ICQNM 2012
August 19 – 24
Rome, Italy

Challenges in Nano/Micro Electronics and Nano/Micro Materials

ICQNM Panel Discussion

Moderator

Stefan Schauer, AIT Austrian Institute of Technology GmbH

Panelists

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Limits of Quantum Cryptography

- rather new field/technology
- one of the major applications of quantum mechanics
- started about 30 years ago with BB84 protocol
- technology is still in its infancy
  - took over 10 years to perform an experiment in a practical setup
  - theory is well developed only for some areas

- challenge 1: *distance*
  - began with a few centimeters in 1984
  - has reached up to 200 kilometers
  - different technologies make an integration difficult
  - far from practical communication
  - quantum networks might be a solution

Limits of Quantum Cryptography

- challenge 2: *bandwidth*
  - large distances don't allow a high transmission rate
  - photon sources and detectors are not perfect and introduce errors
  - nevertheless efficient rates are possible (at a short distance)

- challenge 3: *handling*
  - systems are rather complex and hard to maintain
  - can be integrated in nowadays computer systems

- the field is facing a number of challenges – but also did other technologies, e.g. the computer about 70 years ago
- great progress has been made in the last decade

3D X-ray microtomography

Principle and Challenges

Profa. Dra. : Inaya´Lima

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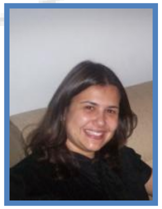
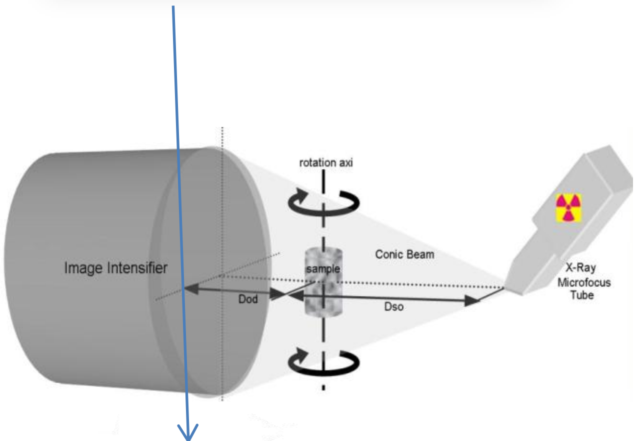
(head of oil and biomedical application in µCT)

PhD Students

3D X-ray microtomography

Principle and Challenges



CHALLENGES

Focal spot: *will determine how effective an X-ray source will be for a particular task, the spectrum of X-ray energies generated, and the X-ray intensity;*

FOCAL SIZE AS SMALL AS POSSIBLE; X-RAY INTENSITY AS HIGH AS POSSIBLE;

ENERGY ESPECTRA OPTIMIZED FOR THE BEST ABOSRPTION CONTRAST;

Calibration: *The two principal signal calibrations are offset and gain, which determine the detector readings with X-rays off, and with X-rays on at scanning conditions, respectively;*

Detector: *Spatial resolution. Detectors influence the image quality through their size and/or quantity, and through their efficiency in detecting the energy spectrum generated by the source;*

Artifacts: *Scanning artifacts can obscure details of interest, or cause the CT value of a single material to change in different parts of an image.*

BEAM HARDENING, RING ARTIFACTS AND MOVEMENTS

3D X-ray microtomography
Capabilities

3-D geometries and properties are calculated either in direct 3D based on a surface-rendered volume model or in 2D from individual binarized cross-section images. All calculations are performed over a selected region. Consistent and accurate selection of the regions or volumes of interest is fundamentally important to obtaining accurate and meaningful data.

Challenges:

Threshold optimal level

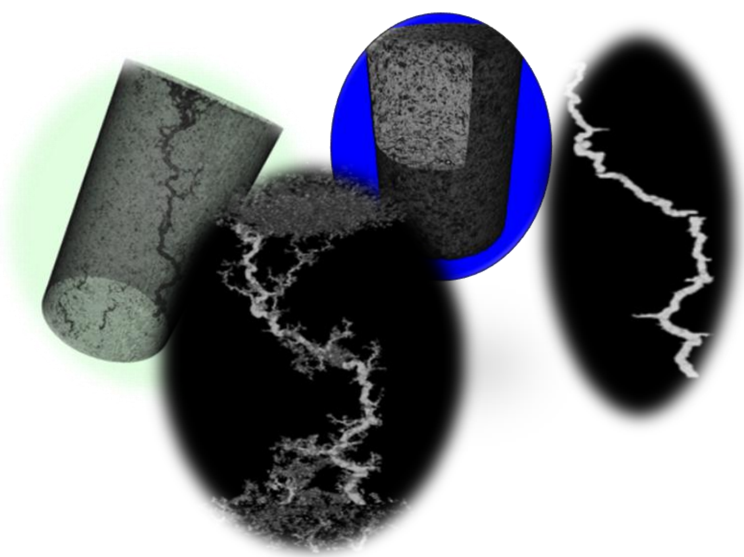
(no standard gold method)

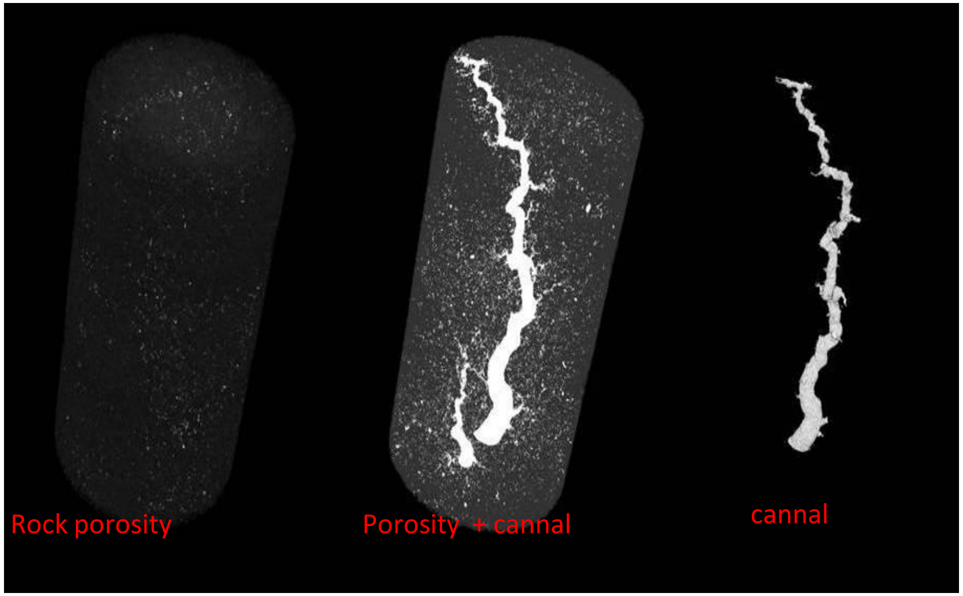
3D MORPHOMETRIC PARAMETERS: *a 3D morphometric parameters integrated for the whole volume of interest*

Nomenclature	Description	Unit
VOI	Volume of interest	mm^3
TV	Total VOI volume	mm^3
ObjV	Object volume	mm^3
ObjV/TV	Percent object volume	%
TS	VOI surface	mm^2
Obj.S	Object surface	mm^2
IS	Intersection surface	mm^2
Obj.S/Obj.V	Object surface / volume ratio	mm^{-1}
Obj.S/TV	Object surface density	mm^{-1}
Fr.I	Fragmentation index	mm^{-1}
Centroids $_{x,y,z}$	Crd.X, CrdY, CrdZ	mm
SMI	Structure model index	none
St.Th	Structure thickness	mm
St.Li.Dn	Structure linear density	mm^{-1}
Sr.Sp	Structure separation	mm
DA	Degree of anisotropy	none
Eigenvalues $_{1,2,3}$	Eigenvalues 1, 2, 3	none
FD	Fractal dimension	none
N. Obj.	Number of objects	none
Po.N(cl)	Number of Closed Pores	none
Po.V(cl)	Volume of Closed Pores	mm^3
Po.S(cl)	Surface of Closed Pores	mm^2
Po	Closed Porosity	%
Po.V(op)	Volume of Open Pore Space	mm^3
Po(op)	Open Porosity	%
Po.V(tot)	Total Volume of Pore Space	mm^3
Po(tot)	Total Porosity	%
EN	Euler number	none

<u>Oil industry:</u> Characterize porous reservoir media;

<u>Challenges:</u> Mineralogy + Metrology

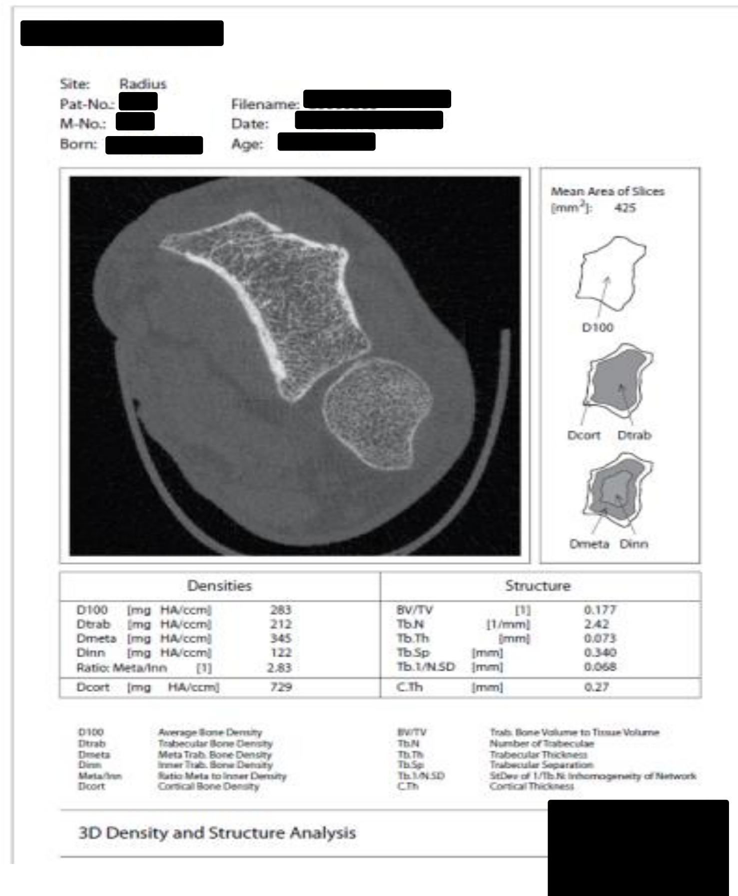




<u>Medicine</u>: Osteoporosis Behavior

<u>Challenges:</u> Standard gold criteria for osteoporosis diagnosis in **µCT**; patient movement in the exam;

Example of one patient exam µCT result



[redacted]

Site: Radius
Pat-No.: [redacted]
M-No.: [redacted]
Born: [redacted]
Filename: [redacted]
Date: [redacted]
Age: [redacted]

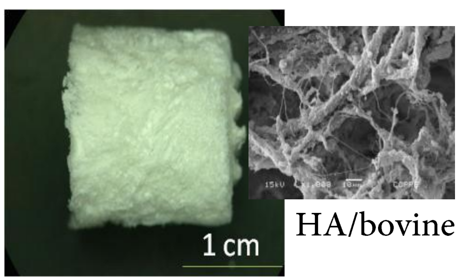
Densities			Structure		
D100	[mg HA/ccm]	283	BV/TV	[1]	0.177
Dtrab	[mg HA/ccm]	212	Tb.N	[1/mm]	2.42
Dmeta	[mg HA/ccm]	345	Tb.Th	[mm]	0.073
Dinn	[mg HA/ccm]	122	Tb.Sp	[mm]	0.340
Ratio: Meta/Inn	[1]	2.83	Tb.1/N.SD	[mm]	0.068
Dcort	[mg HA/ccm]	729	C.Th	[mm]	0.27

D100	Average Bone Density	BV/TV	Trab. Bone Volume to Tissue Volume
Dtrab	Trabecular Bone Density	Tb.N	Number of Trabeculae
Dmeta	Meta Trab. Bone Density	Tb.Th	Trabecular Thickness
Dinn	Inner Trab. Bone Density	Tb.Sp	Trabecular Separation
Meta/Inn	Ratio Meta to Inner Density	Tb.1/N.SD	StDev of 1/Tb.N: Inhomogeneity of Network
Dcort	Cortical Bone Density	C.Th	Cortical Thickness

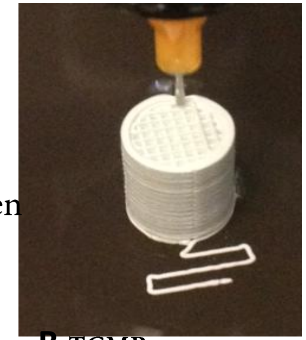
3D Density and Structure Analysis [redacted]

Biology: Scaffold

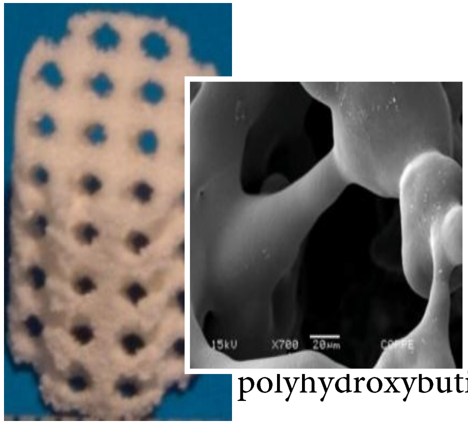
Challenges: porosity (pores shape and morphology, size, distribution), interconnectivity , surface area to volume ratio, wall thickness, anisotropy (non uniformity in the alignment of the scaffold), Surface area to volume ratio (Surface area to volume ratio=surface area of scaffold struts/volume of scaffold material)



HA/bovine collagen



B-TCMP



polyhydroxybutirate

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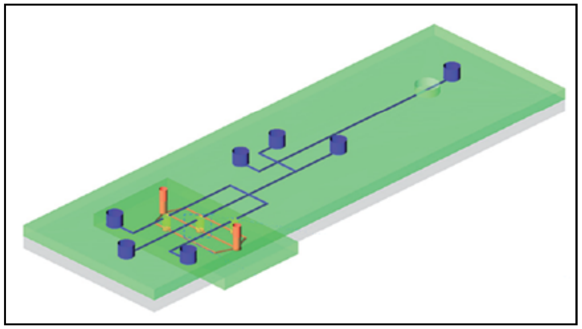
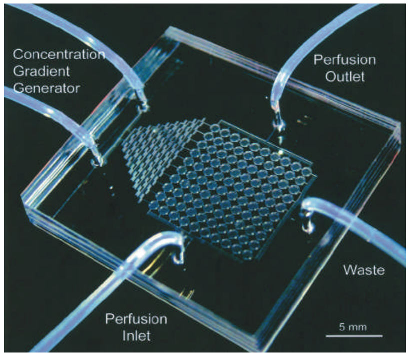
Microfluidic device – Lab-on-a-chip – application for cells analysis

Application of microsystems

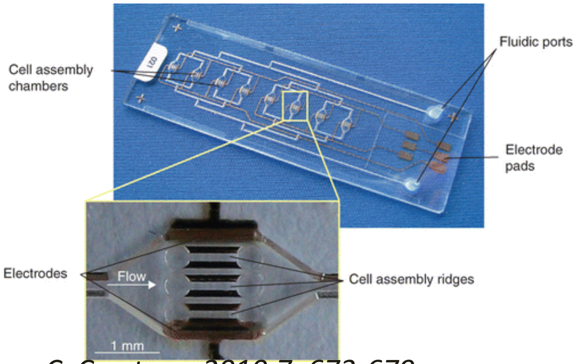
- Cell culture (the usage of bio-compatible, gas-permeable, non toxic materials)
  - Monitoring of cells' adhesion
  - Monitoring of cell – cell interaction
  - Cytotoxicity tests
- Analysis of single cell
- Monitoring apoptosis of cells
- Cell lysis



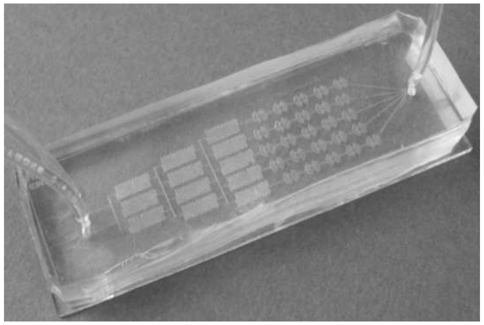
M. Ba et al.,Lab Chip, 2009, 9, 232-238



H. Hung et al.. ,Lab Chip, 2005, 9,44-48



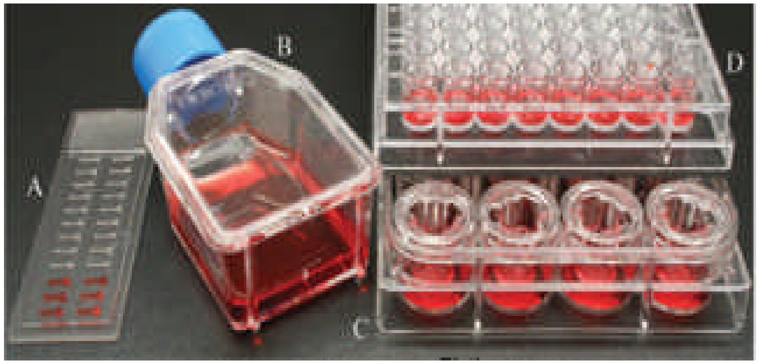
C. Carstens, 2010,7, 673-679



E. Jedrych et al., Sensors Actuators 2011, 160, 1544-1551

Lab-on-a-chip - Microsystem

- integration of laboratory functions on a single chip/plate
- conditions of cells growth similar to *in vivo*
- control cell-cell and cell-matrix interactions
- the control of concentrations of molecules in space and time is possible
- reduction the amount of reactants/ chemical waste/ biological samples
- easy cells' observation (transparent materials)
- space savings
- low cost, short time for analysis



Integration of micro-fluidic optical capillary sensors with a silicon base structure

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This work was supported by the Polish Government NCBiR grant Nr N R02 0008 06/2010, New optoelectronic devices for intelligent classification of biological and organical fluids

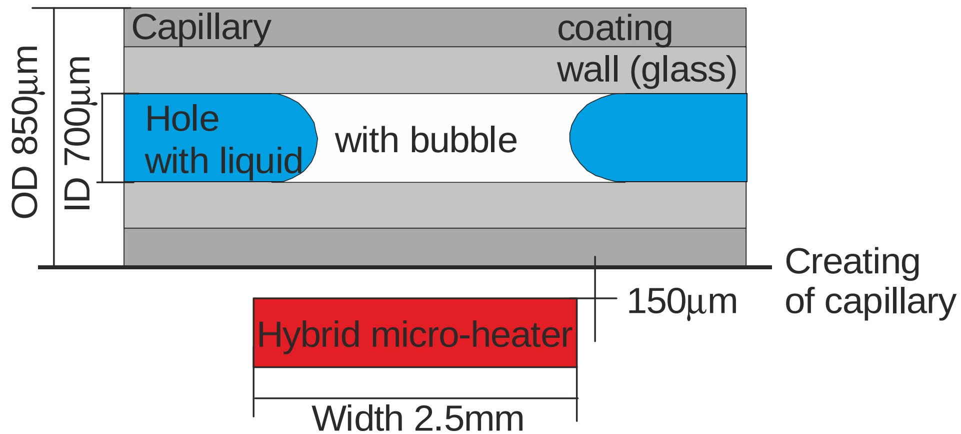
Introduction

The micro-fluidic capillary sensor can be used for intelligent classification of biological and organical fluids. We have shown its principle of work in:

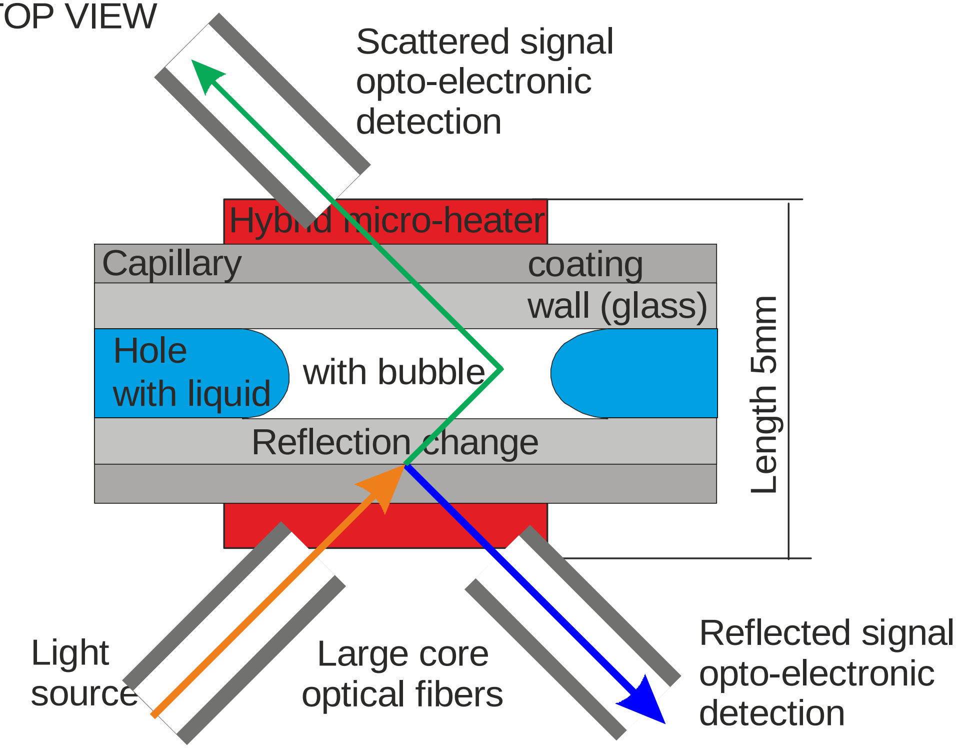
1. Sensing of the Functional State of Fertility of Cows (Sensordevices, 2012, here),
2. Testing usability of biofuels (Integrated Optoelectronic Sensors, 2012, Szczyrk, Poland).

Schematic construction of the capillary head

SIDE VIEW



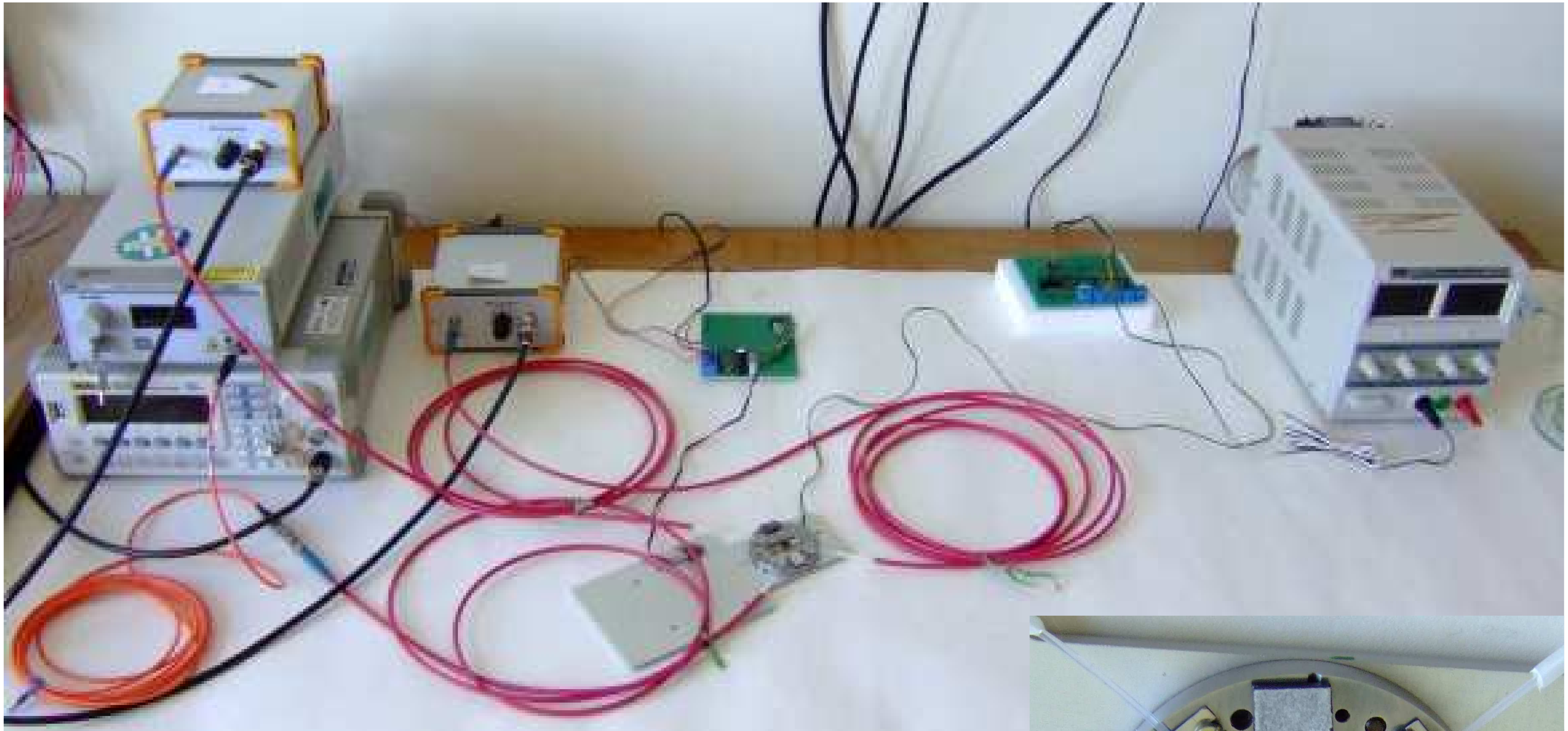
TOP VIEW



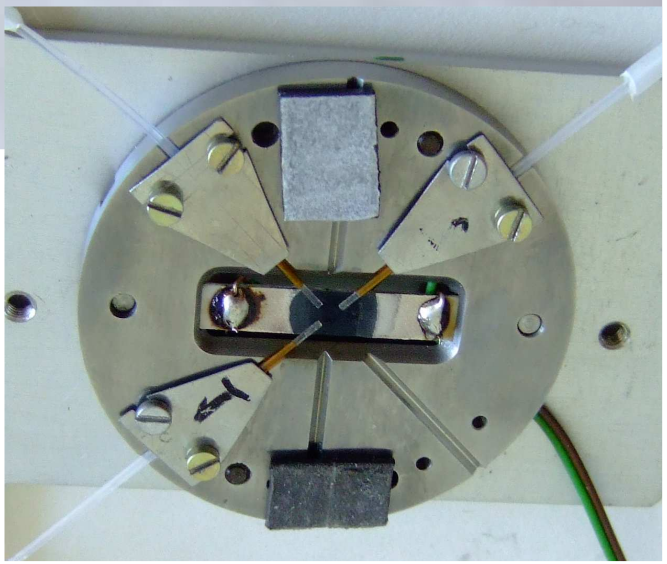
1. Working principle of proposed sensors is monitoring of optical intensity changes that take place in dynamically forced measurement cycles
2. The sensors use fiber optic capillaries in which the phase of the filling liquid changes locally to gas when forced by local heating, while the propagation of light across the capillary is monitored,
3. The sensors examine simultaneously many liquid parameters which are then processed in artificial neural networks The low cost of capillaries make their disposability practically possible.

M. Borecki et al, „Optoelectronic Capillary Sensors in Microfluidic and Point-of-Care Instrumentation", Sensors, (2010)
M. Borecki et al, „Capillary microfluidic sensor for determining the most fertile period in cows", APP, (2010).

View of the system to be integrated

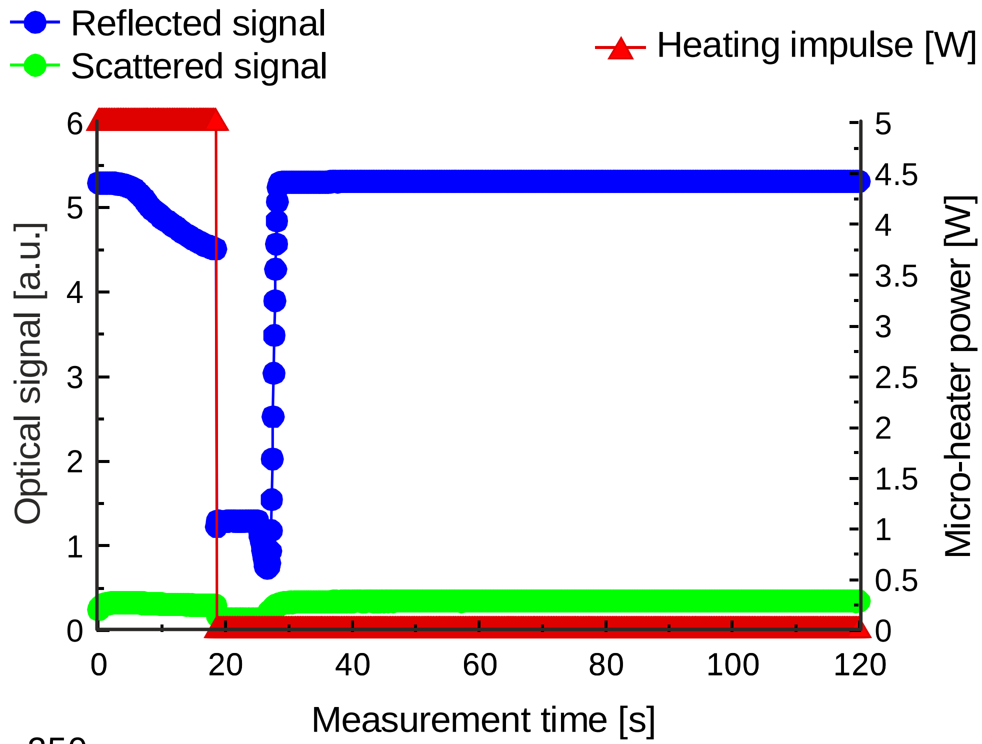


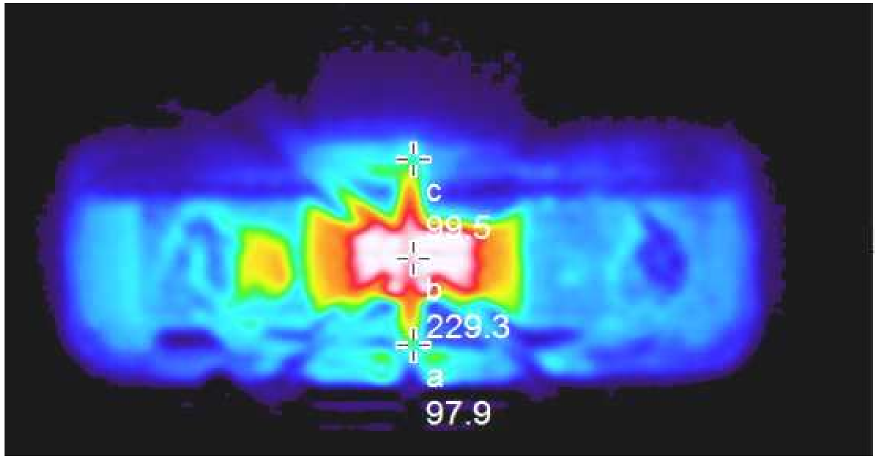
Insert: Close-up view of the sensor head

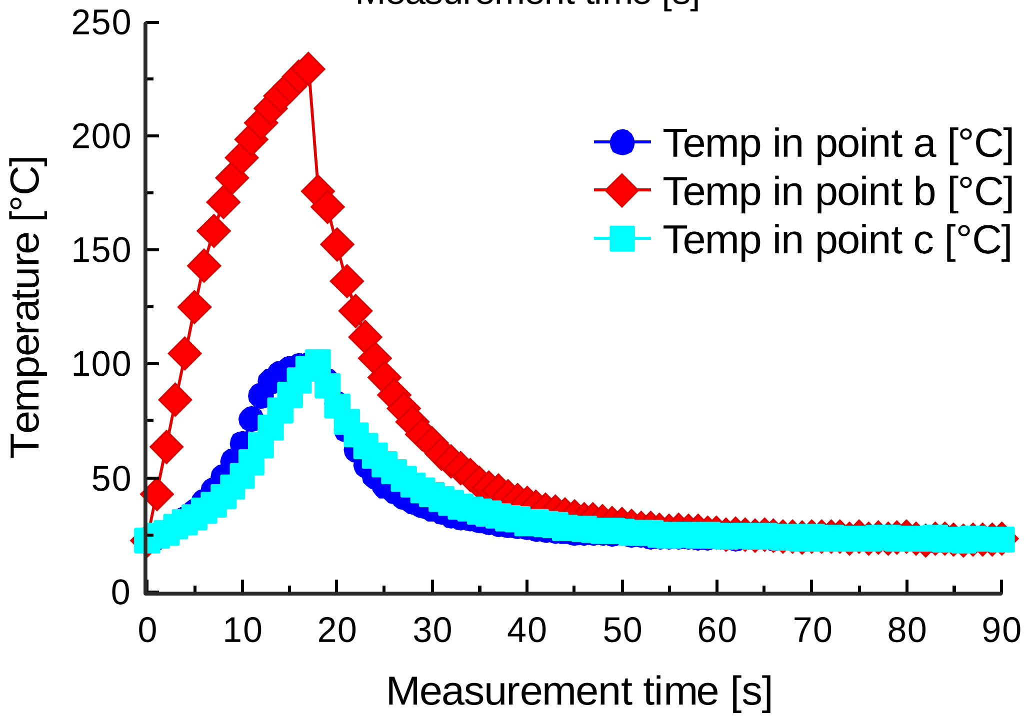


Micromechanical head base with hybrid microheater

Signal and temperature waveforms
for calibration
with DI water and heating power of 5W







Temperature map
just before boiling
at 17s of the
measurement procedure

Elements of the sensor head

The main part of micro-fluidic capillary sensor is sensor head that consist of:

1. Disposable optical capillary optrode with liquid to be analyzed
2. Set of optical fibers; one to input light from source into the capillary, others to collect signals from the liquid,
3. Local micro-heater,
4. Temperature sensors,
5. Base for the mentioned elements.

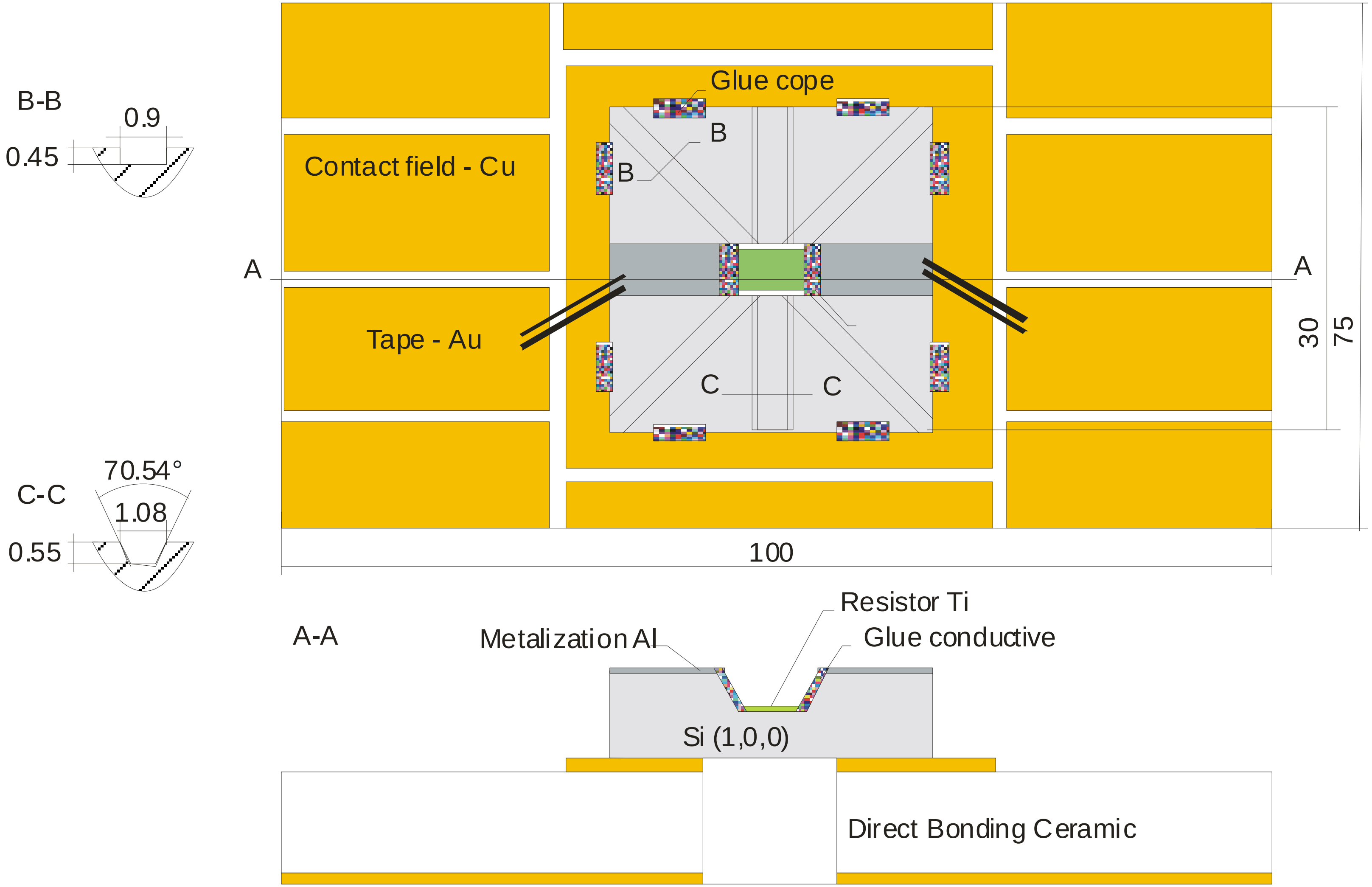
Our objectives

1. Integration of sensor head base with local micro-heater and temperature sensors.
2. To develop a sensor head which could be operated not only in laboratory environment.
3. Development of a method that would yield itself easily to automation, miniaturization and be of low cost.

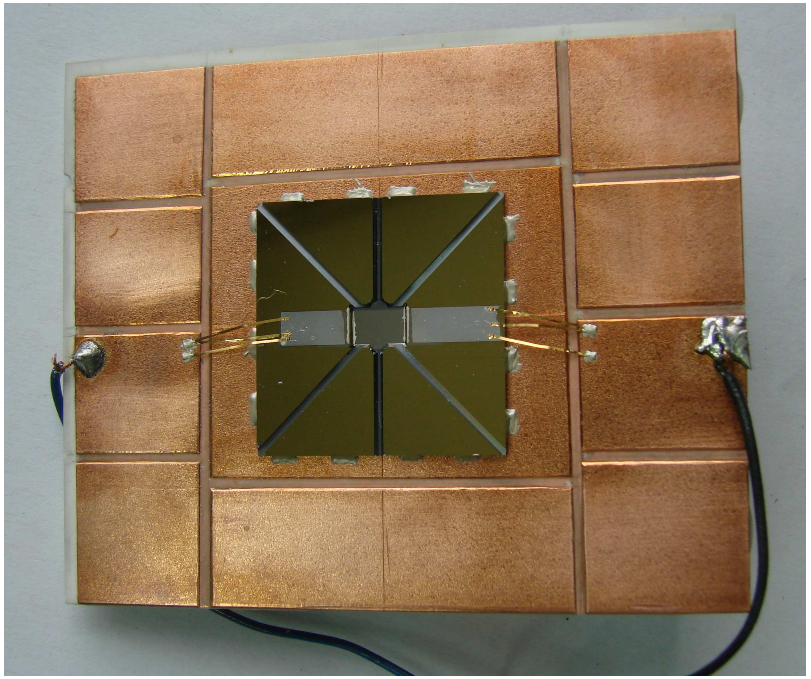
Integration idea

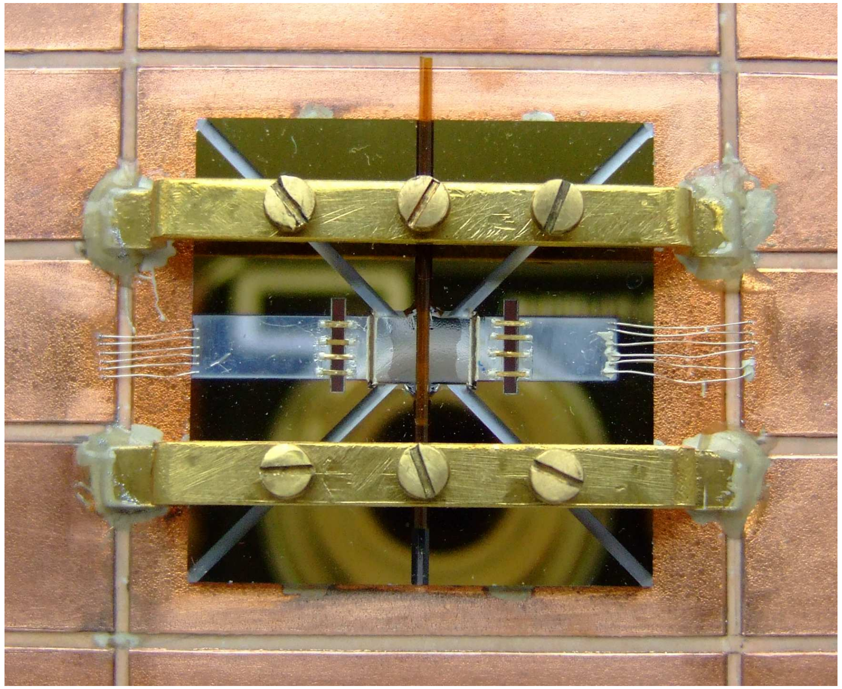
1. The fibers and capillary outer diameter is about 800µm.
- The silicon wafer with the thickness of 900µm is required.

The wafer processing available are:
- IC technologies,
- Micromachining,
- Hybrid technologies.



Capillary basis with use of Si structure

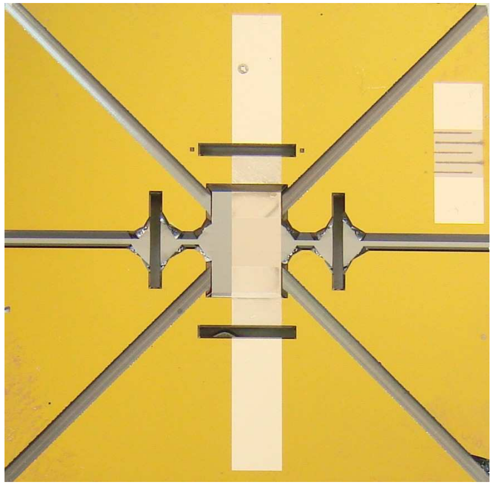




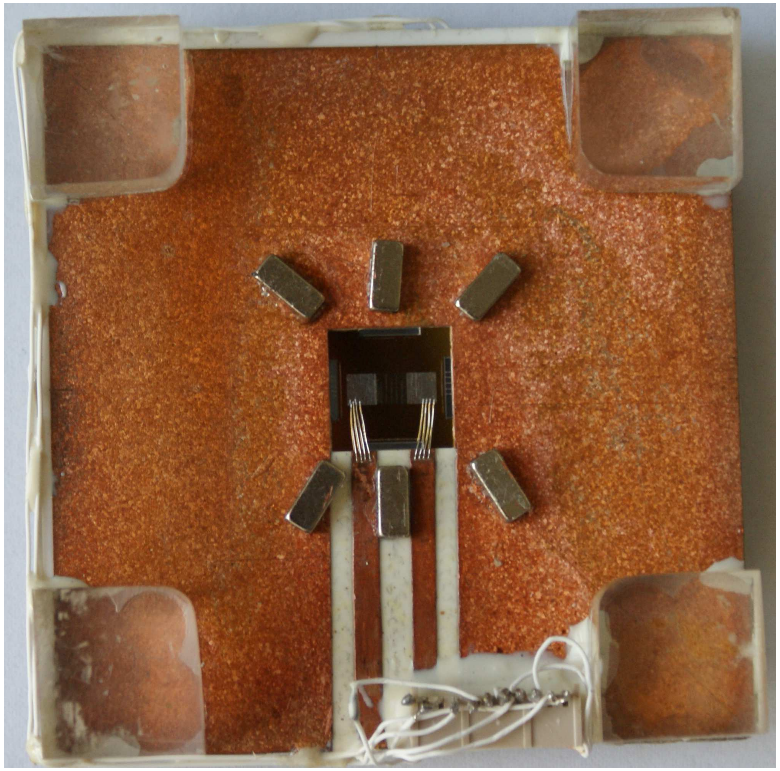
- The heater power required for water boiling in capillary is 25W.
- The heat transfer balance have to be improved.
- The high temperature conductive glue have to be withdraw

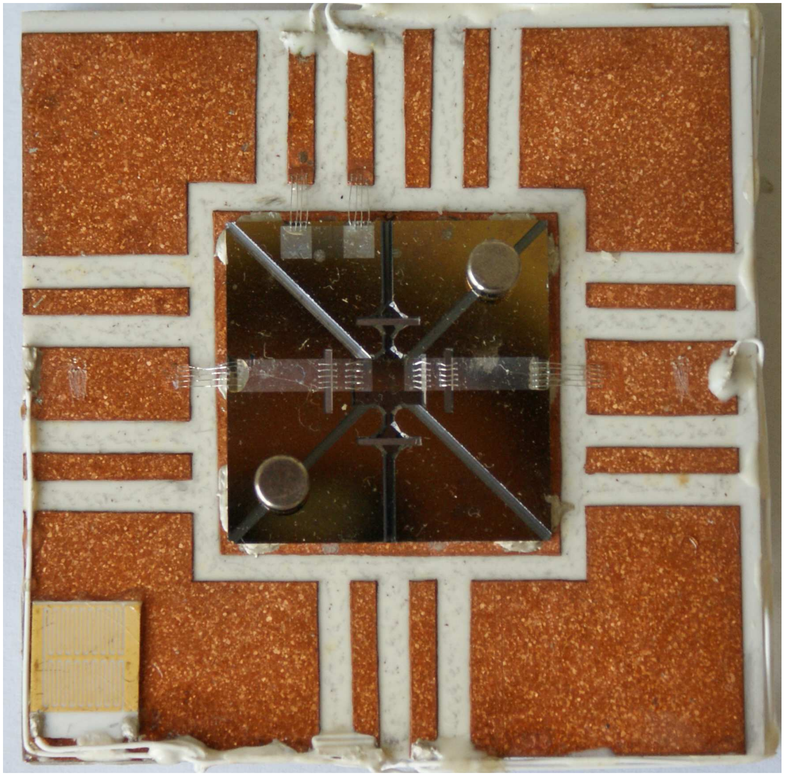
- The screw holders of fiber and capillary are not comfortable in use.
- The magnetic holders work better

Improved construction

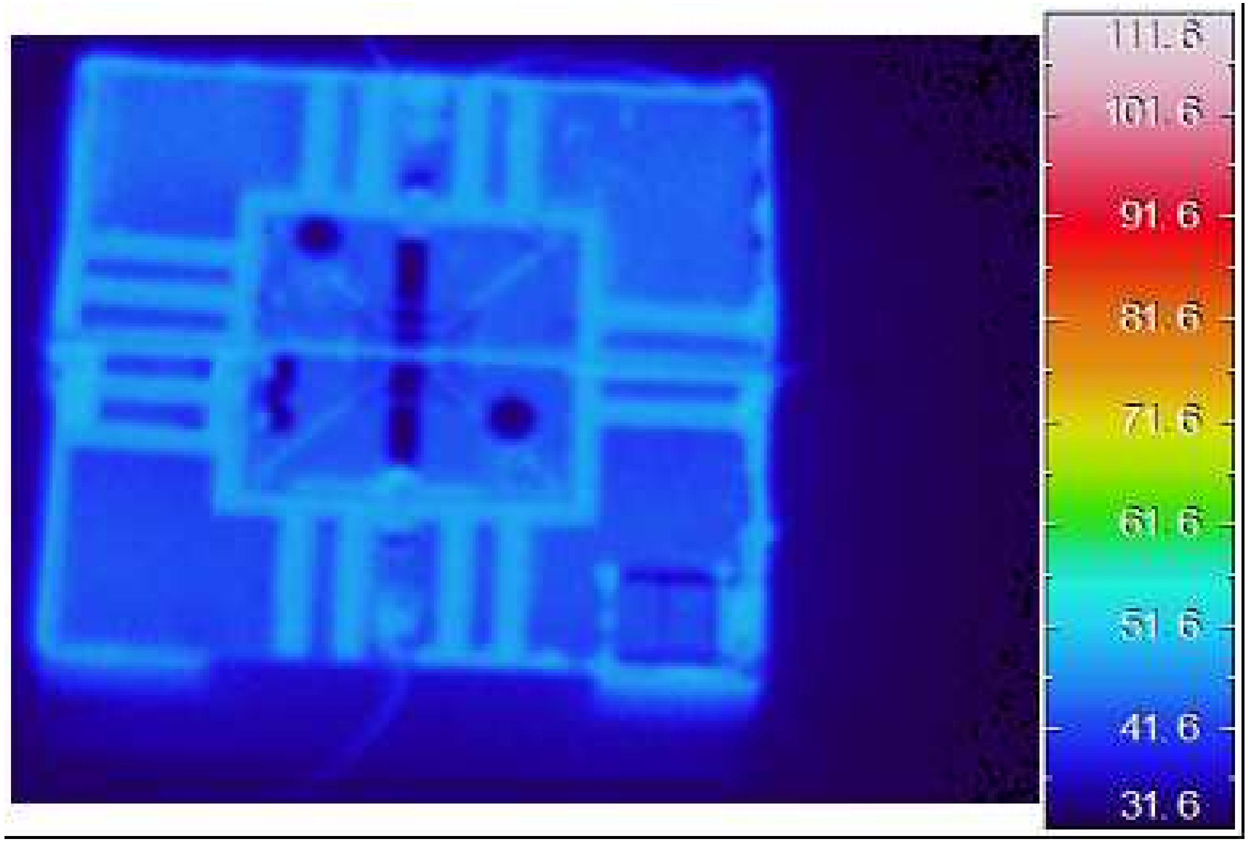


1. Four side heater thermal „air isolation”
   - 16W required for water boiling in capillary
2. Three integrated resistance sensors of temperature
3. Magnetic holders of fibers and capillary



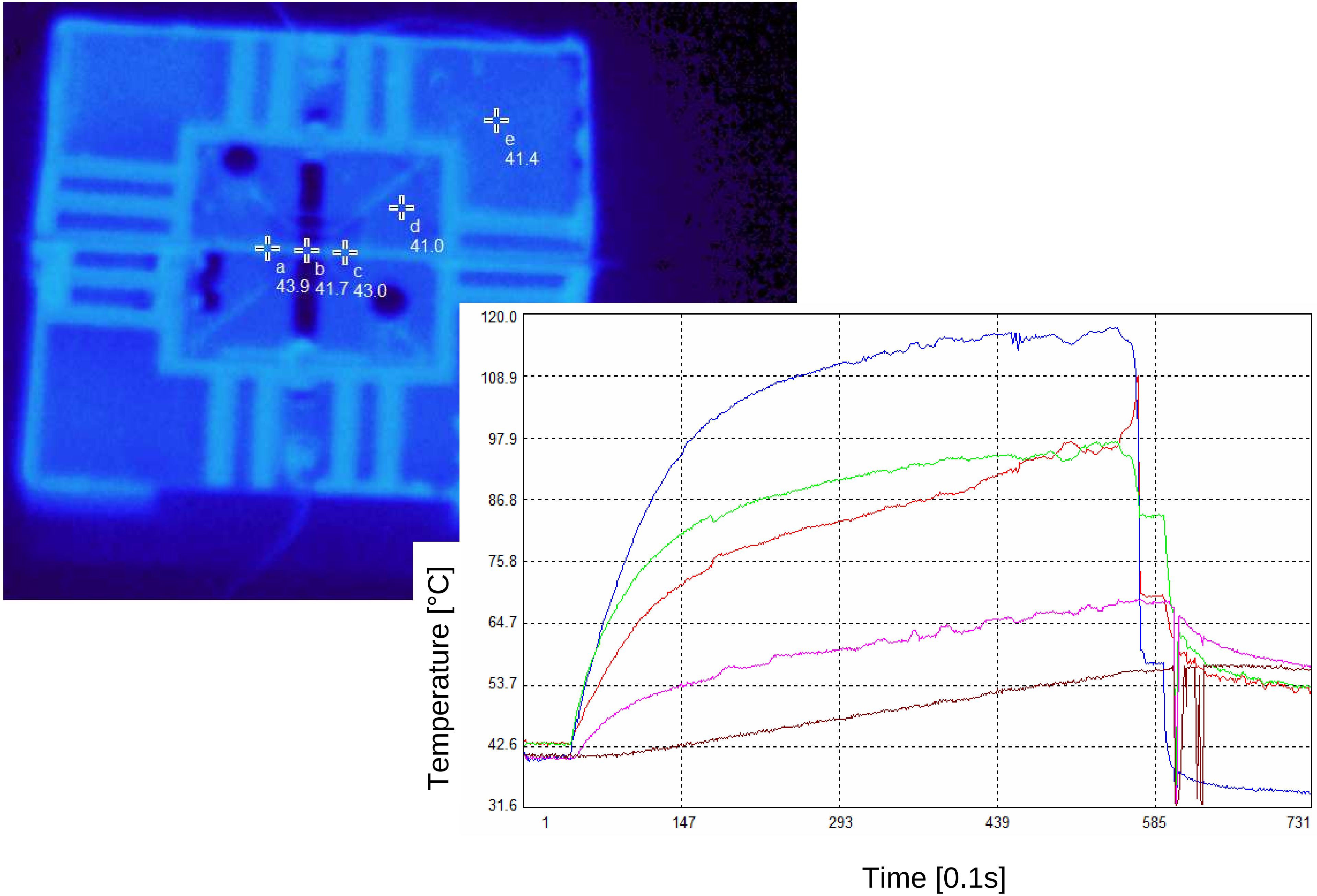


Integrated structure examination – temperature map

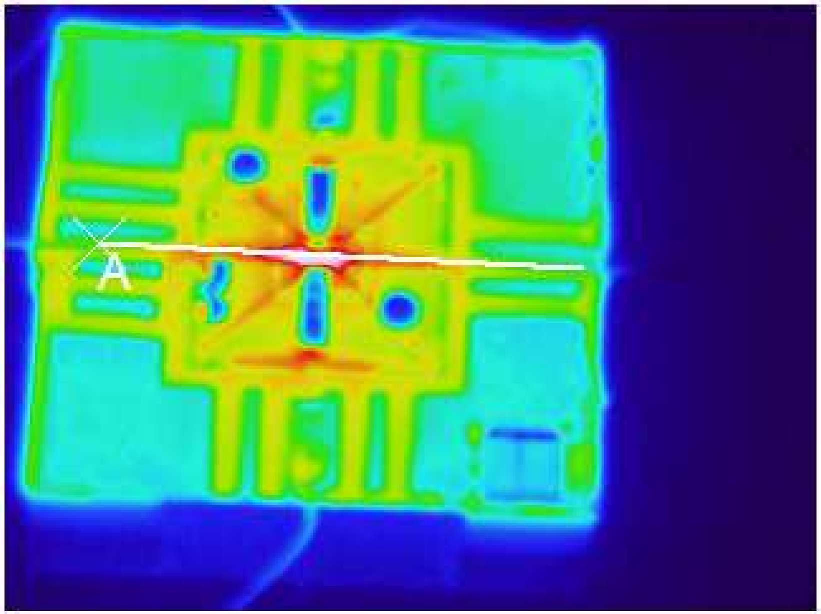


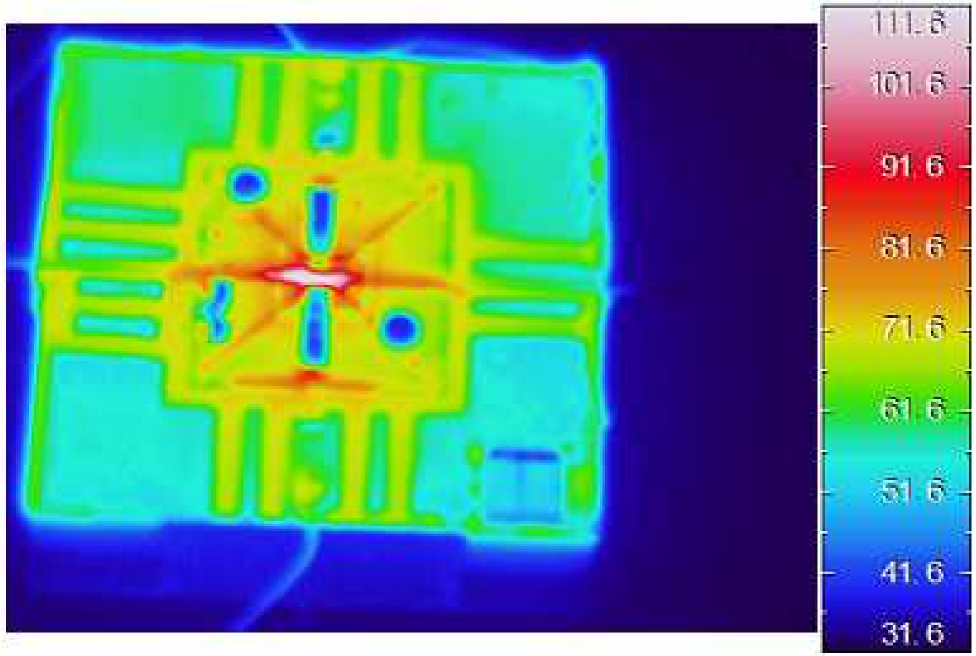
Lower the temperature gradient between capillary and micro-heater without loosing of heat transfer => reduce the distance between capillary and micro-heater from 150µm to 50µm.

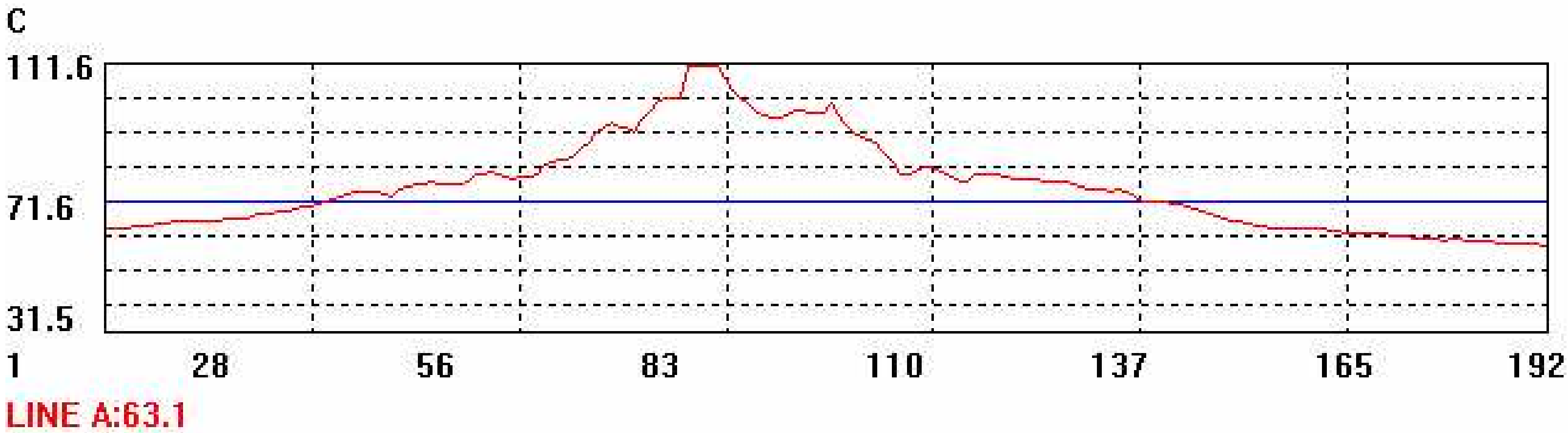
Integrated structure examination – water boiling



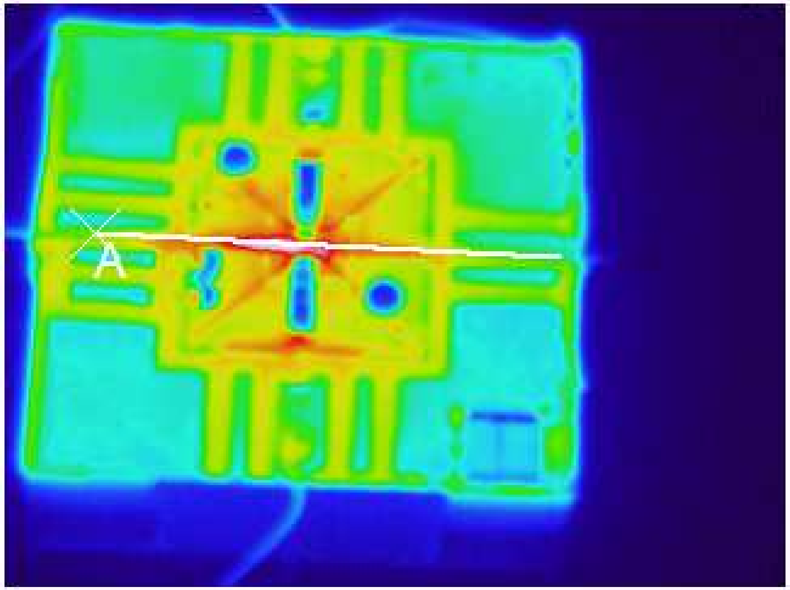
Water boiling – begining 56.20sec

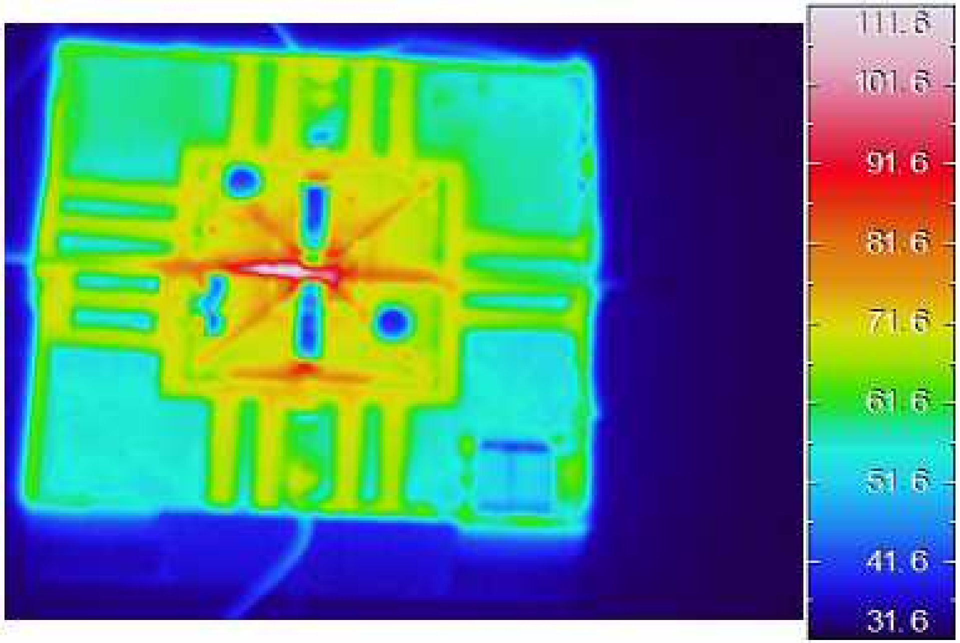


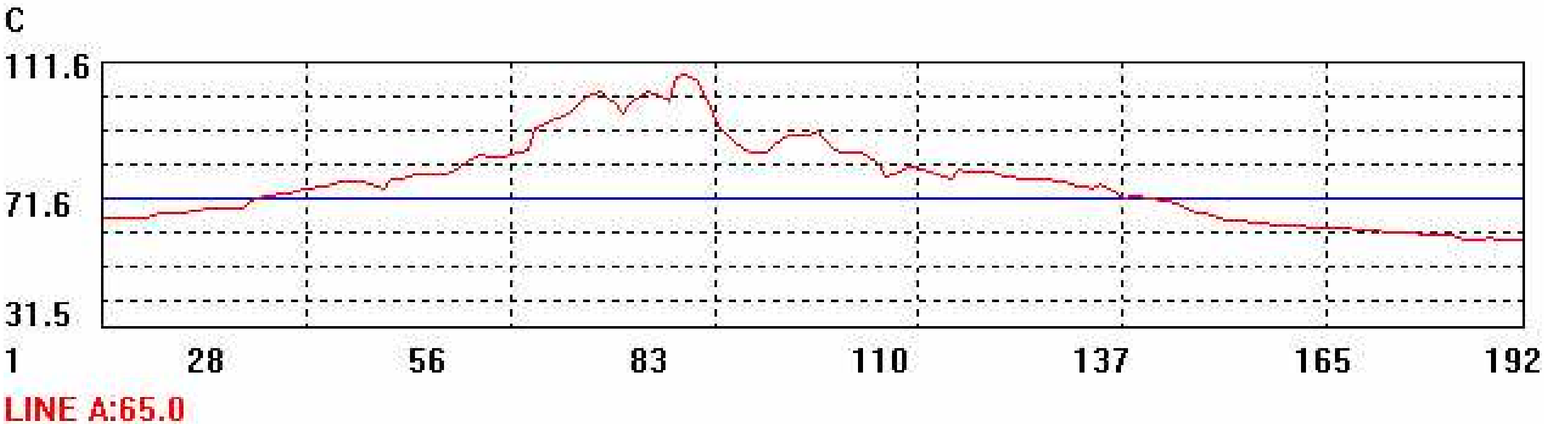




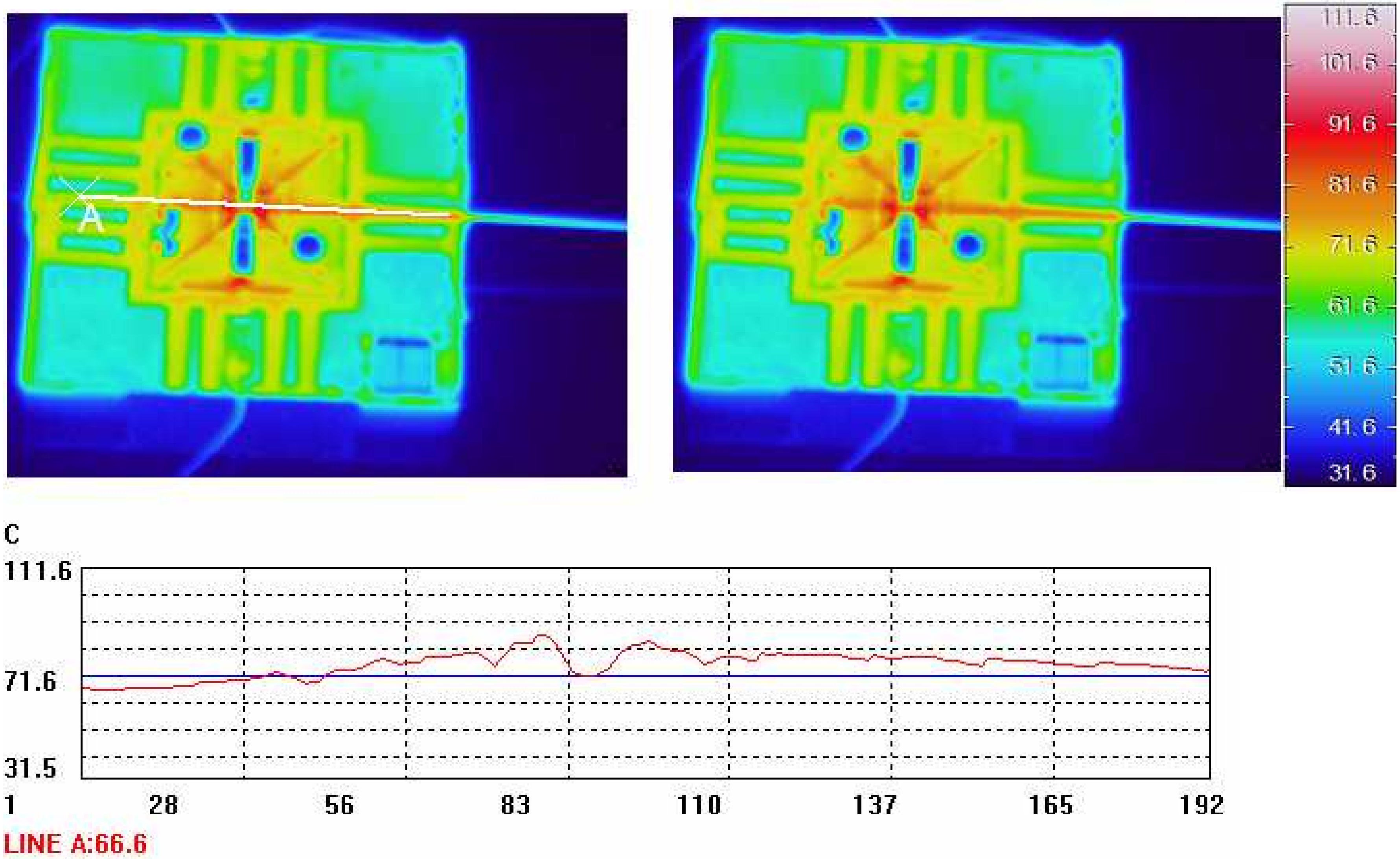
Water boiling – first displacement of vapor 57.0sec



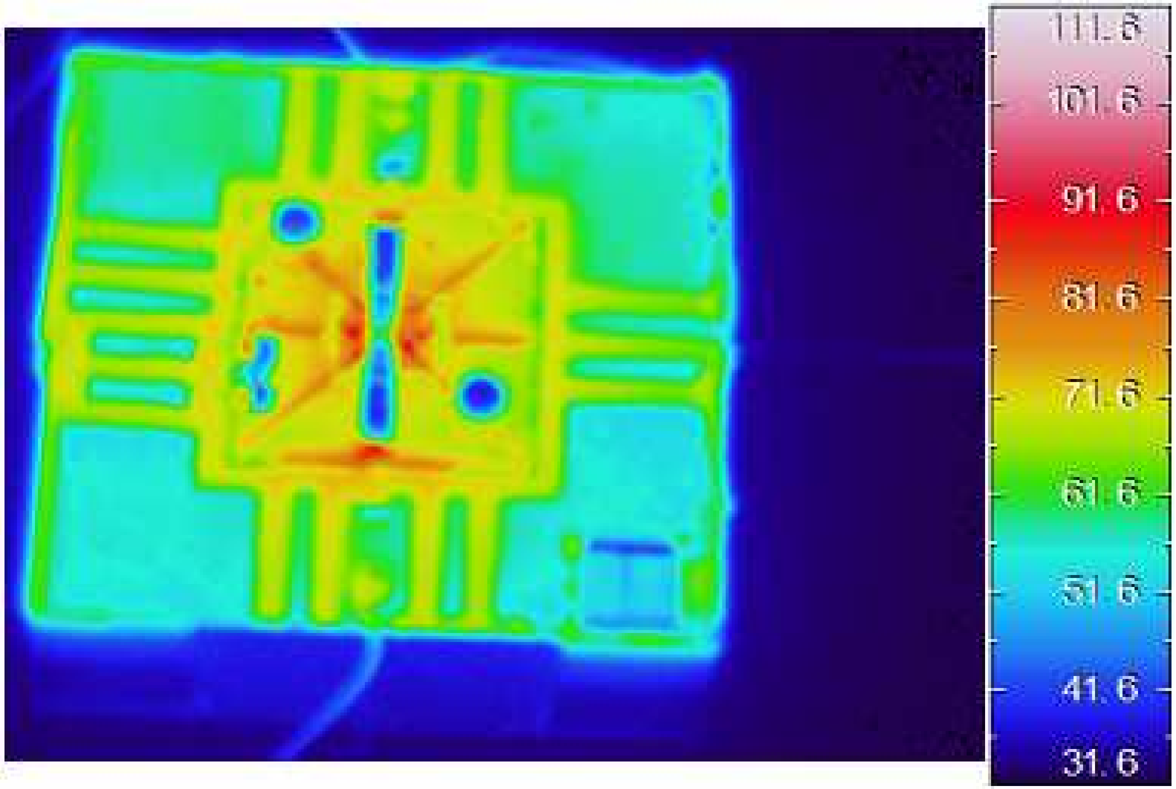




Water boiling–second displacement of vapor 57.01sec micro-heater switch-off



Head cooling - 57.02sec



Conclusion and future work

1. We have fabricated the base for capillary sensors from silicon and from metal. Each material has its advantages and disadvantages.
   - The silicon base is cheaper to mass fabricate using standard microelectronic techniques.
   - The silicon base is easier in fabrication because it does not require assembly and as precise adjustment of the micro-heater's position as the metal base.
2. The difference in heat capacity, thermal resistance and heated area of head bases between constructions causes:
   - lowering of the temperature needed to achieve boiling of water in the capillary to 116°C in silicon base from 230°C for the metal base,

   but results in:
   - Increasing of the heater power to achieve water boiling with the silicon base to 16W from 5W for the metal base,
   - Increasing of time required to achieve boiling of water in the capillary from 17sec in the metal base to 56sec in the silicon base.
3. The silicon base is better for investigation of low boiling point liquids (biological fluids, gasoline) while the metal base allows investigation of higher boiling point liquids (diesel fuels and rapeseed oils).
4. The further improvement of silicon base is possible an is our future work.

Thank you for attention