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

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Outline

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

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- go to Capabilities for product information.

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  Ignition, sensing and condition monitoring equipment

- Ferroperm Piezoceramics
  Manufacturing of advanced piezoelectric ceramic components and integrated piezoelectric thick film devices.

Latest News
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Credits

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Ferroperm Piezoceramics A/S

Is now

Meggitt A/S
Member of

Meggitt Sensing Systems

Producer of Ferroperm™ Piezoceramics and Insensor™
PZT thick-film technology

Higher integration
Smaller size
Less material
Lower cost
Lower weight
Less processing

Ferroperm™ Piezoceramics

Deposition

Screen printing

Pad printing
PZT thick film compatibility

SUBSTRATES

Ceramics

Silicon/MEMS

Stainless steel

LTCC
## Evolution in screen printing of thick film

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Sintering temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramics incl. Alumina, pzt and others</td>
<td>1100-1250°C</td>
</tr>
<tr>
<td>Steel, silicon, LTCC</td>
<td>850°C</td>
</tr>
<tr>
<td>Polymer</td>
<td>150°C</td>
</tr>
<tr>
<td>Textile</td>
<td>100°C</td>
</tr>
<tr>
<td>Composites</td>
<td>&quot;</td>
</tr>
<tr>
<td>Laminates</td>
<td>&quot;</td>
</tr>
<tr>
<td>Paper</td>
<td>&quot;</td>
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</tbody>
</table>
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)
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 °C.
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 a 150 µm thick silicon substrate with dimensions equal to 25x3 mm².

Structure of the thick film based silicon actuator/bender

Energy harvesting device mounted on the shaker

In cooperation with DTU Nanotech
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 mm²
- 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)
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
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
Focused ultrasound energy is delivered non-invasively into multiple layers, tightening and lifting the skin by stimulating collagen growth.
**Thick films properties, PZT and KNN**

<table>
<thead>
<tr>
<th></th>
<th>TF21 standard</th>
<th>TF21 Pre-treated</th>
<th>TF6131 on alumina</th>
<th>TF6131 on silicon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>PZT-based</td>
<td>PZT-based</td>
<td>KNN-based</td>
<td>KNN-based</td>
</tr>
<tr>
<td>Dielectric Constant</td>
<td>520 (free standing)</td>
<td>750 – 800 (free standing)</td>
<td>250 - 350 (semi-clamped)</td>
<td>330 – 340 (semi-clamped)</td>
</tr>
<tr>
<td>tanδ, %</td>
<td>0.8</td>
<td></td>
<td>0.7 – 1.0</td>
<td>1.5 – 2.0</td>
</tr>
<tr>
<td>d₃₃, pC/N</td>
<td>200*</td>
<td>200*</td>
<td>130 – 140</td>
<td>120 - 130</td>
</tr>
</tbody>
</table>

*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
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
**Paste**

Paste is based on Meggitt A/S powder

The piezoelectric charge coefficient \(d_{33} \sim 30 \text{ pC/N}\) 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
- Thick film on Polycotton
- Thick film on Filter
- Filter Cleaner testing_full area_1.wmv

Ferroperm™ Piezoceramics
<table>
<thead>
<tr>
<th>Materials</th>
<th>Piezoelectric charge coefficient, $d_{33}$ (pC/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ26 (bulk component)</td>
<td>290</td>
</tr>
<tr>
<td>TF2100 InSensor® (thick film)</td>
<td>200</td>
</tr>
<tr>
<td><strong>Lead free thick film</strong></td>
<td><strong>150</strong></td>
</tr>
<tr>
<td>Flexible thick film (PZT on textile)</td>
<td>40</td>
</tr>
<tr>
<td>PVDF (thin film)$^1$</td>
<td>-8</td>
</tr>
<tr>
<td>Copolymer P(VDF-TrFE)$^2$</td>
<td>-33</td>
</tr>
</tbody>
</table>


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 ELiminating BAteries – 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 m²
- Area with process ventilation for labs and production: 300 m²
- Dust free area with humidity and temperature control: 120 m²
- New equipment for tape casting
- Lead free lab with separate ventilation to avoid cross contamination 30 m²
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)
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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