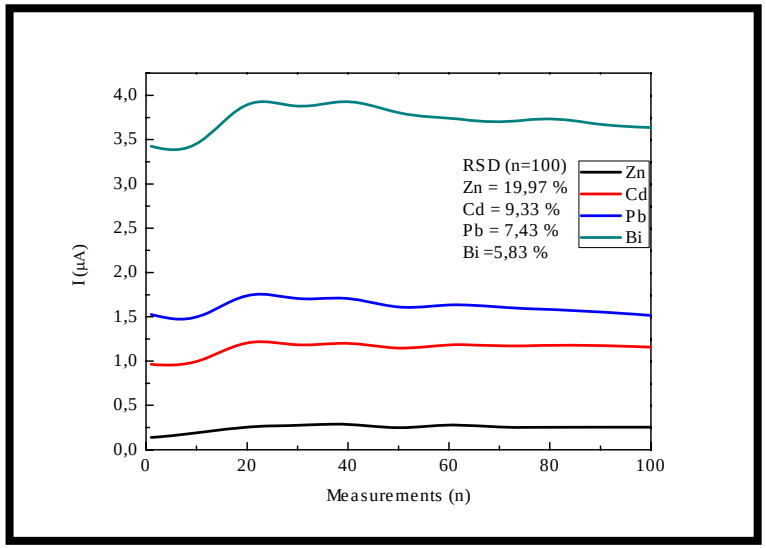




B/C [ppm]	Ion	Sensitivity [nA.nmol^{-1}.l.mm^{-2}]	R^2	LOD (ppb)
10 000	Pb	20.84	0.999	2.58
	Cd	26.14	0.999	2.05
	Zn	19.86	0.996	4.18



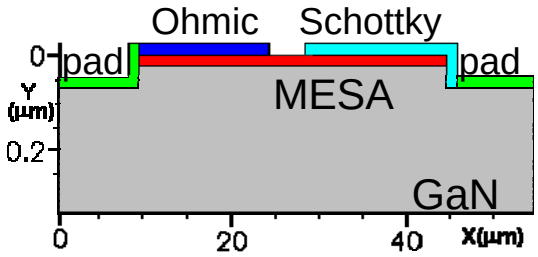
Results:

- Ultra low detection limit (nmol.l^{-1})
- High sensitivity
- High selectivity (simultaneous detection of Cd, Zn, Pb)
- High repeatability of measurements

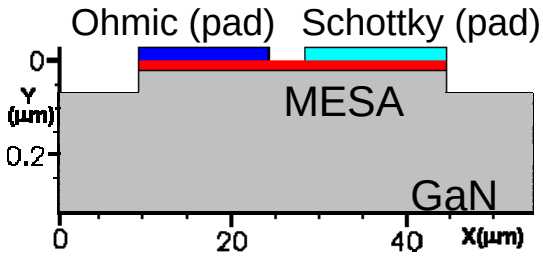
Max. conc. in water: c(Pb) = 20 µg/l, c(Cd) = 5 µg/l, c(Zn) = 100 µg/l

Analysis of the leakage current of AlGaN/GaN Schottky diode dependent on ohmic contact pad electrode position

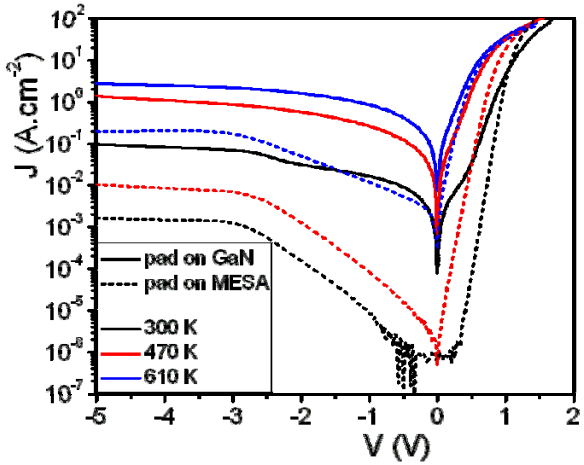
pad on GaN



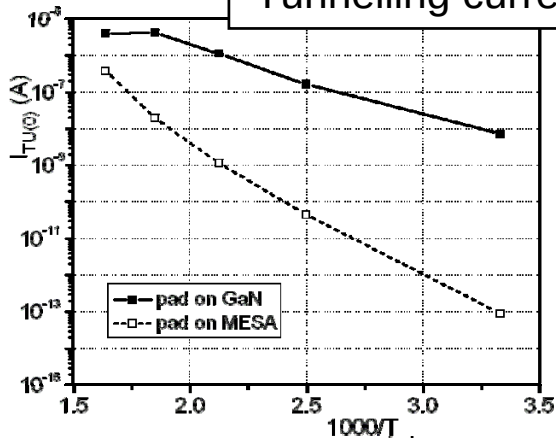
pad on MESA



Experimental I-V characteristics

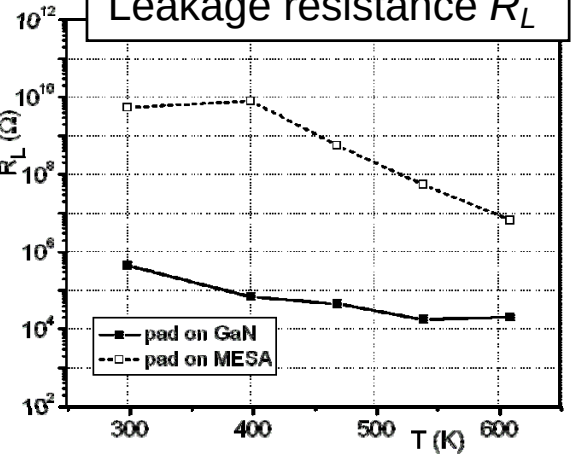


Tunnelling current

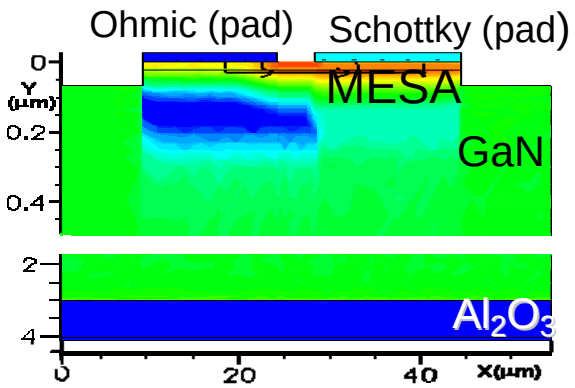


2-D simulation results - Current density distribution at V_{SK} = -3 V

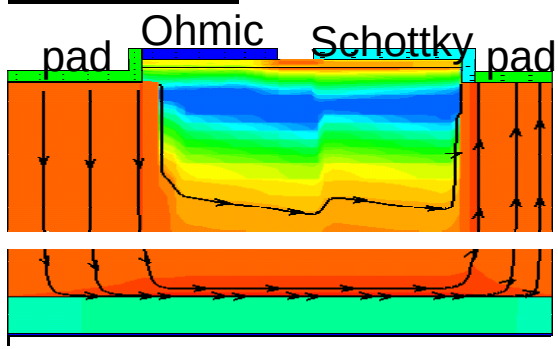
Leakage resistance R_L



pad on MESA



pad on GaN



J (A.cm-2) 3.1E-08 9.4E-04

Advanced complex characterization

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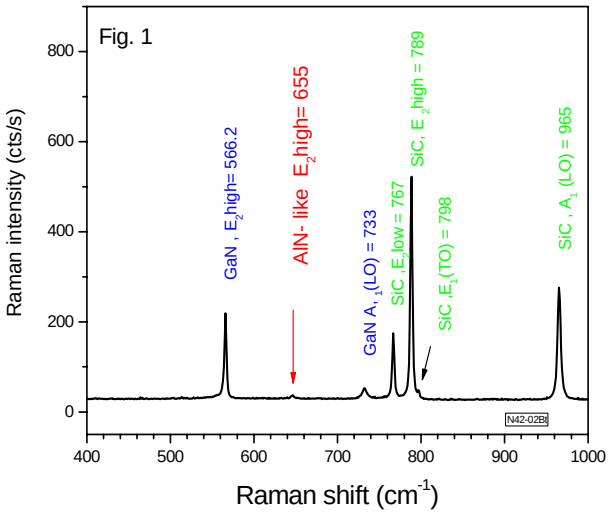
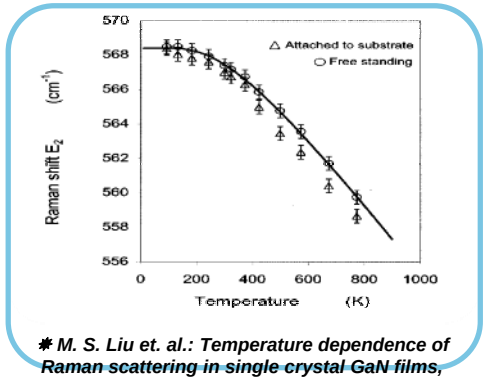
Micro-Raman spectroscopy and PL system,

MonoVista CRS 75A|BX51, (300 – 1050 nm), Spectroscopy&Imaging (S&I), Germany
UV- VIS- NIR konfocal Raman microscope. Excitation lasers: He-Cd 325 nm, Ar -tunable 488&514 nm

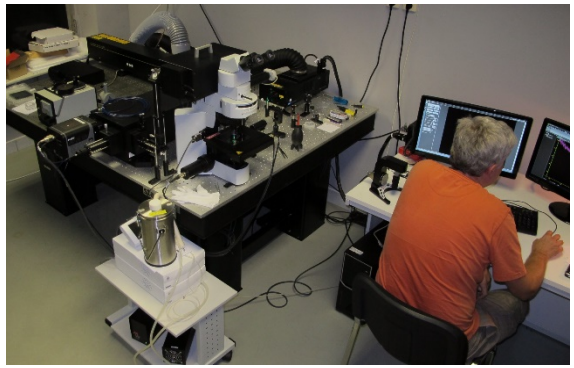
InAlN/GaN/AlN/SiC - HEMT

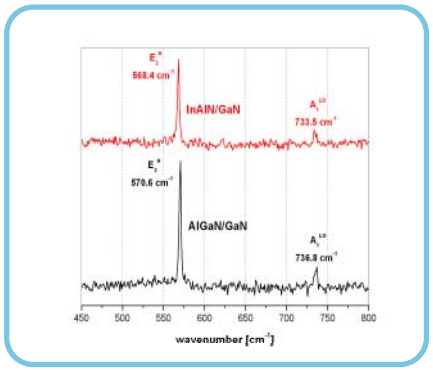


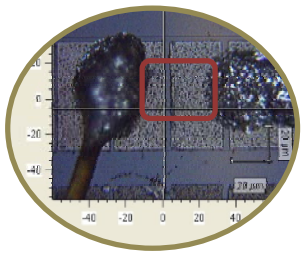
Thermal assessment (micro Raman spetroscopy)

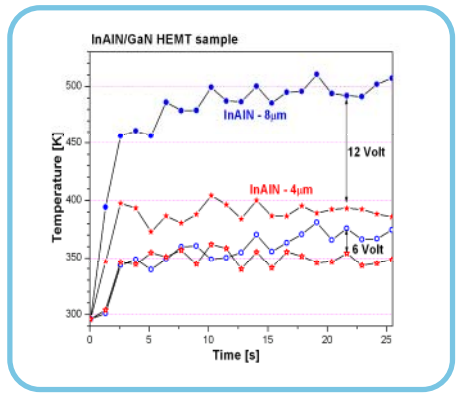


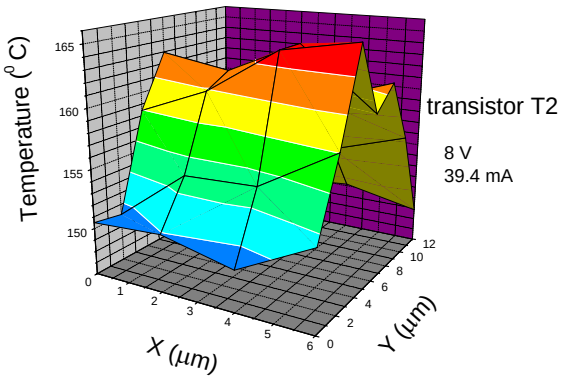
✸ *M. S. Liu et. al.: Temperature dependence of Raman scattering in single crystal GaN films,* **Applied Physics Letters *74***



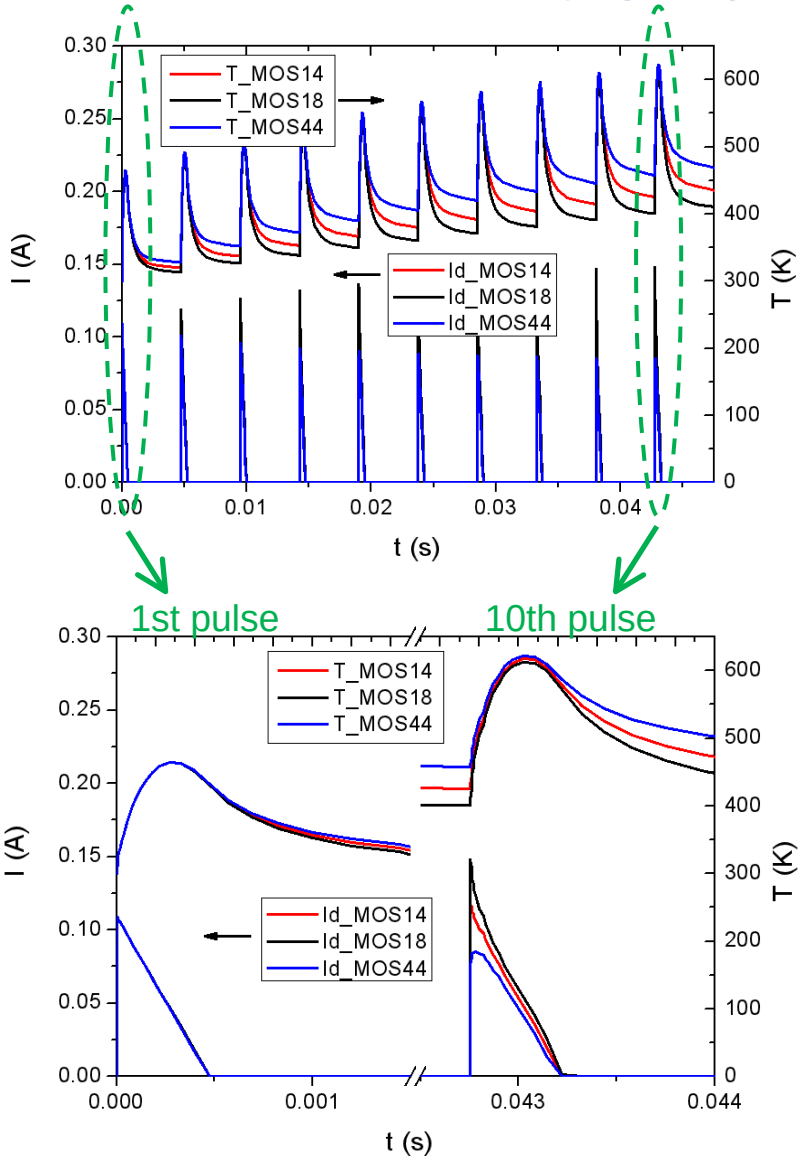






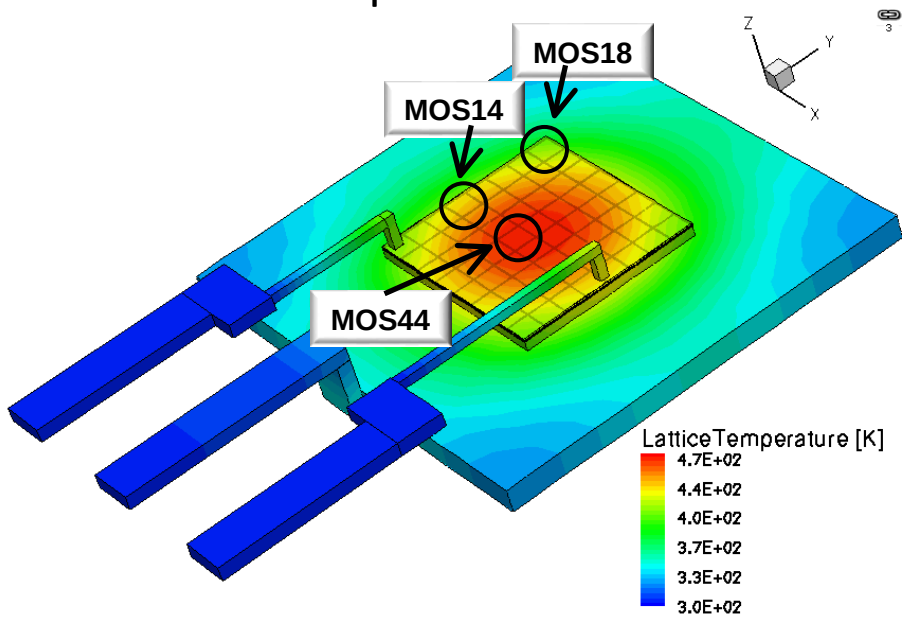


Interaction between SDEVICE and HSPICE for electro-thermal circuit simulations



Temperature (T) and drain current (I) for selected MOSFET parts during 10 UIS pulses

Structure temperature distribution



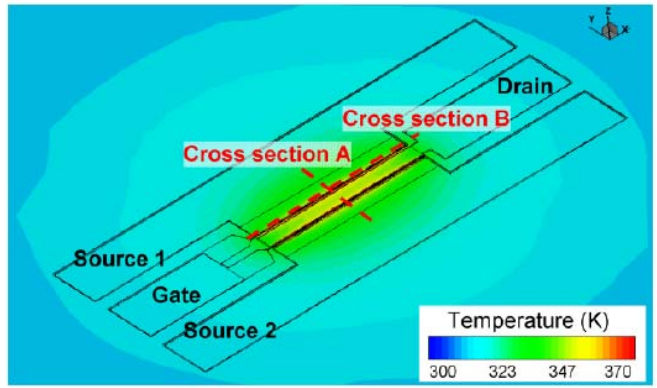
3-D distributed parameters of the MOSFET are taken in to account

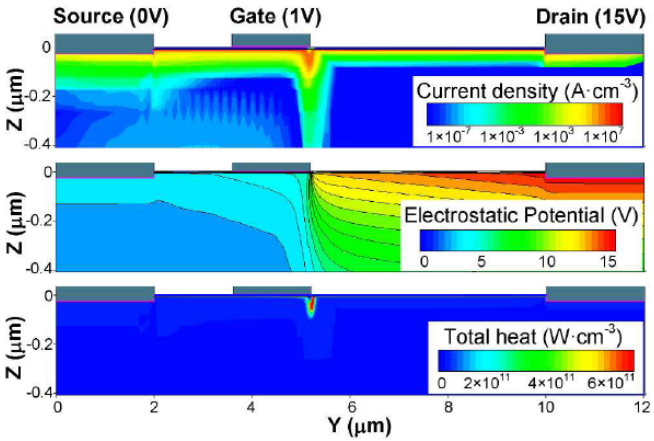
HEMT 3-D MIXED-MODE ELECTROTHERMAL SIMULATION

> TCAD tools (Synopsys Sentaurus)

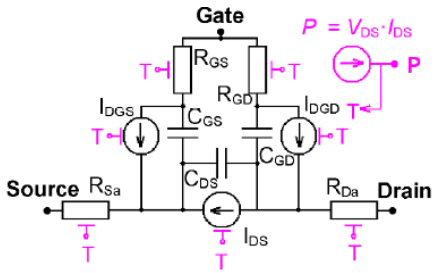
> Electro-thermal SPICE model of HEMT

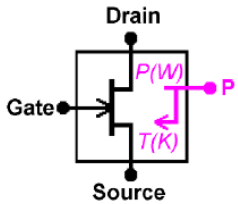
Done work:
-prepared 2D and 3D calibrated TCAD models
- *2-D FEM electrothermal simulations*
- *temperature dependent analytical circuit model*
- *3-D mixed-mode electrothermal simulation*

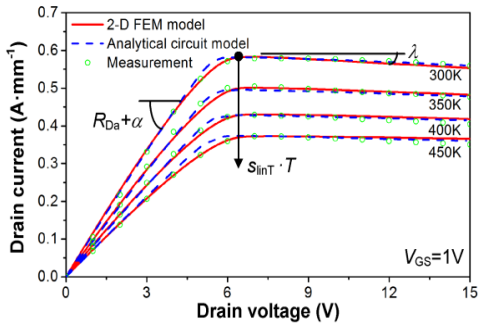


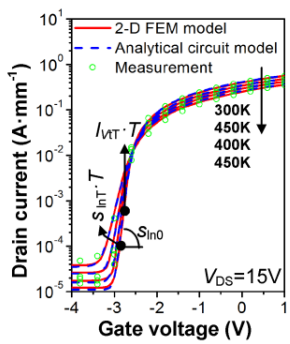


Current density, electrostatic potential, and total heat distribution during on-state operating conditions. Most of the generated heat is located under the drain side of the gate edge.









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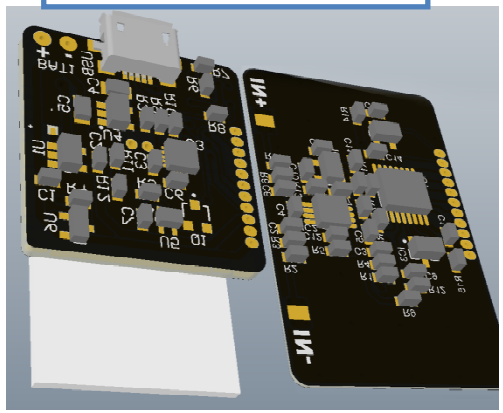
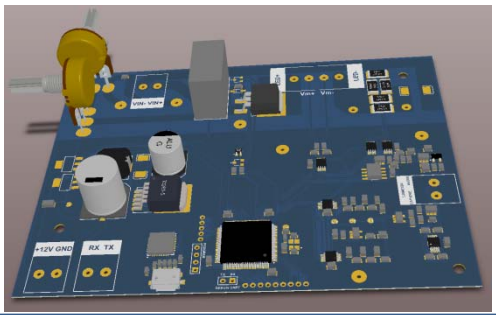
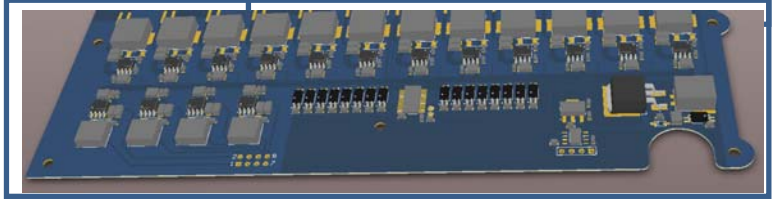
SMART Electronic systems for general control of illumination

New lighting modules

Drivers and control units







SMART Control unit for >50 modules

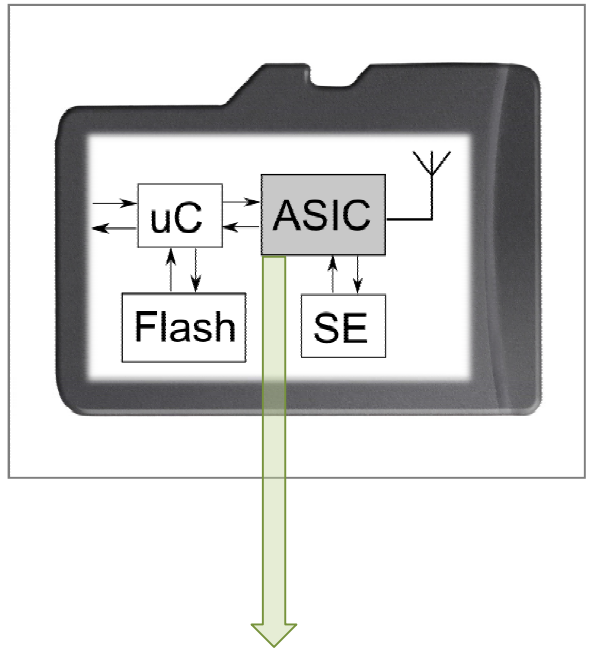
OLED for future luminance

OMS

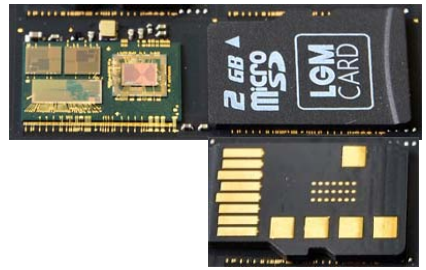
SMART Integrated systems for mobile payment

Institute of Electronics and Photonics

contactless mobile payment



3D integrated system in a MicroSD card



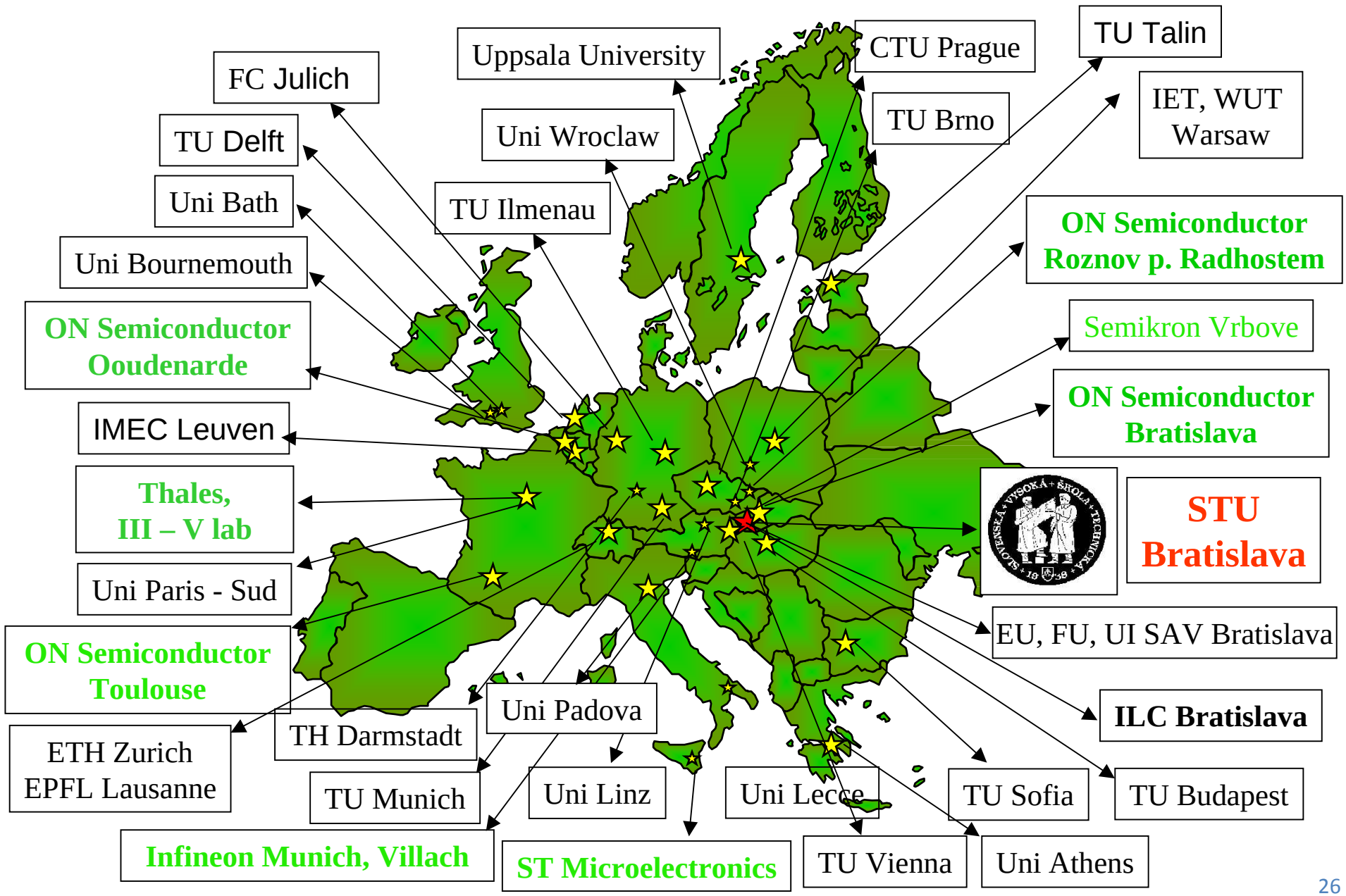
Communication ASIC :

- 4x4 mm
- CMOS 0,35 µm
- 90 µm substrate thickness
- mixed-signal (analog, digital, RF)

Technology transfer ⇒ R-DAS ⇒ Logomotion

Partnership of Institute of Electronics and Photonics FEI STU

Institute of Electronics and Photonics



Projects

7 FP Projects

- MORGaN – IP (III-V lab, Alcatel-Thales)
- SMAC - IP (ST Microelectronics)
- IDESA, IDESA 2 - CSA (IMEC)
- EURO-DOTS, EURO-DOTS 2 - CSA (IMEC)
- Guardian Angels - FET Flagship (EPFL, ETH)
- Albatross – Marie Currie (Tyndall)

1st Horizon 2020 project

- INREP (Uni Bath)

1st ECSEL projects

- PowerBase (Infineon)
- Osiris (III-V lab)

ENIAC JU Projects

- END (ON Semiconductor)
- MAS (Infineon))
- ERG (ST Microelectronics)
- E2SG (Infineon)
- E2COGaN (ON Semiconductor)
- eRamp (Infineon)
- SafeSens (NXP)

Staff Members

- 10 Full + 10 Associate Professors
- 18 Postdocs under 35 Years
- 8 Engineers (before defence of PhD)
- about 30 PhD Students

Collaboration, Technology Transfer

SME's

- NanoDesign, POWERTEC, R-DAS - spin off
- Logomotion, Lox-Technologies, Sylex, ARETA Pro, Applied Precision, Danubia Nanotech

Large Enterprise

- OMS (one of the top leading companies in lighting modules in Europe)
- ON Semiconductor (BDC)
- Samsung
- ST Microelectronics
- Infineon
- Semikron

Research Institutes – exploitation of complementary tools and methods

- International Laser Centre
- Institute of Electrical Engineering of SAS
- Institute of Informatics of SAS
- Faculty of Natural Sciences Comenius University

Application areas – Future potential

- **Quality of life (SMART sensors)**
  - Health, ageing society
  - Wellness, sport
  - Environmental monitoring
- **Low power analogue/mixed/rf IC's and systems design...**
- **New materials** (organic materials, c-nanotubes, graphen, metal oxides, wide bandgap semiconductors)
- **Organic electronics**
- **Energy harvesting (photovoltaics)**
- **Smart power devices (SJ FET, GaN, ...)**
- **Smart sensors**
- **LED/OLED lighting control (industrial electronics)**
- **Photonics.....**

Conclusions

- **Long term involvement of IEP FEI STU in KET fields**
  - experienced staff with very good physical background
  - well equipped laboratories
- **Frequent and fruitful national and international collaboration (FP 7, ENIAC JU, HORIZON 2020...)**
- **Large team of experienced researchers combined with enthusiastic young experts and PhD students**
- **Scientific school in Micro/Nano - Electronics and Photonics at STU Bratislava –** implementation of new knowledge and obtained results in related curricula, education of new young experts

The effort, enthusiasms and continual support of the institute crew is greatly appreciate

Thank you for your attention