Multi-Material Micro Manufacture (4M)

Coordinator: Dr. Stefan Dimov, Cardiff University, UK

Banner image courtesy of DMG UK

4M Partnership

Co-ordinator: Cardiff University (UK)

15 Core Partners

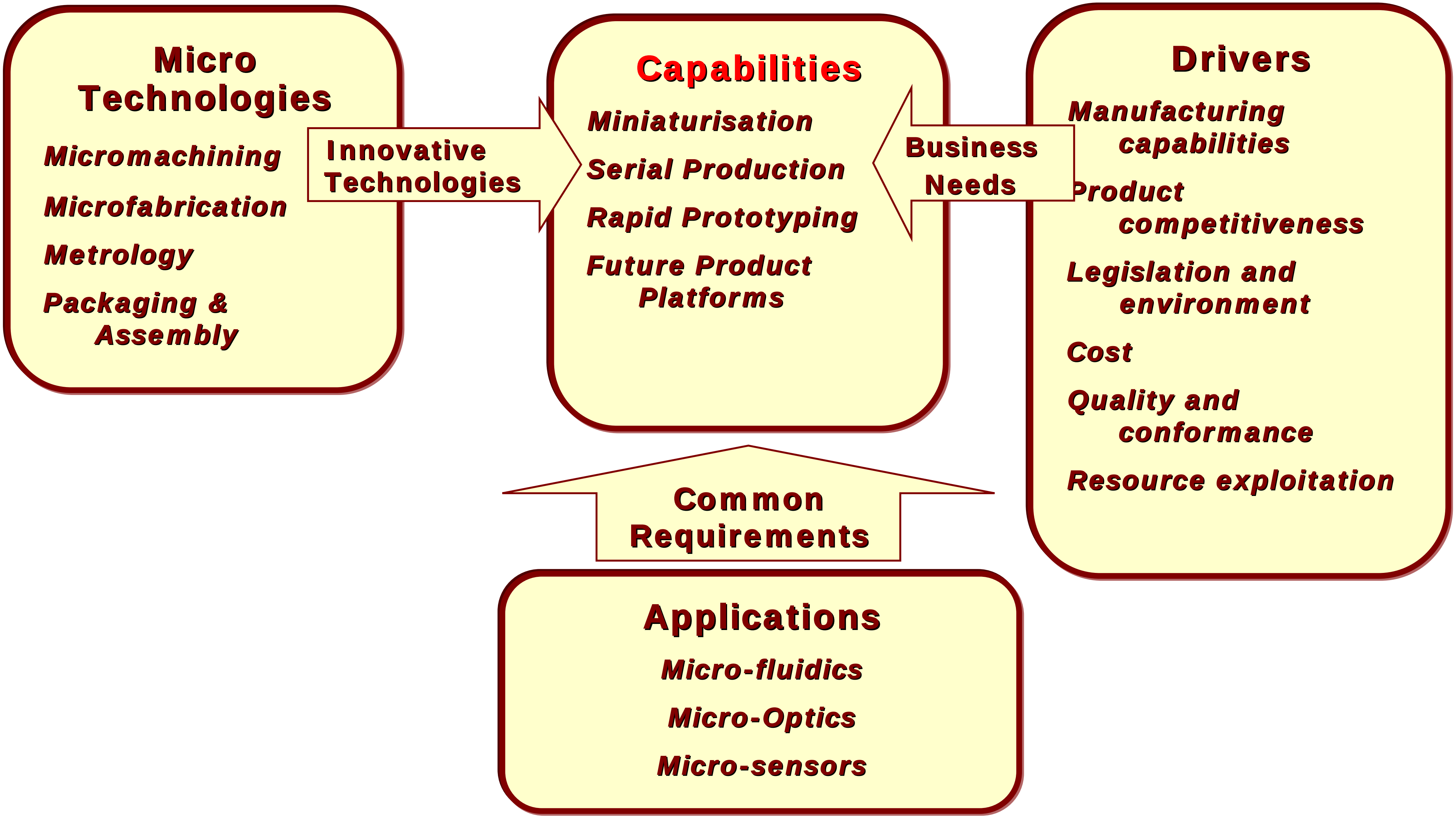
- Belgium: KU Leuven;
- France: CEA;
- Germany: IMTEK, IZM, FZK, IPT, IBMT, Erlangen
- Netherlands: TNO;
- Spain: TEKNIKER;
- Sweden: IVF and KTH;
- UK: Cardiff, Cranfield, RAL

15 Countries

15 Associate Partners

- Austria: IMFT
- Bulgaria: BAS
- Denmark: DTU
- France: LPMO
- Germany: IZFM, HSG-IMAT and BLZ
- Greece: Patras
- Hungary: BUTE
- Italy: Naples
- Rumania: IMT
- Slovenia: Ljubliana
- Sweden: IMEGO
- UK: Bath and SCU

4M Scope: Establishment of 4M Capabilities



Example of a Divisional Programme: Microoptics

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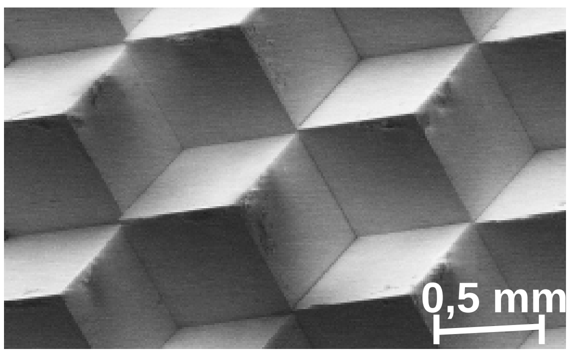

Source: IPT

Demonstrator 1: Triple mirror array (IMTEK; IPT) - Plastics, blanks

- Systematical analysis of microoptical systems and their associated process chains
- Identification of process limitations in relation to master and replication technologies
- Proposal of innovative manufacturing solutions for identified gaps in current technological capabilities
- Development of demonstrators
- Preparation of National and European research projects to address the identified gaps

Two Calls for Cross-Divisional Integration Projects

To support the "vertical" integration of technology- and application-driven activities, in particular:

- Application-driven projects that require the inputs of Technology Divisions and lead to development of demonstrators;
- Technology-Application mapping projects leading to the development of design guidelines for a range of applications.

The Results of the First Call

Two projects were funded:

- *Micro-Chip (Lead by Micro-Optics Division & IPT)* – to study the dependence between the material behaviour and the process capabilities.

- *Development of a 4M micro-pump (led by Micro-Fluidics Division & IZM)* – to develop a demonstrator, a micropump, that have a very simple design and could be produced using 4M technologies for serial manufacture (low unit cost).

The Results of the Second Call

Four Cross-Divisional projects will be funded:

1. **Three-dimensional electronic packaging and interconnection;**
2. **Sensors Systems in Foil;**
3. **Metrology Solutions for Deep High-Aspect Ratio micro-Features;**
4. **Integrated Biophotonics Polymer Chip;**

(IMT is participating in the proposals 1 and 4)

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Microfabrication of gas sensors using mixed technologies

Project developed in cooperation between: IMT,
Forschungszentrum Karlsruhe, Cardiff University; Cranfield University, IMEGO, Fundacion Tekniker; IVF- Industrial Research and Development Corporation .

The main goal:

Developing a novel class of chemoresistive gas sensors,

Increased reproducibility;

- ***Very small dimensions;***
- ***The possibility of integrating the sensing element and electronics in the same package (system in package);***
- ***Reduced power consumption;***
- ***Possibility of making portable devices.***

by using mixed techniques such as:

- ***Laser milling techniques;***
- ***Conductive ceramic technology;***
- ***Thin & thick film technology;***
- ***Bulk micromachining techniques***

Microfabrication of gas sensors using mixed technologies

Design and technological steps (IMT)

The sensor consists of an integrated heater and a platinum temperature sensor built on top of a suspended membrane.

STEP A.
Laser machining of electroceramic heater channels **(100 μm width) & subsequent filling with conducting ceramic**

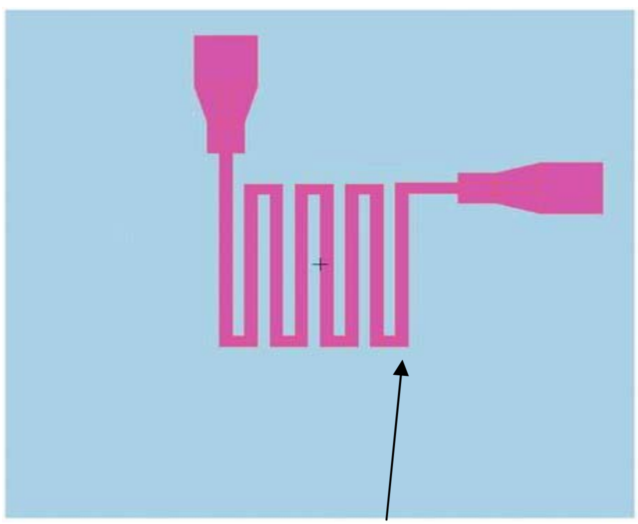

Fig.1. Heater layout

STEP C.
Deposition of the metallic interdigitated capacitor

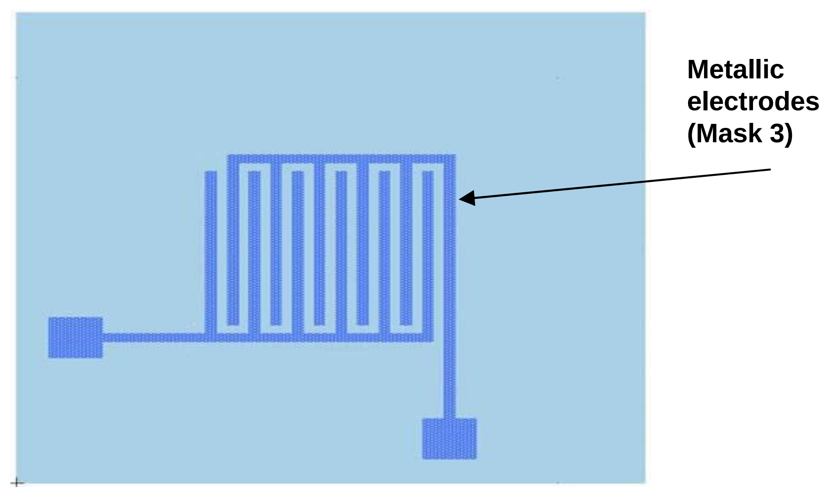

Fig.2 Metallic interdigitated capacitor

Design and technological steps (IMT)

***Stage 2*:**
Releasing the membrane
During this step, the final backside allows the membrane to be released, Fig.6.

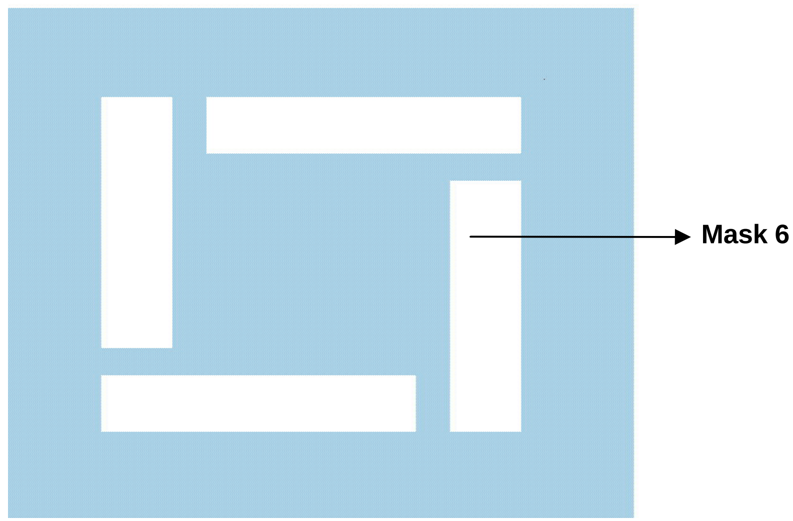

Fig.3. Lift – off mask for sensitive layer deposition

Microfabrication of gas sensors using mixed technologies

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Design and technological steps (IMT, IVF, IMEGO, Teckniker, Forshung Material Karlsruhe, Cranfild University, Cardiff University)

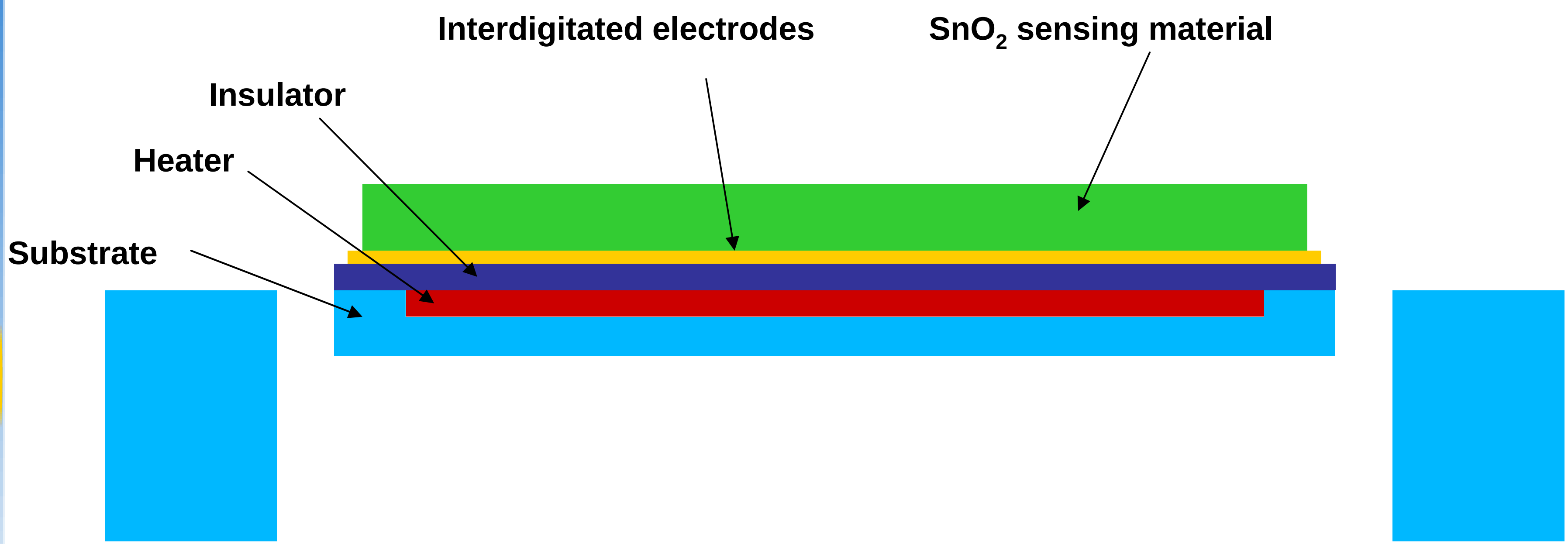
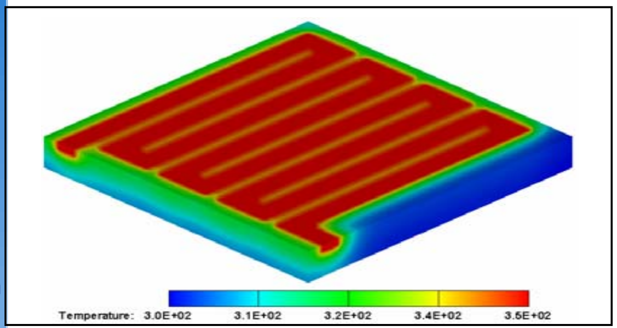


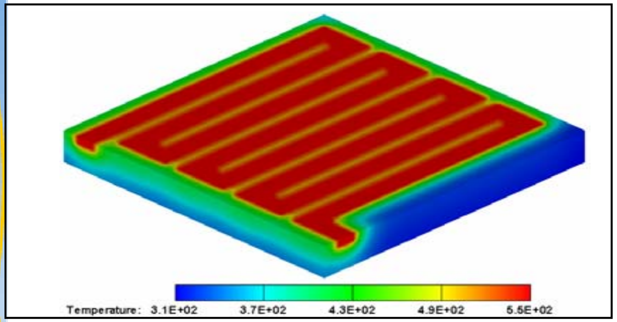
Fig4. Mask 6 - Membrane releasing

Microfabrication of gas sensors using mixed technologies

Simulation of AuPdPt heater (IMT)

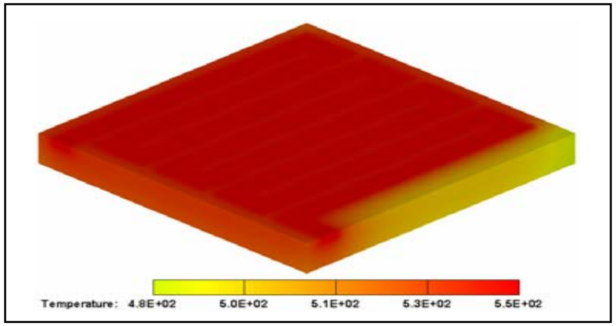


a) T= 350^{0}C

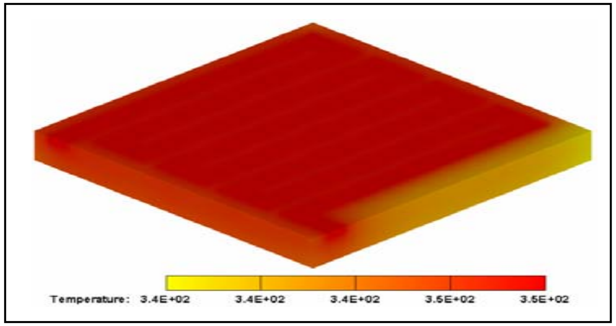


b) T= 550^0*C*

Fig 5. Thermal distribution after 0.02s at a)350^{0}C; b) 550^{0}C



a) T= 350^{0}C

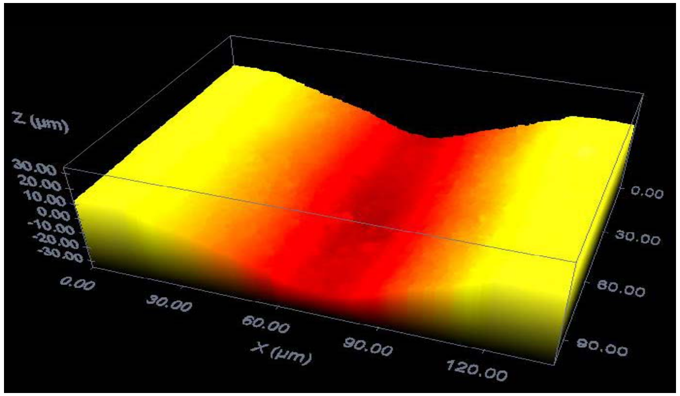


b) T= 550^0*C*

Fig.6. Thermal distribution after 0.2s at a) 350^{0}C; b) 550^{0}C

Microfabrication of gas sensors using mixed technologies

Heater fabrication (Cardiff,Tekniker, IVF, ZFK)



The heater was configured by laser milling of 40 microns depth cavities in LTCC and alumina substrates.

Trenches filled with LTCC AuPtPd paste or conductive TiN ceramic paste using Doctor Blading in a screen printing machine

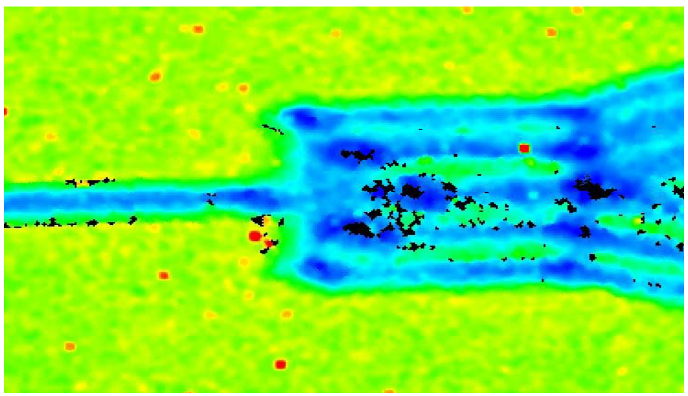


Fig 7. The laser milled cavities in LTCC substrate

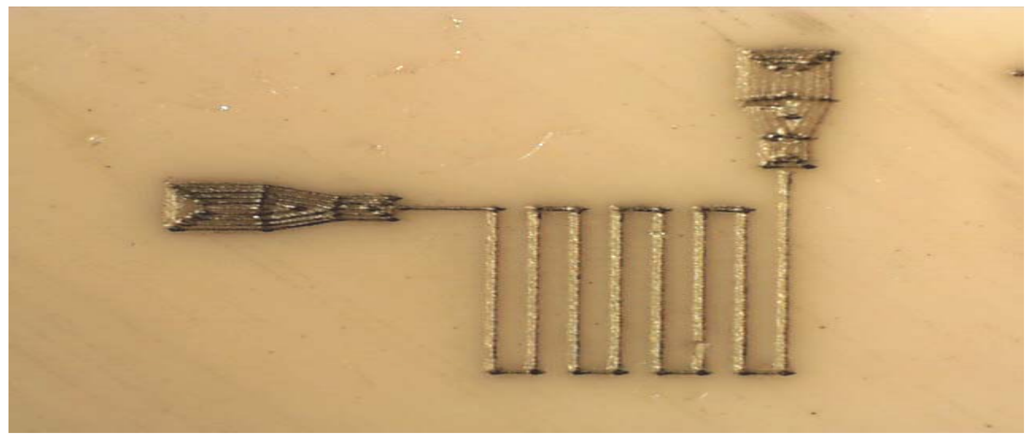


Fig 8. The cavities in the LTCC substrate filled with AuPtPd past after sintering at 850 °C

Microfabrication of gas sensors using mixed technologies

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Heater measurements (AuPdPt) - IVF

The power temperature responses were recorded by measure the temperature of one heater element with an AGEMA thermo camera (*Fig.17 and 18*).

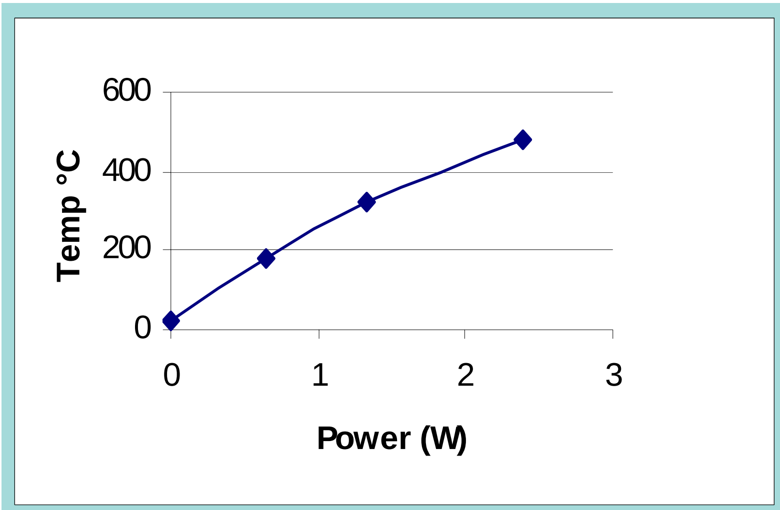

Fig 9. Temperature versus power of one heater element

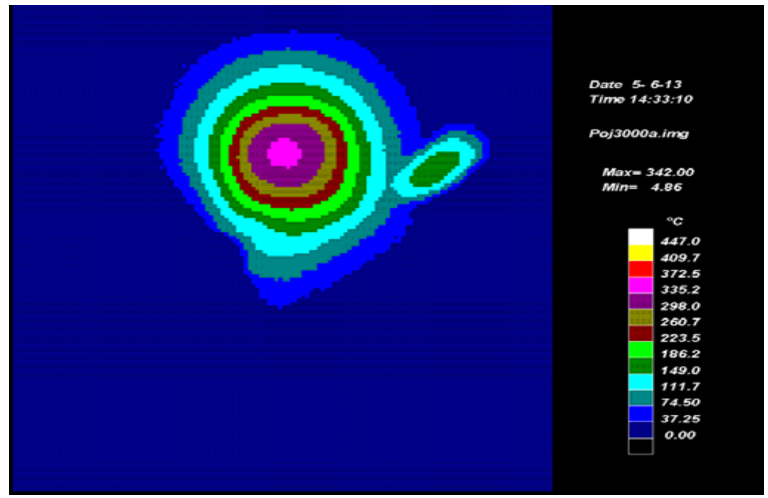

Fig. 18. The temperature distribution of the heating element at 3 W input power

The packaging of the sensor will be realised by the Cross divisional project: Three-dimensional electronic packaging and interconnection

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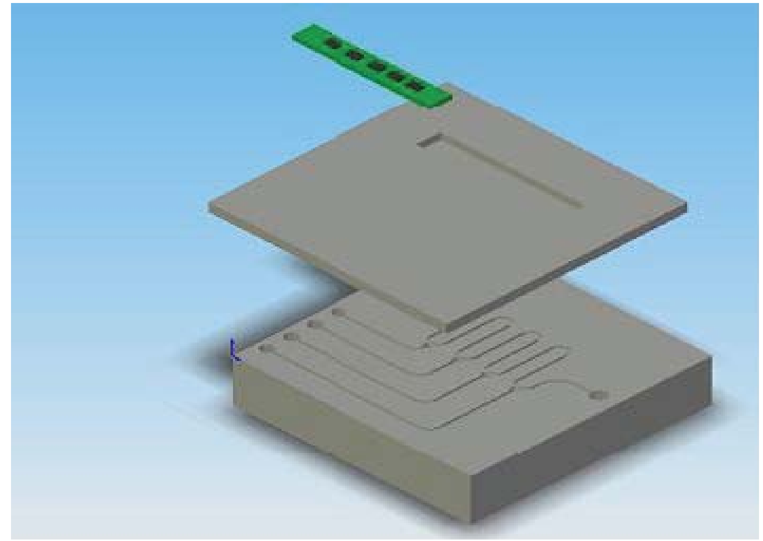
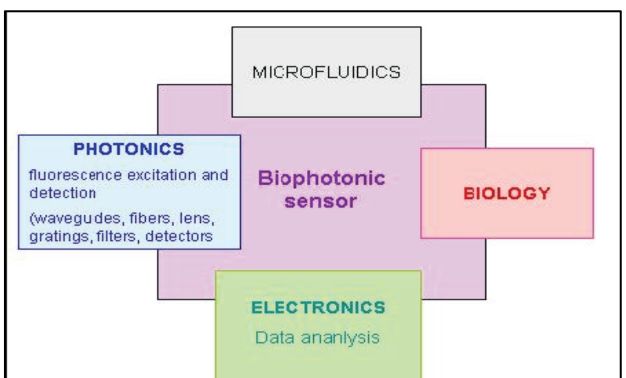
4m Cross Divisional Project:
Integrated Biophotonics Polymer Chip

The goal of this project is to analyse the possibility of realizing **compact biophotonic sensors for living cells** by *heterogeneous integration of optical waveguides, photodetectors and electronics within a polymer microfluidic chip*. The project addresses research challenges for 2010 and beyond in the context of information technologies for health care and biotechnology



Fluidic System with waveguides, photodetectors and electronics



Parteners:

- **FZK representing Division " Polymer Processing**
- **IMT Bucharest– Microphotonics Lab representing Division "Micro-optics"**

IZM representing Division "Assembly & Packaging"

Micropellistor for methane detection

Partners: National Institute for R&D in Microtechnologies, Institute of Physical Chemistry “I.G.Murgulescu” of the Romanian Academy

Introduction

Old gas sensing devices built by covering a platinum *resistor* with a doped (with a catalyst) ceramic *pellet* were called *pellistors*. The reaction takes place inside the ceramic pellet impregnated with the catalyst (heated at 300-500^{o}C) and involves oxygen and a flammable gas. The resulting heat is detected as an imbalance of the bridge in which the sensor is connected.

Using micromachining techniques we can manufacture a miniaturized pellistor that will have several advantages over the standard design:

- **increased reproducibility;**
- **possibility of integrating an area of sensing devices and the electronics on the same chip;**
- **reduced power consumption;**
- **possibility of making portable devices.**

Micropellistor for methane detection

IMT-Bucharest
National Institute for Research and Development in Microtechnologies

Heater Simulation

In the first set of simulations we determined the heater resistance and the voltages required to heat the heater at a temperature above 300ºC.

Because the device operates at high temperature it is necessary to use a temperature dependant resistivity for the electro thermal simulations. By applying a 1mA current on one pad of the heater and considering the opposite pad grounded it is possible to determine the resistance of the heater (including the pads).

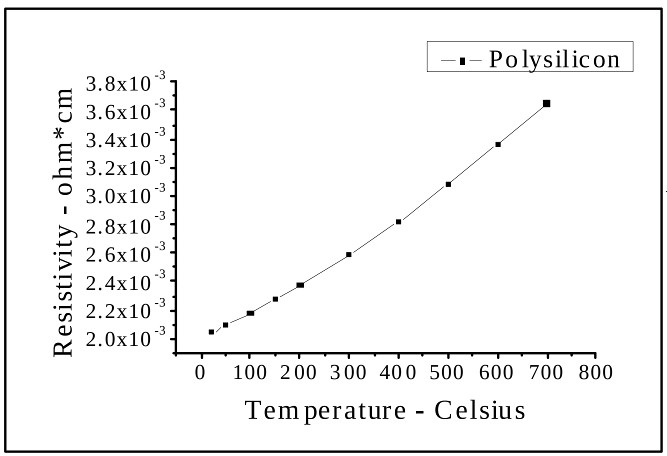


Figure.1 Polysilicon resistivity for temperatures between 20^0 C and 700^0C

A potential of 3 Volts was measured (Figure 2), resulting a resistance of 3.04 KΩ and a temperature of 334ºC (Figure 3).

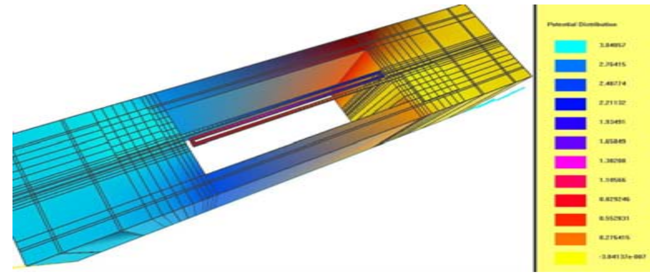


Figure 2. Potential distribution at 1mA

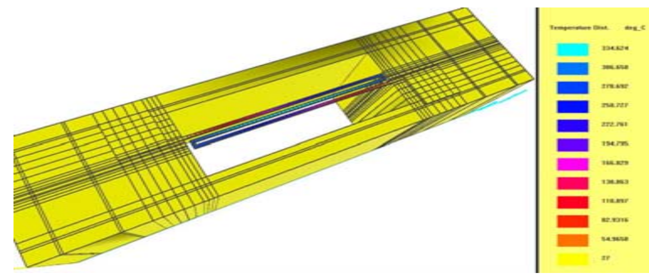


Figure 3. Temperature distribution at 1mA

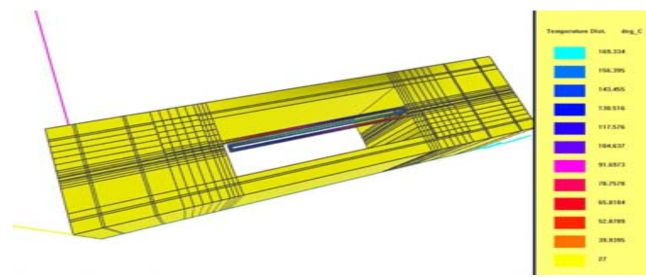


Figure 4. Temperature for V=2 Volts, (Tmax=169ºC)

Micropellistor for methane detection

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Device Simulation

ConvertorWare2004

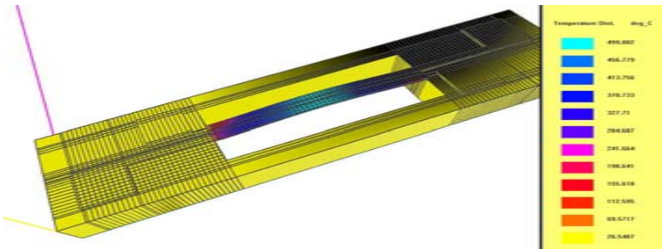

Figure 5. Thermal distribution at 10.5 Volts

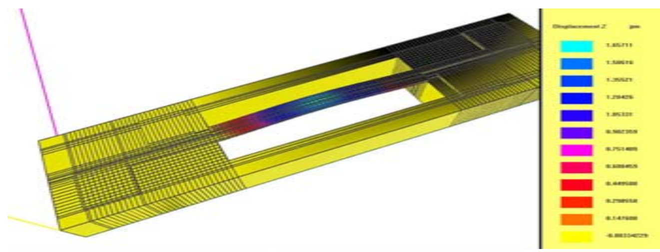

Figure 6. Z-axis Displacement at 10.5 Volts (also showing deformation)

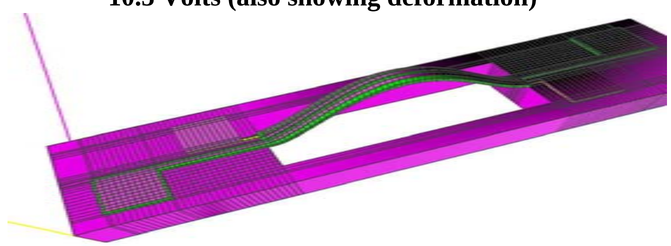

Figure 7. Deformation at 10.5 Volts (10 times exaggerated)

The sensor simulations at 4V, 7.5V and 10.5 V are presented in table 1

Simulation Nr.	Voltage (V)	T_{max} (^{o}C)	maximum z-axis displacement (microns)
1	4	113	0.31615
2	7.5	301	0.96589
3	10.5	499	1.65711

Table 1. Sensor simulation results

Three types of results were obtained from electro thermal simulations run on the full device: z-axis displacement, deformation and temperature distribution. The device needs higher voltages to heat at temperatures higher than 300^{o}C, because of heat dissipation in the above layers

Micropellistor for methane detection

Preparation and characterisation of alumina porous layer

Aluminum isopropoxide [Al(O-i$C_3H_7)_3$] from Merck was used as Al_2O_3 source, H_2O as solvent, and CH_3COOH as catalyst. The deposition of the films were realized on silicon and on configurated substrate, by spinning at a 2000 rpm, folowed by a thermal treatment at 5000C based on the DT/TG analysis of the unsupported gels.

The thermally treated films films were characterised by: X-ray diffraction (XRD), Spectroellipsometry (SE)

Substrat	Al_2O_3 %	Voids %	d (Å)	E_g
Silicon	80,00	20,00	635	8.67

Table 2. Structural and morphological characteristics of the alumina films

Conclusions

- **The purpose of these simulations was to determine if the device would operate with low power (low voltage) consumption and also if this design could work at the temperatures higher than 300°C for the catalytic reaction to take place. From the simulation we were also able to determine the weak points of the device (deformation of the membrane).**
- **The results from the simulations will help us to improve the design, technological steps and also packaging of the structures. The novelty of this device consists in reducing power consumption (suspended membrane), miniaturization and compatibility with IC technology.**
- **The preparation and deposition by sol gel technique of alumina layer, helped us to obtain miniaturised sensors, in a new technology, very sensitive to combustible gas detection.**

4M RAS Center for NMS and ACC

- Setting up a RAS Center for NMS as a nodal point of information from 4M to external users and inverse. The RAS Centre will became a “portal’ to the 4M experts and infrastructure to accelerate the take up of MNT across Europe.

This will be achieved through offering a suite of technology transfer services to companies especially SME’s.

RAS for NMS

Location: IMT –Bucharest, Romania with participation of all 4M NMS partners

IMT will provide :

- Dedicated Web page to NMS RAS Center, set up and maintenance
- Connections to 4M Main page, to NMS partners, If requested to all 4M partners
- The web page will display information about 4M area of interest, events within 4M, description of the RAS Center, NMS partners and their offer addressed to SMEs.
- Electronic tool for proposal preparation, electronic brokerage, consultancy

http://www.imt.ro/4M_RAS_Romania/

4M RAS Center for NMS and ACC

- Aims
- Contact
- Partners
- Offer
- Activities
- Database
- Home

www.4m-net.org

www.imt.ro

RESEARCH ADVISORY CENTER for NMS and ACC

supported by

Multi Materials Micro Manufacturing, 4M, Network of Excellence

RAS is the nodal point of information, the portal to the 4M experts and infrastructure to accelerate the take-up of MNT across Europe.

The portal is supported by the Center for Technology Transfer (CTT-Baneasa)

RAS for NMS - Actions

In the process of assisting SMEs to joint 4M technologies:

- **identification of SMEs from NMS** (all NMS partners will be involved)
- identification of SMEs needs, questionnaire distributed at different events and on web (NMS RAS page)
- publishing the offer addressed to SMEs
- publishing the list of experts available for technical consultancy of SMEs (from all NMS partners countries or others if necessary)
- assisting SMEs or clusters of SMEs from technical and managerial point of view in setting up Consortia for national and EC R&D funding
- Assisting SMEs in application consultancy interventions – one - or two - day consultancy interventions
- Other users of 4M technologies will be supported by consultancy and experiments (if requested): researchers from Academia, students, start-up companies.

IMT-Bucharest
National Institute for Research and Development in Microtechnologies

Va multumesc!

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