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School of Electronics and Computer Science

MICROFLEX Project: MEMS on New Emerging Smart Textiles/Flexibles

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ESD Research Group
Smart Fabrics 2011
5th April 2011

μFLEX

Overview

- Introduce the MicroFlex project
- What are MEMS?
  - How are they made
  - MicroFlex developments
- Case Study: Printed strain gauge on fabric
- Case Study 2: Printed piezoelectrics on fabrics

Research at Southampton

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- ECS was founded over 60 years ago
- 106 academic staff (36 professors)
- 140 research fellows, 250 PhD students
- Research grant income: over £12 million
- Over 20 years experience in developing printable active materials
- 4 research projects on smart fabrics:
  - Microflex (EU Integrated Project)
  - Bravehealth (EU Integrated Project)
  - Energy Harvesting Materials for Smart Fabrics and Interactive Textiles (EPSRC)
  - Intelligent prosthetics (UK MOD)

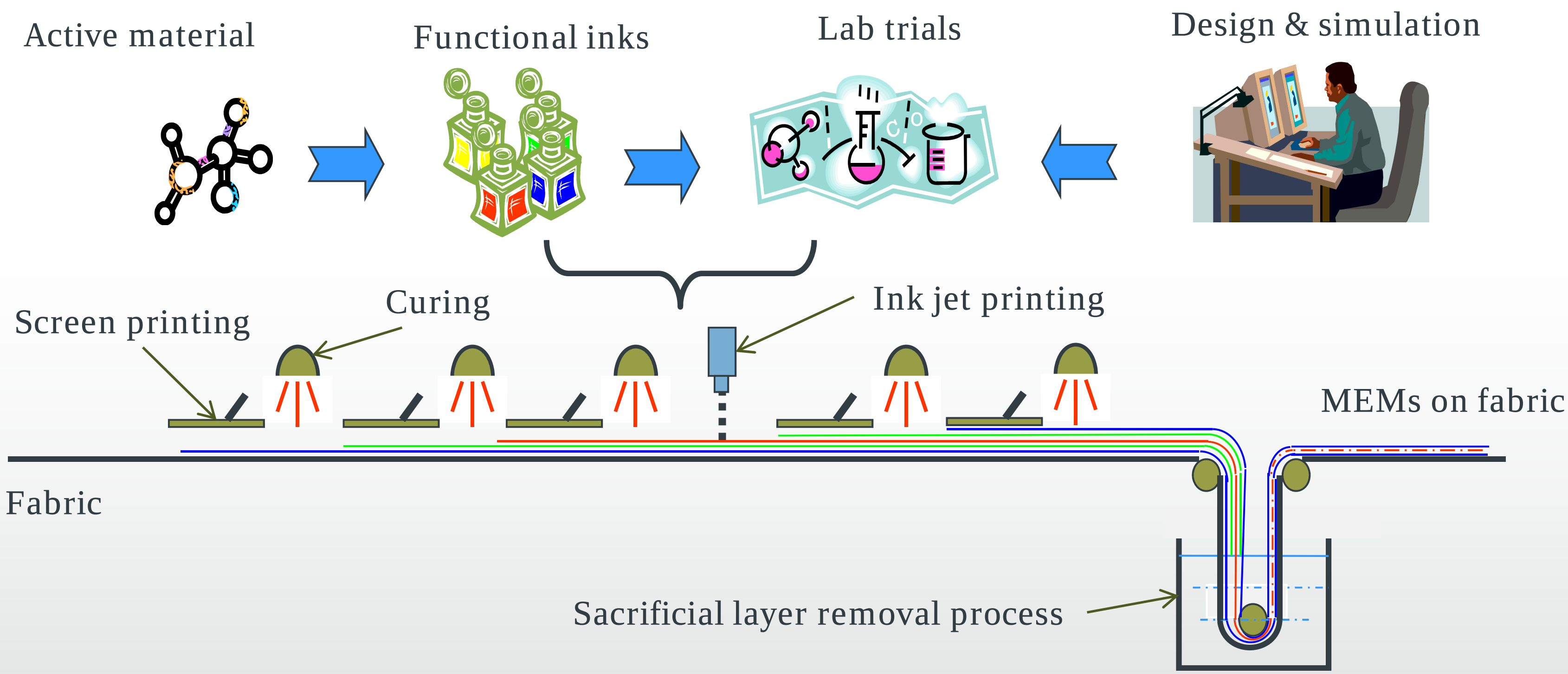
£100 million Mountbatten Building, housing state of the art cleanroom.

MicroFlex Project

- The MicroFlex Project is a EU FP 7 funded integrated project, 7.7 M€ Budget, 5.4 M€ funding.
- 4 Year project, end date 30th October 2012.
- 13 Partners, 7 industrial, 9 countries.
- Develop MEMS processing capability for the production of flexible smart fabrics. Based on screen and inkjet printing.
- Develop new functional inks to be compatible with fabrics.
- Produce industrial prototypes demonstrating the functionality of the new inks.

http://microflex.ecs.soton.ac.uk

Envisaged Process Flow



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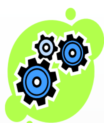
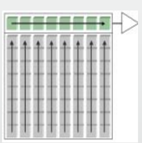
Example Functions and Applications

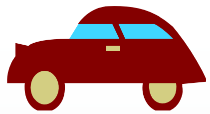

Drug delivery


Mechanical action


Lighting


Sensor


Medical — Smart bandage, auto sterilization uniform, active monitoring underwear

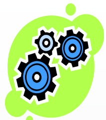

Transport — Luminous cabin, smart driver seat, auto clean filters


Workwear — Danger warning workwear (heating suite, high visibility, gas sensing, temperature sensing, movement sensing, alarm sounder

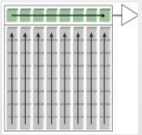

Consumer — Massage and cooling/heating armchair, surroundings customisation

Example Functions and Applications


Drug delivery


Mechanical action


Lighting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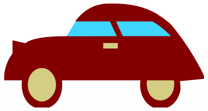
Transport: Luminous cabin, smart driver seat, auto clean filters


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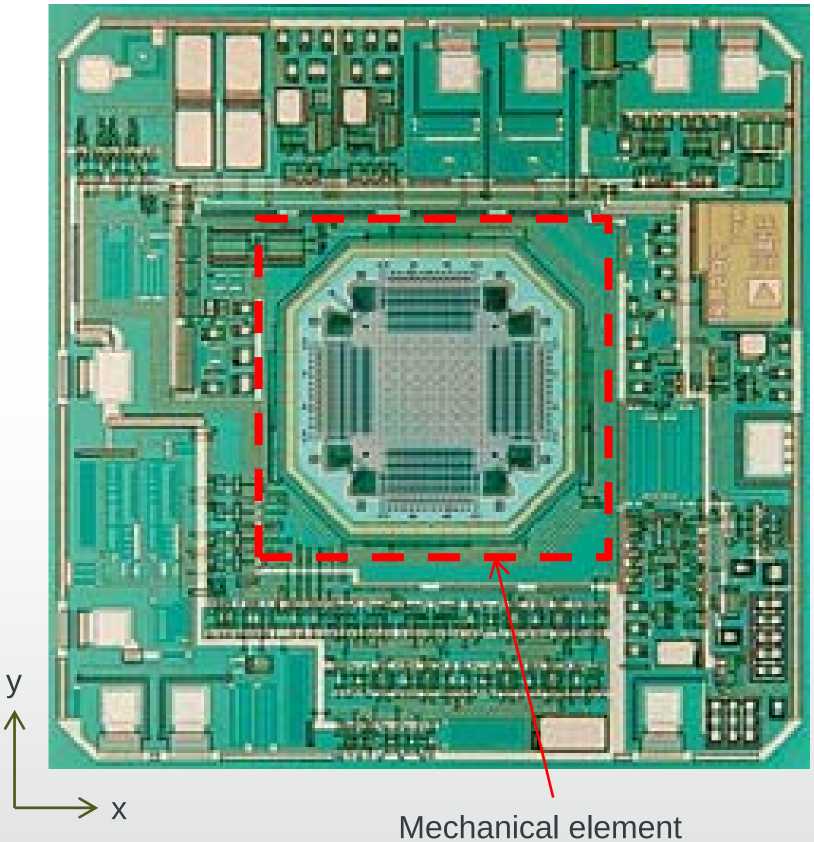
MEMS

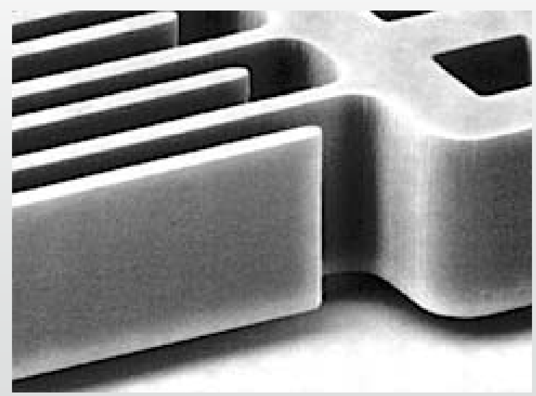
- The MicroFlex project is concentrating on fabricating sensors and actuators (transducers).
- MEMS stands for **M**icro**E**lectro**M**echanical **S**ystems, i.e. they are systems that include mechanical and electrical functionality.
- Typical MEMS are miniature sensors and actuators.
- MEMS technology is dominated by Silicon microfabrication technology, although polymer materials / processes becoming increasingly used.

Example MEMS

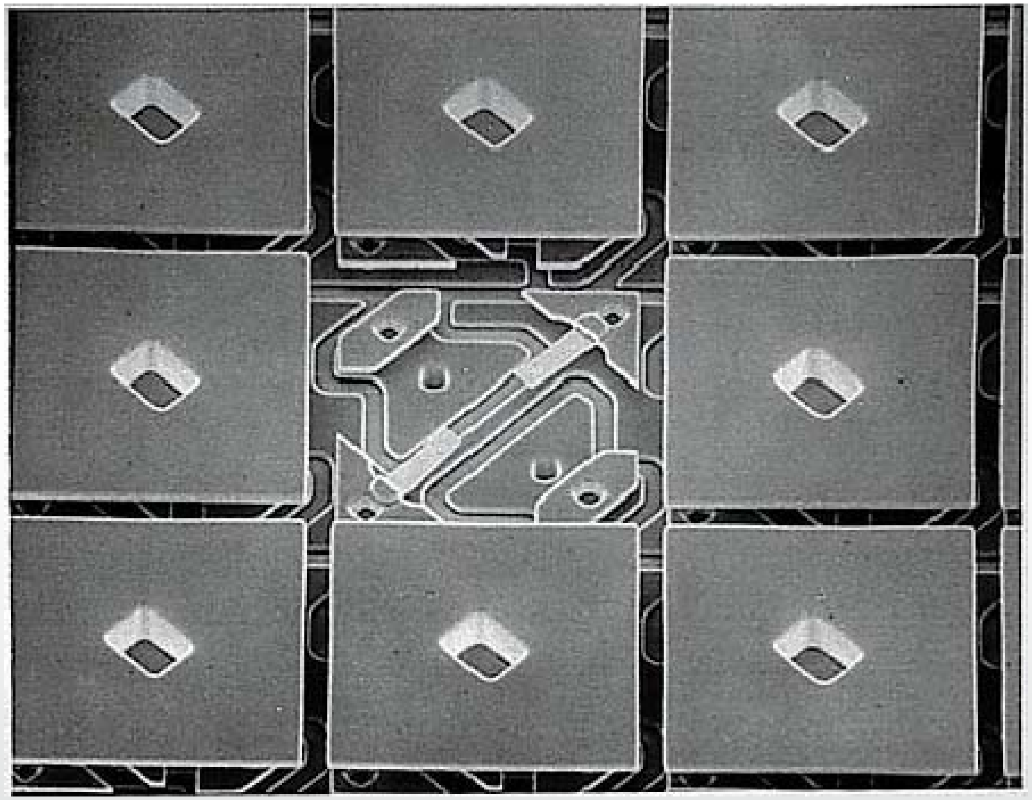


Analogue devices ADXL 50 2 axis accelerometer, 3 mm^2 surface area for integrated electronics and mechanical sensing element

Inertial mass displacements sensed by interdigital electrode array.

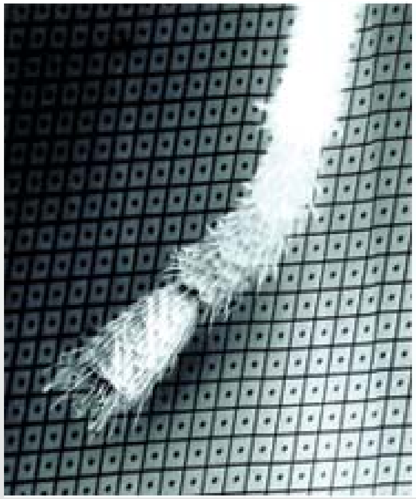


Example MEMS 2



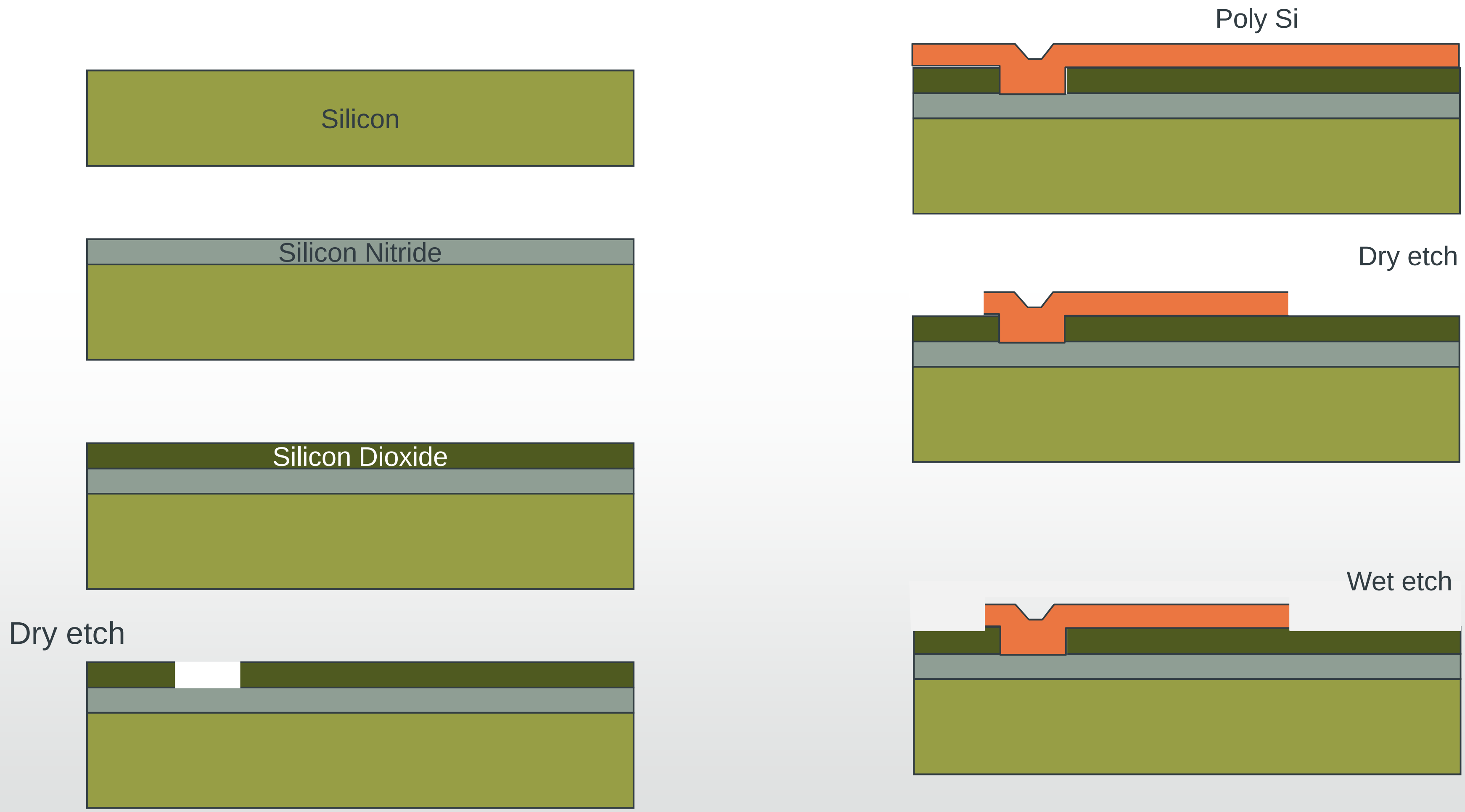
http://www.dlp.com

Texas Instruments Digital Light Processors (DLP) 2 million mirrors, 13µm wide



TEXAS INSTRUMENTS

MEMS Fabrication



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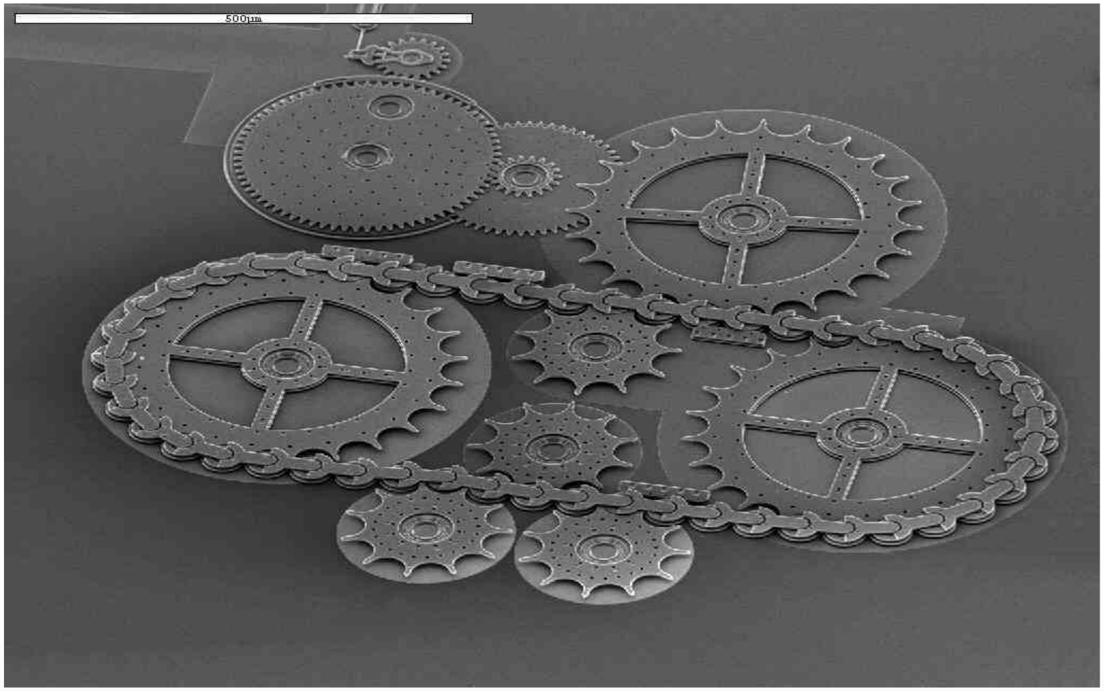
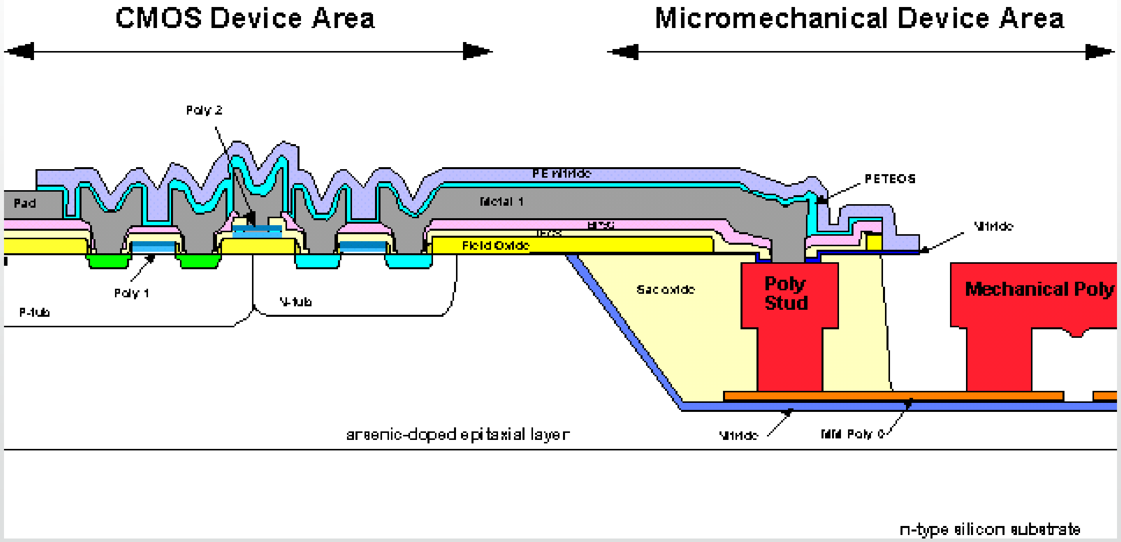


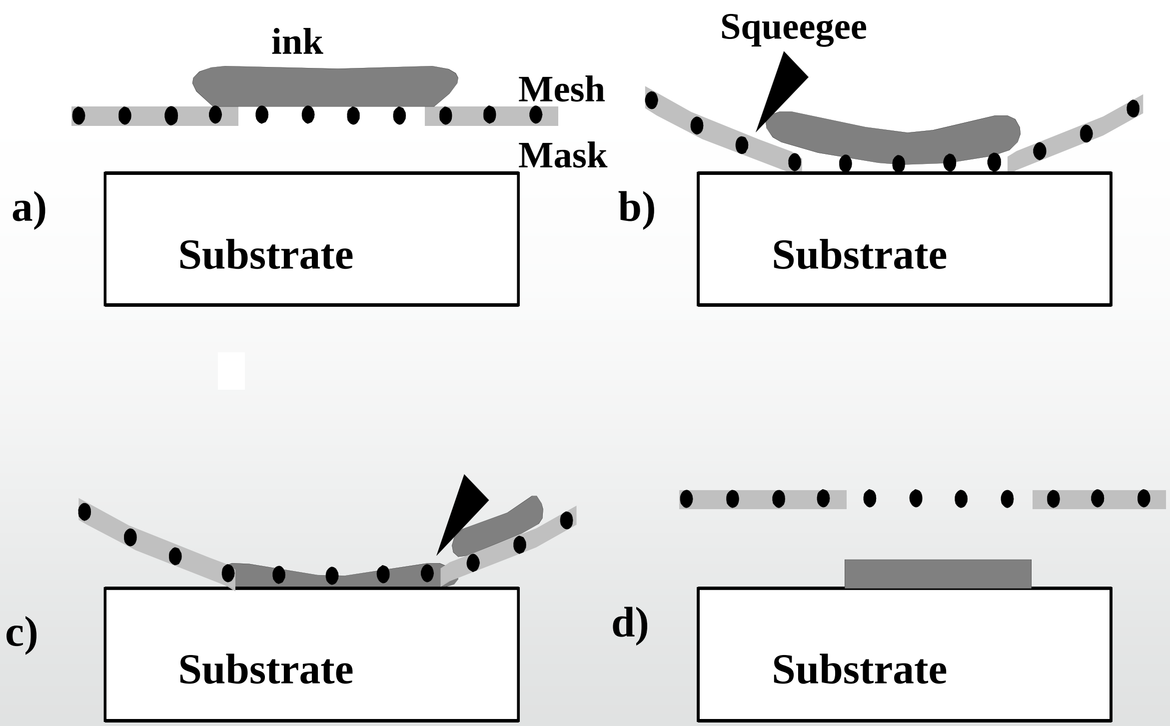


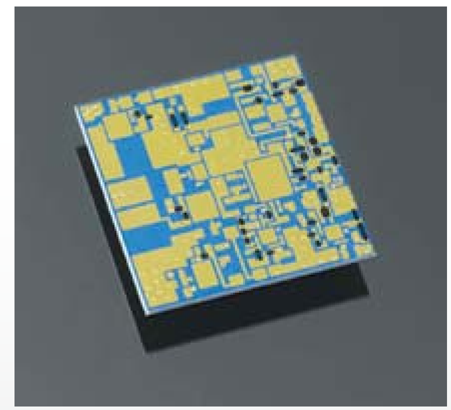
MEMS Fabrication on Fabrics

- Fabrics present a very different substrate compared with a silicon wafer
  - Rough, uneven surface with pilosity
  - Flexible and elastic
  - Suitable for low temperature processing
  - Limited compatibility with solvents and chemicals
- MicroFlex aims to use standard printing techniques to deposit a range of custom inks in order to realise freestanding mechanical structures coupled with active films for sensing and actuating.

Screen Printing

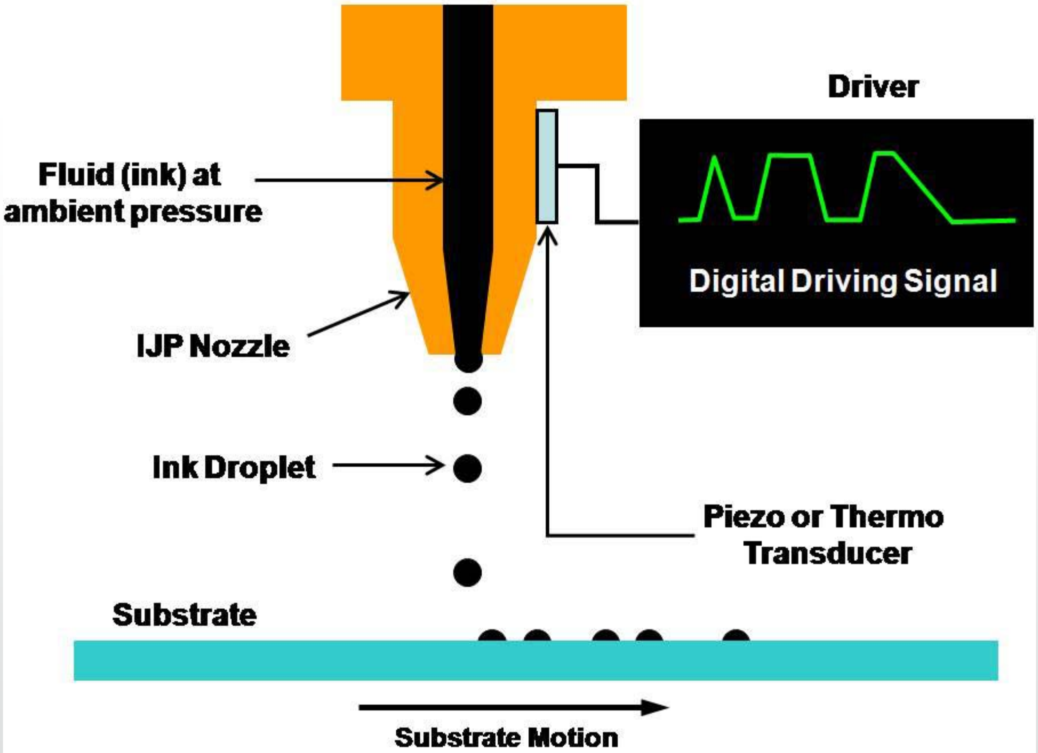
Also known as thick-film printing, this is normally used in the fabrication of hybridised circuits and in the manufacture of semiconductor packages.



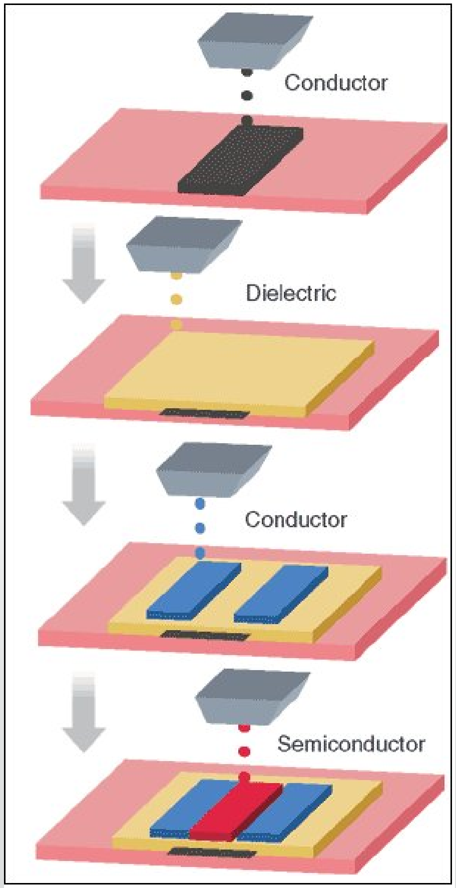


Inkjet Printing

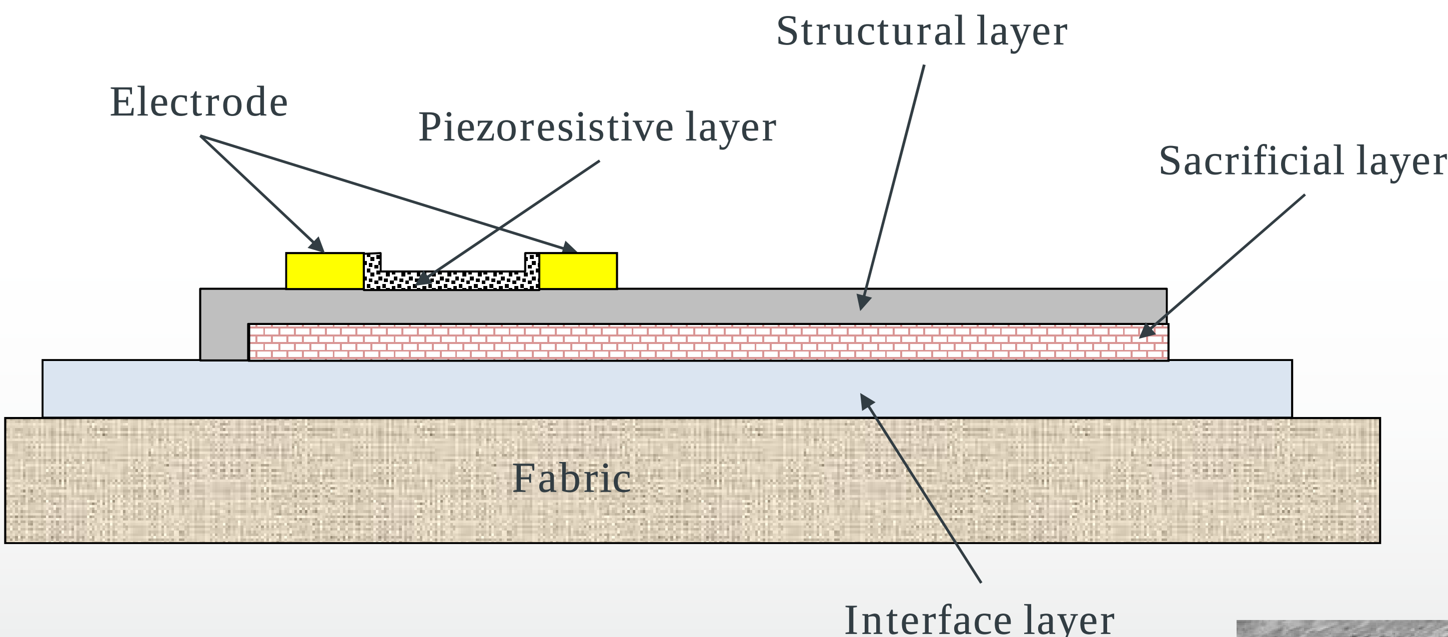
Non contact direct printing onto substrate, used for fabrics and electronics applications.



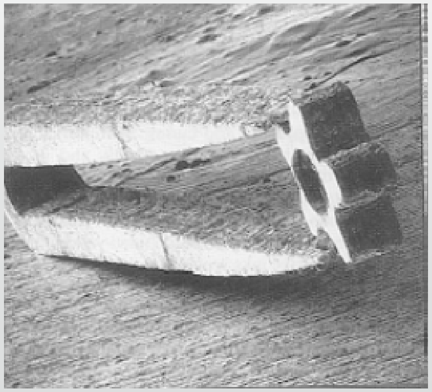
http://spie.org/x18497.xml?ArticleID=x18497



Printed MEMS Process



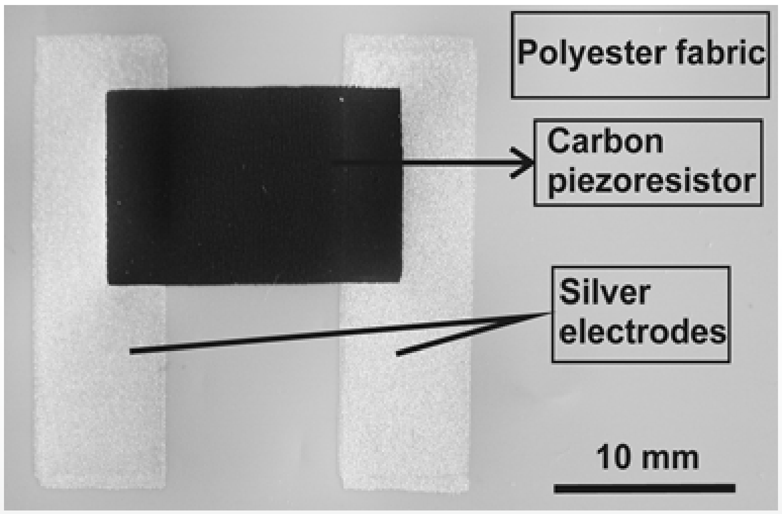
- Sacrificial layer requirements: printable, solid, compatible, can be easily removed without damaging fabric or other layers.
- Structural layer requirements: suitable mechanical/functional properties.



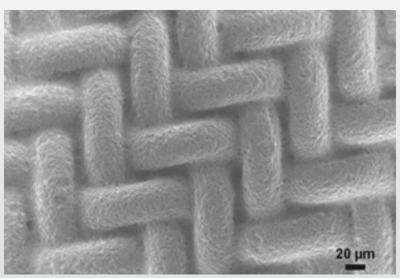
Case Study: Strain Gauge

- The MicroFlex project is structured so as to initially demonstrate the functional inks, and then use these in the sacrificial layer process.
- Printed strain gauge demonstrated by project partners Jožef Stefan Institute, ink developed by ITCF and fabric from Saati.
- Exploits the piezoresistive effect: the resistance of a printed film changes as it is strained (stretched) due to a change in the resistivity of the material.
- Useful for sensing movement, forces and strains.

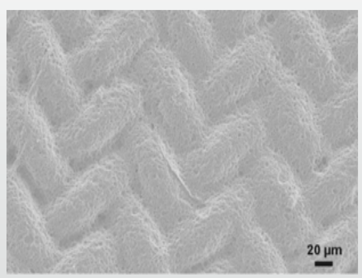
Printed Sensor



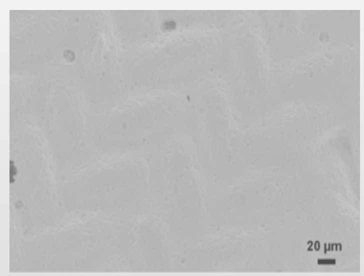
- Silver electrodes printed using a low temperature polymer silver paste.
- Piezoresisive paste is based on graphite.
- Cured at 120-125 ^{o}C



1 print



2 prints



3 prints

Results

- Sensitivity illustrated by the Gauge factor:

$$GF = \frac{\Delta R / R}{\varepsilon}$$

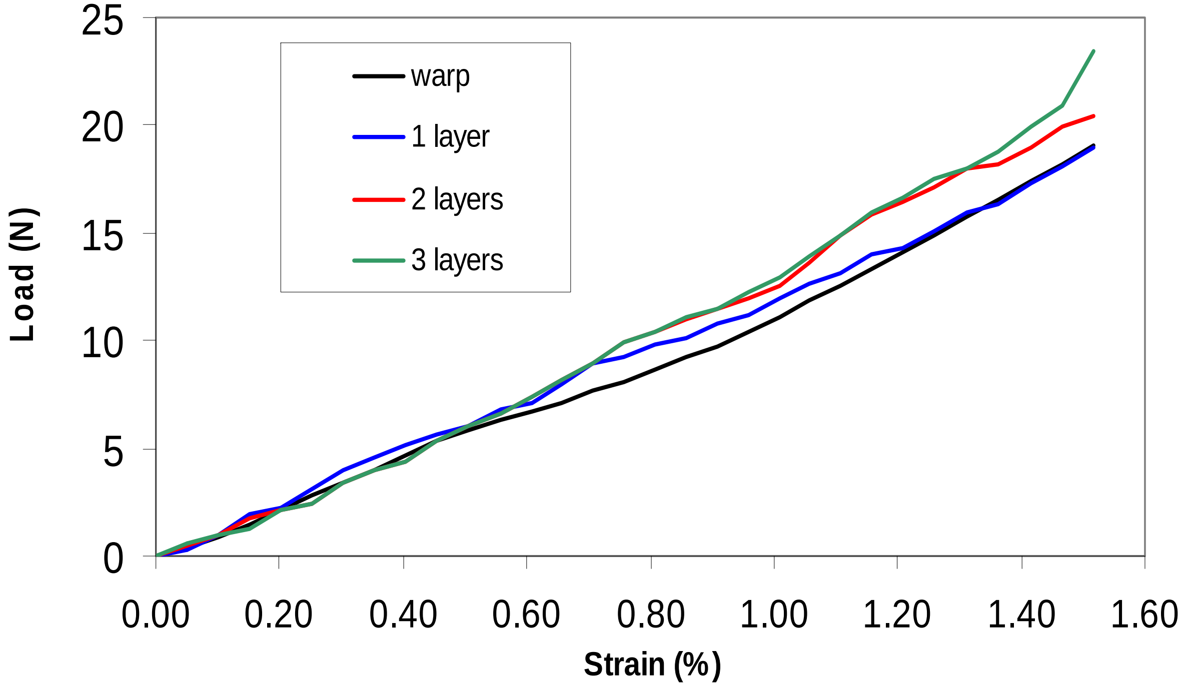
- Clear increase in resistance demonstrated as the fabric is strained.

N° of graphite layer	**R_0 (Ω) at 0 % strain**	**R(Ω) at 1.5 % strain**	**Gauge factor**
1	1905	2064	5.6
2	1100	1198	5.9
3	328	358	6.1

- Conventional metal foil GF = 2

Strain vs Load

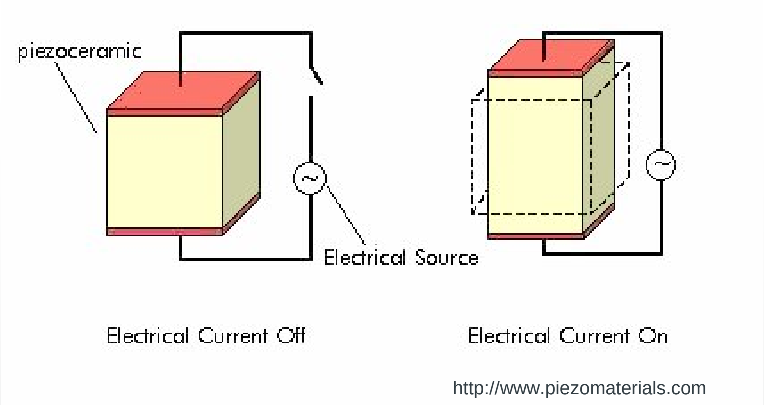
- By measuring resistance the load on the fabric can be calculated.



B. Perc, *et al.* 'Thick-film strain sensor on textiles', 45th International Conference on Microelectronics, Devices and Materials - MIDEM, Slovenia 9-11 Sept 2009.

Piezoelectric Films

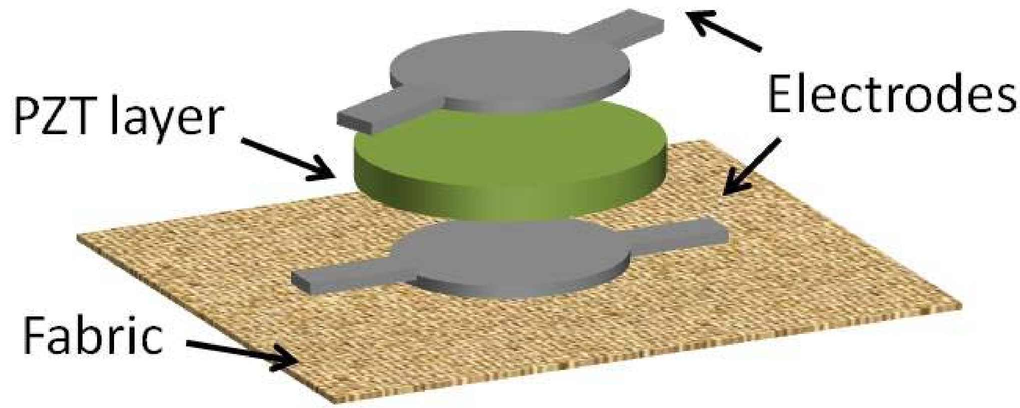
- Piezoelectric materials expand when subject to an electrical field, similarly they produce an electrical charge when strained.

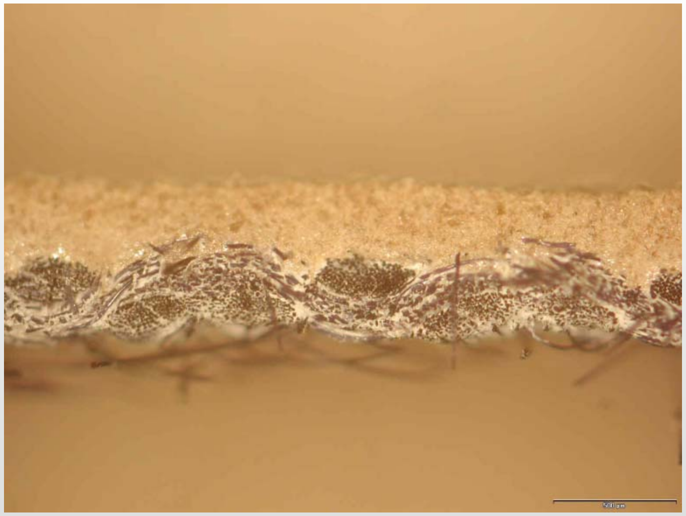


- Ideal material for sensing and actuating applications.
- Meggitt have developed a screen printable piezoelectric paste that can be printed onto fabrics.

Piezoelectric Structure

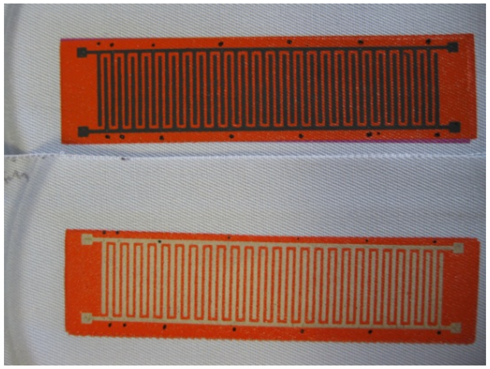
- Piezoelectric material sandwiched between electrodes.
- Polarising voltage required after printing to make the piezoelectric active.
- Cured at temperatures below 150 °C.
- Promising sensitivity demonstrated (d_{33} ~ 30 pC/N)



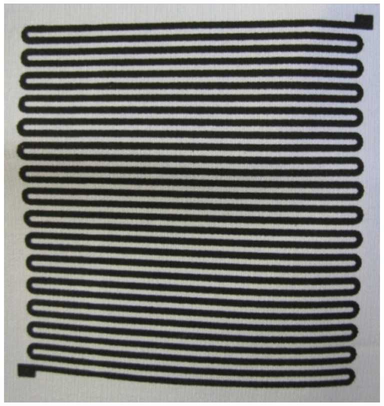


Images courtesy of Meggitt Sensing Systems

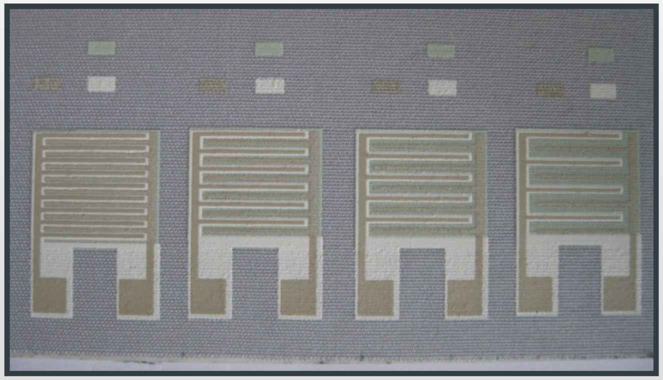
Other Examples



Screen and inkjet printed conductors on fabric. Evaluating conduction and flexibility.



Screen printed heater on fabric. Evaluating heating effects on fabric.



Screen printed electro-luminescent lamp on fabric. Evaluating lamp performance and compatibility with fabric.

Conclusions

- MEMS technology is widely established in a multitude of applications.
- MicroFlex will develop the materials and processes required to fabricate MEMS on fabrics.
- Range of active inks has already been demonstrated.
- Currently preparing phase one prototypes based upon these active inks.
- Sacrificial layer fabrication process has also been demonstrated and will be combined with active inks in phase two prototypes.

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Acknowledgements

Colleagues at Southampton, MicroFlex partners and EU for funding (CP-IP 211335-2).

Paul Boyé · Elasta · ardeje · LEITAT Technological Center · MEGGITT smart engineering for extreme environments · Fabric by KLOPMAN · bonfort TEXTILE INDUSTRIES · ifth Activateur de projets · ITCF DENKENDORF · Otto-von-Guericke-Universität Magdeburg · SAATI · Jožef Stefan Institute Electronic Ceramics Department-K5

Thanks for your attention!