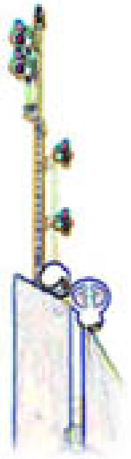
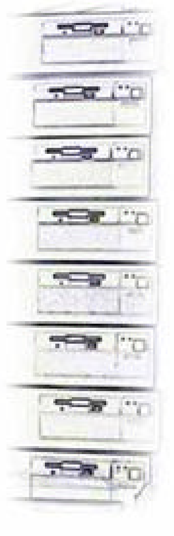
University of
Massachusetts
Dartmouth

IARIA SensorComm





Panel 2

Tuesday September 18

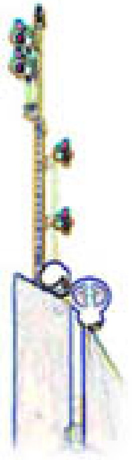
Moderator

Dr. Paul Fortier

College of Engineering: Electrical and Computer Engineering Department

Panel Topic

Advances on Miniaturization and Computation

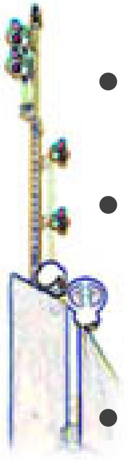


Panelist

Michal Borecki, Warsaw University of Technology, Institute of Microelectronics and Optoelectronics Poland

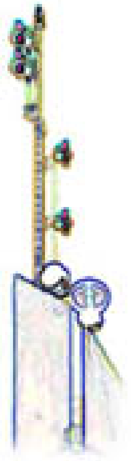
Arcady Zhukov, Department Materials Physics, Faculty of Chemistry, University Basque Country (UPV/EHU), San Sebastian, Spain and IKERBASQUE, Basque Foundation for Science, Bilbao, Spain

Are there limits to how small we can go? Or is Moore's law dead?



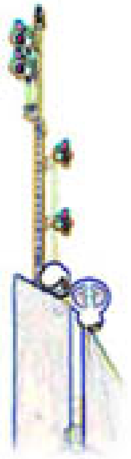
- Present technology is at ~14 nanometers across
- Proposed improvements may bring us down to Silicon's atomic size of about 0.2 nanometers
- That leaves no room for 2D architectures to continue to grow
- A new revolution is needed

What Technologies may move us forward

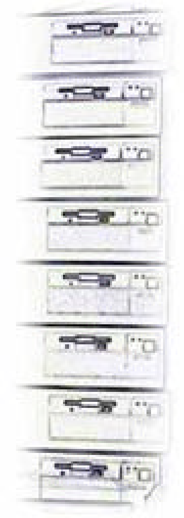


- Optics / photonics
- Quantums
- Architecture advances (SoC, SiP, SoS, ???)
- Wafer manufacturing improvements (TSV and wafer stacking
- Materials (CNT, Graphene fibers, glass, …

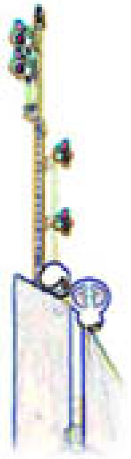
Are HW Technology Advances Enough?



- SoC, SiP, SoS, …. Where is their limit?
- Is the CLOUD the answer??
- Quantum Computing ???
- Photonic Computing???
- New model?

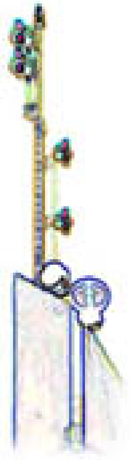


What about advances in Computation



- Decentralized processing
- Massive parallelism
- Cloud computing (but at what cost?? Lose control of source)
- New Algorithms supporting increased processing capacity

Algorithms and the Cloud



- What can we hope for the cloud and algorithms running on it to deliver?

Miniaturization is not simply Processors and memory

Shrinking sensors, actuators, combined technologies, e.g. NEMS, MEMS, etc

Gains may come from other places in the application

IoT, massive data production, data always available from anywhere and anytime for almost any conceivable use, what may come from this?

New computational models

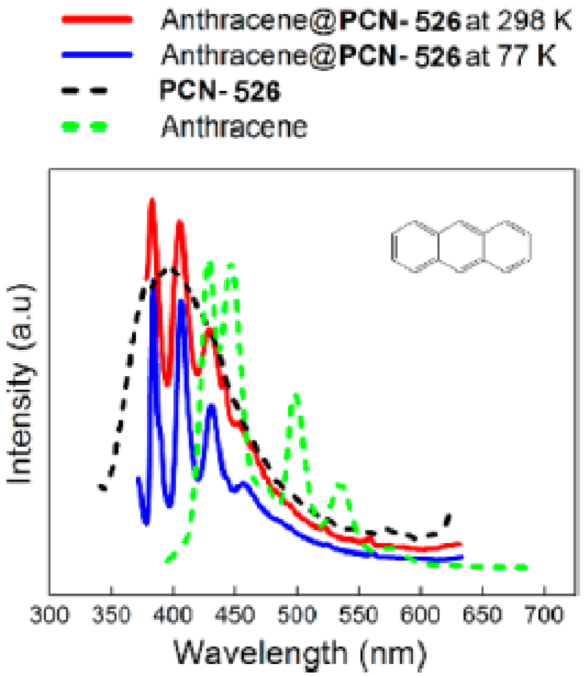
New Architectural models (relieve the memory bottleneck)

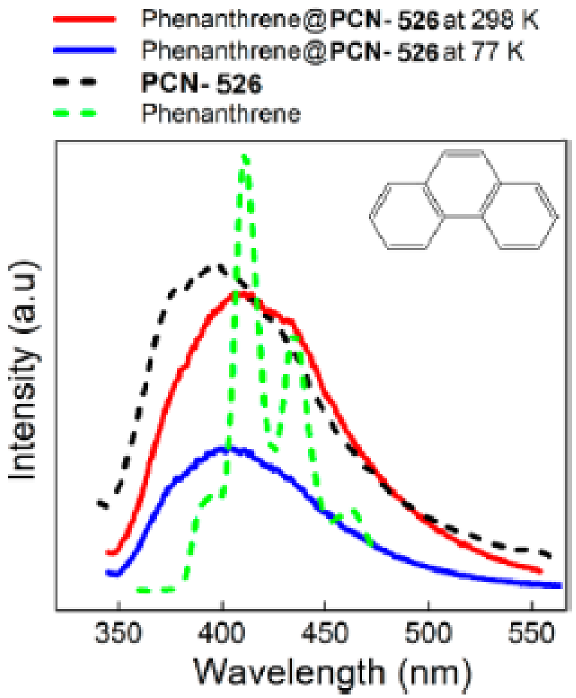
Optoelectronics sensors miniaturization - outlier data generation and automatic rejection

M. Borecki

Warsaw University of Technology, 75 Koszykowa Str., 00-662 Warsaw, Poland

Extension of fluorescence tests with controlled temperature of the medium





The emission spectrum of
Porous Coordination Network (PCN)
Anthracene
Anthracene@PCN at 298 K (red)
Anthracene@PCN at 77 K (blue)

The emission spectrum of
Porous Coordination Network (PCN)
Phenanthrene
Phenanthrene@PCN at 298 K (red)
Phenanthrene@PCN at 77 K (blue)

Dahuan Liu et al., „A Reversible Crystallinity-Preserving Phase Transition in Metal–Organic Frameworks: Discovery, Mechanistic Studies, and Potential Applications," J. Am. Chem. Soc., 2015, 137 (24), pp 7740–7746

Standard and capillary liquid vessels and probes

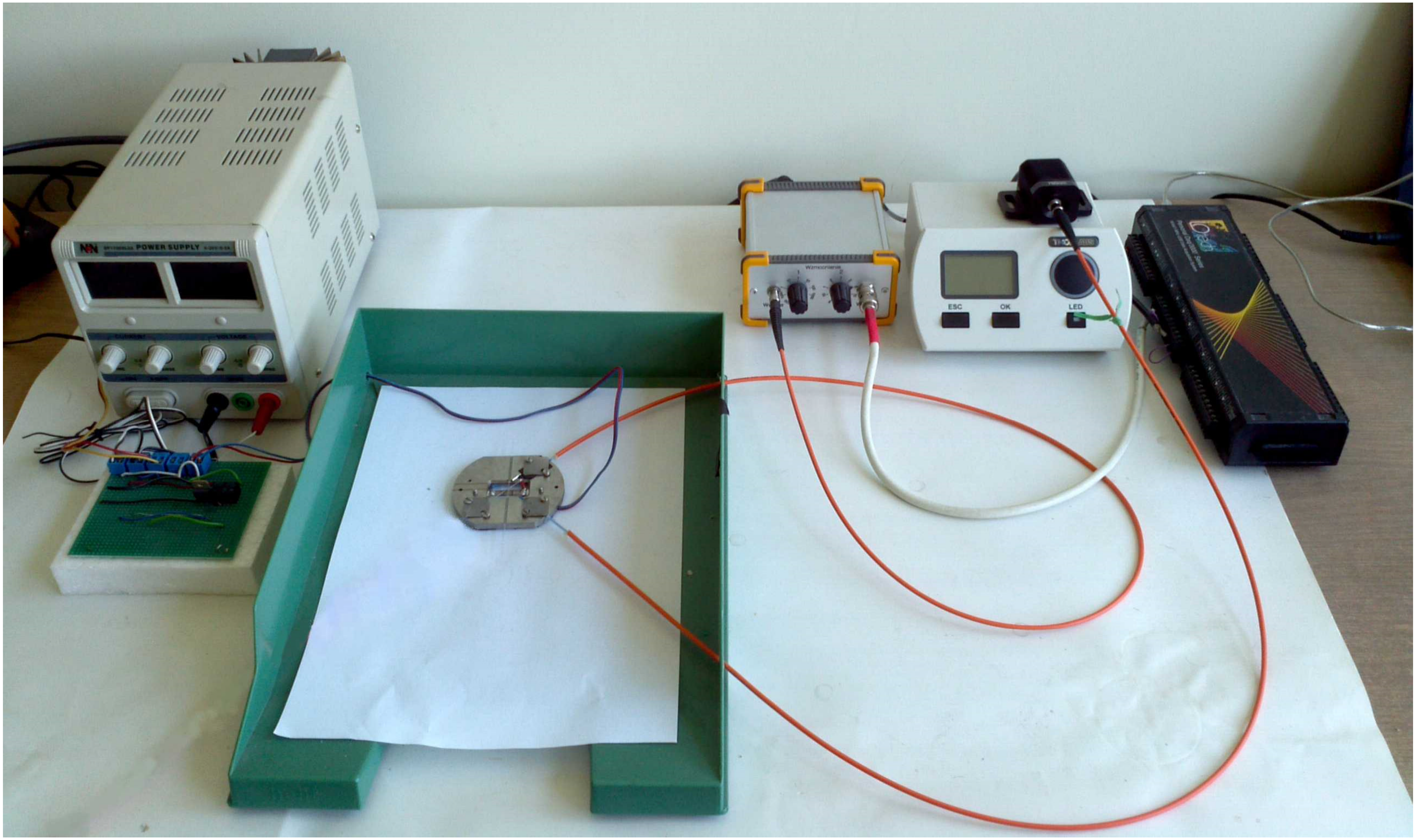
Plastic
small volume
cuvette

Ocean optics;
small volume capillary sampling

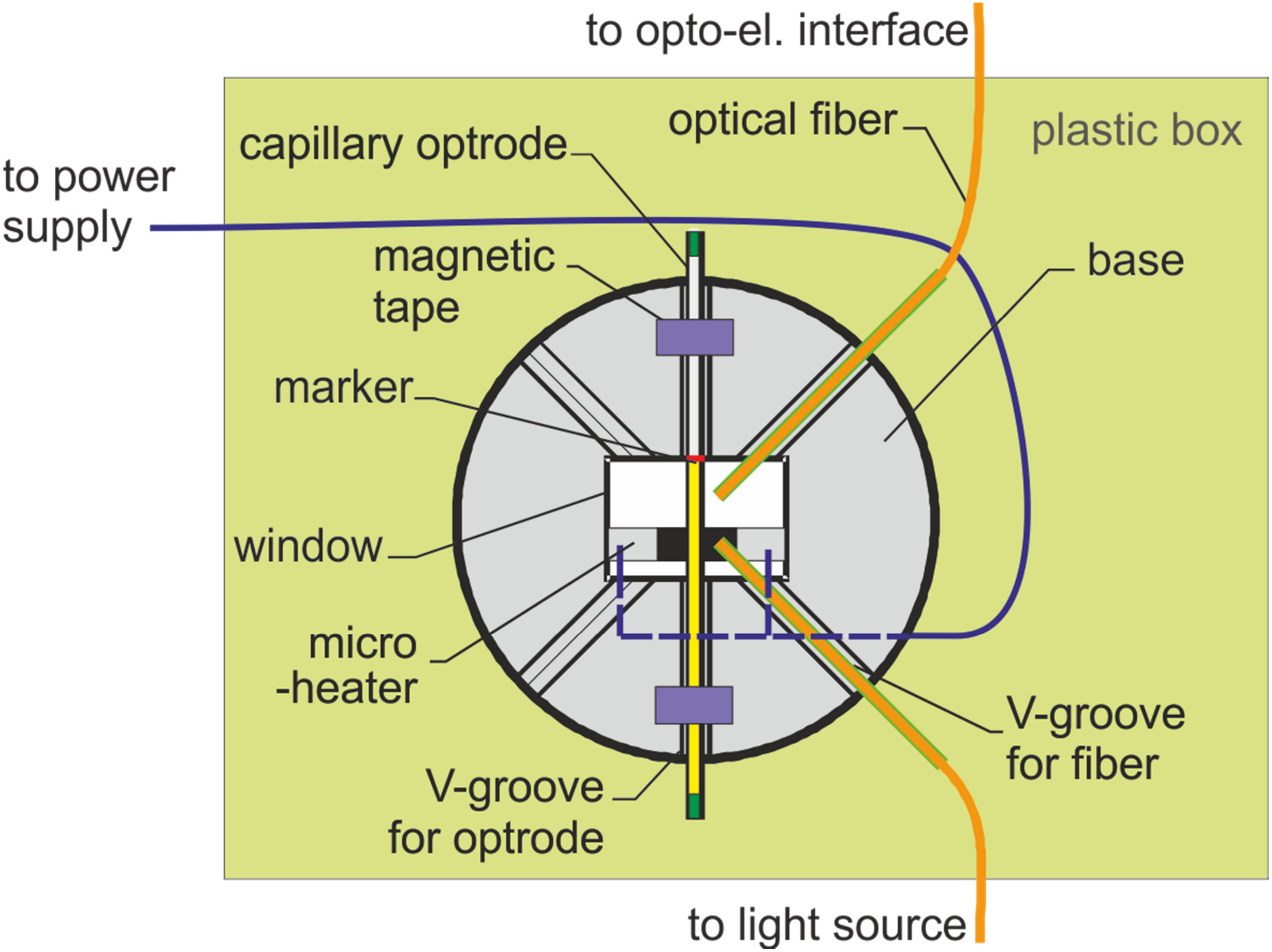
GE healthcare;
UV-grade capillary cell
(130-1100EUR)

When a capillary optrode CV7087Q is considered, the approximated fluorescent aperture is 0.7mm. This fluorescent aperture is 10 times lower than when a classical cuvette is used. Therefore, the optical power used for excitation of fluorescence in the proposed head may be significantly lower (100 times) than when a commercial spectrophotometer integrated device is used.

Capillary sensor set-up with local sample heating

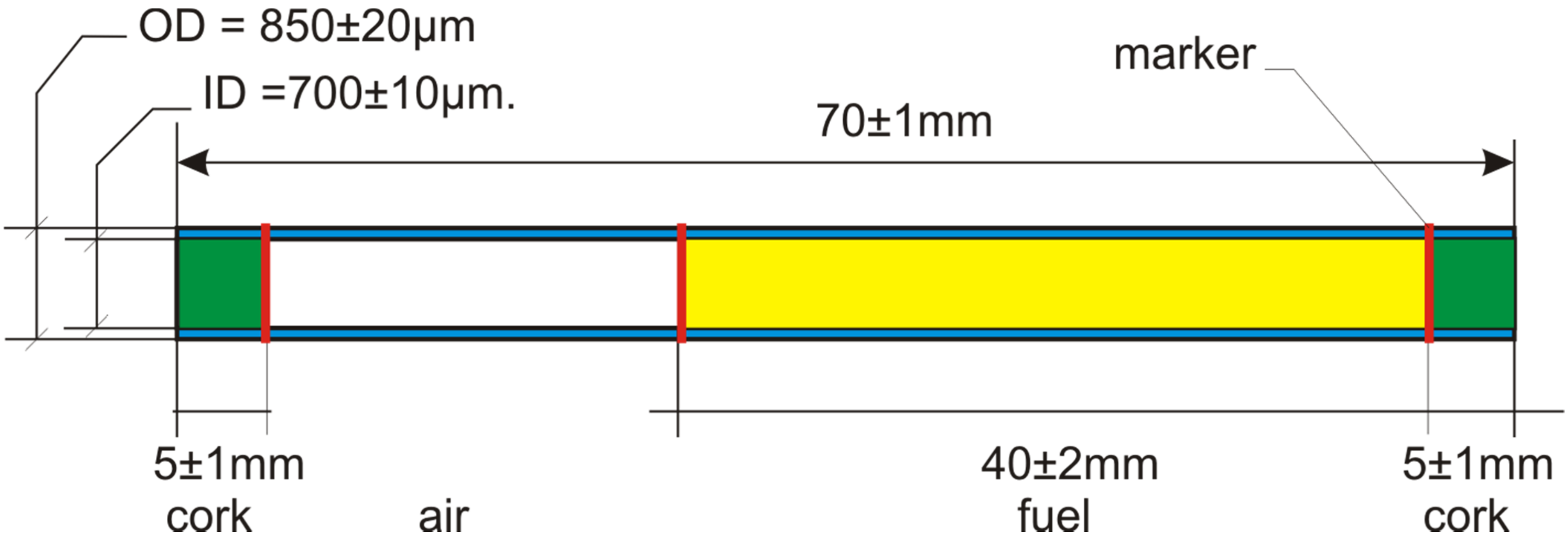


Capillary sensor head



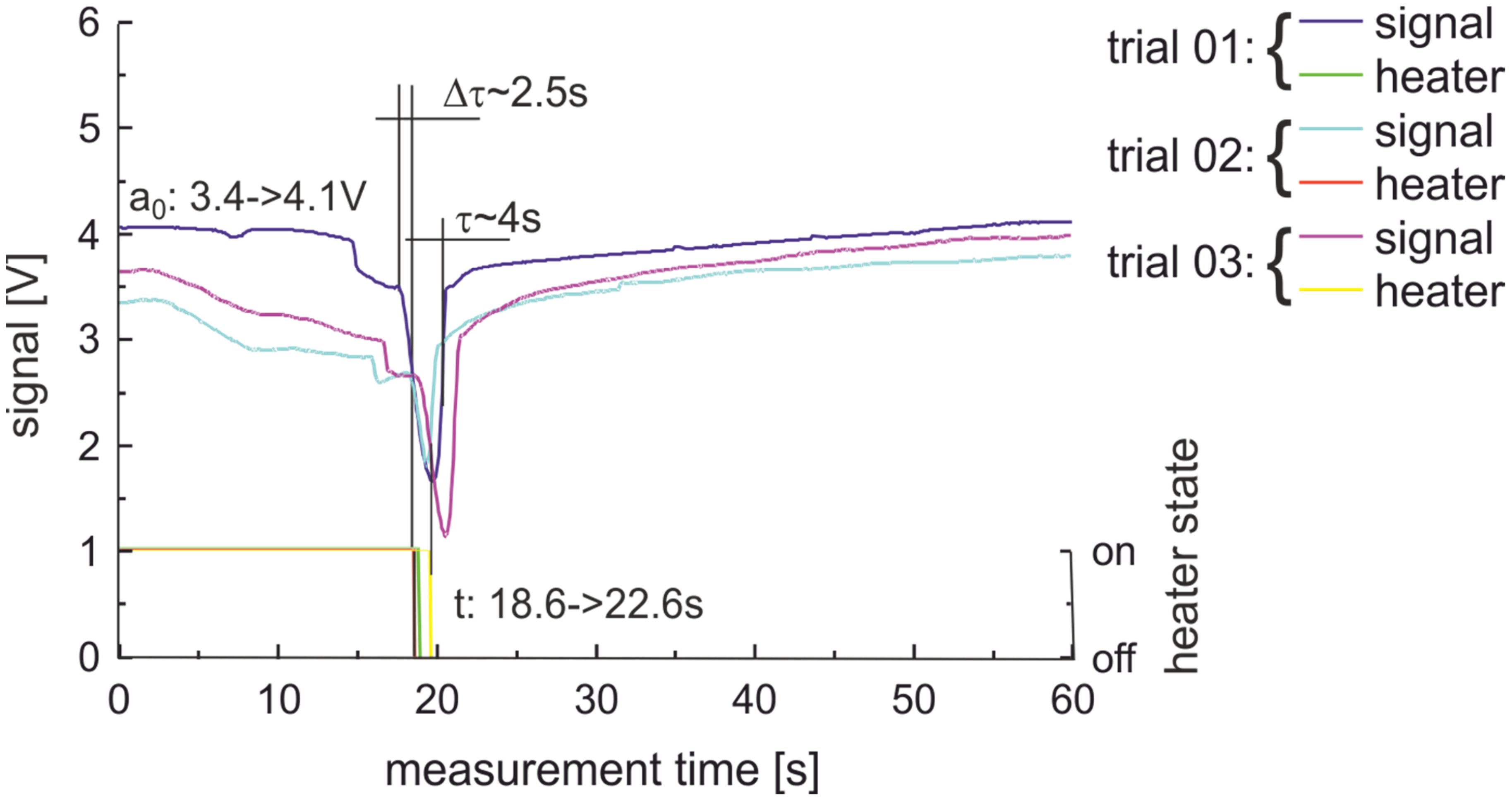
Capillary optrode

Reduction of optrode dimension increases the effect of imperfections on the measurement result

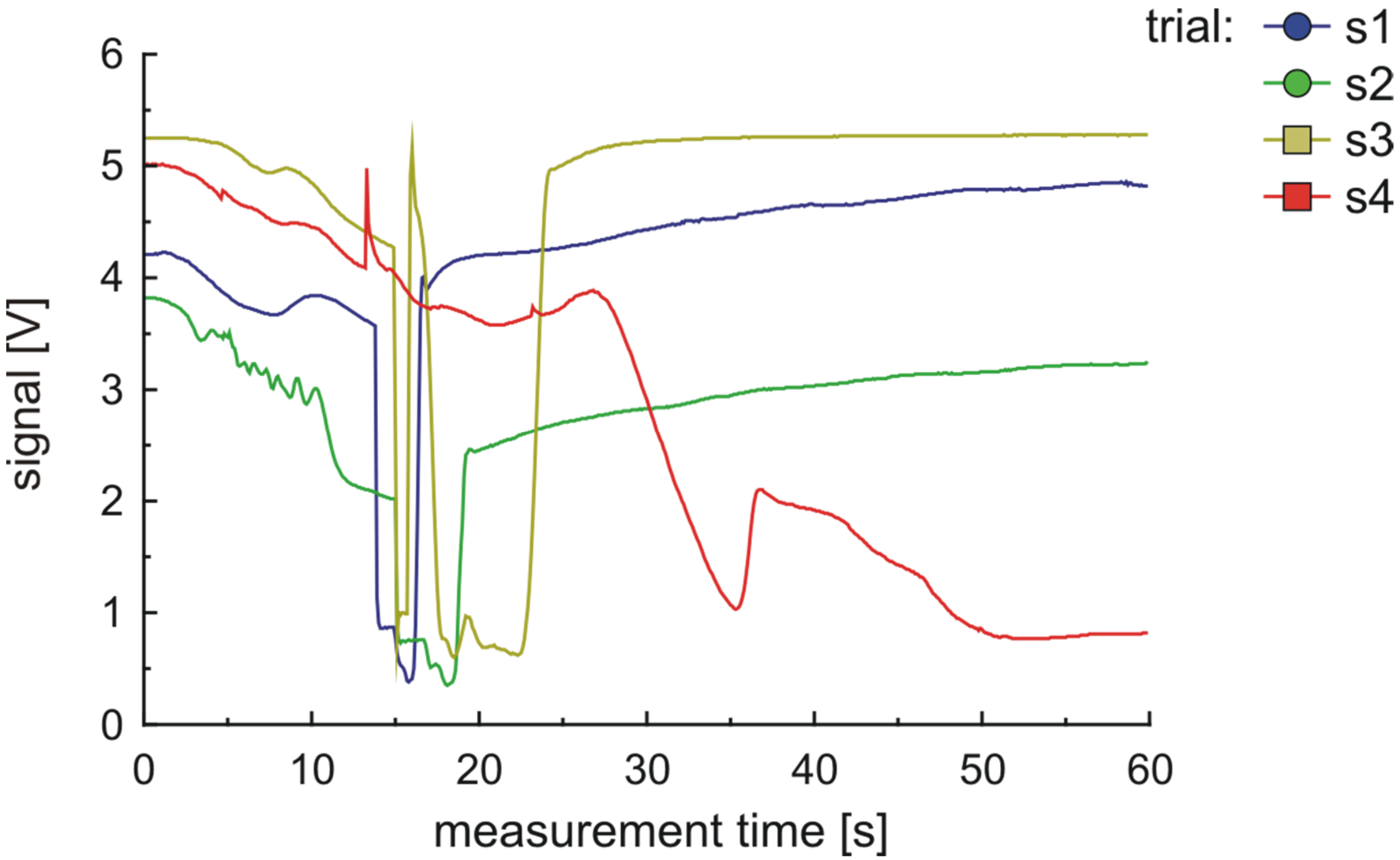


M. Borecki; P. Prus; M. L. Korwin-Pawlowski; P. Doroz; J. Szmidt, „Automatic detection of outlier data received in multi-parametric capillary sensors of diesel fuels fit for use", Proc. SPIE 10808,, 108080A (1 October 2018); doi: 10.1117/12.2500289

100% bio-diesel fuel properly examined



Data registered by untrained operator of 70% bio-diesel fuel



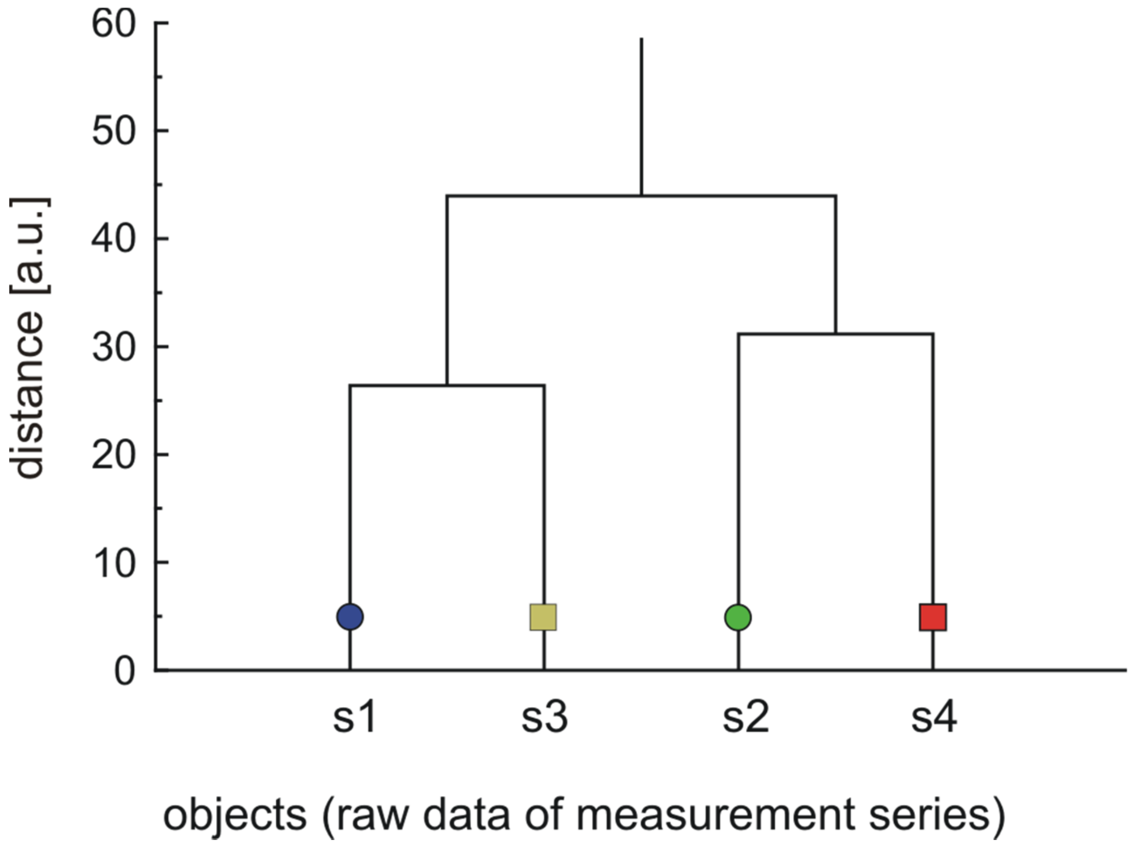
s1 and s2 – proper data; s3 uncertain data; s4 outlier data

M. Borecki; P. Prus; M. L. Korwin-Pawlowski; P. Doroz; J. Szmidt, „Automatic detection of outlier data received in multi-parametric capillary sensors of diesel fuels fit for use”, Proc. SPIE 10808,, 108080A (1 October 2018); doi: 10.1117/12.2500289

Dendrogram cluster analysis

of raw data signals registered by untrained operator

Direct application of cluster analysis does not support the desired results



s1 and s2 – proper data; s3 uncertain data; s4 outlier data

The vector pattern of data created on the base of physical phenomena of measurement

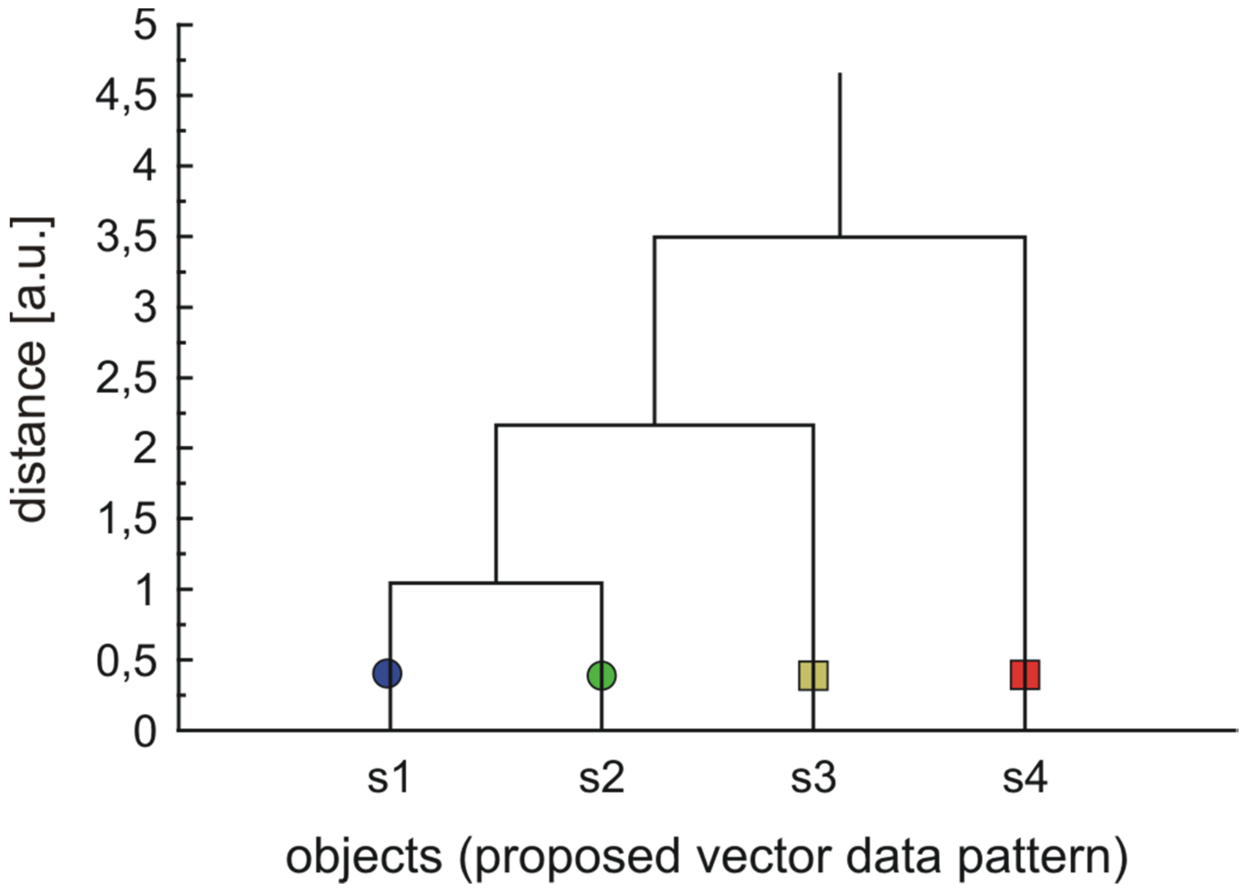
Trial number	**time of local heating required to vapor phase creation (t) [s]**	**time of vapor phase existence (t) [s]**	**first maximum of derivative (pd1) [V/s]**
s1	13	3	-1.5
s2	15	5	-0.75
s3	15	9	-1.75
s4	35	3	0.5

data of signals registered by untrained operator

s1 and s2 – proper data; s3 uncertain data; s4 outlier data

Dendrogram cluster analysis of vector pattern

of data registered by untrained operator



s1 and s2 – proper data; s3 uncertain data; s4 outlier data

M. Borecki; P. Prus; M. L. Korwin-Pawlowski; P. Doroz; J. Szmidt, „Automatic detection of outlier data received in multi-parametric capillary sensors of diesel fuels fit for use”, Proc. SPIE 10808,, 108080A (1 October 2018); doi: 10.1117/12.2500289

CONCLUSION

1. Outlier data generation as a result of complex measurement procedures seems quite probable, especially when measurement is performed by untrained operators.
2. Detection of outlier data received in multi-parametric capillary sensors is essential in sensor automation.
3. Uncertainties of raw data in capillary sensor with local sample heating are results of similar amplitude course of registered signal for optrode improperly filled and turbid flow of liquids.
4. Two techniques of digital automated signal processing were examined.
   - Results show the failure of classic statistical raw data processing with cluster analysis aimed for outlier detection.
   - Cluster analysis applied for processed data to the vector form of pattern results are correct. The use of vector pattern of data is effective when physical phenomena of the measuring procedure are taken into account.
   - For statistical data analyses the well defined set of data is required.

eman ta zabal zazu
Universidad del País Vasco
Euskal Herriko Unibertsitatea

ikerbasque
Basque Foundation for Science

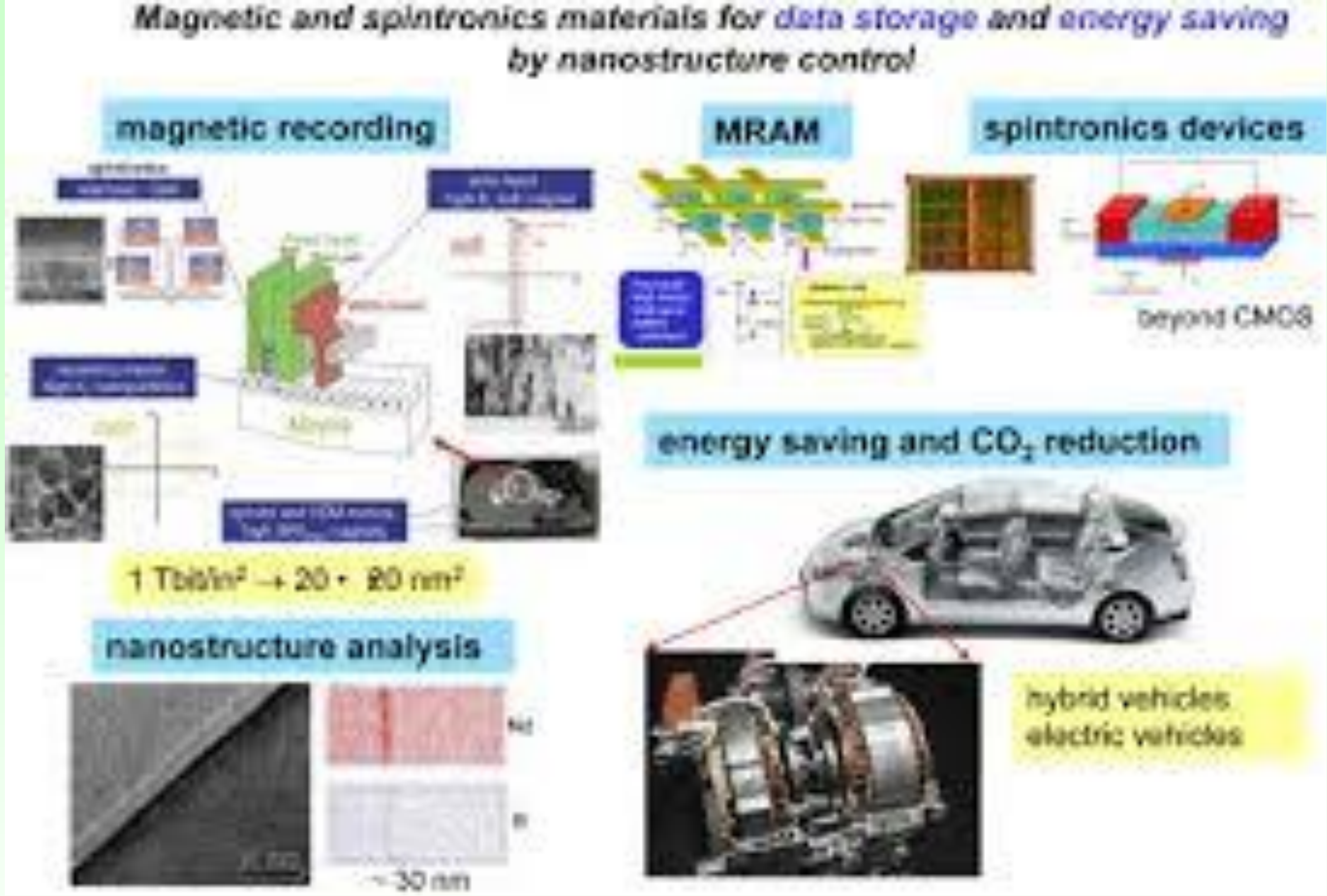
The University of the Basque Country
Faculty of Chemistry
Department of Material Physics
Magnetism Research Group

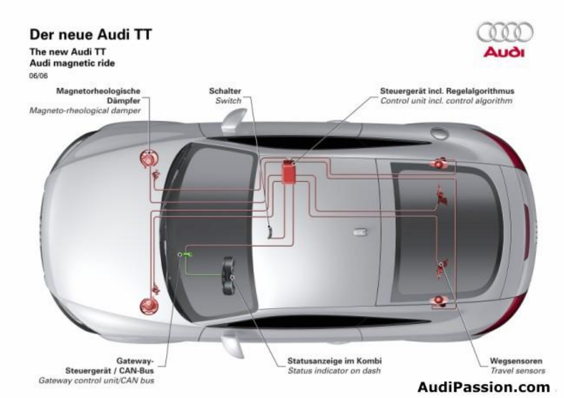
Magnetic sensor: last tendencies

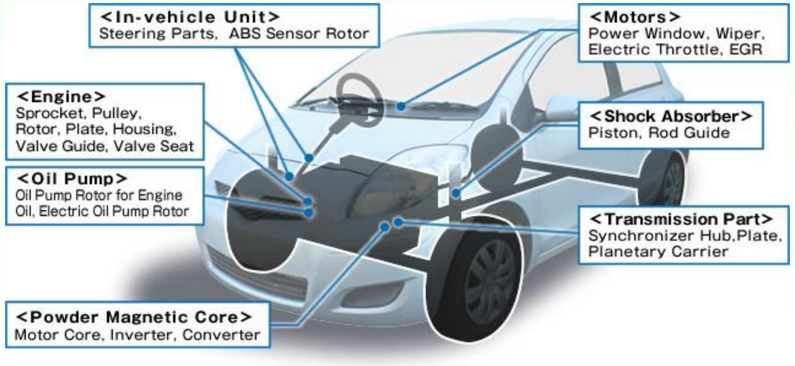
A. Zhukov[1,2,3]

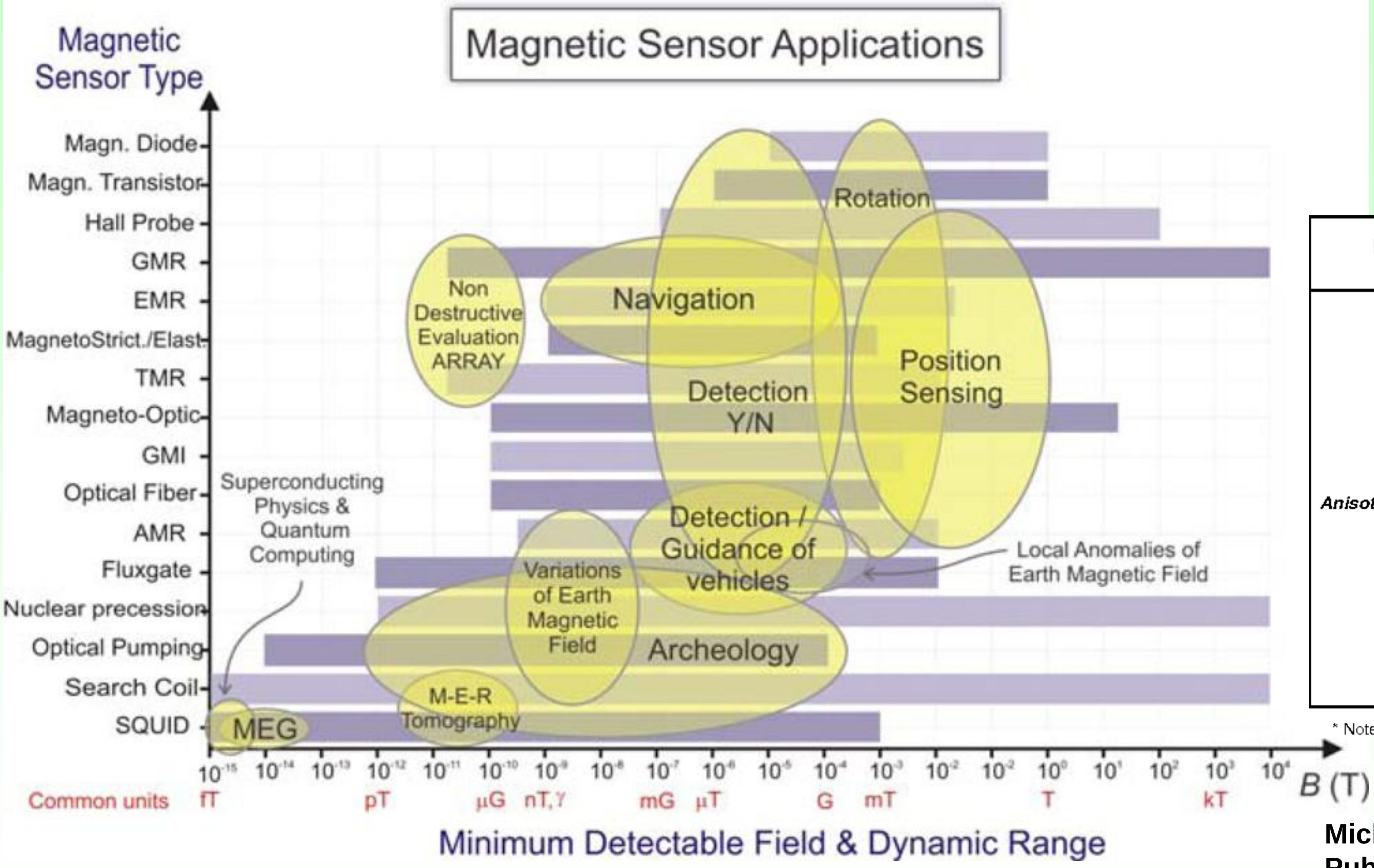
[1]Dpto. de Fís. Mater., UPV/EHU San Sebastián 20009, Spain
[2]Dpto. de Fís. Aplicada., UPV/EHU San Sebastián 20009, Spain
[3] Ikerbasque, Basque Foundation for Science , Bilbao, Spain.

Applicaions of Magnetic materials

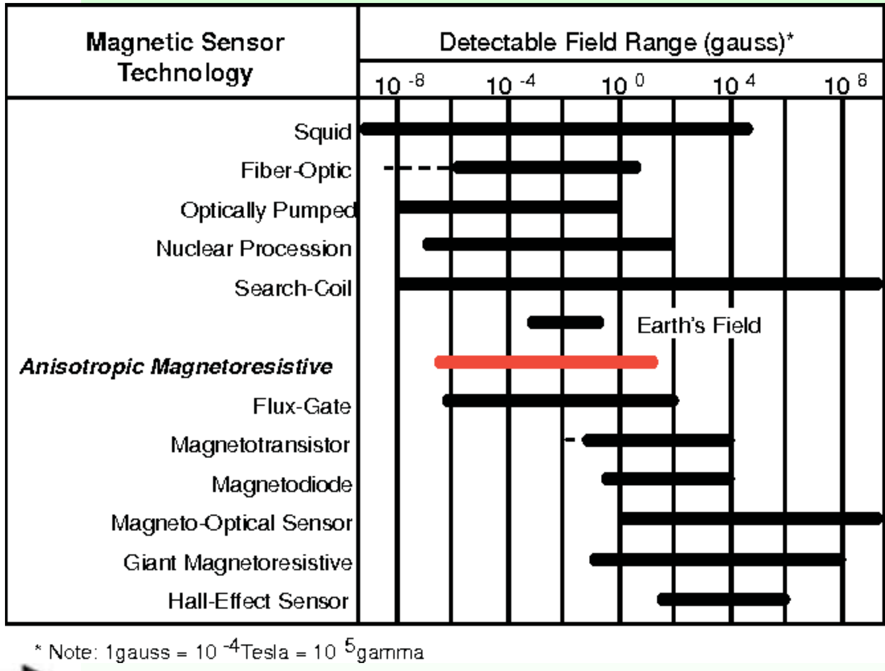






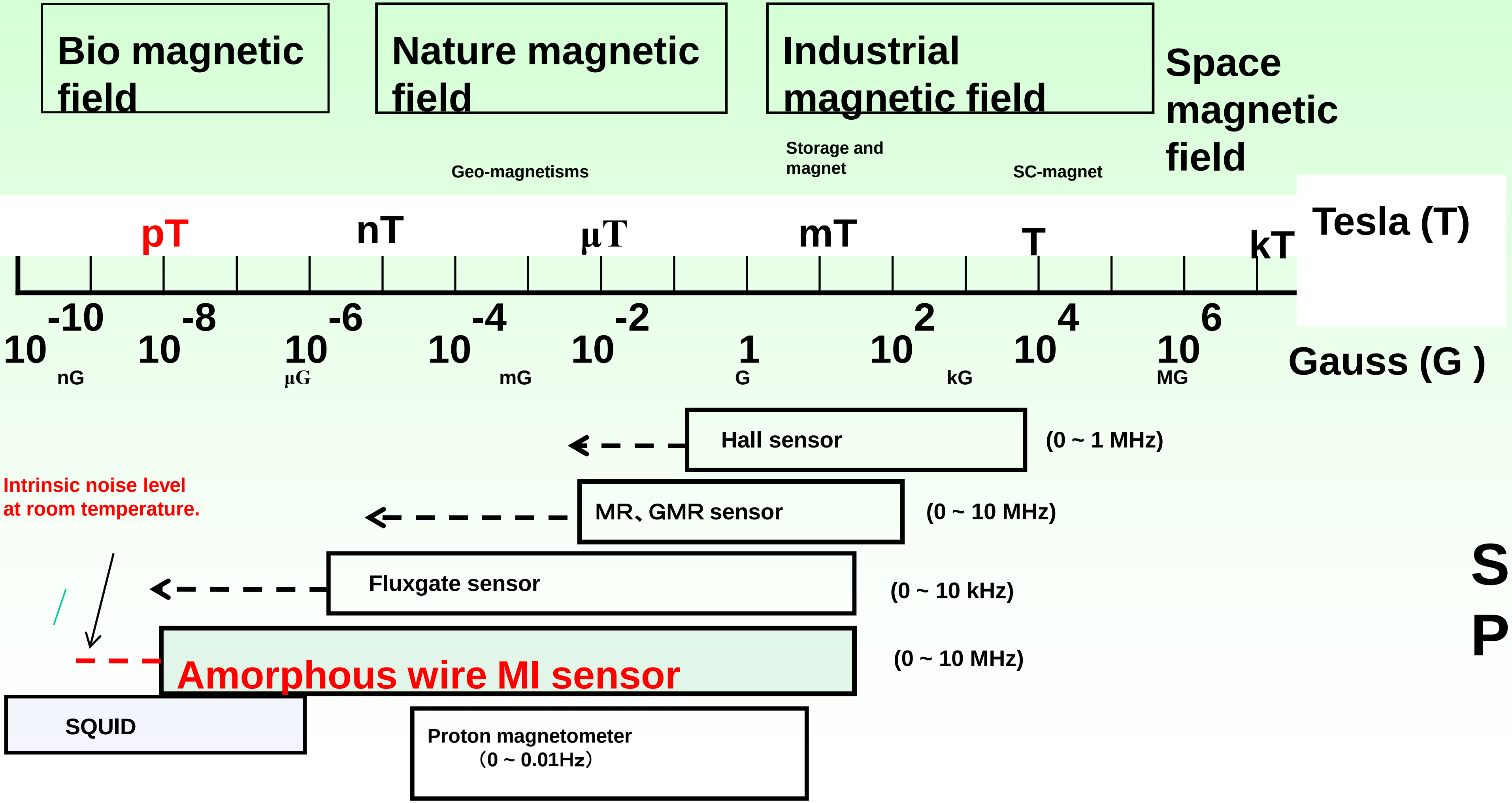


Source: M. Díaz-Michelena *Sensors* **2009**, *9*(4), 2271-2288; doi:10.3390/s90402271



Michael J. Caruso, Lucky S. Withanawasam
Published 1999

Magnetic Field and Magnetic Sensors



Bio magnetic field

Nature magnetic field

Industrial magnetic field

Space magnetic field

Geo-magnetisms

Storage and magnet

SC-magnet

pT nT µT mT T kT **Tesla (T)**

10^{-10} nG 10^{-8} 10^{-6} µG 10^{-4} mG 10^{-2} 1 G 10^{2} kG 10^{4} 10^{6} MG **Gauss (G)**

Hall sensor (0 ~ 1 MHz)

MR、GMR sensor (0 ~ 10 MHz)

Fluxgate sensor (0 ~ 10 kHz)

Amorphous wire MI sensor (0 ~ 10 MHz)

SQUID

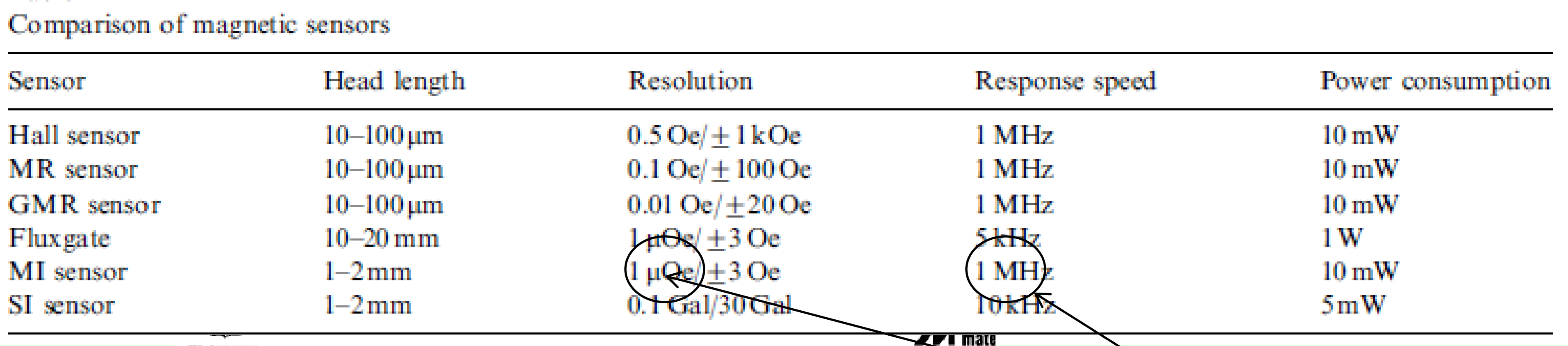
Proton magnetometer
（0 ~ 0.01Hz）

Intrinsic noise level
at room temperature.

Source–
Prof. K.Mohri

Magnetic sensors:

Comparison of different magnetic field detection methods

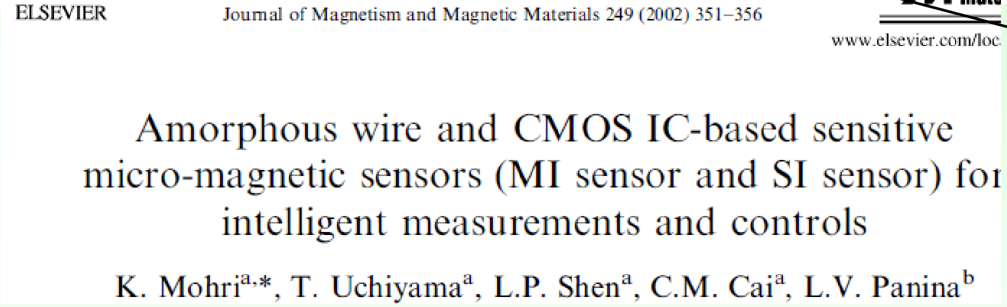


Comparison of magnetic sensors

Sensor	Head length	Resolution	Response speed	Power consumption
Hall sensor	10–100 μm	0.5 Oe/±1 kOe	1 MHz	10 mW
MR sensor	10–100 μm	0.1 Oe/±100 Oe	1 MHz	10 mW
GMR sensor	10–100 μm	0.01 Oe/±20 Oe	1 MHz	10 mW
Fluxgate	10–20 mm	1 μOe/±3 Oe	5 kHz	1 W
MI sensor	1–2 mm	1 μOe/±3 Oe	1 MHz	10 mW
SI sensor	1–2 mm	0.1 Gal/30 Gal	10 kHz	5 mW

Advantages

Source



ELSEVIER

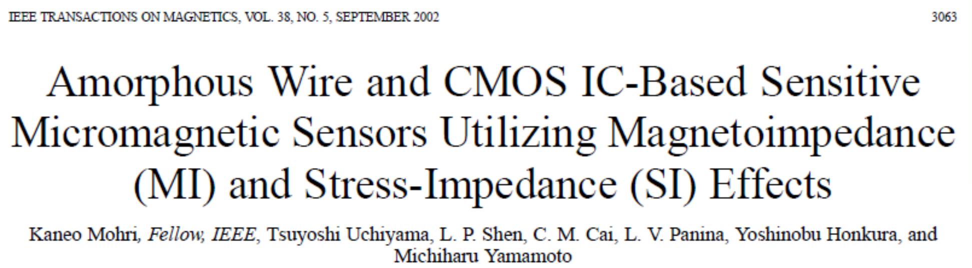
Journal of Magnetism and Magnetic Materials 249 (2002) 351–356

www.elsevier.com/loc

Amorphous wire and CMOS IC-based sensitive micro-magnetic sensors (MI sensor and SI sensor) for intelligent measurements and controls

K. Mohri[a,*], T. Uchiyama[a], L.P. Shen[a], C.M. Cai[a], L.V. Panina[b]

Source



IEEE TRANSACTIONS ON MAGNETICS, VOL. 38, NO. 5, SEPTEMBER 2002 3063

Amorphous Wire and CMOS IC-Based Sensitive Micromagnetic Sensors Utilizing Magnetoimpedance (MI) and Stress-Impedance (SI) Effects

Kaneo Mohri, *Fellow, IEEE*, Tsuyoshi Uchiyama, L. P. Shen, C. M. Cai, L. V. Panina, Yoshinobu Honkura, and Michiharu Yamamoto

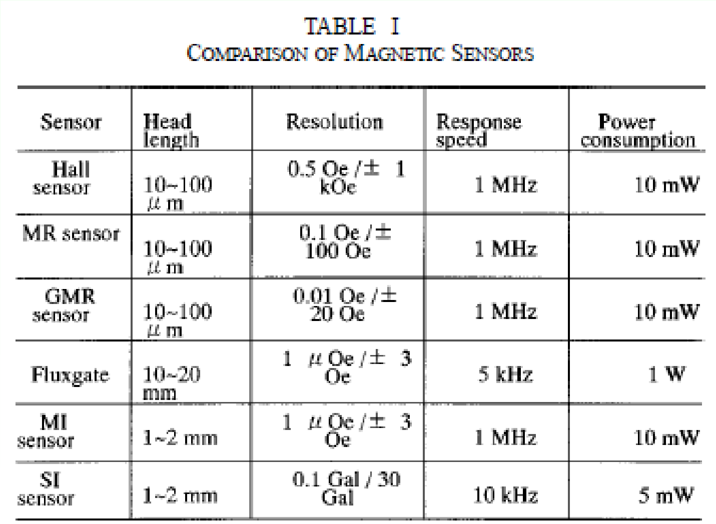
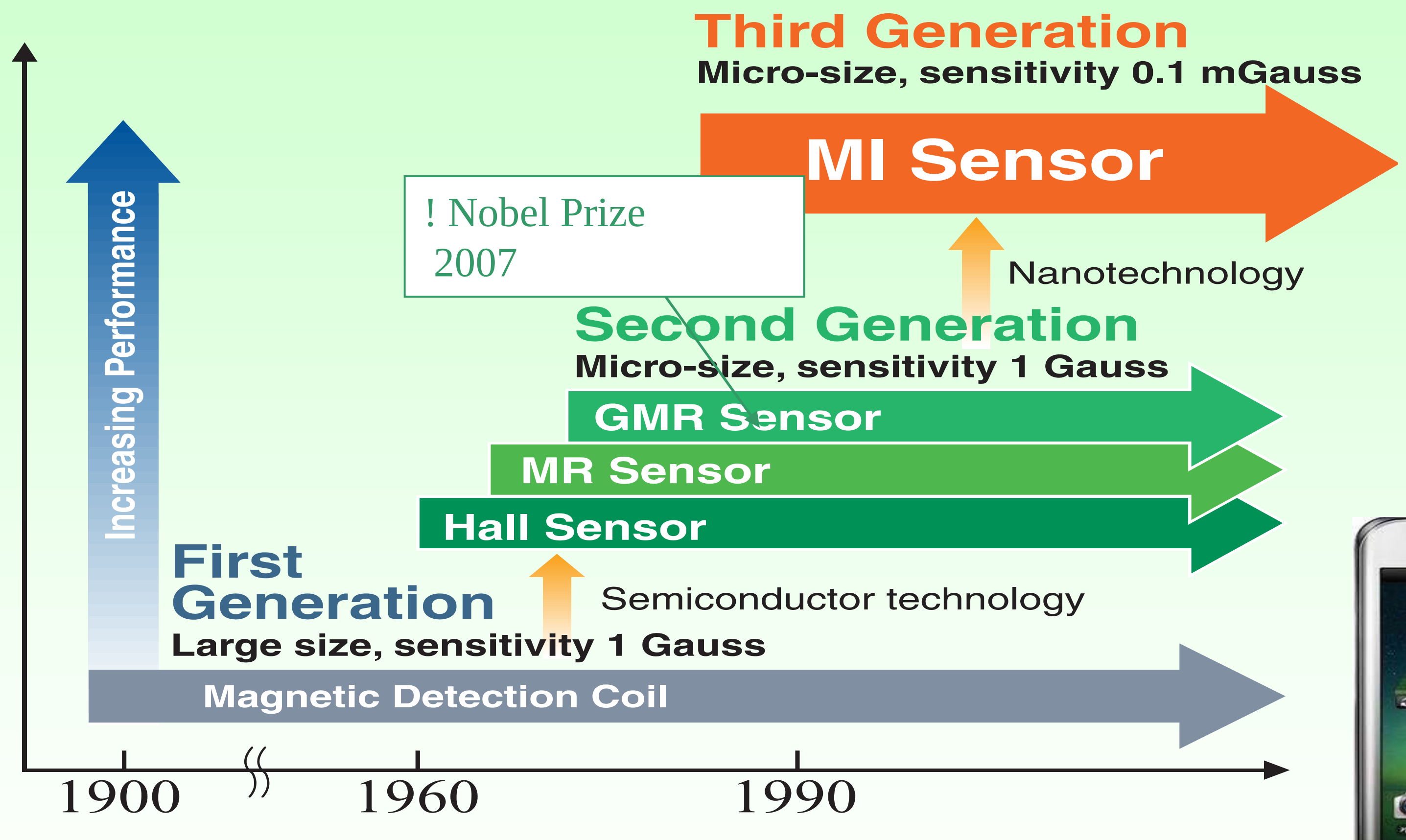


TABLE I
COMPARISON OF MAGNETIC SENSORS

Sensor	Head length	Resolution	Response speed	Power consumption
Hall sensor	10~100 μm	0.5 Oe /± 1 kOe	1 MHz	10 mW
MR sensor	10~100 μm	0.1 Oe /± 100 Oe	1 MHz	10 mW
GMR sensor	10~100 μm	0.01 Oe /± 20 Oe	1 MHz	10 mW
Fluxgate	10~20 mm	1 μOe /± 3 Oe	5 kHz	1 W
MI sensor	1~2 mm	1 μOe /± 3 Oe	1 MHz	10 mW
SI sensor	1~2 mm	0.1 Gal / 30 Gal	10 kHz	5 mW

Third Generation of Magnetic Sensors

MI element based on Amorphous Microwire



Third Generation

Micro-size, sensitivity 0.1 mGauss

MI Sensor

! Nobel Prize 2007

Nanotechnology

Second Generation

Micro-size, sensitivity 1 Gauss

GMR Sensor

MR Sensor

Hall Sensor

First Generation

Semiconductor technology

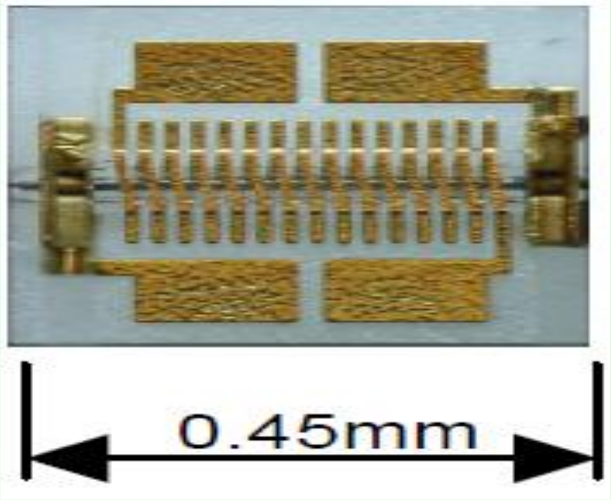
Large size, sensitivity 1 Gauss

Magnetic Detection Coil

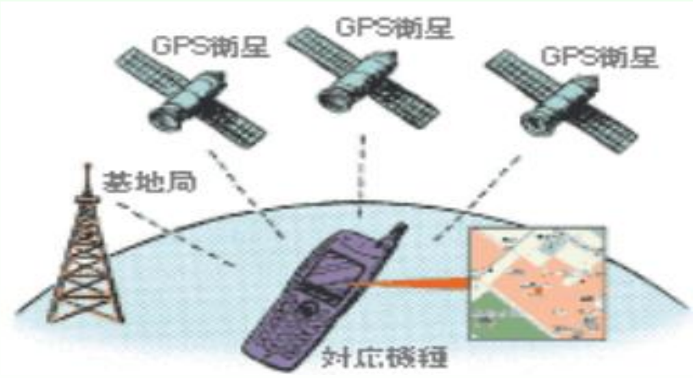
Increasing Performance

1900 1960 1990

Magnetic Sensor History



Based on Amorphous Microwire since 2010



Industrial application in Smart phone using MI sensor

Last tendencies: Size reduction, frequency increasing

Source: Aichi Micro Intelligent Corporation

GMI applications

MI element based on Amorphous Microwire

CASIO 2013.June 68250yen

Amorphous wire：
（glass-coated wire）
Metal dia. ： 11.3 μm
Total wire ： 14.5 μm
Wire length： 520 μm

Amorphous Wire 3-axis Electronic Compass chip:*AMI 306*

Resolution	0.16 μT （160 nT）
Dynamic range	± 1.2 mT （ ±12 Oe）
Power voltage Vdd	1.7 V
Power current Ｉdd	150 μA
Power consumption	255 μW
Operating temperature	−45 ～ 80 ℃
Chip dimension	2.04 × 2.04 × 1.0 mm
Reversibility for big disturbance magnetic field shock	∞

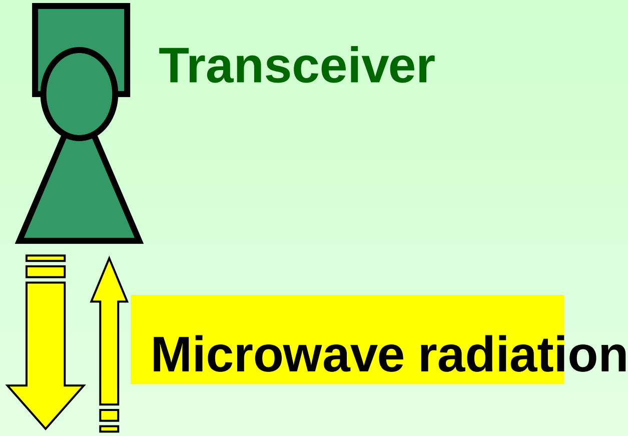
Advantageous of MI sensor :

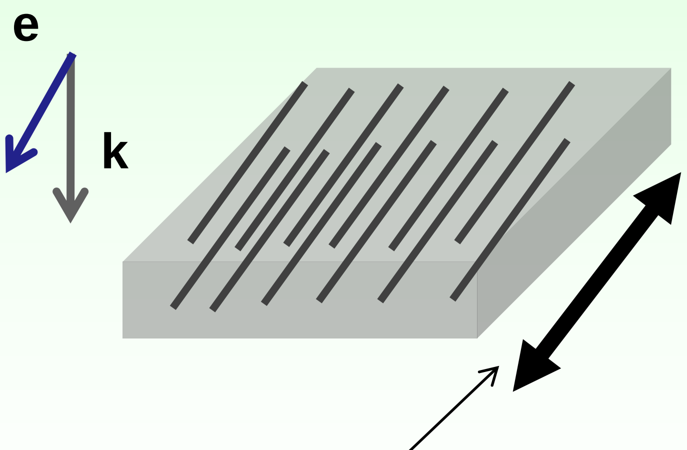
1) Micro size and small power consumption (sub-mW)
2) High sensitivity with resolution of 0.01 % for dynamic range (Pico-Tesla resolution)
3) Quick response with GHz
4) High reversibility for big magnetic field disturbance shock
5) High temperature stability

Advanced 3−axis MI sensor chip installed in watch

Rovided by Prof. K. Mohri

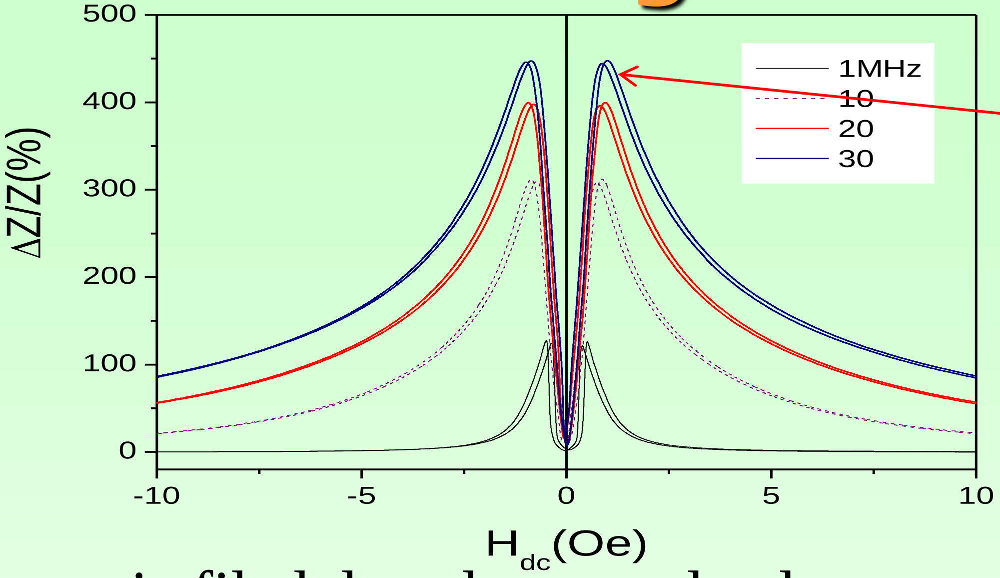
Smart composites fo NDC



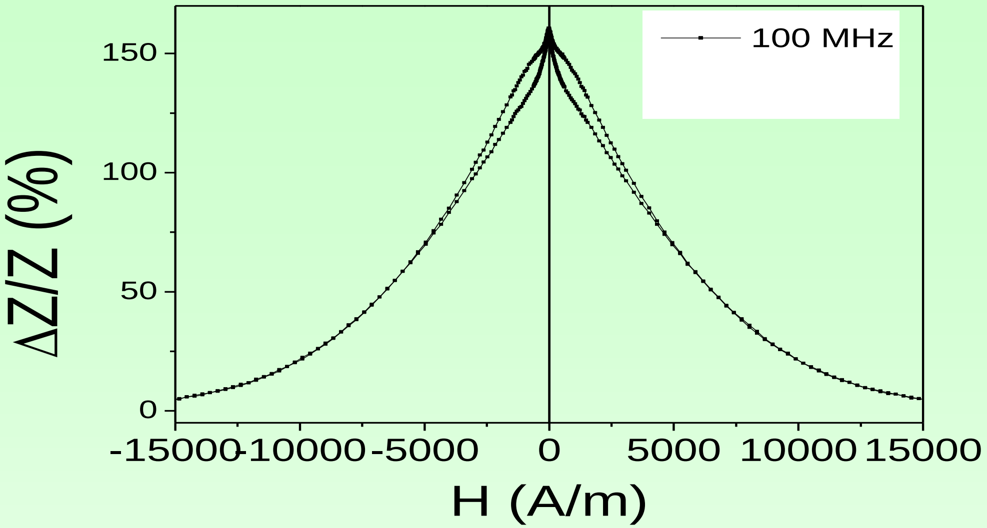


External stimuli: strain, compression, magnetic field, or heating

Giant Magneto-impedance effect

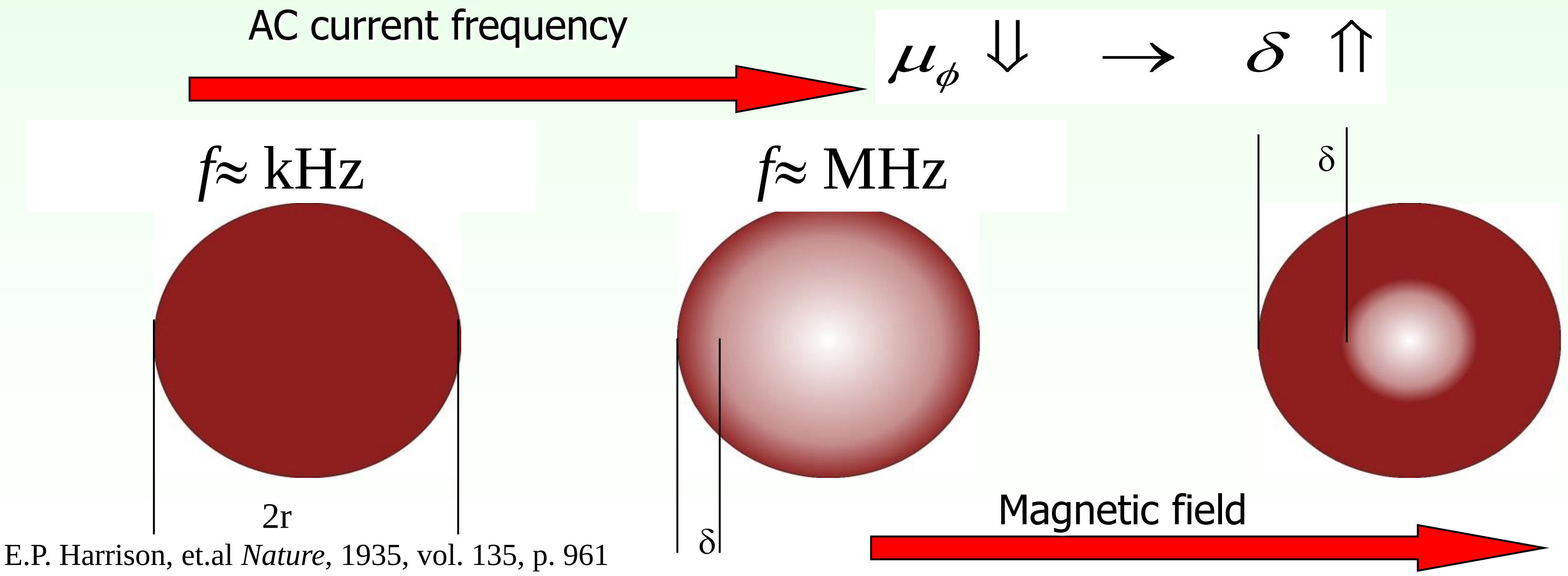


500% change per 1 Oe



Magnetic filed depedence and value are affected by magnetic anisotropy

- Skin Effect of the Magnetic Conductor



E.P. Harrison, et.al *Nature*, 1935, vol. 135, p. 961

$$\delta = \sqrt{\frac{\rho}{\pi \mu_\phi f}}$$

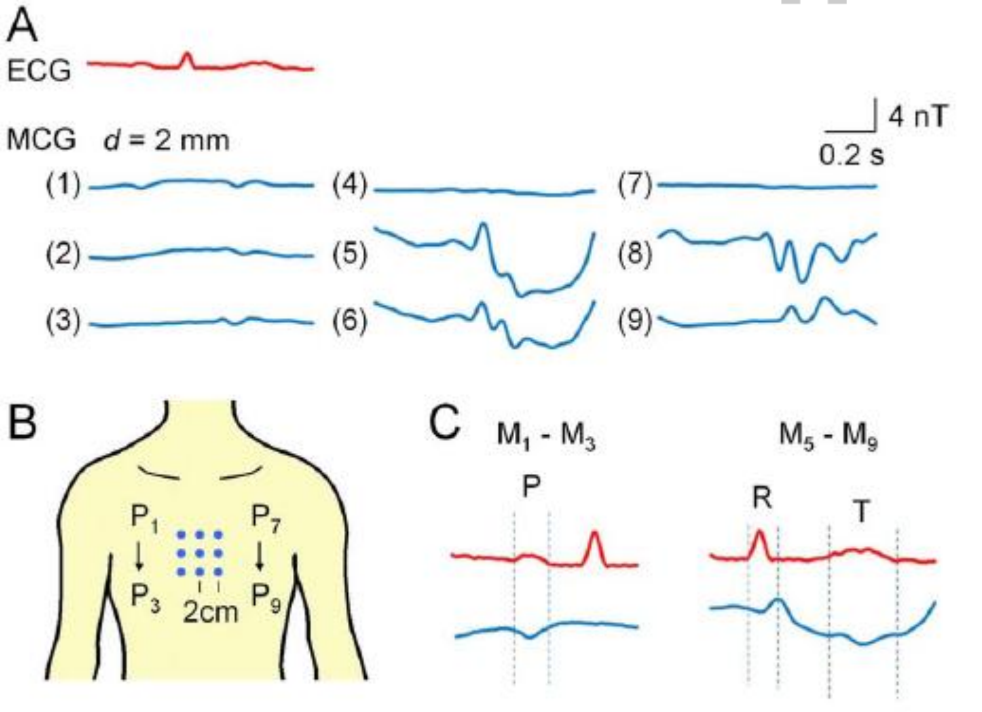
$\mu_\phi(H,f)$

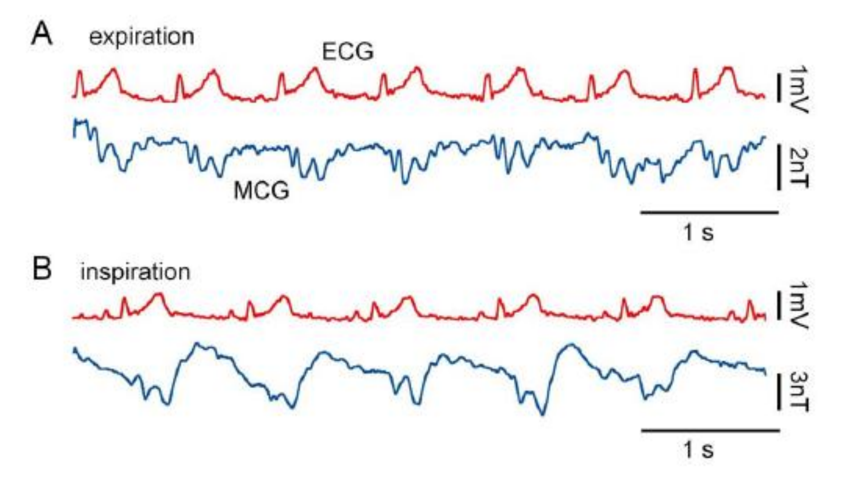
$$\delta < r$$

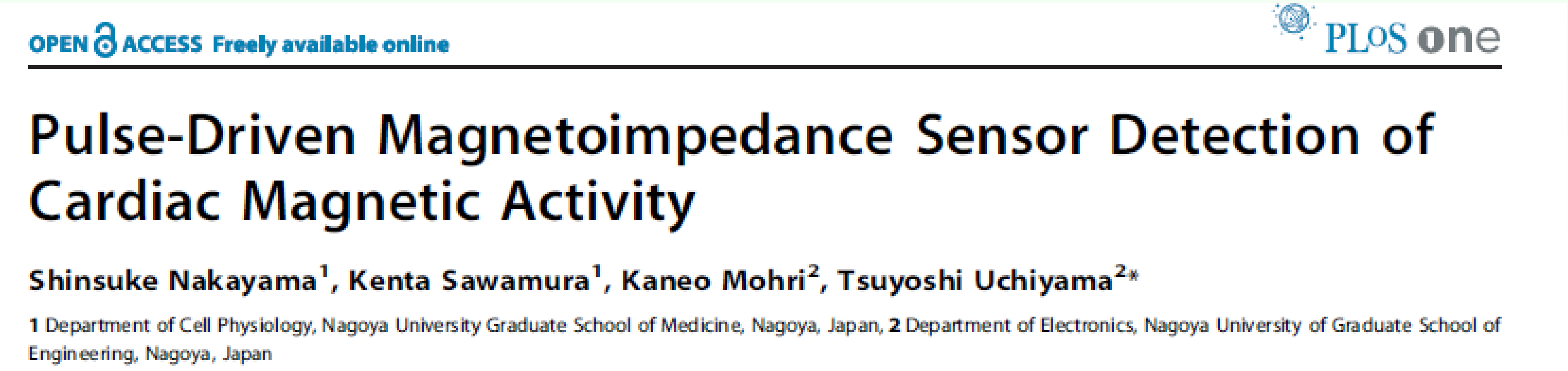
(at high enough f)

Z(H)

GMI sensors pplications for health monitoring







OPEN ACCESS Freely available online

PLoS one

Pulse-Driven Magnetoimpedance Sensor Detection of Cardiac Magnetic Activity

Shinsuke Nakayama[1], Kenta Sawamura[1], Kaneo Mohri[2], Tsuyoshi Uchiyama[2]*

[1] Department of Cell Physiology, Nagoya University Graduate School of Medicine, Nagoya, Japan, [2] Department of Electronics, Nagoya University of Graduate School of Engineering, Nagoya, Japan

Magnetic materials…



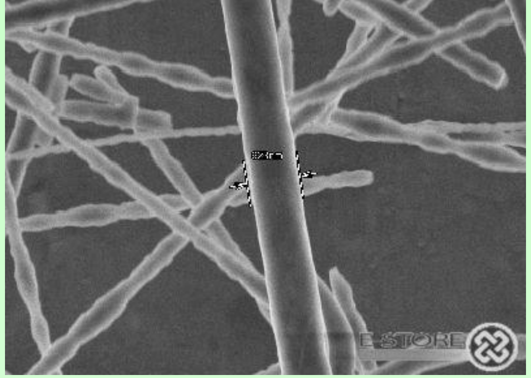






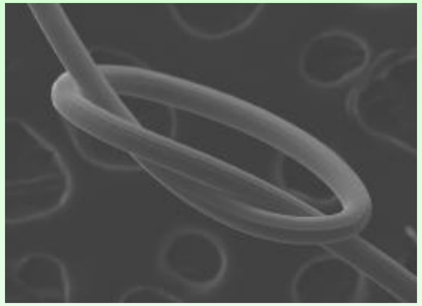
Magnetic wires:

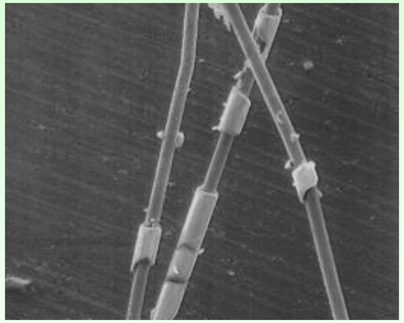
-Iron whiskers
-Wiegan magnetic wires
(CoVFe,1970-th)

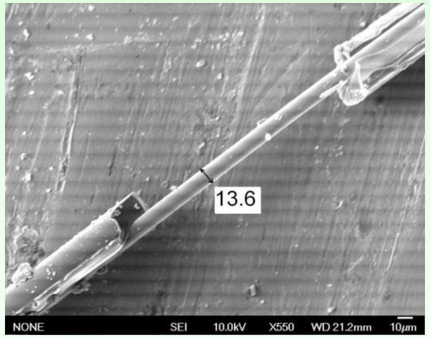


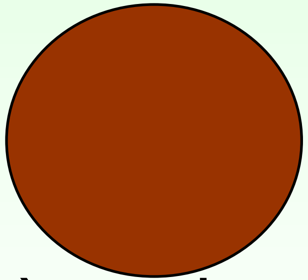
Amorphous: milli
(since 80-th) micro
nano

wires

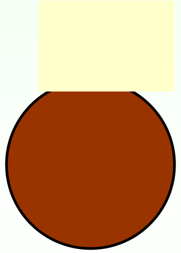




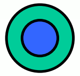




In-rotating water wires
(can be drawn to 20-30 µm) – rough surface



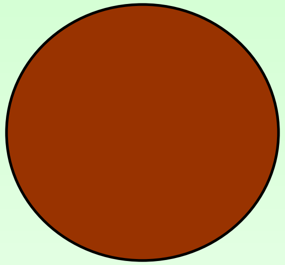
Melt extracted (40-50 µm)- not perfectly cylindrical cross section



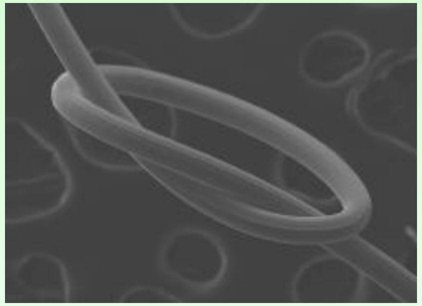
Glass coated (0.1-50 µm)- glass coating (stresses)

Comparison of microwires with other soft magnetic materials

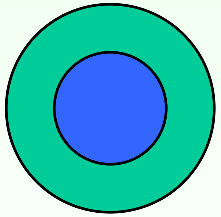
Ribbons, Cross section above 4×10^{4} μm^{2}, fast and cheap fabrication, extremely soft magnetic properties, too big for microsensors applications



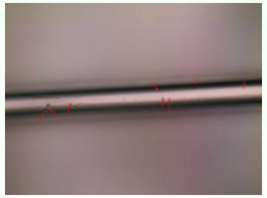
Wires, cross section above 2×10^{3} μm^{2}, fast and cheap fabrication, good magnetic properties, effect of sample Length - too big for microsensors applications



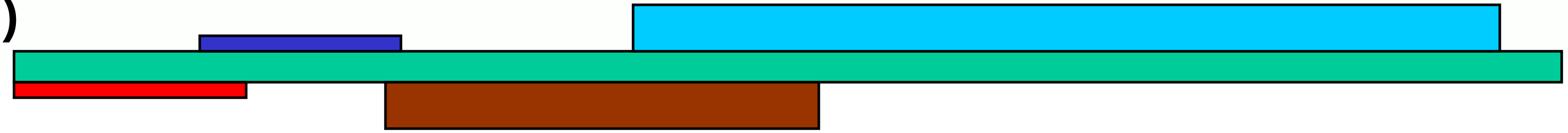
Thin films, cross section 0.1– 10^{2} μm^{2}, slow fabrication, Higher cost, worse magnetic softness, good compatibility in integrated circuits, effect of substrate



Microwires, typical cross section above 4- 2×10^{3} μm^{2}, fast and cheap fabrication, extremely soft magnetic properties, good for microsensors applications

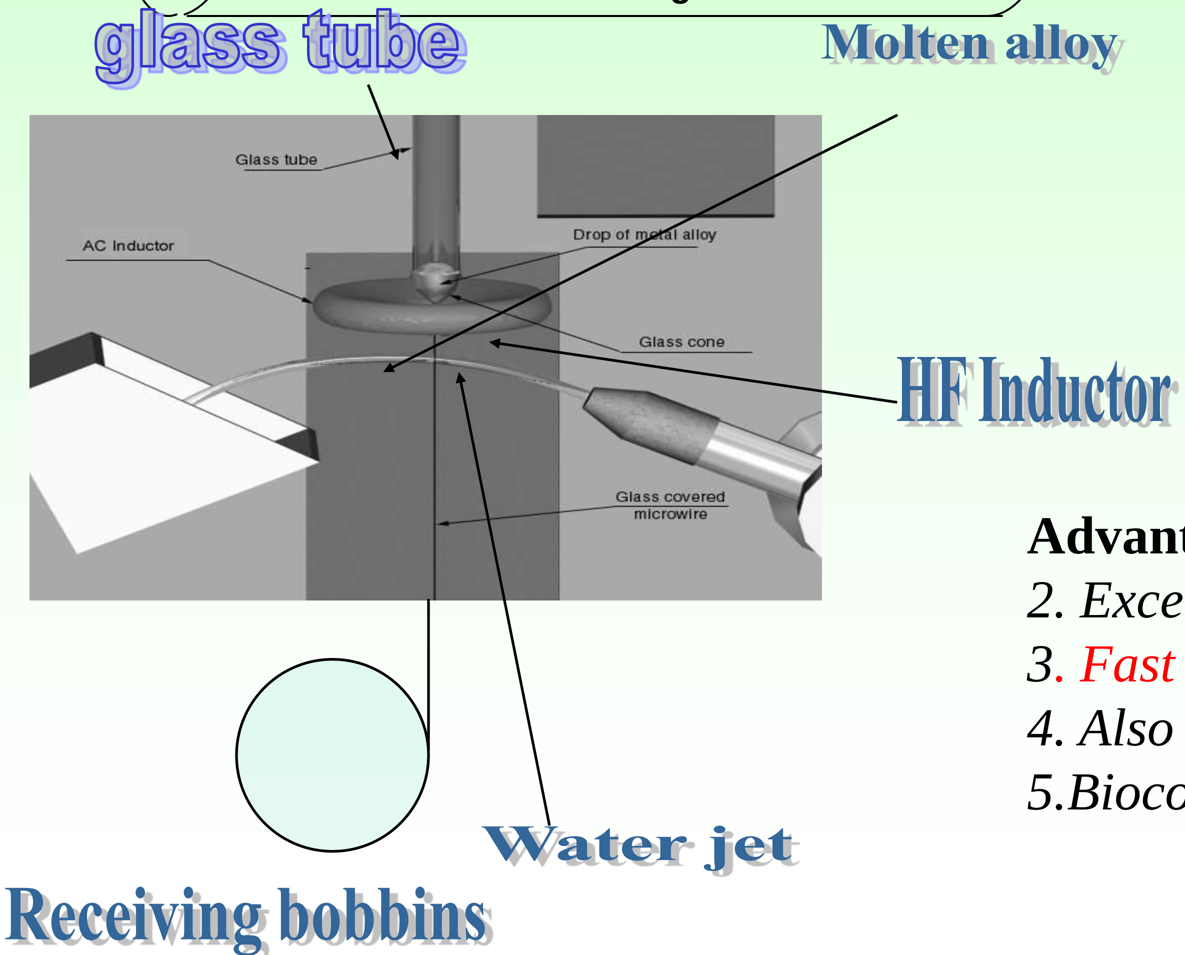


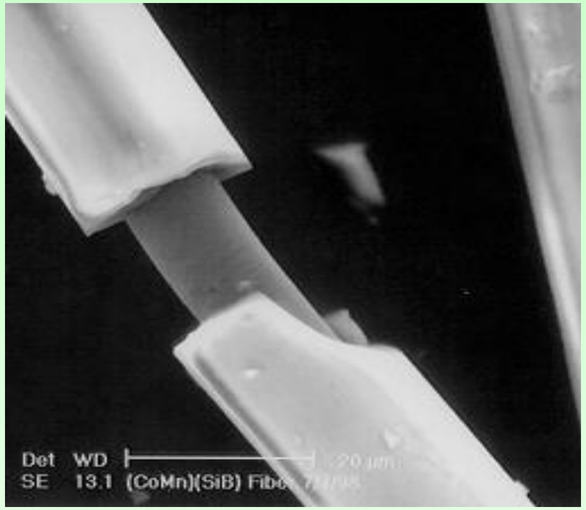
Scale (cross section)



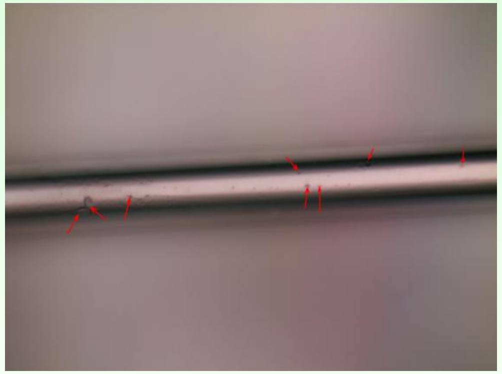
Fabrication of Glass coated microwires (thinnest wires)

- Co, Ni , Fe and Cu rich compositions



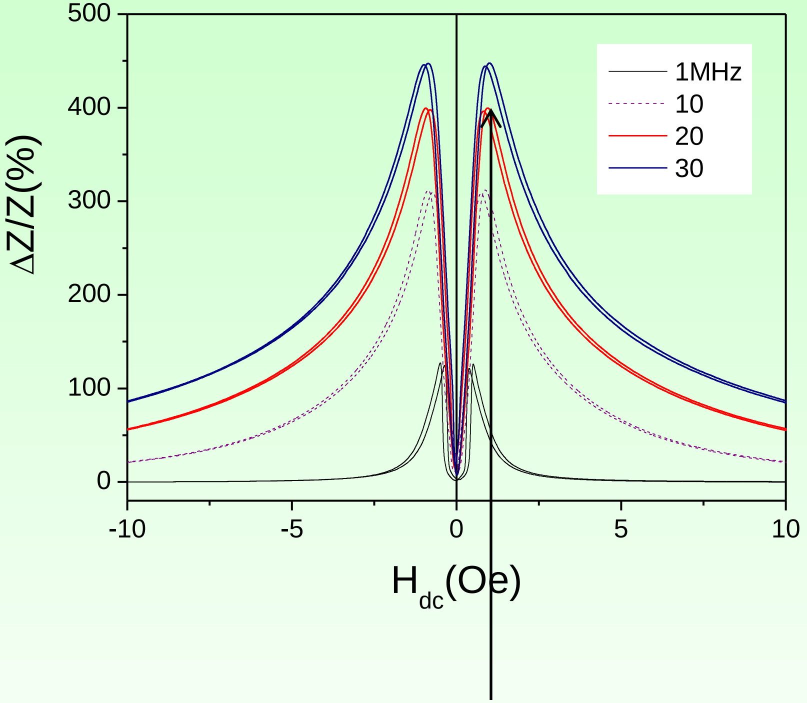


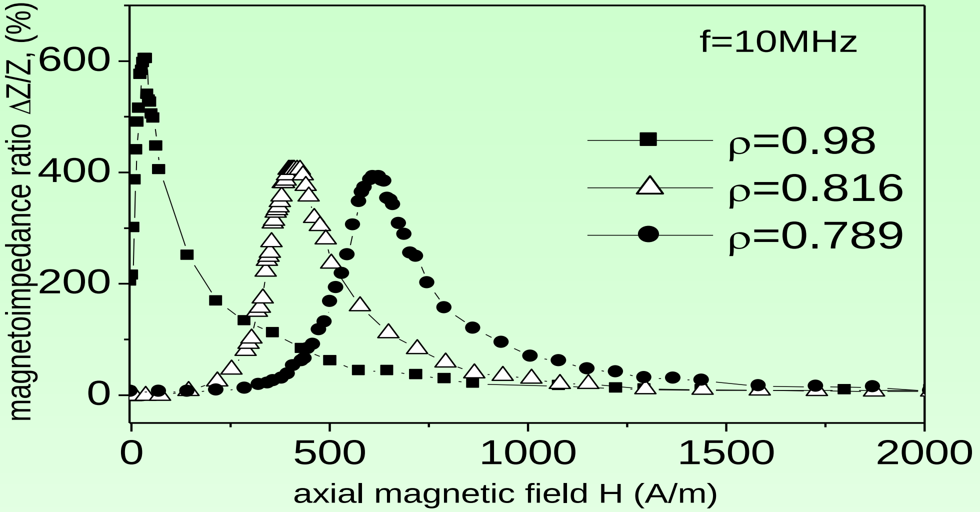
Typical dimensions:
Total diameter 3-40 microns
Metallic nucleus diameter 1-30 microns
Glass coating thickness 1-10 microns
Length - few km (up to 10 in 1 bobbin)



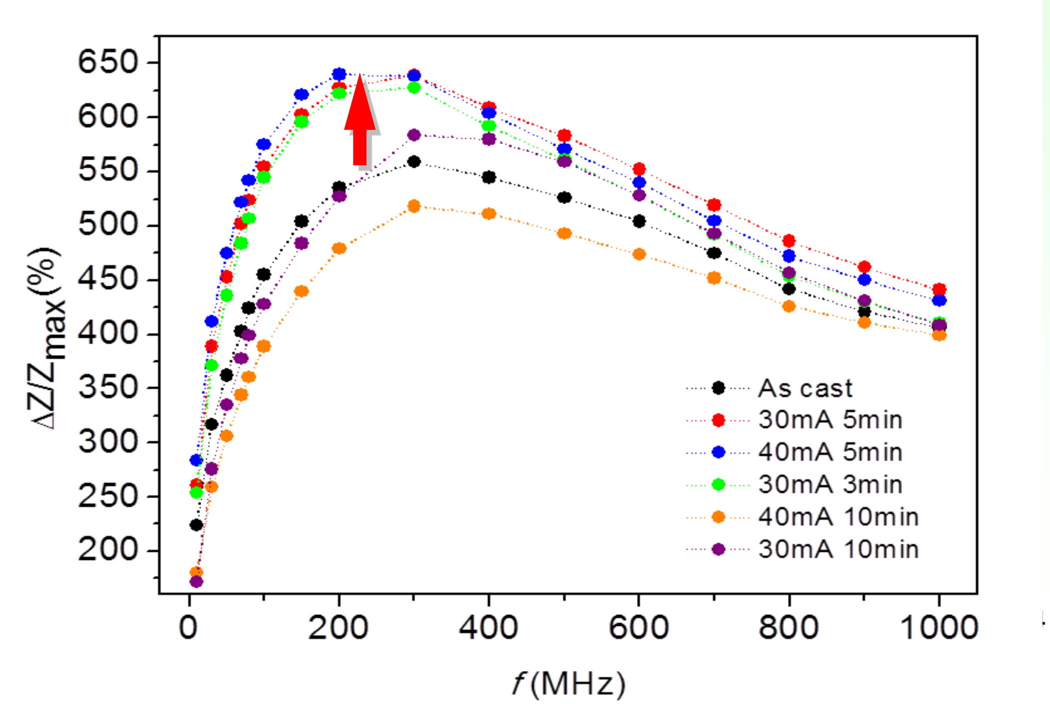
Advantages: *1. Unexpensive and simple fabrication method*
2. Excellent soft magnetic properites and high GMI effect
3. Fast DW propagation
4. Also recently Heusler-type and granular microwires
5.Biocompatibility (glass-coating)

GMI en microwires

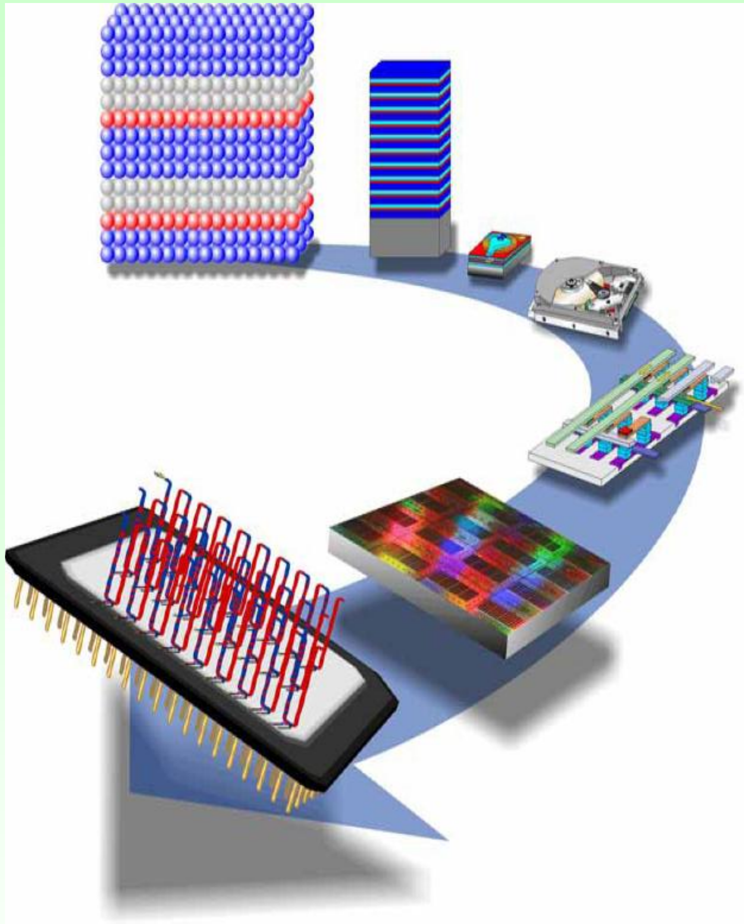




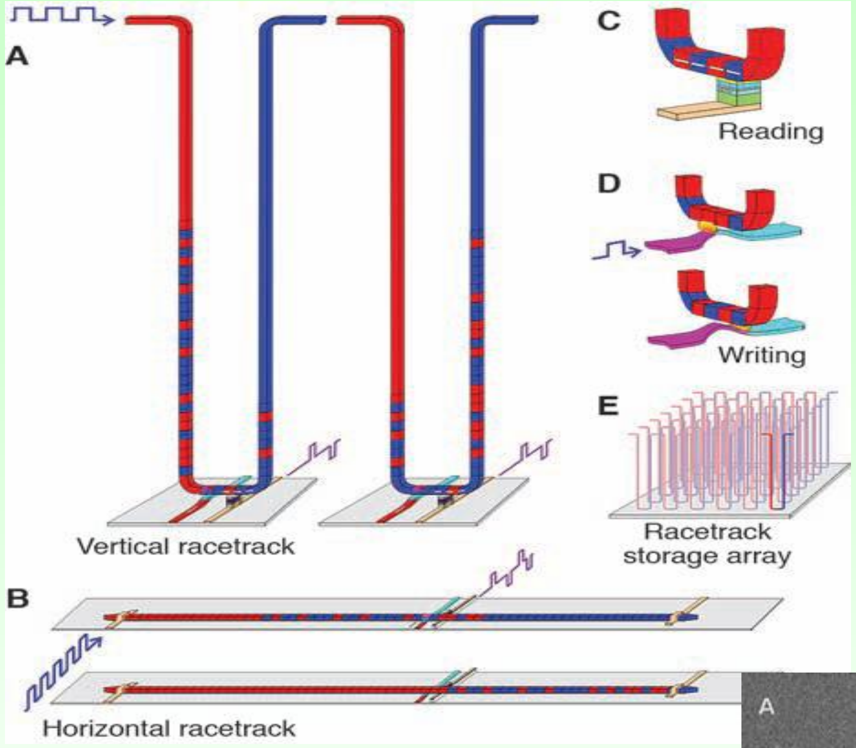
GMI effect, high sensitivity
450%/Oe: 1 Oe = 0,1 mT)
1% MI change ≈0,0002 mT

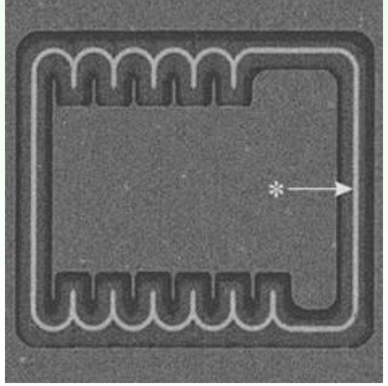


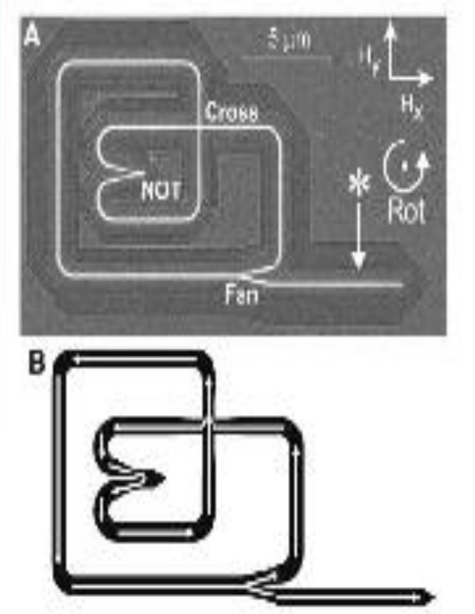
Proposed magnetic memory and logic based on DWP



Possible MRAM and logic applications
Stuart S. P. Parkin, *et al.*
Science **320**, 190 (2008);







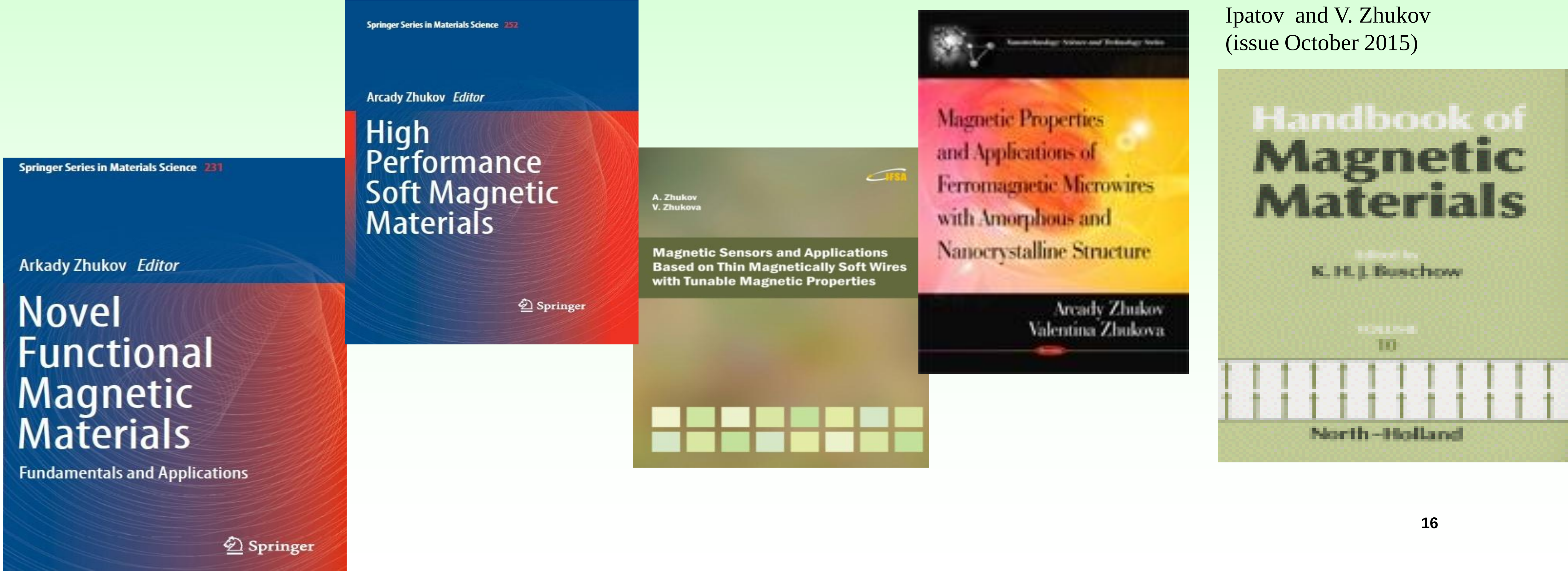
Controlled and fast DW movement
One of 10 most prominent applications (MIT ranking)

Conclusions

- **Soft magnetic properties and GMI effect can be realized in magnetic microwires**
- **By appropriate post-processing we can considerably improve GMI effect and magnetic softness in Co-rich magnetic microwires**

Thank you for the attention!

“Advances in Giant Magnetoimpedance Materials” by A. Zhukov, M. Ipatov and V. Zhukov (issue October 2015)



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IARIA SensorComm Panel 2: Advances on Miniaturization and Computation

Paul Fortier, UMass Dartmouth, Panel Moderator and Panelist

Advances in miniaturization and computation can be looked at in very different ways. From a hardware perspective, miniaturization and improvements in design have contributed to a continuous improvement in computational speeds (e.g. instructions per second continue to rise). Though miniaturization alone will not solve the always increasing demand by algorithms computation for more speed in order to solve more complex problems. Technology is nearing the limit for 2D wafer densities. Does this mean the end to Moore's law? Possibly not if one takes into consideration advances in computer architecture. For example advances in 3D chips using wafer stacking and through silicon vias have resulted in drastic increases in the number of processing engines and memory available in the same footprint. Such improvements in computer fabrication technologies have led to realizing systems on a chip (SoC) designs as well as systems in a package (SiP) architectural complete systems implementations. One issue to address are the limits to wafer stacking. One could also look towards possible new technologies such as optical computing or quantum computing as areas where additional capacity may be found.

Miniaturization does not just imply processing and storage, but also sensors, actuators, and other peripherals. What does the future hold in these related technologies and what are the impacts of their decreasing Space, Weight, Power (SwaP) and costs? The argument may be that we are reaching limitations for getting much more from standalone computational engines, possibly one should look into advances in computation provided from distributed or cloud computing. Advances in computation are a bit vaguer. Do we consider only standalone computers and algorithms running on them, or do we consider distributed, and cloud based algorithms? What big new computational advances have occurred recently? Possibly big data and big data analytics driven by cloud computing. One issue to consider is who owns an algorithm in the cloud? How secure is the algorithm?

The two additional panelists provided different views on the panel's topic from very different perspectives

Michal Borecki from the Warsaw University of Technology Poland, looked at optical sensor miniaturization and trends. Dr. Borecki presented; Optoelectronics sensors miniaturization - outlier data generation and automatic rejection. His statement follows;

Optoelectronic sensors miniaturizations results in improvement of sensors fit for use, but also introduce, depending on sensing principle, different outlier data. These outlier data may come from random pollution of medium in which the measured factor is positioned as well as may come from lack of precise in sample holding. Fortunately, vector data pattern generation of characteristic point of measurement and measurement multiplication enables automatic rejection of outlier data.

Arcady Zhukov, from the University Basque Country (UPV/EHU), Spain also looked at magnetic sensor miniaturization and improvements. His presentation; Magnetic sensor: last tendencies, focused on trends and improvements in magnetic sensors and their applications. His statement follows;

One of the recent tendencies related with development of industrial applications in the field of magnetic sensors is the miniaturization of the magnetic sensors. Certain industrial sectors, like magnetic sensors, microelectronics, security etc, need cheap materials with reduced dimensionality and simultaneously with high magnetic properties (particularly enhanced magnetic softness). This tendency stimulated development of technology for magnetic materials with reduced dimensionality, such as thin films and thin wires. Particularly magnetic wires exhibiting giant magnetoimpedance effect are using in real technological applications for low magnetic field detection owing to high magnetic field sensitivity allowing to achieve magnetic field sensitivity similar to cryogenic devices.