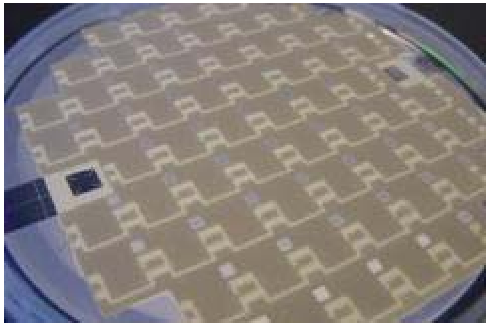
InSensor®

Piezoelectric Thick Film Technology Integrated Self-sustained Systems for Industrial Applications



Wanda W. Wolny, Rasmus Lou-Moeller, Erling Ringgaard, Konstantin Astafjev and Tomasz Zawada

Meggitt A/S, Hejreskovvej 18A, 3490 Kvistgaard, Denmark, wanda.wolny@meggitt.com

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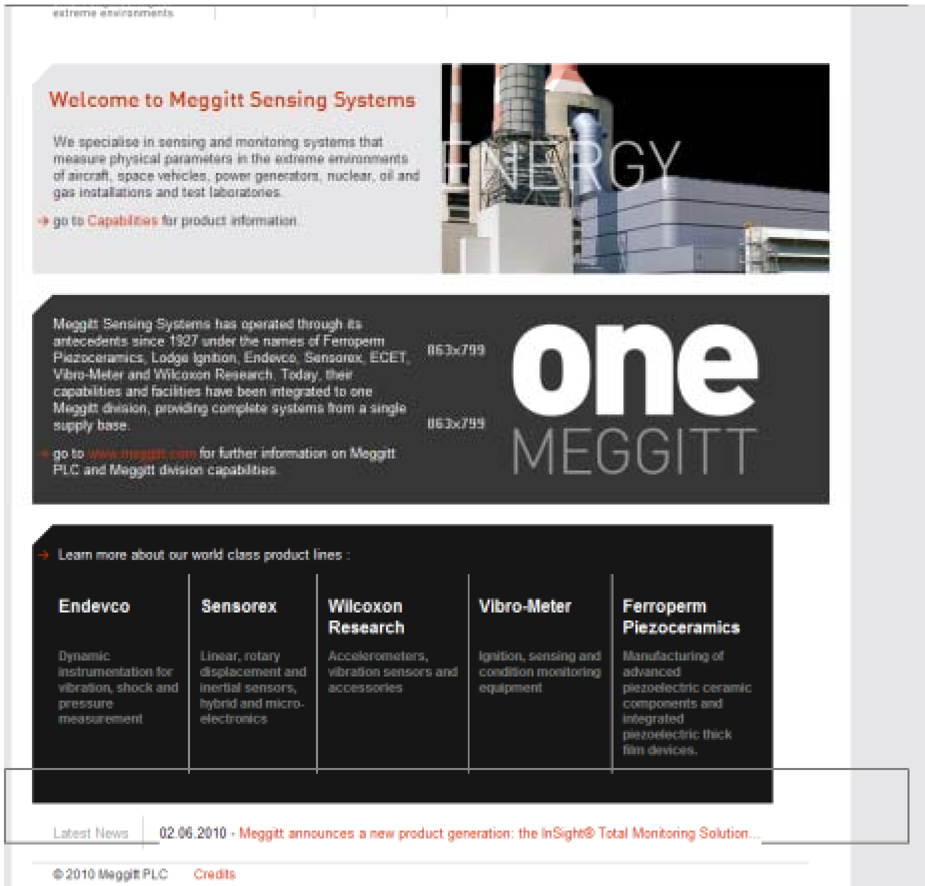
Outline

- Introduction of Meggitt A/S
- PZT thick-film technology
- Devices
- Lead free materials
- Thick film on flexible substrates
- Conclusions

Meggitt A/S –
Meggitt Sensing Systems



www.meggittsensingsystems.com

Ferroperm Piezoceramics A/S

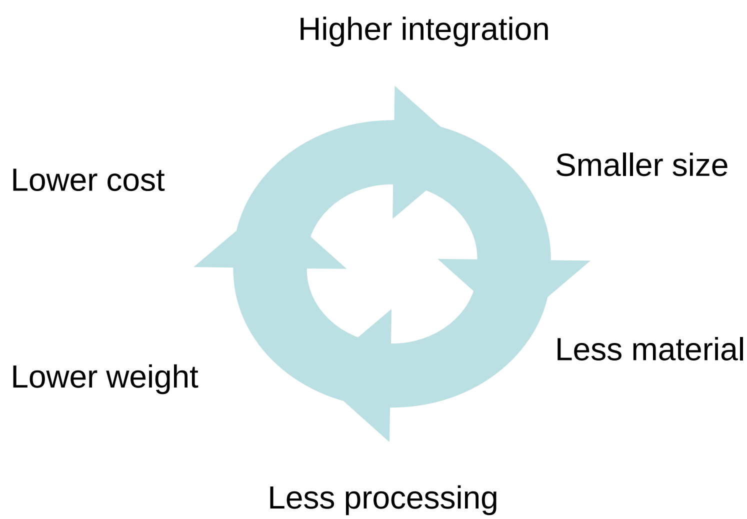
Is now

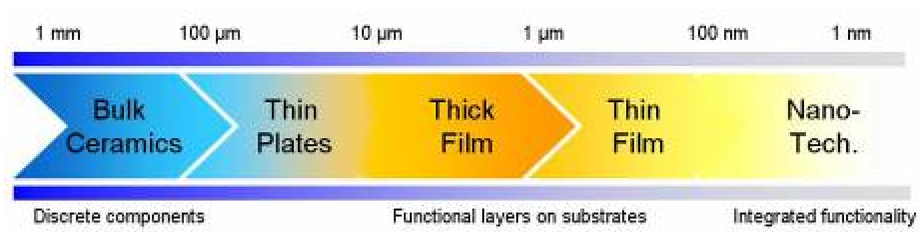
Meggitt A/S
Member of

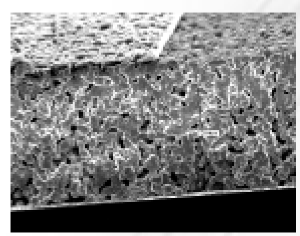
Meggitt Sensing Systems

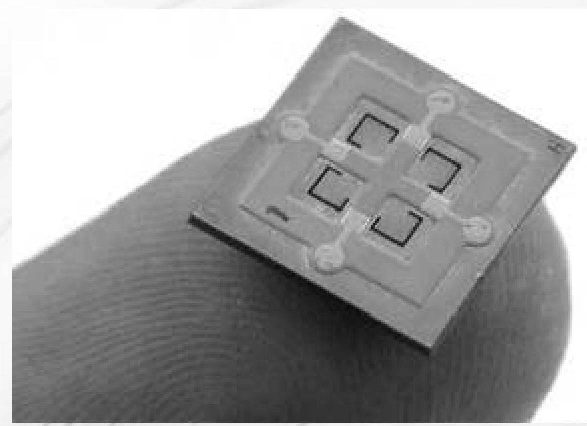
Producer of Ferroperm™ Piezoceramics and Insensor™

PZT thick-film technology



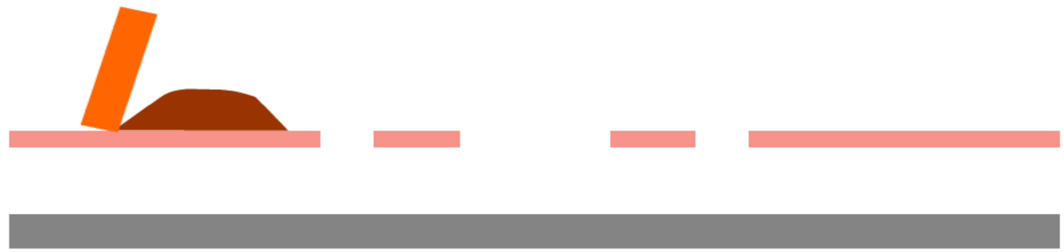




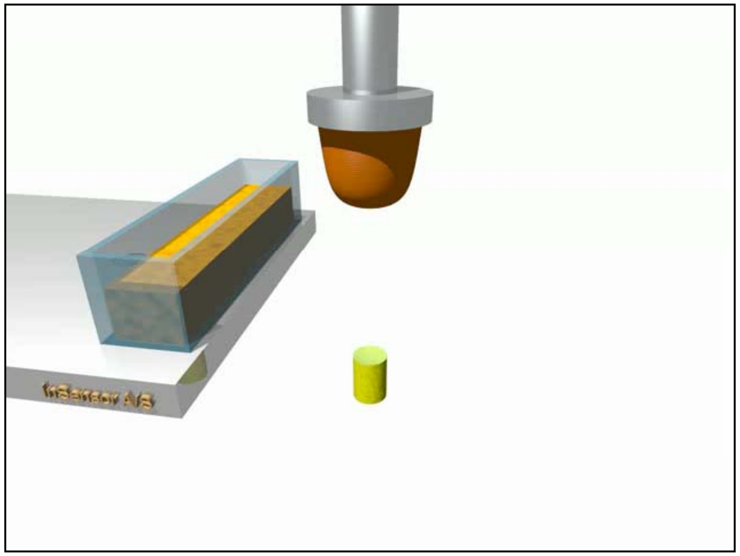


Deposition

Screen printing



Pad printing



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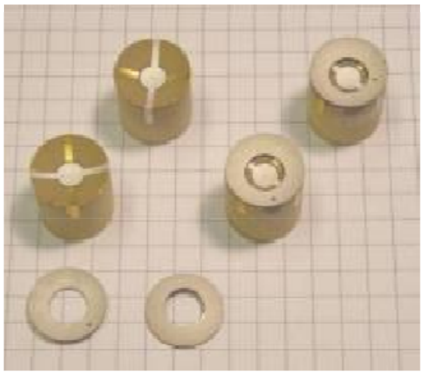
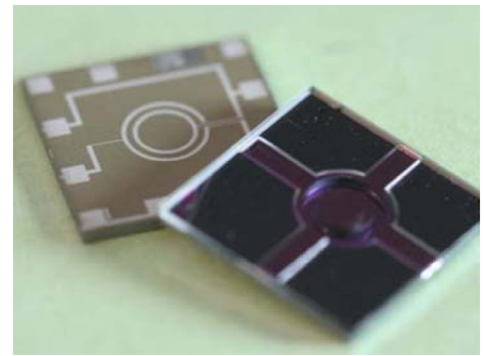
PZT thick film compatibility

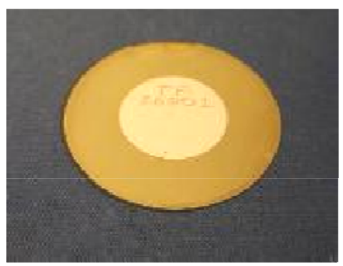
SUBSTRATES



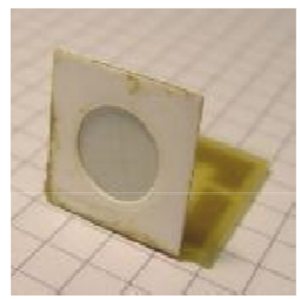
Ceramics



Silicon/MEMS



Stainless steel



LTCC

Evolution in screen printing of thick film

Substrate	Sintering temperature
Ceramics incl. Alumina, pzt and others	1100-1250ºC
Steel, silicon, LTCC	850ºC
Polymer	150ºC
Textile	100ºC
Compostes	”
Laminates	”
Paper	”

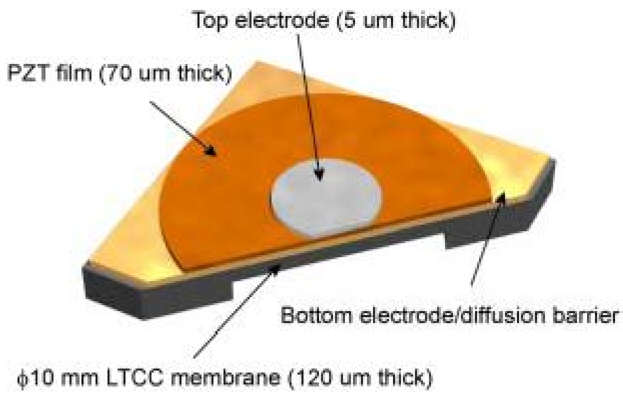
Devices & Systems

- Integrated sensors (MEMS accelerometers)
- Energy harvesting devices (battery-less, wireless integrated sensors systems)
- Medical (high-frequency, ultra resolution imaging)
- SHM (Structural Health Monitoring) in aeronautics, off-shore oil platforms, wind turbines
- Implantable sensors (lead-free, biocompatible materials)
- ICT integrated devices
- Microsystems (e.g. microfluidic, micro-pumps, micro-valves)

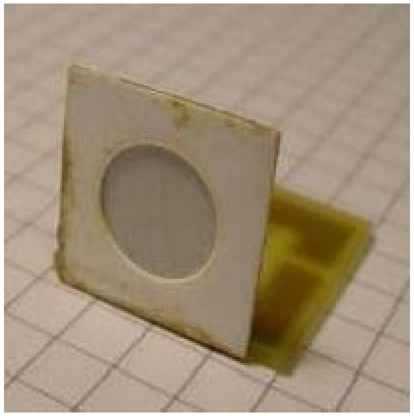
LTCC membrane with integrated PZT thick film

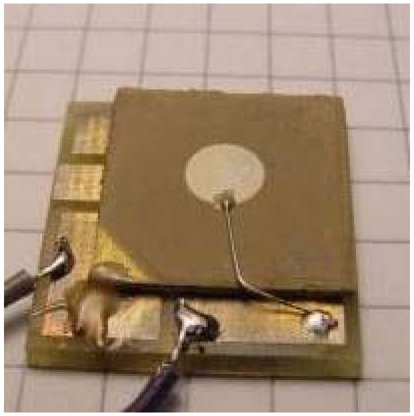
- The membrane structure has been fabricated using laser patterned LTCC foils and laminated in standard conditions together with sacrificial layers
- The PZT thick film as well as the electrodes have been deposited by means of screen printing and sintered in the post firing process at 850 ºC

In cooperation with PWR - TML



General structure and the dimensions of the membrane actuator based on the LTCC and PZT thick films

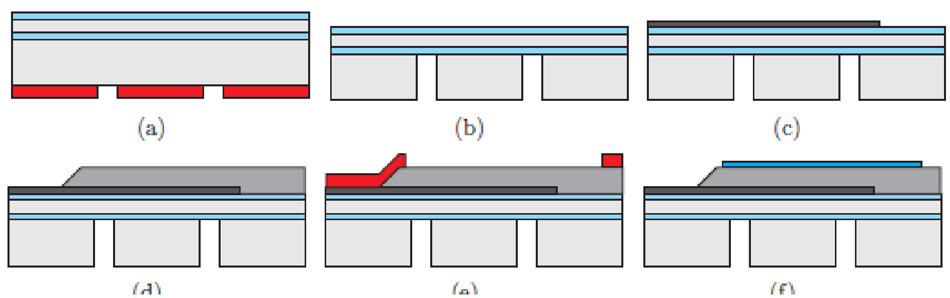


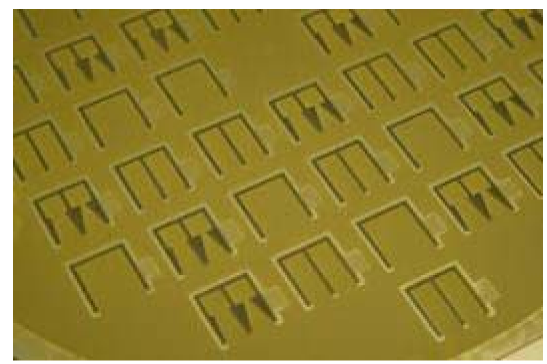


Photograph of the membrane cavity (top) and the packaged device (bottom)

Integration with silicon MEMS technology

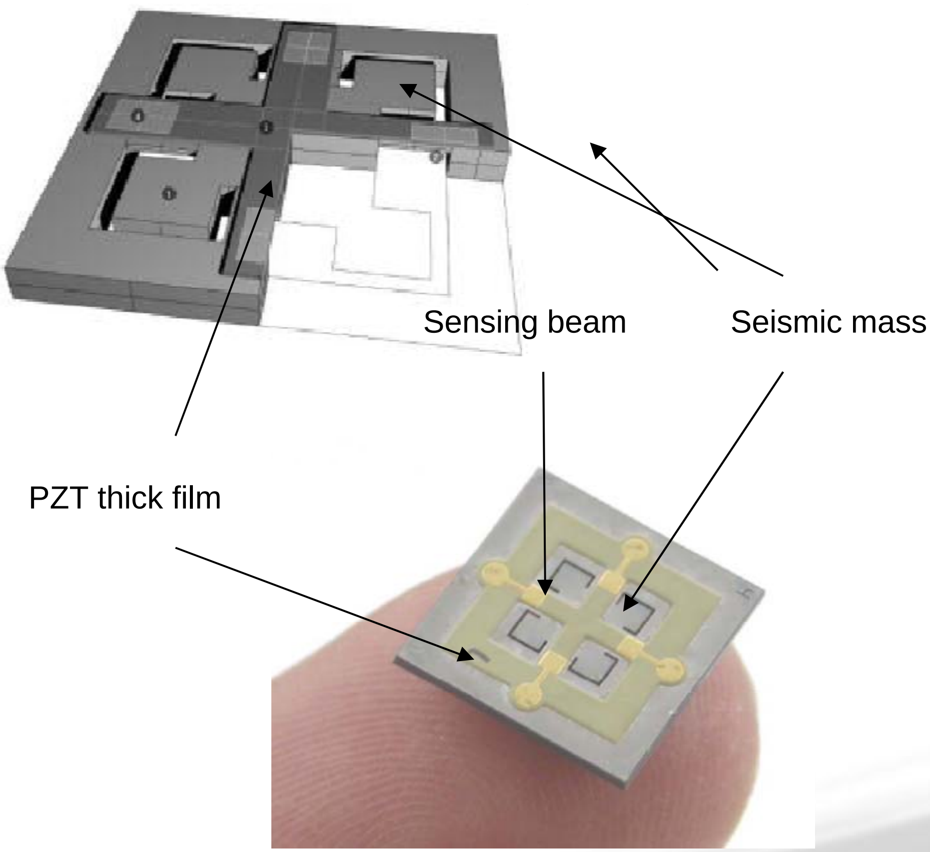
- Screen printing for making patterned thick film on a substrate
- Silicon micromachining for making complex structures in silicon
- Photolithography for making patterned electrodes



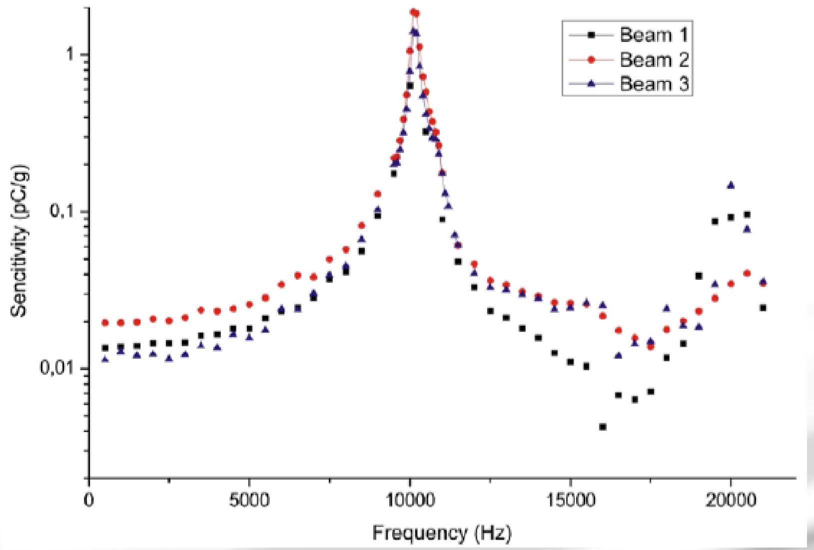


"PZT thick film can be considered as being a part of the MEMS technology portfolio"

MEMS accelerometer



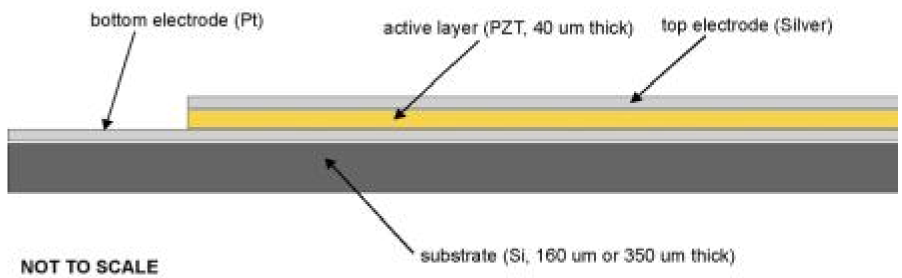
Cross-section of the MEMS structure and the fabricated accelerometer chip



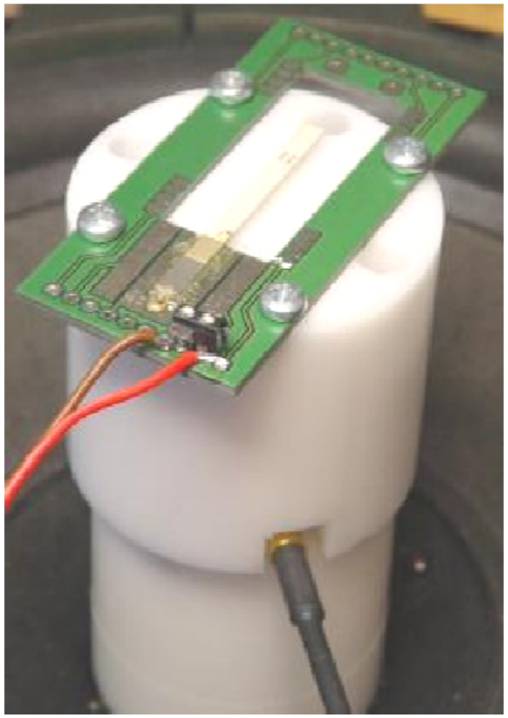
Normalized sensitivity in the vertical direction – frequency sweep

Energy harvesting devices

- PZT thick film based structure has been manufactured
- The 40 μm thick film has been deposited on 150 μm thick silicon substrate with dimensions equal to 25x3 mm^2



Structure of the thick film based silicon actuator/bender



Energy harvesting device mounted on the shaker

In cooperation with DTU Nanotech

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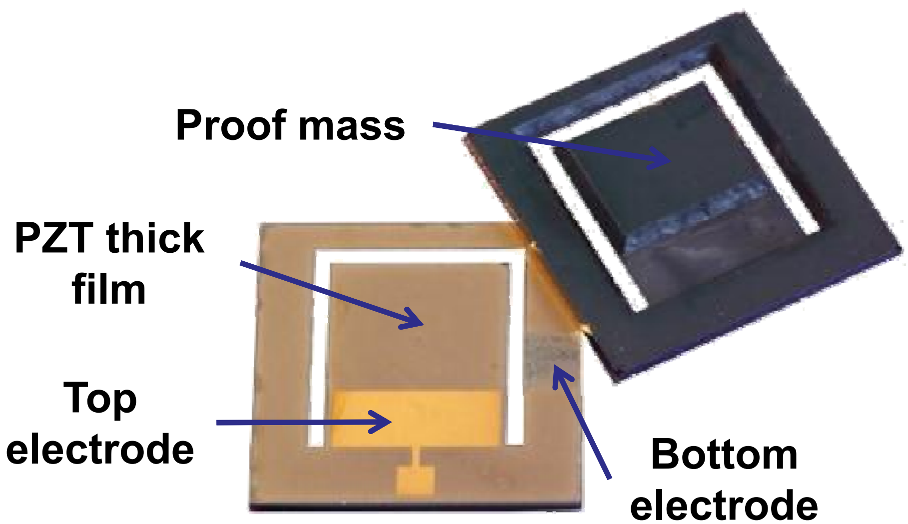
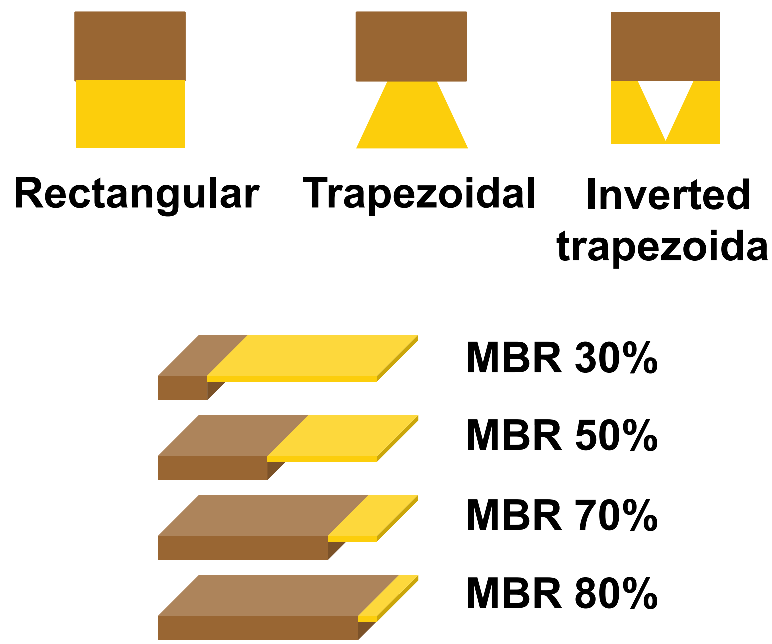
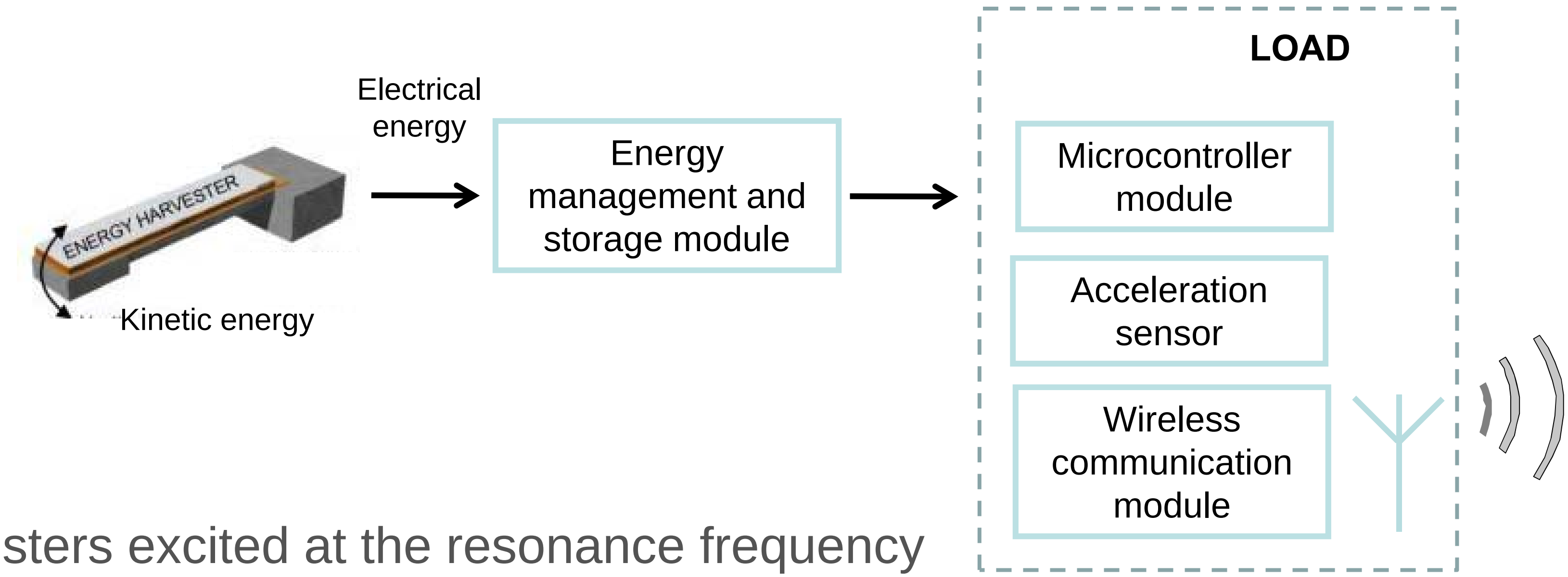
Energy harvesters

- Realized with silicon micromachining technology (DTU) and PZT thick films deposited by screen-printing technique (MSS)
- Single clamped cantilevers with a silicon proof mass at the free end
- Planar dimension 10x10 mm^2
- Different cantilever shapes, and mass-beam length ratios (MBR)

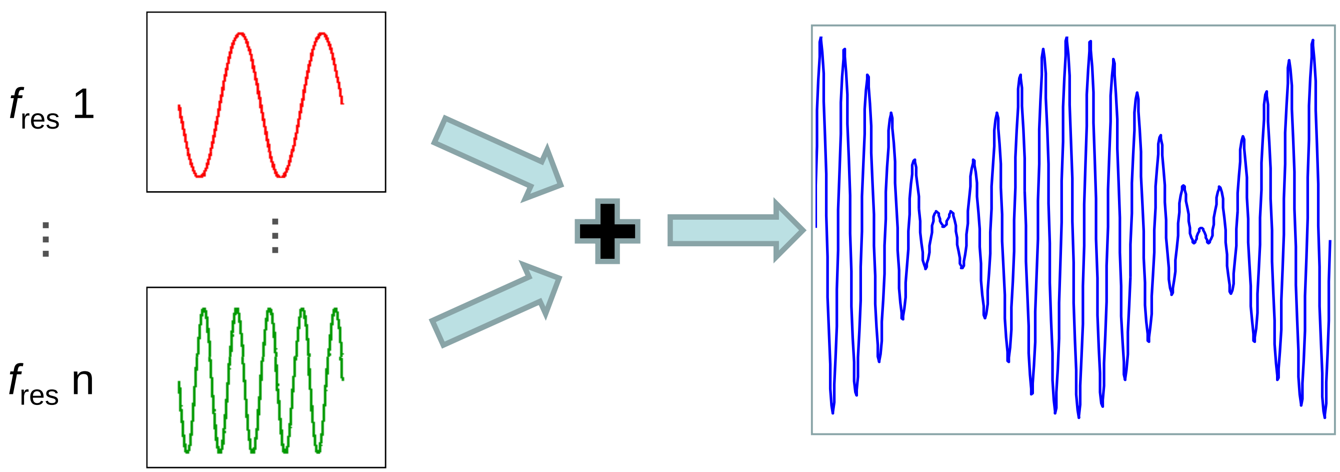




Wireless sensor prototype



- Harvesters excited at the resonance frequency
  - Multi-frequency excitation signal (RMS acceleration 0.77 *g*)



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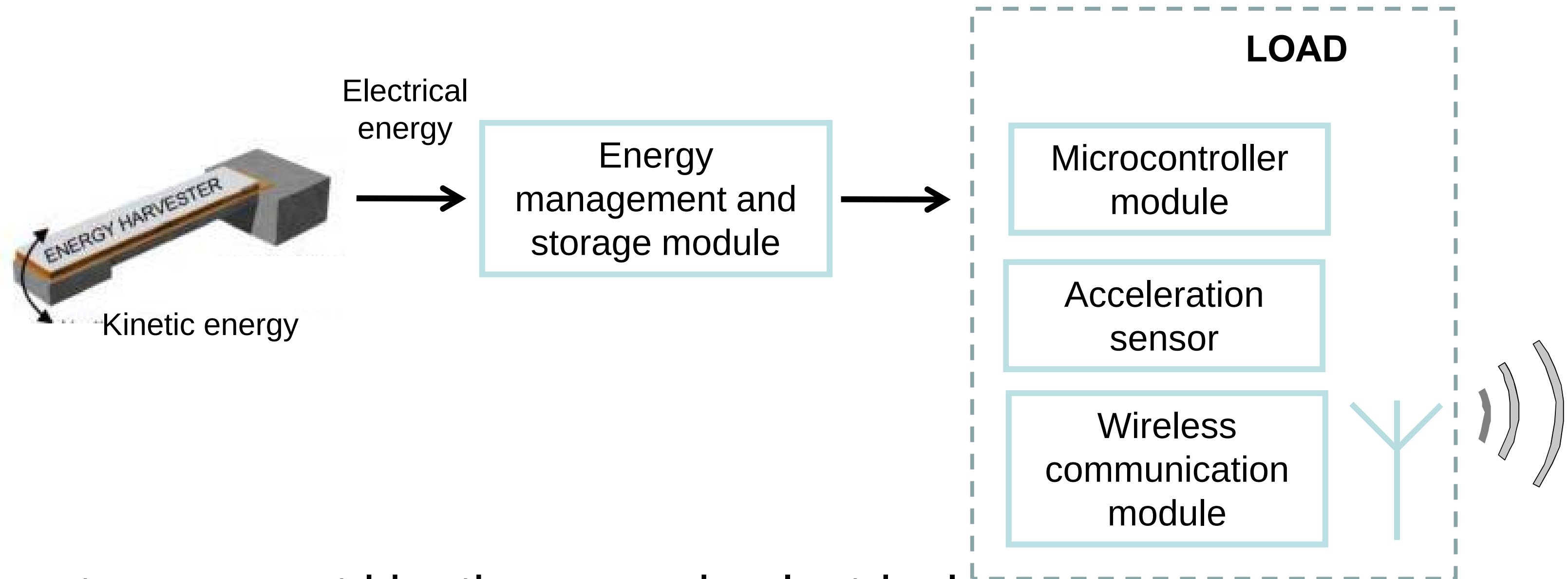
Wireless sensor prototype



- Harvesters convert kinetic energy in electrical energy
- Electrical energy is stored and conditioned
- When electrical energy is sufficient the load is powered
- Microcontroller repeats acceleration measurement and data transmission at fixed time intervals

Results

- Power harvesters realized with silicon micromachining technology and screen-printed PZT thick films
  - Open-circuit voltage up to 3 V @ 0.5 *g* peak
  - Maximum power range 12 μW ÷ 16 μW @ 0.5 *g* peak
- Self-power wireless sensor prototype
  - Excitation frequency tuned with the harvester resonance frequency
  - fixed wake up interval
  - 3D acceleration measurement
  - Radio frequency data transmission

Structural Health Monitoring (SHM)   AISHA II

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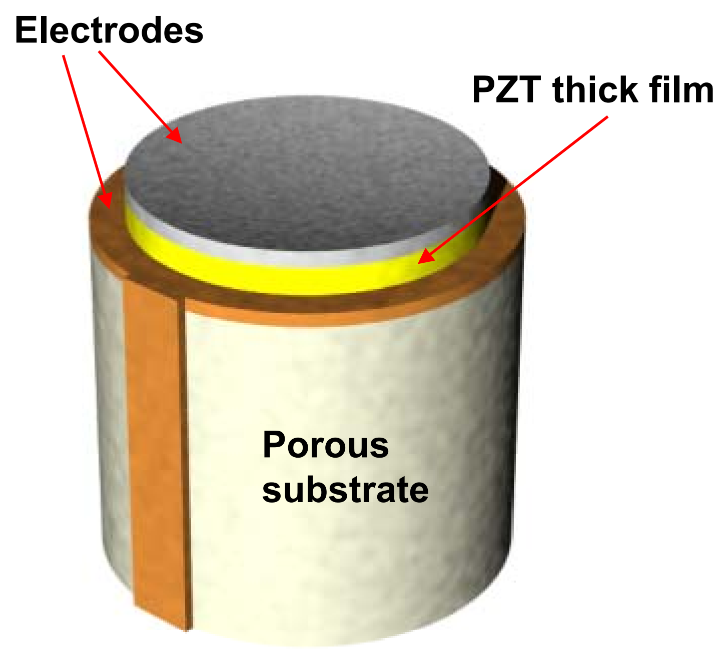
High Frequency Acoustic Transducers

- The porous structure of the film makes it a perfect candidate for medical imaging due to the following:
  - Low acoustic impedance
  - Low dielectric constant
  - High frequency (more than 20 MHz)



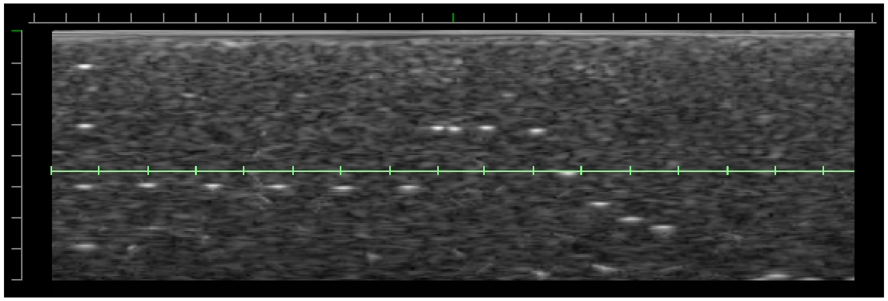
Typical structure of a thick film based HF acoustic transducer

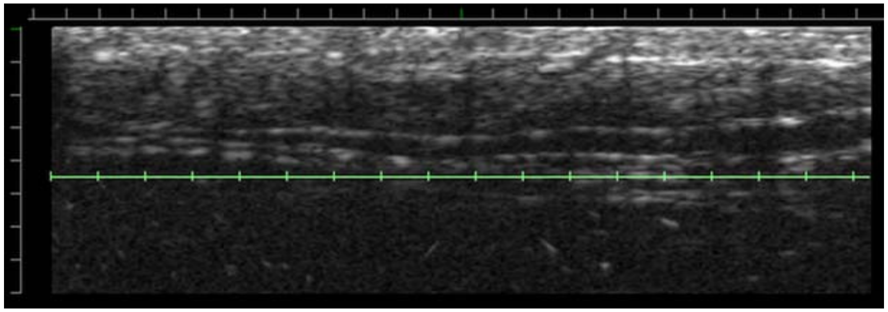
In cooperation with IPPT

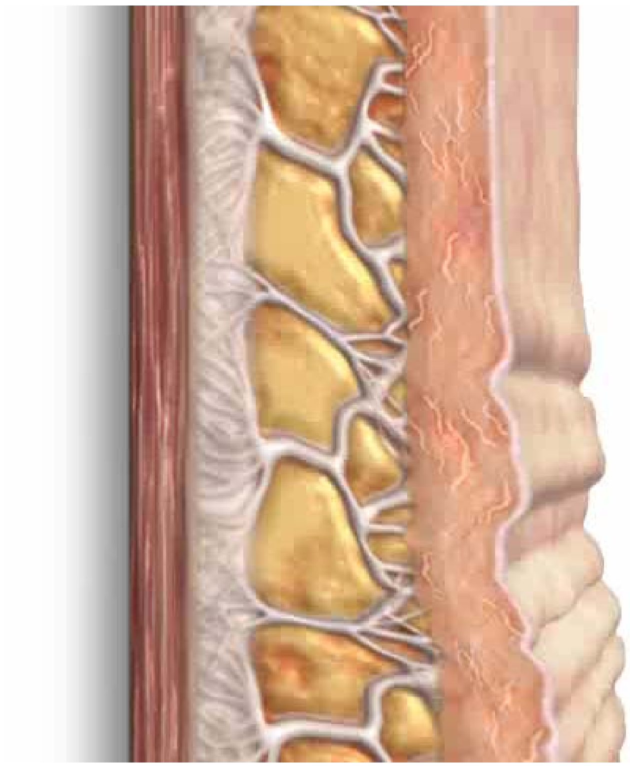
Ultherapy


Facility
Clinician
Patient Name
Patient ID 1234
DS 7 – 4.5
4.5 mm
479 / 800
THERAPY
1.05 J
1.5 mm
25.0 mm
IMAGING
marker
text
image
save
scan
region
Forehead
0 / 35 Lines
Patient Total
0 Lines

High frequency imaging transducer







Focused ultrasound energy is delivered precisely into multiple layers sparing intervening tissue

Over time, formation of new collagen … the skin.

non-invasively … lifts


GOOD MORNING AMERICA Health
GMA Health
FACIAL REJUVENATION
Non-Surgical Face-Lift
abc NEWS .com
THE VIEW

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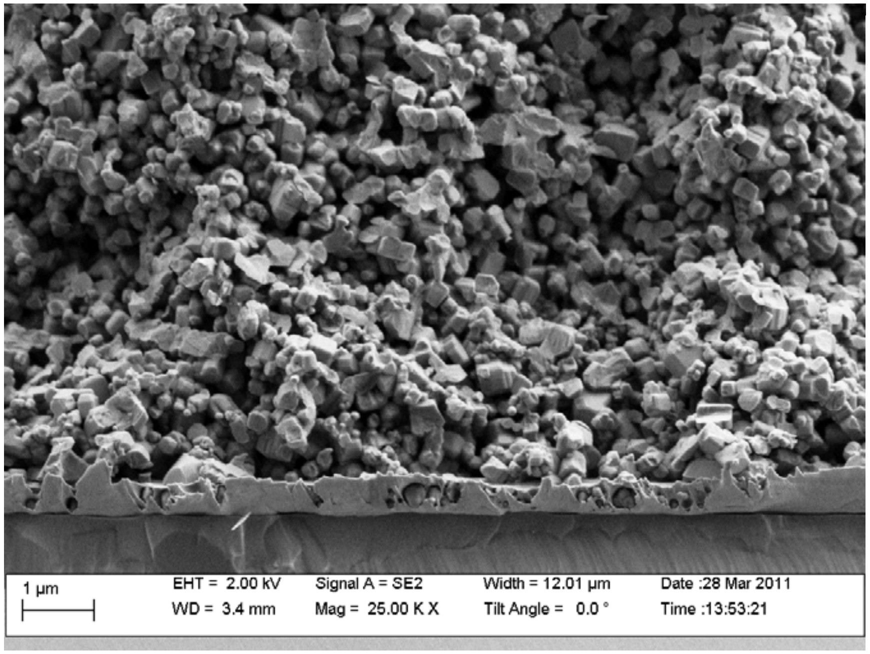
Thick films properties, PZT and KNN

	TF21 standard	TF21 Pre-treated	TF6131 on alumina	TF6131 on silicon
Material	PZT-based	PZT-based	KNN-based	KNN-based
Dielectric Constant	520 (free standing)	750 – 800 (free standing)	250 - 350 (semi-clamped)	330 – 340 (semi-clamped)
tanδ, %	0.8		0.7 – 1.0	1.5 – 2.0
d_{33}, pC/N	200*	200*	130 – 140	120 - 130

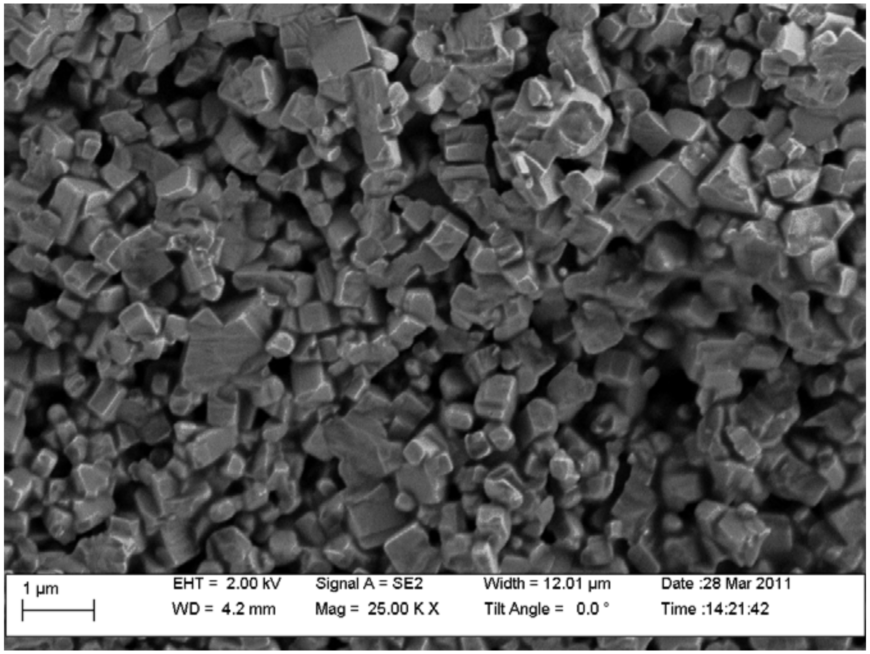
*Apparent value, measured for the free standing PZT material of the same composition and with the same level of porosity.

KNN - Thick films microstructure

TF6130 film on silicon substrate



TF6131 film on alumina substrate



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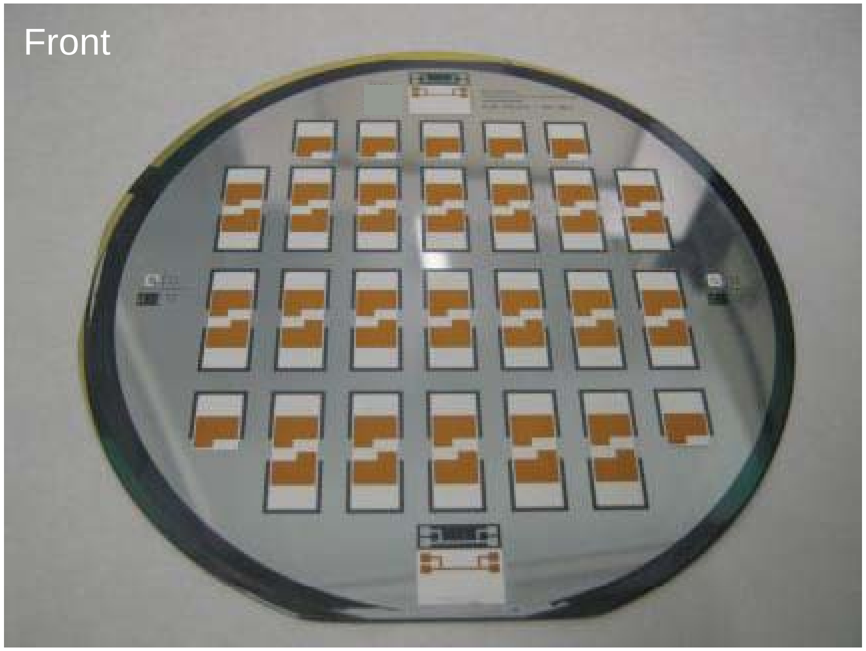
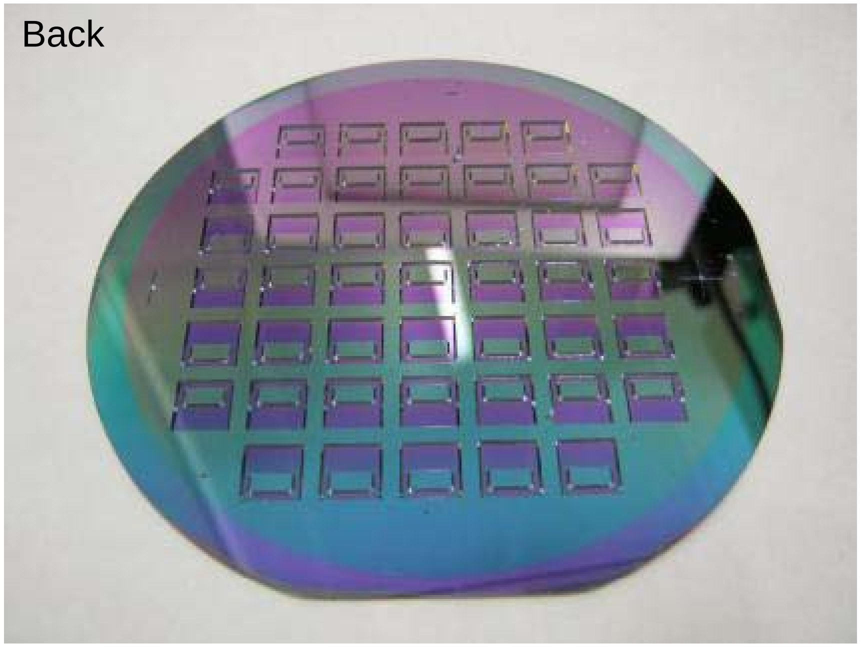
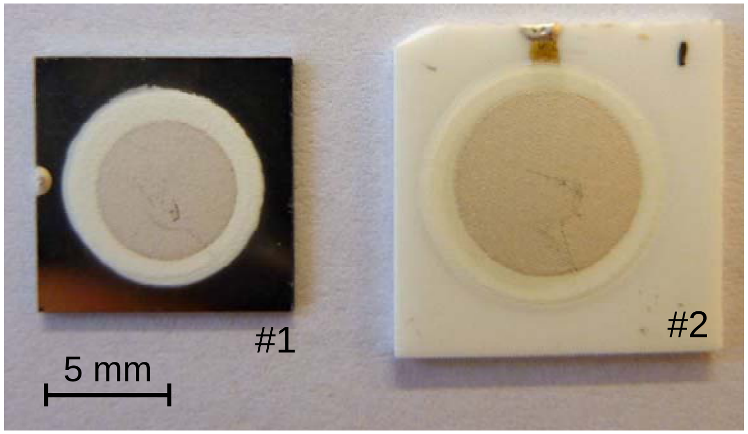
Lead-free thick film devices

Lead-free thick films based MEMS devices







KNN-based thick films printed on silicon (#1) and alumina (#2) substrates.

Low temperature processing

- Trade mark
- Patent pending


KHIM – KONTORET FOR HARMONISERING I DET INDRE MARKED
VAREMÆRKER OG DESIGN

REGISTRERINGSBEVIS

Dette Registreringsbevis er hermed udstedt for Fællesskabsmærket gengivet herunder. De følgende oplysninger er indført i EF-varemærkeregistret.

OHIM – OFFICE FOR HARMONIZATION IN THE INTERNAL MARKET
TRADE MARKS AND DESIGNS

CERTIFICATE OF REGISTRATION

This Certificate of Registration is hereby issued for the Community Trade Mark identified below. The corresponding entries have been recorded in the Register of Community Trade Marks.

Registrerede / Registered 28/03/2011

No 009299348

PIEZOPAINT

President / The President

António Campinos

MEGGITT

Paste

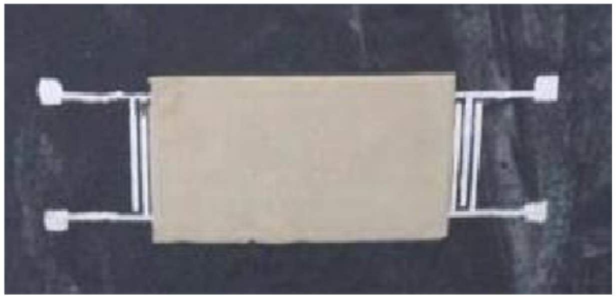
Paste is based on Meggitt A/S powder

The piezoelectric charge coefficient (d_{33} ~ 30 pC/N) is measured by Berlincourt method

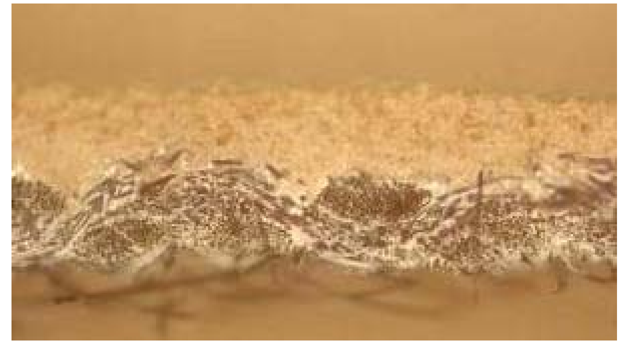
Screen printing have been successfully carried out on several fabrics/textiles including poly-cotton, filters and polyurethane coated fabrics

Fabricated piezoelectric paste

Demonstrators

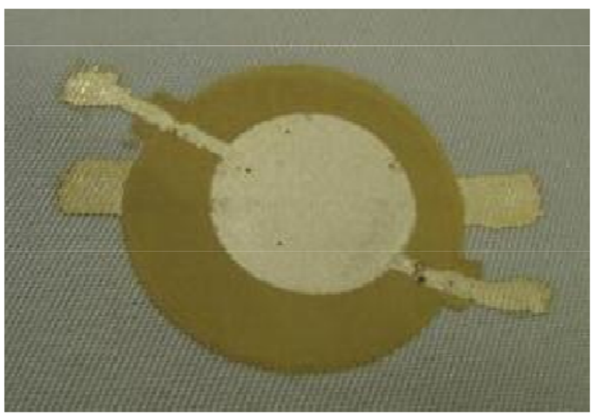


Thick film on plastic



Cross section: Thick film on fabric

Filter Cleaner testing_full area_1.wmv



Thick film on Polycotton

Thick film on Filter

Filter Cleaner testing_full area_1.wmv

Materials	Piezoelectric charge coefficient, d_{33} (pC/N)
PZ26 (bulk component)	290
TF2100 InSensor® (thick film)	200
Lead free thick film	**150**
Flexible thick film (PZT on textile)	40
PVDF (thin film)[1]	-8
Copolymer P(VDF-TrFE)[2]	-33

[1] Kawai, H., *Jpn. J. Appl. Phys*, 8, 975-976, (1969)
[2] Kenji, O., Hiroji, O., Keiko, K., J. Appl. Phys. 81, 2760, (1996)

Conclusions

- Thick film properties are well established and reproducible.
- The technology can be applied to different substrates incl. silicon and textile and used for MEMS
- Printing technology offers integration opportunities
- Printing technology can be used for large area light weight active devices
- Printing technology can be fast and efficiently scaled up
- The next generation of devices can also include energy harvesting device and be self sustainable and maintenance free

Acknowledgements

Danish National Advanced Technology Foundation through **π-MEMS**, (Contract No. 009-2005-1) and **EL**iminating **BA**tteries – energy harvesters for integrated systems, project no. 036-2009-1

Π-MEMs & ELBA

EC through the **MINUET** project (Contract No. NMP2-CT-2004-505657), the **MICROFLEX** project (Contract No. CP-IP 211335-2) and the **NoE MIND** (Contract No. NMP2-CT-2004-505657) and

The Piezoinstitute AISBL

New facility

- Office area for R&D and InSensor: 135 m^2
- Area with process ventilation for labs and production: 300 m^2
- Dust free area with humidity and temperature control: 120 m^2
- New equipment for tape casting
- Lead free lab with separate ventilation to avoid cross contamination 30 m^2

New facility (engineers lab)

R&D group
- Seven full time engineers (Msc. and PhD)
- One technical assistant

- Fully equipped testing room including environmental testing chamber

New facility (lead free lab)

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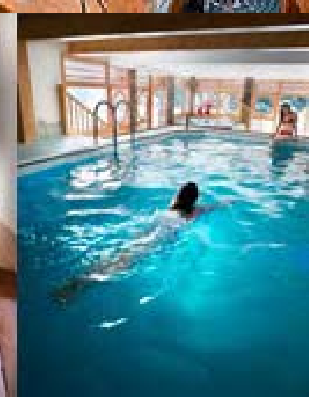
PIEZO 2013

Electroceramics for end- users VII

17-20 March 2013
Hotel du Golf
Les Arcs 1800, French Alps (810 to 3226 m)

piezo2013@univ-tours.fr

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Thank you