Flexible piezoelectric materials for emerging applications

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Outline

1 Company introduction

2 Emerging applications

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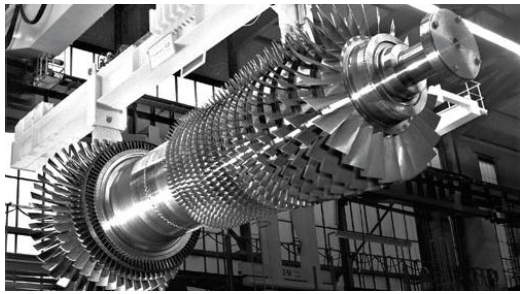
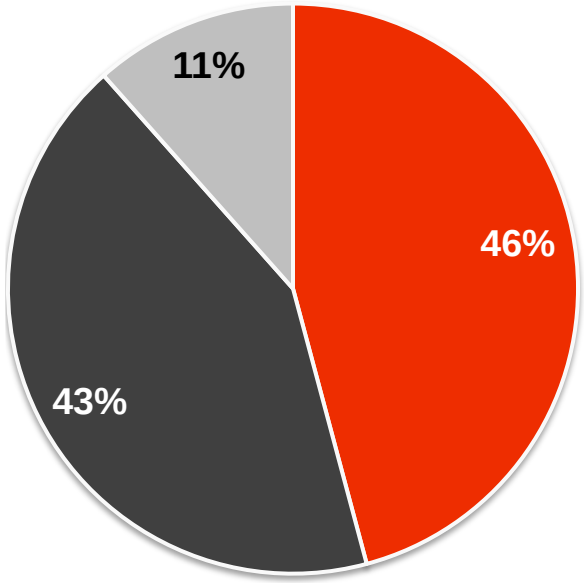
1 Company introduction



Overview

- Provides high technology products and systems for the aerospace, defence and other specialist markets, including: medical, industrial, energy, test and automotive
- 60 years experience in extreme environment engineering
- Broad geographic footprint with 10.000 employees worldwide,
- Annual sales, *£1.65B*
- Listed on London Stock Exchange (MGGT)

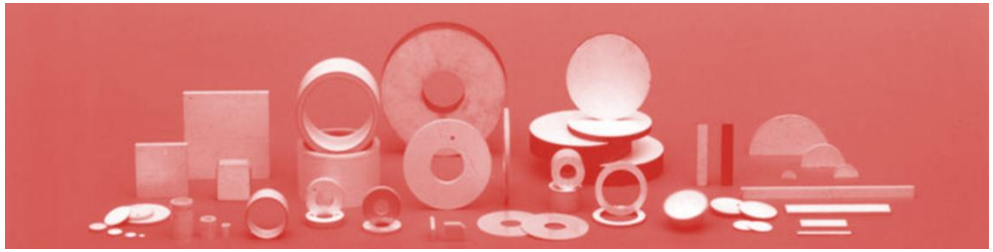


OE 52% / Aftermarket 48%

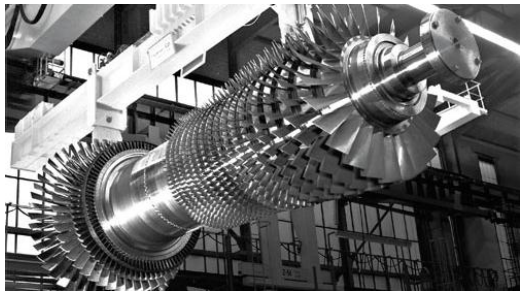
- Civil aerospace
- Military
- Energy and other

CTS | Ferroperm Denmark

- We are a manufacturer of piezoelectric materials, components, devices
- 2-3 million units produced annually
- Major markets
  - Medical ultrasound
  - Underwater acoustics
  - Acceleration sensors
  - Flow meters
  - Energy Harvesting
  - NDT



2 Emerging applications



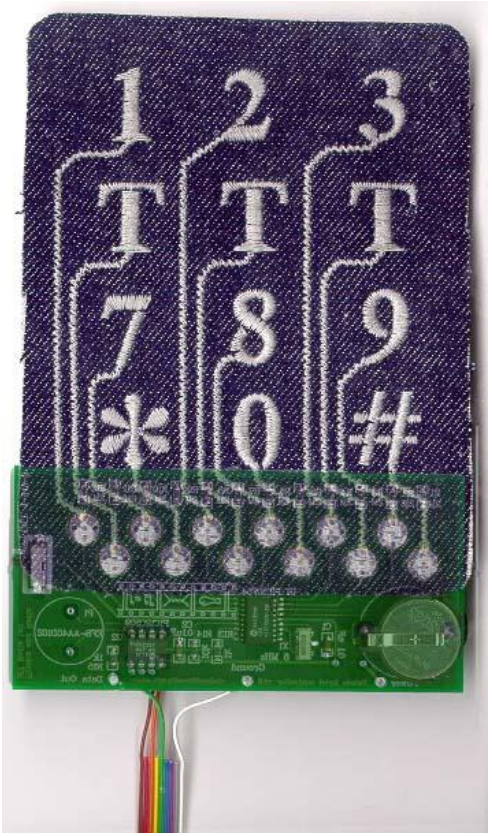
Emerging applications

» New functional materials that are flexible and can be processed at very low temperatures (below 100 °C) may open a new opportunity for new emerging applications, bringing a number of added value products to the market:

- Smart textile (incorporating **active** devices into the garments),
- Structural health monitoring (SHM) and non-destructive test (NDT) systems (covering large areas with functional materials, incorporating sensor systems into the plastic or composite materials),
- etc.

Smart Textile

- Smart textile materials become more and more popular nowadays and are widely used in various areas, allowing incorporation of built-in technological elements into everyday textiles and clothes.
- Most of the commercially available smart textiles are limited to **passive elements**, such as printed conductive elements (wires) or simple switches (buttons).
- Development of new materials may open a new opportunity for smart textiles by incorporating **active devices** such as buzzing elements or motion sensors into the garments.



MIT Media Laboratory, Cambridge

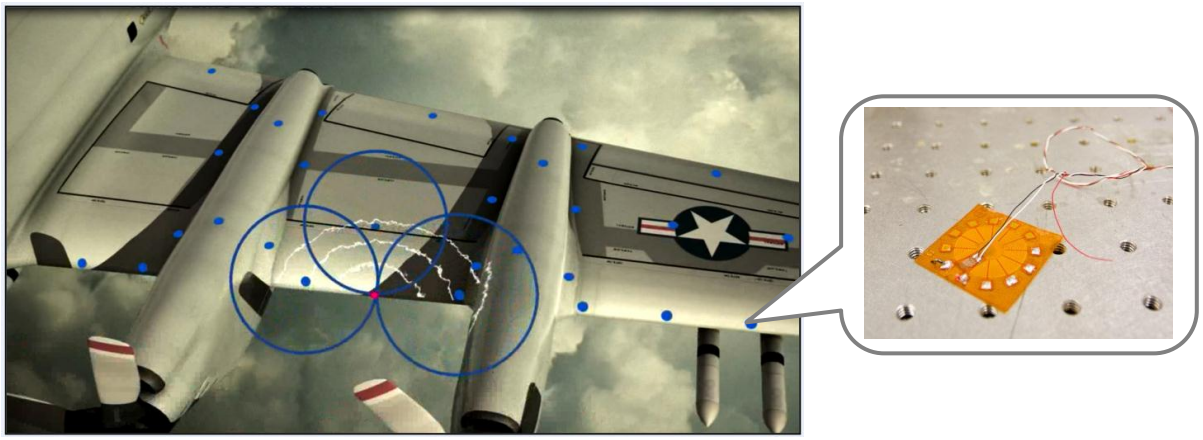
Smart Workwear

Intelligent clothing or smart clothing represents a combination of **active electronic components** that are embedded into the textile fibre and connected to classical electronic devices or components.

- 1 – Piezoelectric vibrating element,
- 2 – Motion sensor,
- 3 – CO Sensor,
- 4 – Piezoelectric buzzer,
- 5 – Electroluminescent lights,
- 6 – Temperature Sensor.

Structural health monitoring (SHM)

- System of sensors on the basis of flexible functional materials, imbedded into e.g. helicopter's tail boom or airplane’s wings, allowing to have:
  - Impact detection and localization at large areas,
  - Monitoring the structural integrity (cracks, delamination of airplane covering etc) and localization of the problems,
  - Reduced weight, reduced assembly cost, ability to cover large areas.

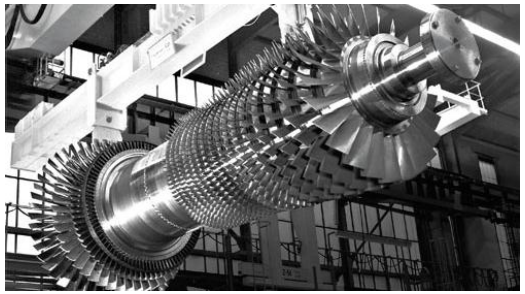


defensenews.com

Challenges

- The most obvious choice of the material for such applications is piezoelectric materials.
- Most of the piezoelectric materials are manufactured at very high temperatures (around 900 – 1300 °C), rigid, and therefore are not compatible with textile and plastic/composite materials.
  - Compatibility with flexible materials/fabrics/plastics etc,
  - Compatibility with commercial printing techniques (e.g. pad-, screen-, or ink-jet printing),
  - Low processing temperature (< 100 °C),
  - Reliability and ability to “survive” repeated washing (in the case of smart textile) or harsh environment (SHM and NDT systems),
  - Low manufacturing cost and suitability for large scale production.

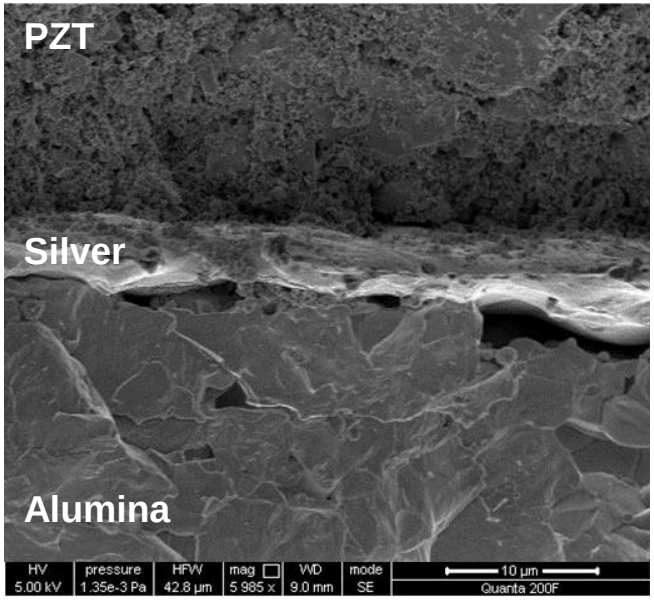
3 | Flexible piezoelectric materials – PiezoPaint™



Flexible piezoelectric materials - PiezoPaint™

Low temperature flexible piezoelectric materials has been developed on the basis of commercially available piezoelectric PZT based ceramics and polymer materials.

- Ultra low processing temperature (100 °C),
- High piezoelectric activity (d_{33} > 40 pC/N) and low dielectric losses (no power dissipation – no unnecessary heating),
- Flexibility and compatibility with screen-, pad-, and stencil printing techniques,
- Low manufacturing cost and suitability for the large scale production,
- Ability to adjust the properties, depending on the final application.

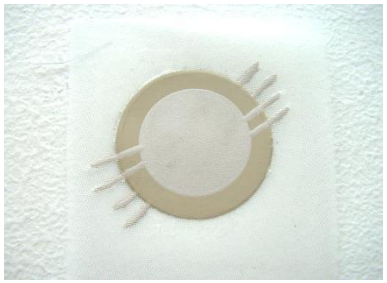


PiezoPaint™ - The substrates

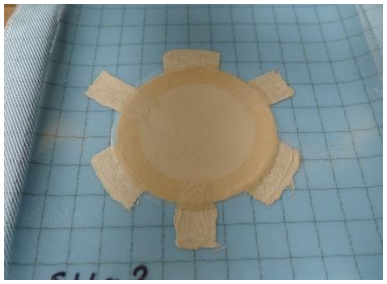
Can be applied onto:

- Fabrics
- Textiles
- Composites
- Metals
- Plastics/polymers
- Laminates
- Ceramics
- Paper
- PCB
- Etc.

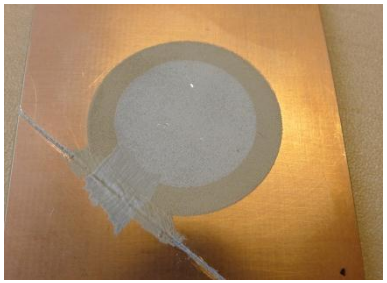
PiezoPaint™ on polymer



PiezoPaint™ on fabric



PiezoPaint™ on PCB



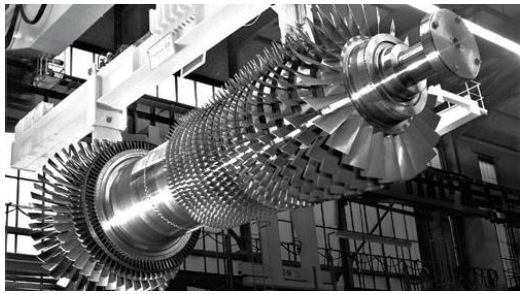
PiezoPaint™ - Properties

Properties of PiezoPaint™ materials can be adjusted, depending on the final application and customer requirements:

Material	Type	ρ, g/cm^3	T_{op}, °C	ε	tanδ, %	d_{33}, pC/N
PVDF	Co-polymer	1.8	< 90	10 – 12	-	-30
PP-30	PZT	4.9	< 150	90	2.5	28
PP-50A	PZT	5.0	< 150	100	2.5	40
PP-50B	PZT	5.2	< 150	125	3.0	40
PP-50LF	Lead-Free	< 4	< 150	250	4.0	25

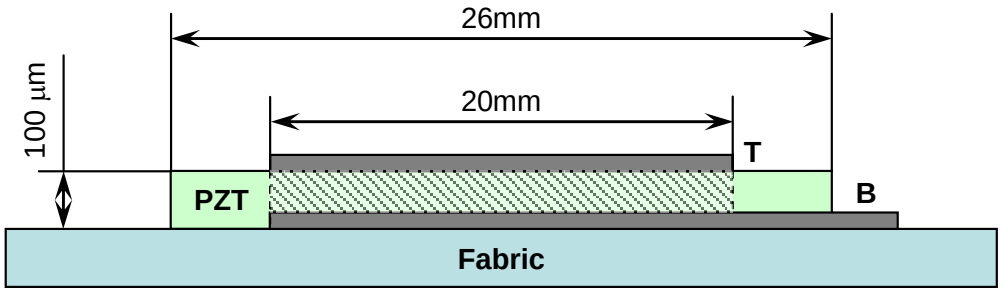
Properties are for semi-clamped samples, in the case of the films printed onto alumina substrates (cured)

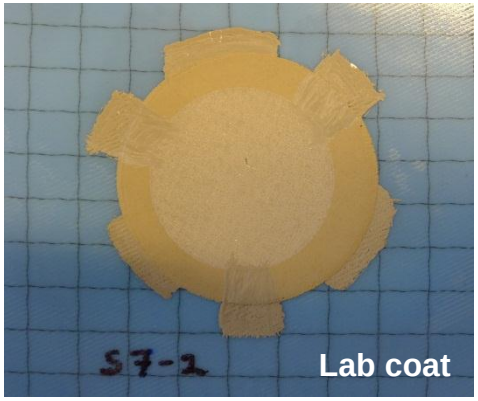
4 Examples of applications

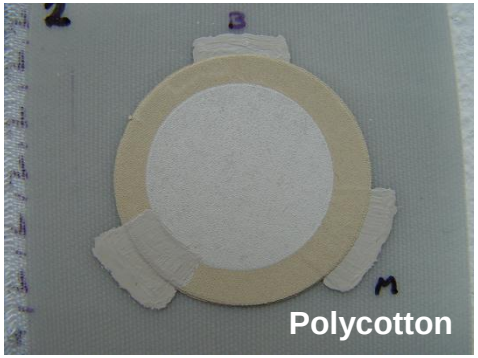


PiezoPaint™ - Examples

Piezoelectric buzzer on textile:



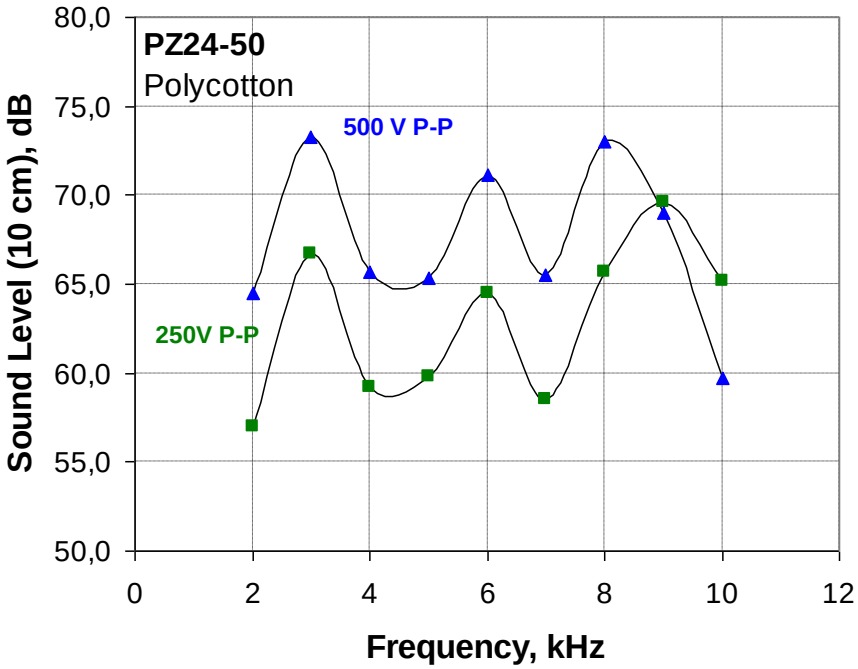


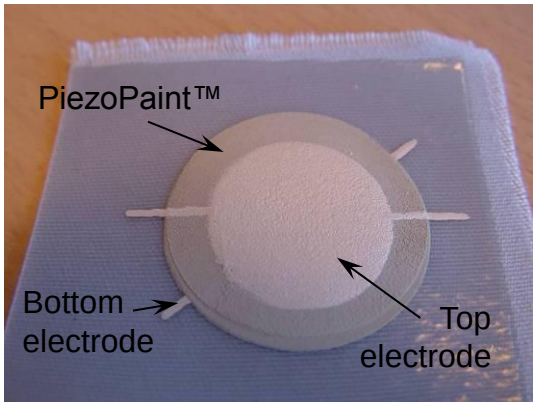


- Represents a simple structure, where the piezoelectric thick film is sandwiched between the top and the bottom electrodes,
- Entire structure can be encapsulated with PVC or UV curable dielectrics, available e.g. from DuPont,
- Flexible and can be applied on any structures, including the lab coats or workwear.

PiezoPaint™ - Examples

Piezoelectric buzzer on textile:



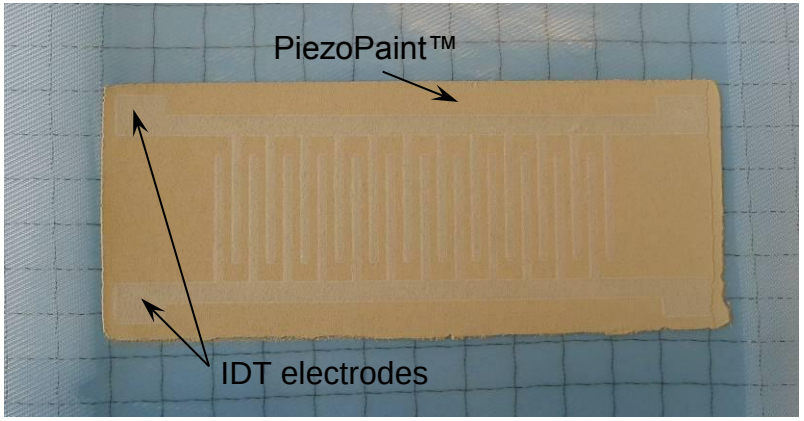


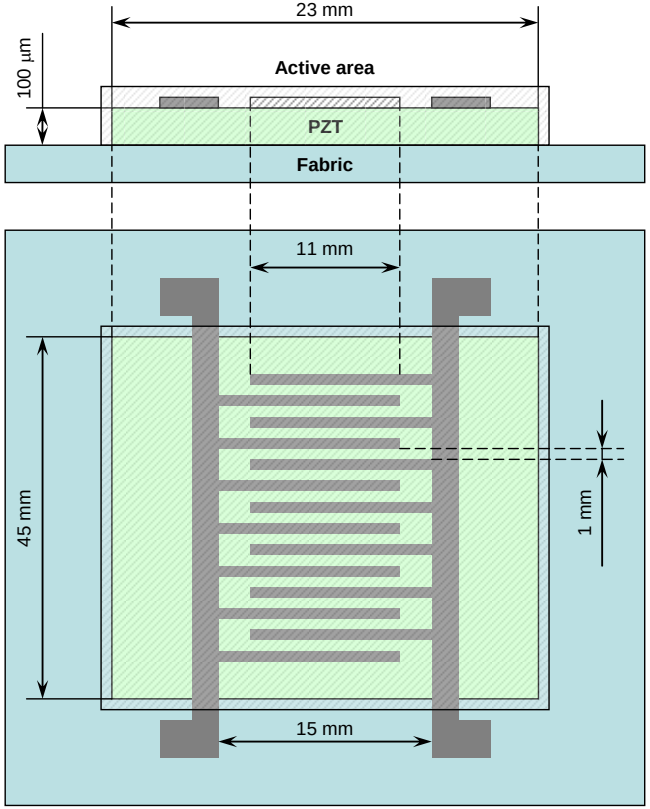
- Up to 75 dB of sound pressure,
- Flexible and can be applied on any structures, including the lab coats or workwear.

PiezoPaint™ - Examples

Piezoelectric motion sensor:

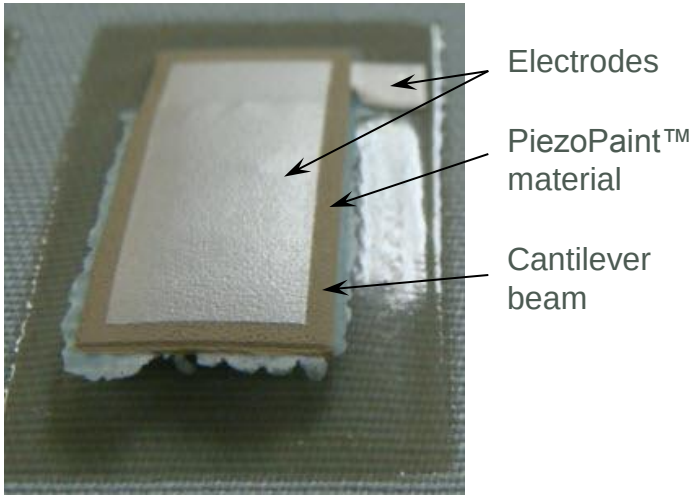
- Printed on lab coat's sleeve,
- The sensor is connected to the workwear's control system and sensing the bending of the sleeves.
- The level of output signal is about 100mV,

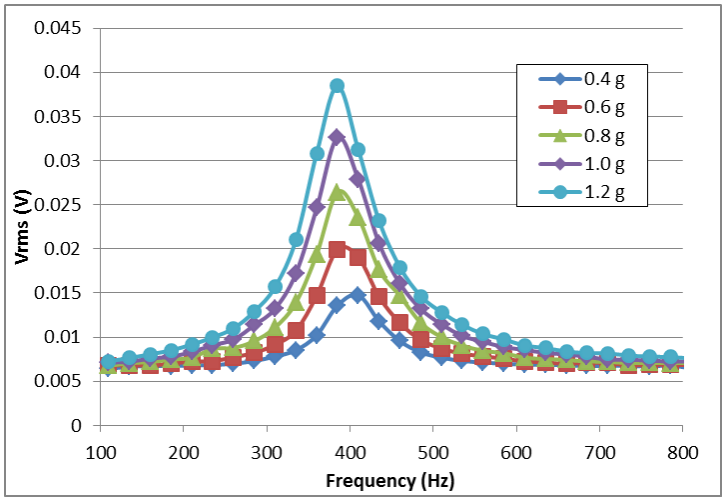




PiezoPaint™ - Examples

Piezoelectric accelerometer / energy harvester:



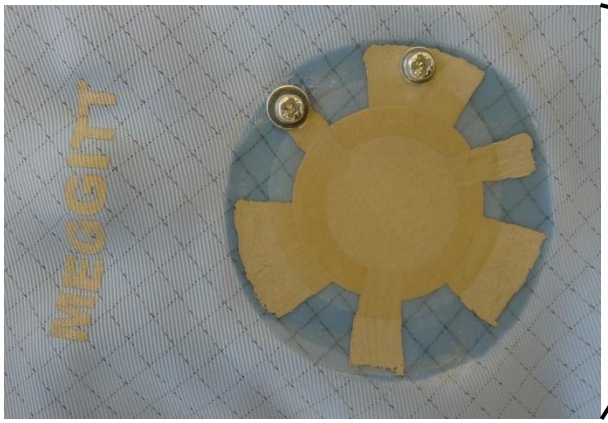


Courtesy of University of Southampton, UK

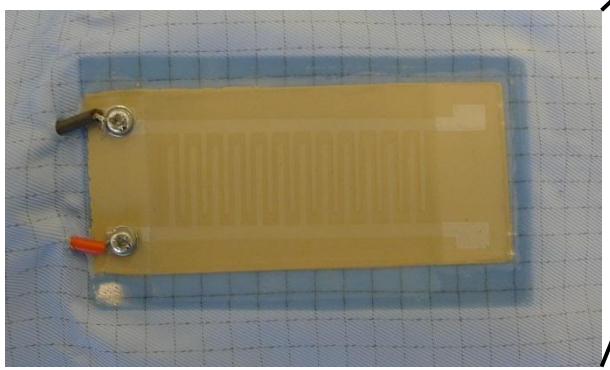
» The sensor has good linearity and produces a peak output of nearly 60 mV which would be sufficient for a motion sensor detection system.

PiezoPaint™ - Lab coat prototype

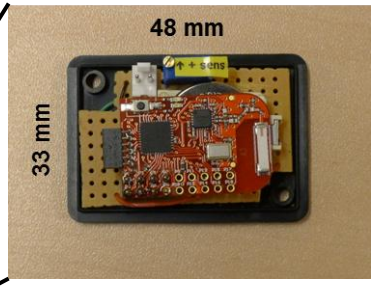
Piezoelectric buzzer



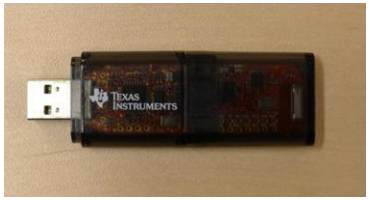
Piezoelectric motion sensor



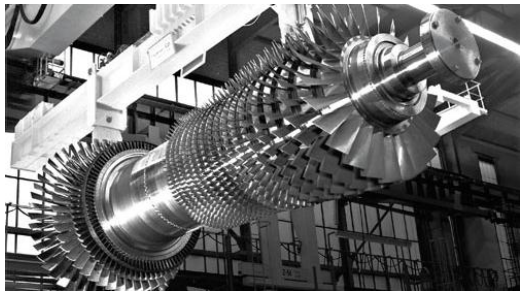
Transmitter



Receiver (USB stick)



5 Conclusions



Conclusions

- New flexible piezoelectric material – PiezoPaint™, that can be processed at extremely low temperatures (< 100 °C) has been developed,
- PiezoPaint™ material developed is compatible with most of the commercially available printing techniques, and can be applied on any structures, including textile, fabrics, plastics, PCBs, etc,
- Properties of PiezoPaint™ material can be adjusted, depending on the application.
- PiezoPaint™ material has relatively high piezoelectric charge coefficient (d_{33} > 40 pC/N), low dielectric losses, and it is compatible with large scale production,
- A number of prototypes on the basis of PiezoPaint™ material has been successfully developed and demonstrated, including smart textile and others,
- PiezoPaint™ patent pending,
- As CTS | Ferroperm we see a number of potential benefits for the company from entering this research field, such as development of new products for different markets (Structural Health Monitoring in aerospace, Energy Harvesting etc), entering new markets with higher added value products, and establishing cutting edge background technologies in the field of e.g. piezoelectric materials and devices.

Acknowledgments

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Thank you