European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

WGs and MC Meeting at LINKOPING, 3 - 5 June 2015

Action Start date: 01/07/2012 - Action End date: 30/06/2016

Year 3: 1 July 2014 - 30 June 2015 (*Ongoing Action*)

THE APPLICATION OF ADDITIVE TECHNOLOGIES FOR CERAMIC MEMS GAS SENSORS

A.A.Vasiliev[1], A.V.Sokolov[1], N.N.Samotaev[2], V.P.Kim[3], S.V.Tkachev[3], S.P.Gubin[3], G.N.Potapov[4], Yu.V.Kokhtina[4], A.V.Nisan[4]

[1]NRC Kurchatov Institute, Kurchatov sq., 1, Moscow, Russia, A-A-Vasiliev@yandex.ru

[2]National Research Nuclear University "MEPhI", Moscow, Russia

[3]LLC AkKo Lab, Moscow, Russia

[4]LLC Ostec, Moscow, Russia

COST EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

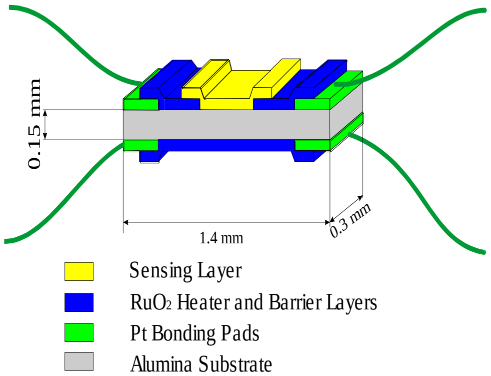
EuNetAir

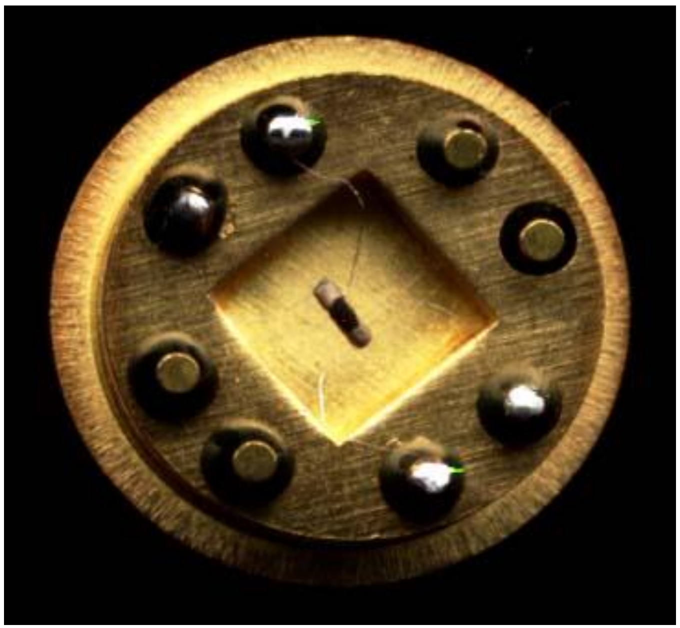
European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability

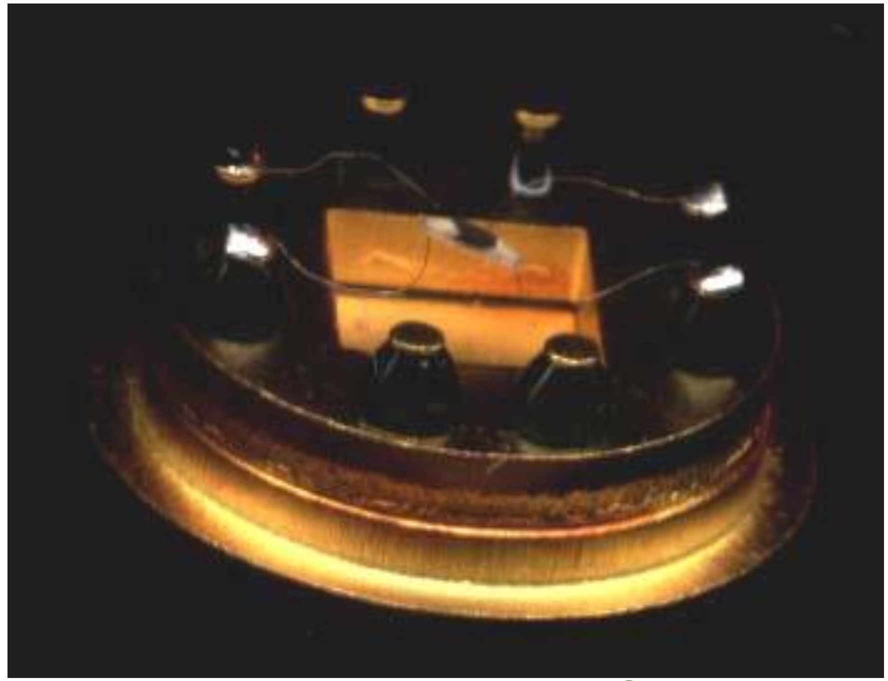
Technologies for the fabrication of MOX semiconductor and thermocatalytic sensors

- *Volume ceramic technology.*
- *Wire microcoil for thermocatalytic sensors.*
- *Screen printing.*
- *Silicon micromachining.*

Thick film sensor



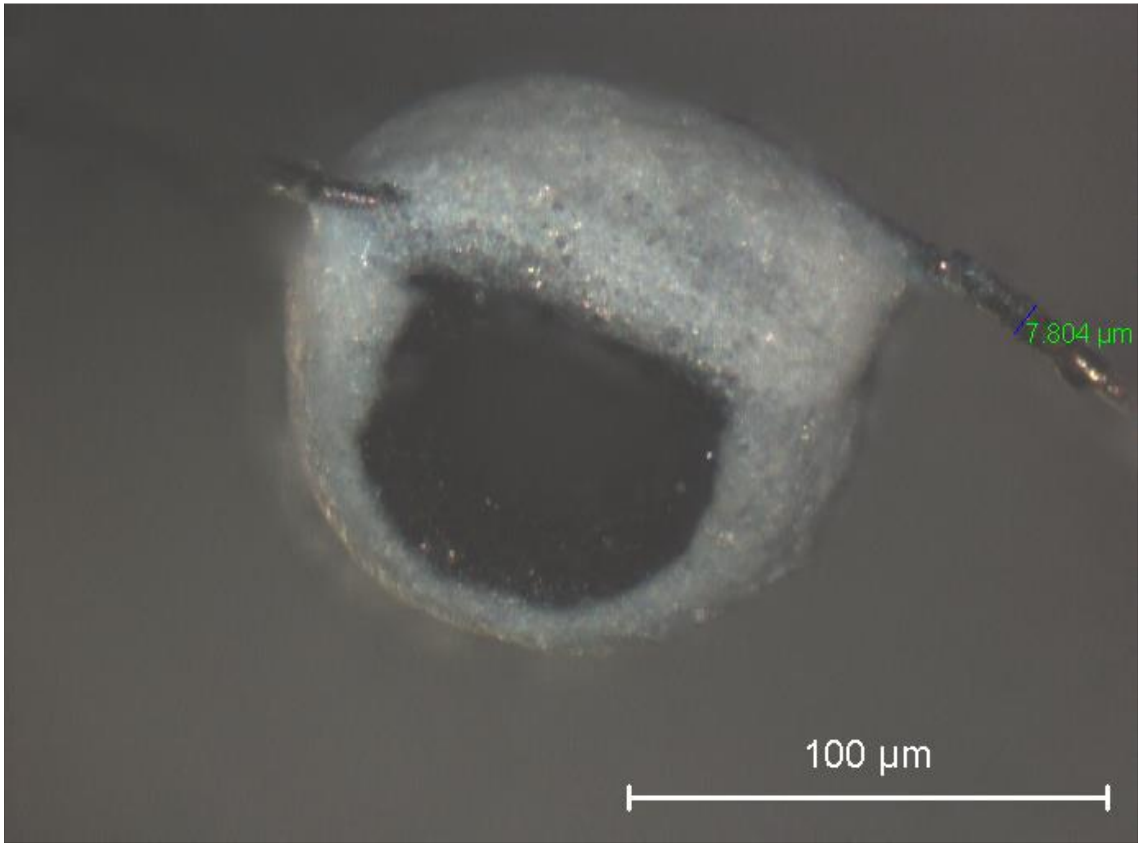




TO-8 packaged thick film sensor chip.

Chip size 2.5 x 0.3 x 0.1 mm

Wire Microcoil technology for thermocatalytic sensors

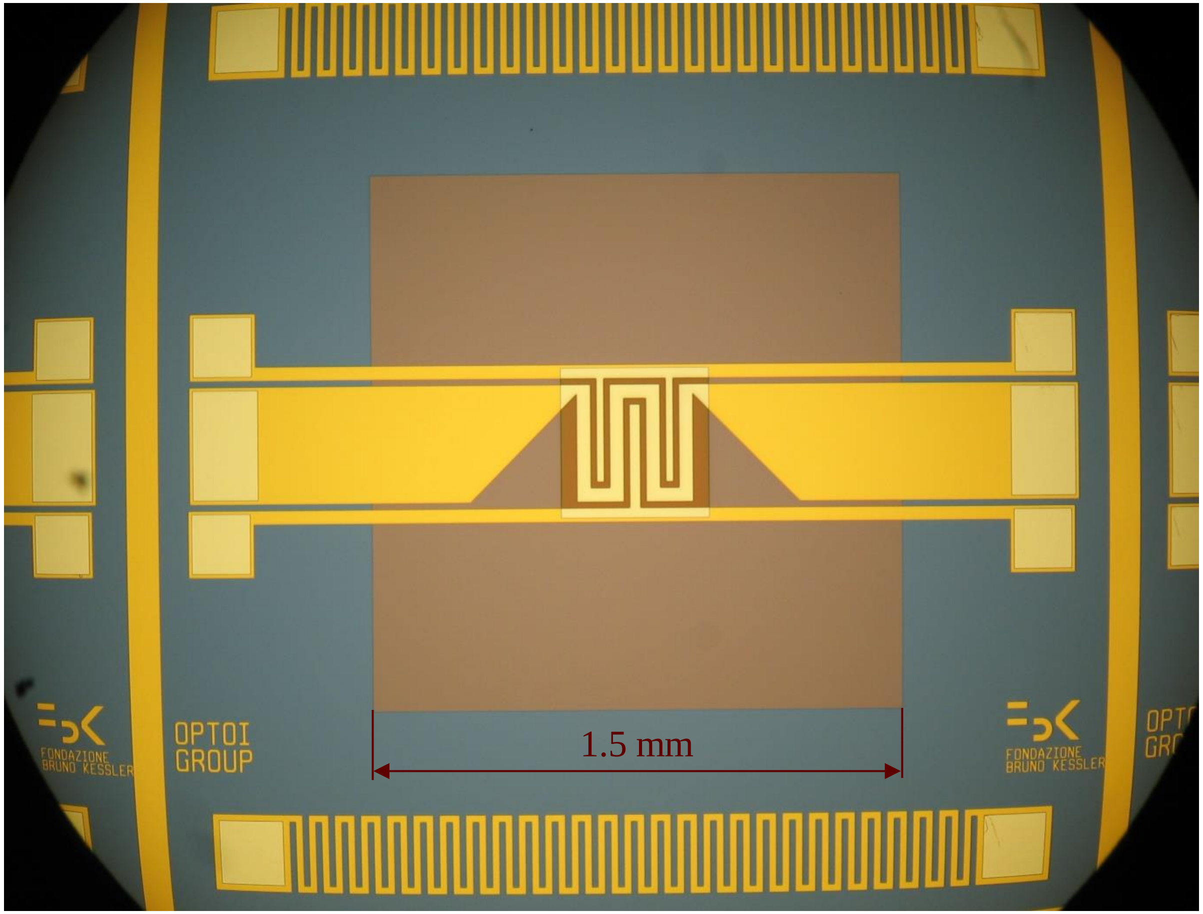


Thermocatalytic gas sensing element made of 10 micron Pt wire in glass shell. Sensing layer is alumina (~100 m^2/g) impregnated with Pt/Pd catalyst.

Sensor fabricated by LLC "IGD", Moscow, Russia.

Mass-produced sensors of this type are applied for the detection of methane in coal mines in a concentration range of ~0.1 – 10 vol. %.

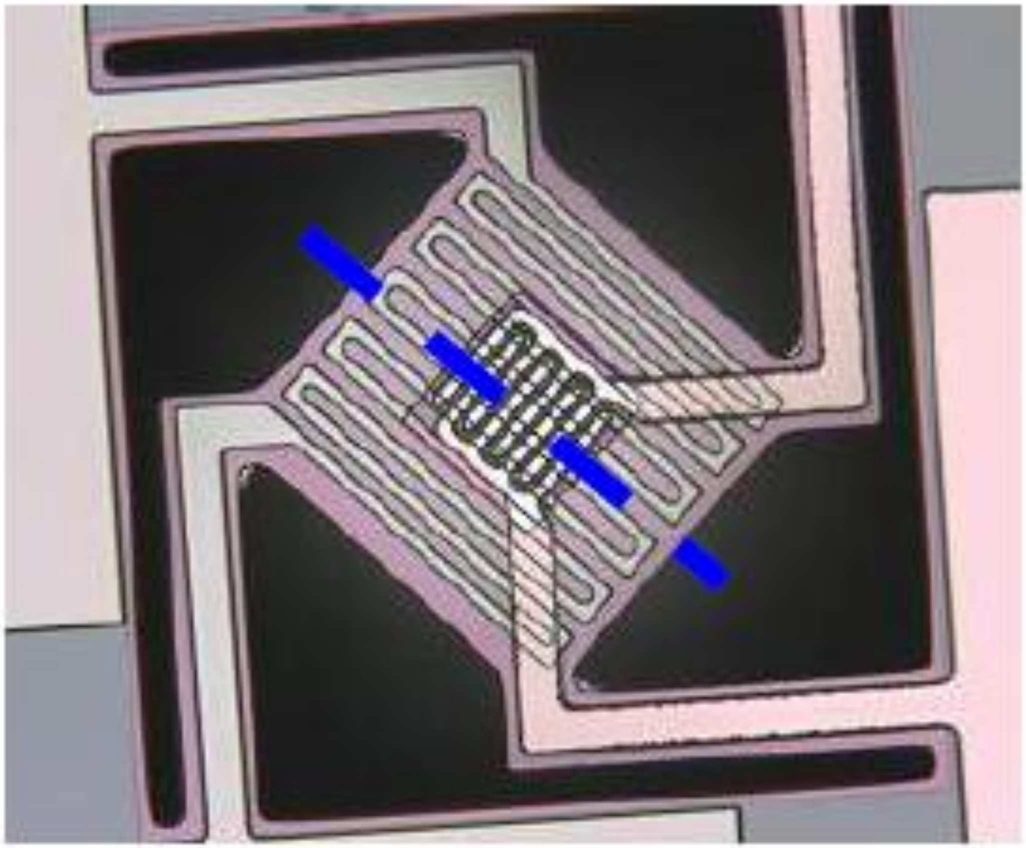
SiO_2/Si_3N_4 based MEMS platforms (FBK, Trento, Italy)



MEMS platform with multilayer SiO_2/Si_3N_4 membrane. Membrane thickness is of about 1.2 μm, power consumption ~50 mWt at permanent heating up to 450^{0}C.

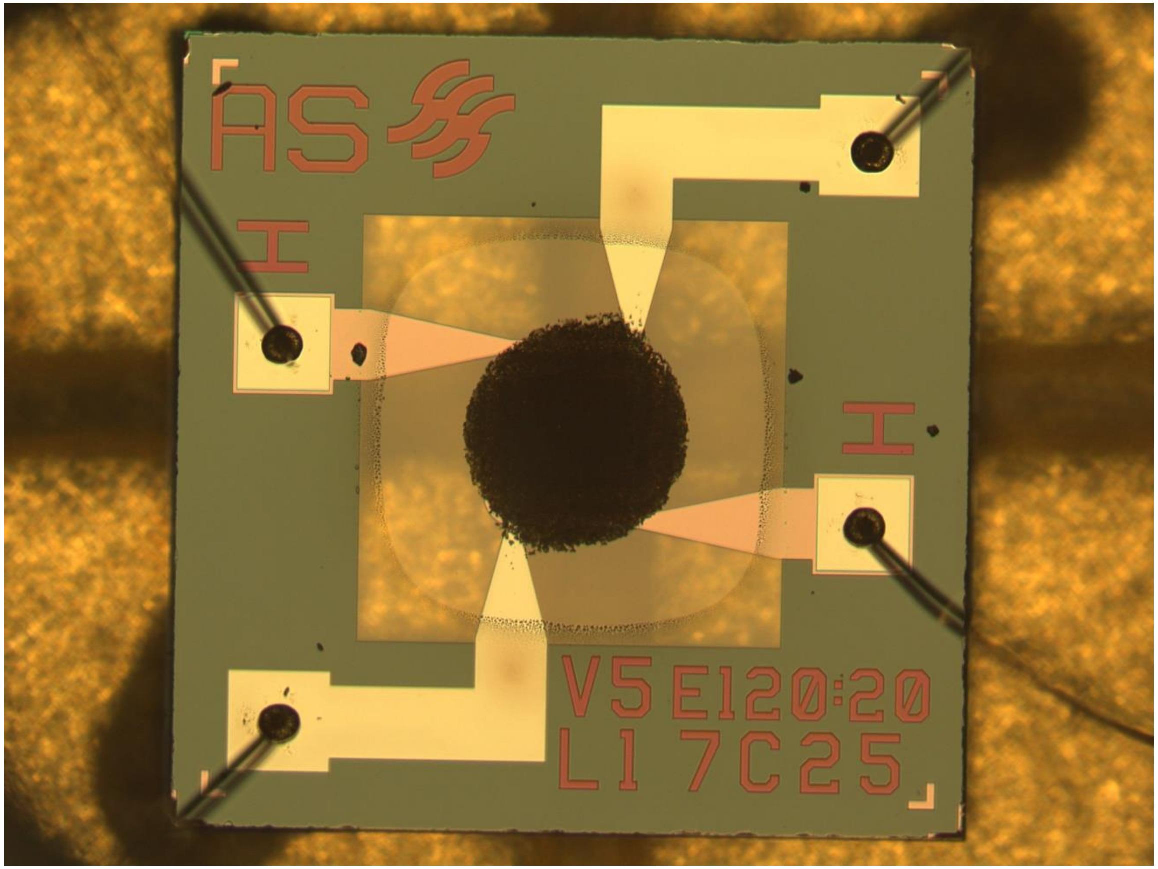
- **5 million cycles;**
- **maximum working temperature 450^{0}C;**
- **maximum annealing temperature in furnace 720^{0}C.**

MEMS sensor of Figaro Inc.



The idea of the application of this shape of the microhotplate is the minimization of bending and, therefore, stresses in the membrane of gas sensor. However, the connections of the microhotplate to the legs are the concentrators of the strains.

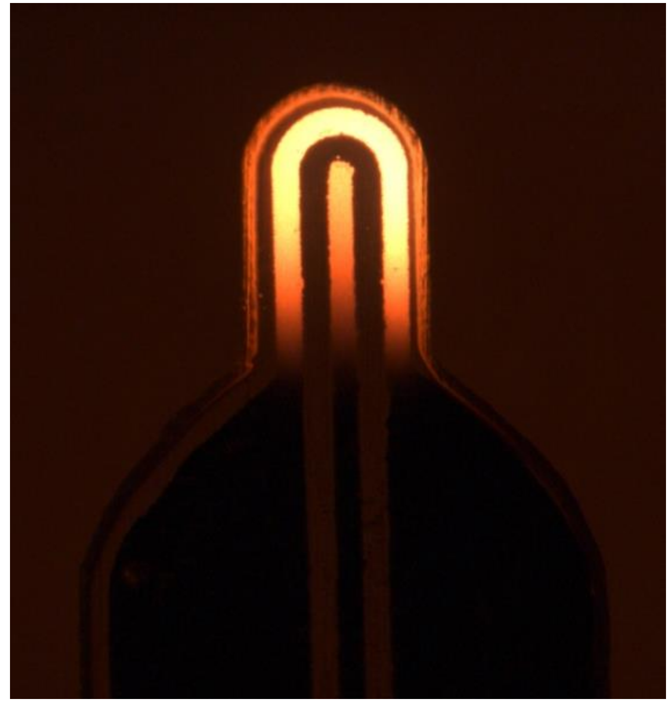
Air quality sensor of “Applied Sensors”



Air quality sensor chip made using silicon technology with Pt heater and SnO_2-Sb_2O_5/Pd sensing layer.

Alumina Chip with Pt Microheater

Sensor chip based on anodic alumina. Thickness of alumina is of 30 mm, diameter of the chip is of 6.8 mm, the size of hot area of microhotplate is of 300 x 300 μm. The size of the chip is compatible with TO-5 package.



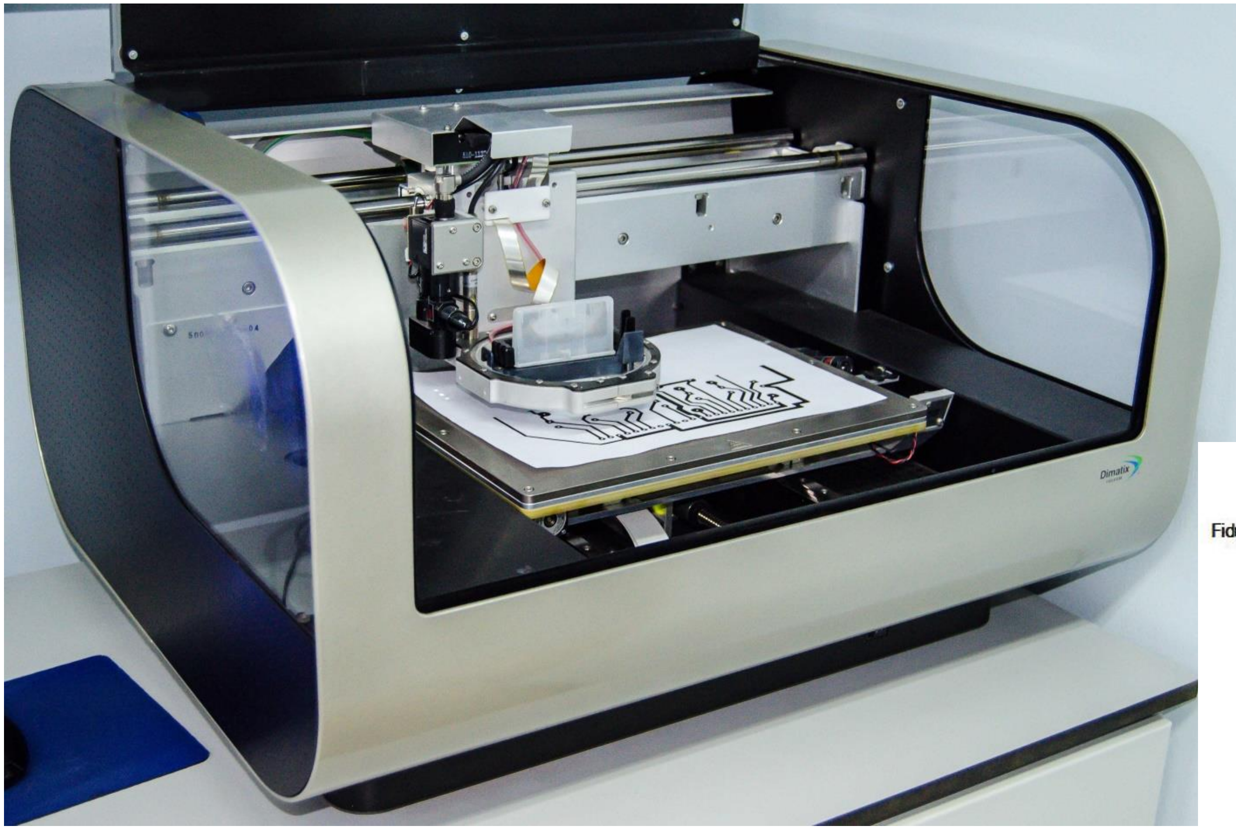
Hot area of the microhotplate under optical microscope. Temperature of the microhotplate is of 680^{0}C.

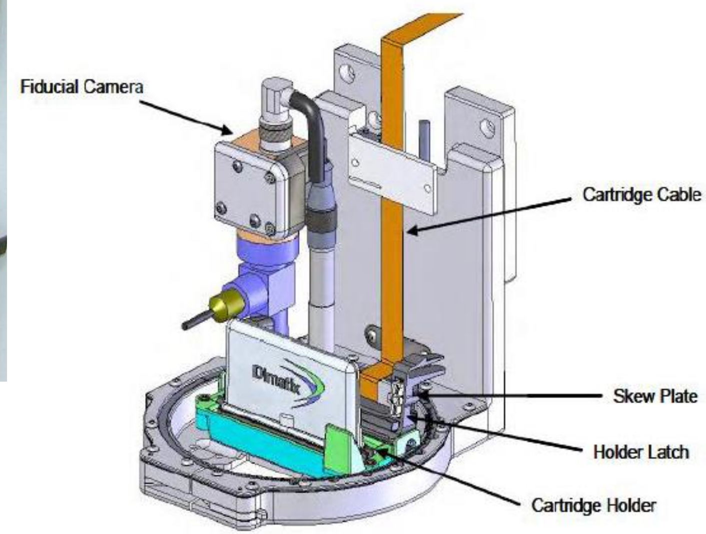
Problem Statement

The target is the development of the microheater platform free of the disadvantages of existing MEMS devices fabricated using silicon technology:

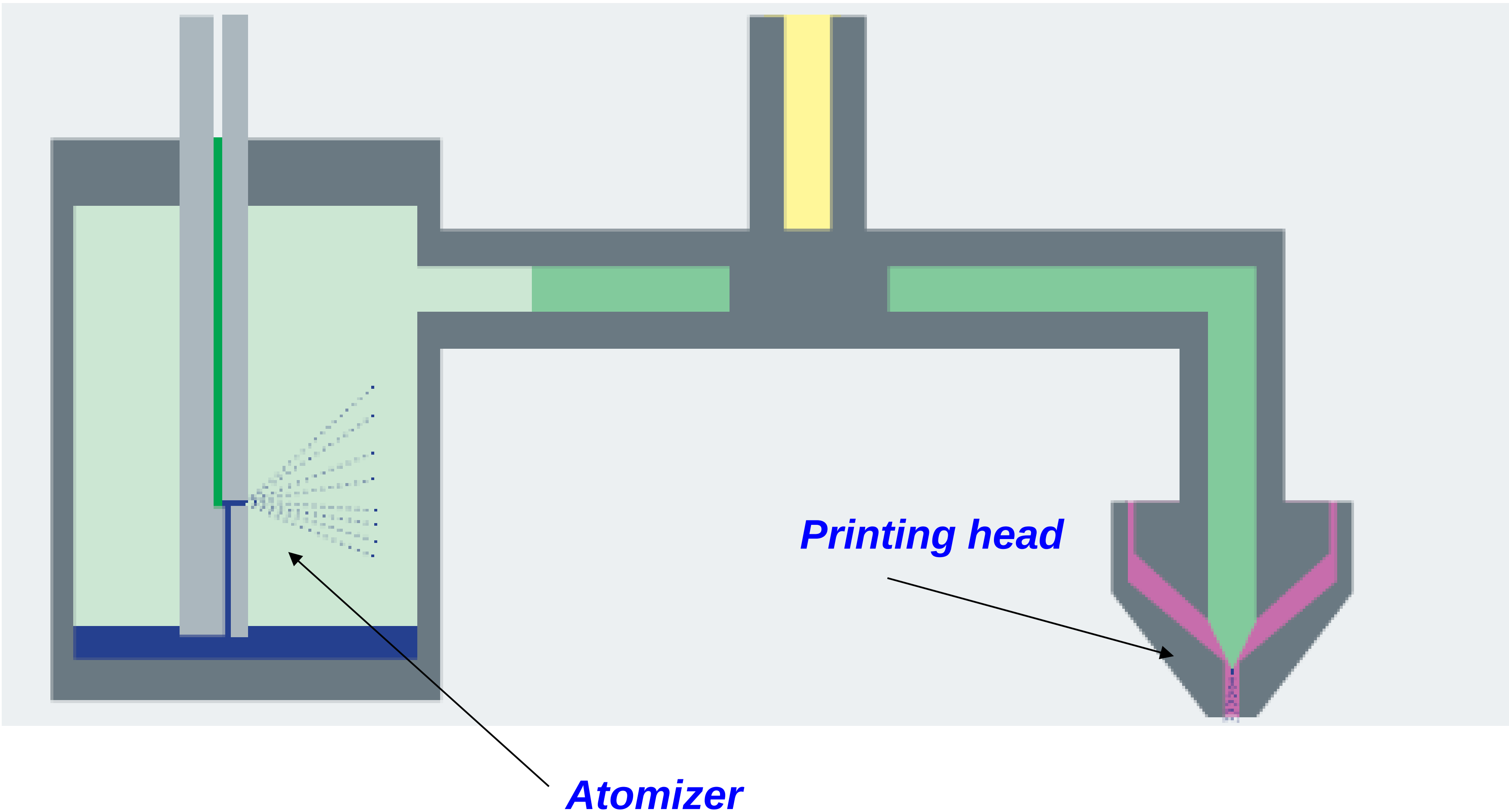
1. ***complex technology needing clean room facilities inadequate to sensor production scale;***
2. ***incompatibility of materials used in silicon technology (Si, SiO_2/Si_3N_4 membrane, Pt).***
3. ***low efficiency of Pt sputtering process and high consumption of precious metals in sputtering;***
4. ***bending of membrane in temperature cycling leading to destruction of the microheater;***

Ink-jet Printer Dimatix DMP 2831

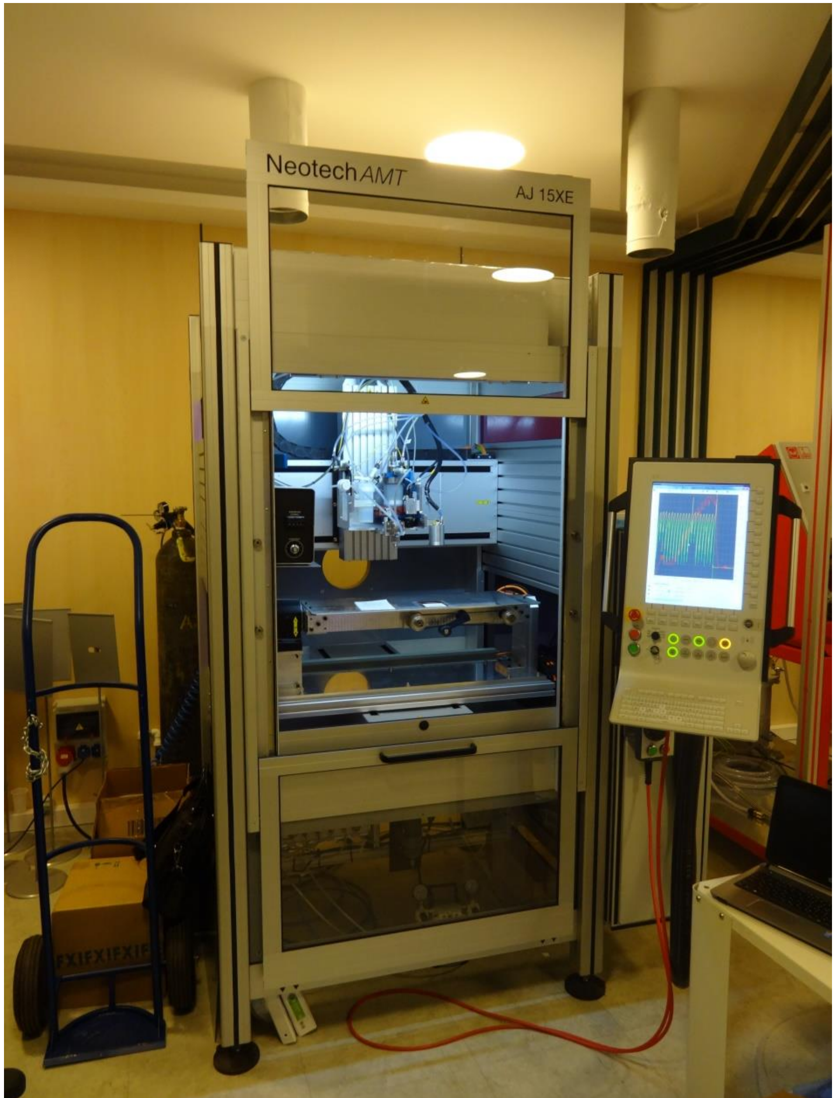


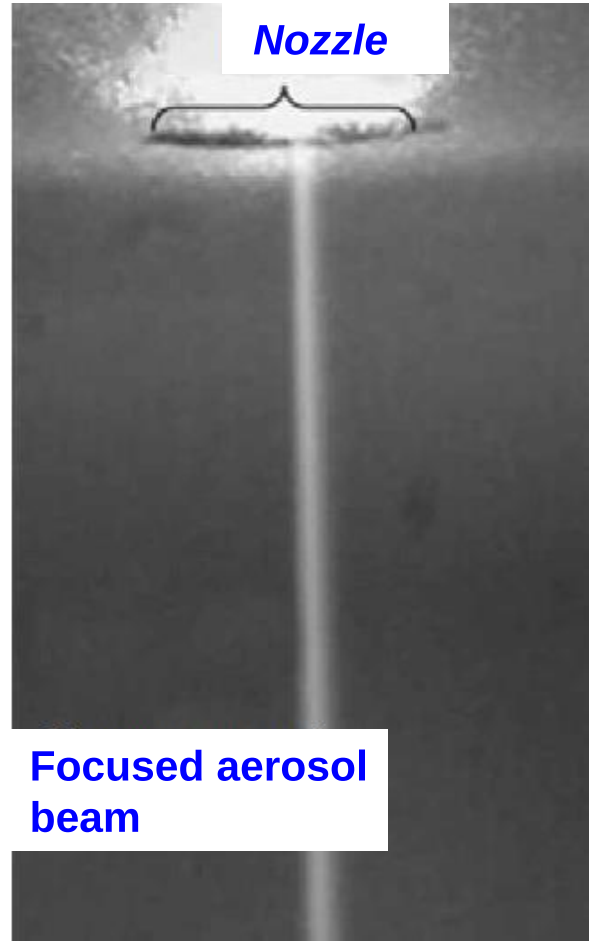


Aerosol printing machine



Aerosol printing machine

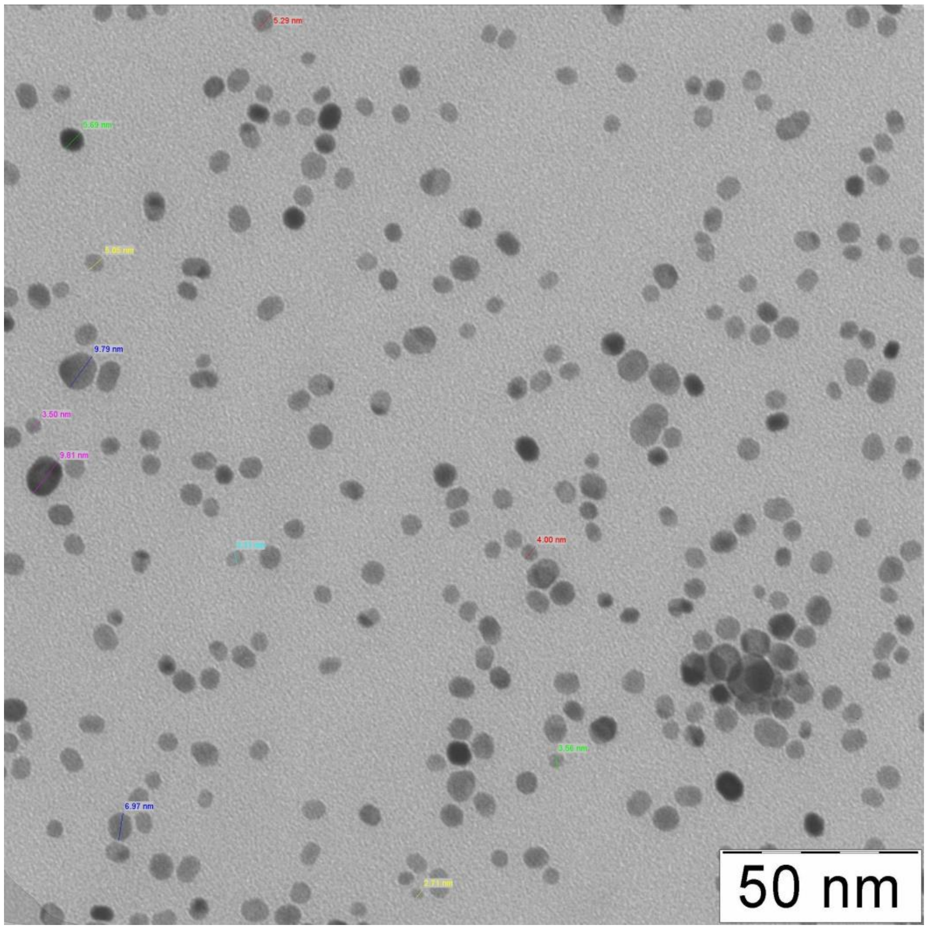


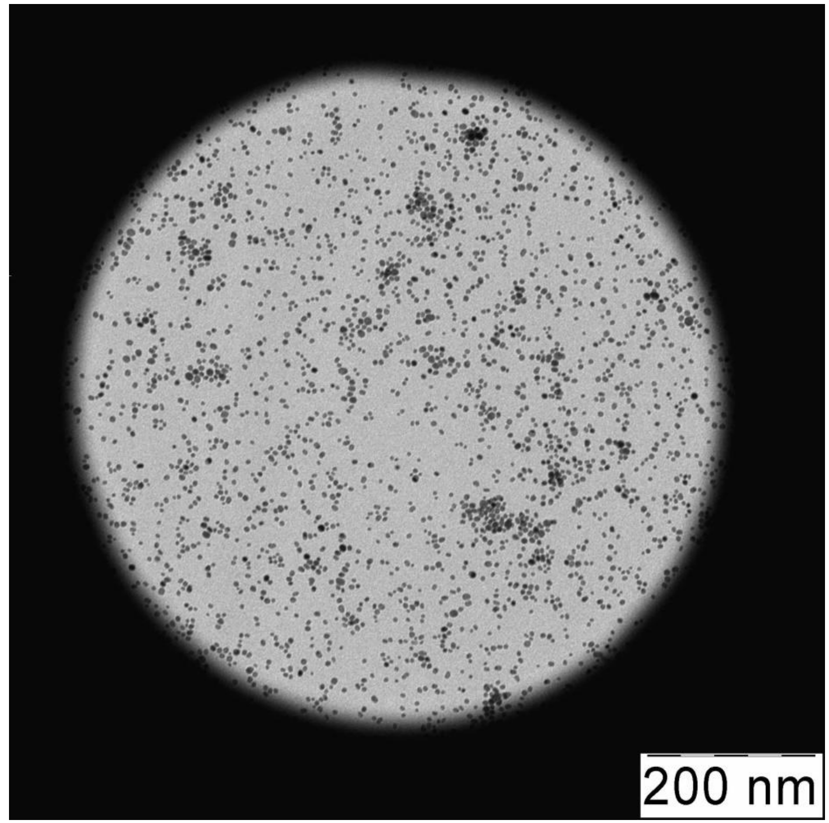


Au, Ag, and Pt Inks Used for the Printing

Printable ink consists of organic solvent (viscosity of about 10 cPs) with dispersed Pt, Au, or Ag nanoparticles (10 – 30 nm in diameter)

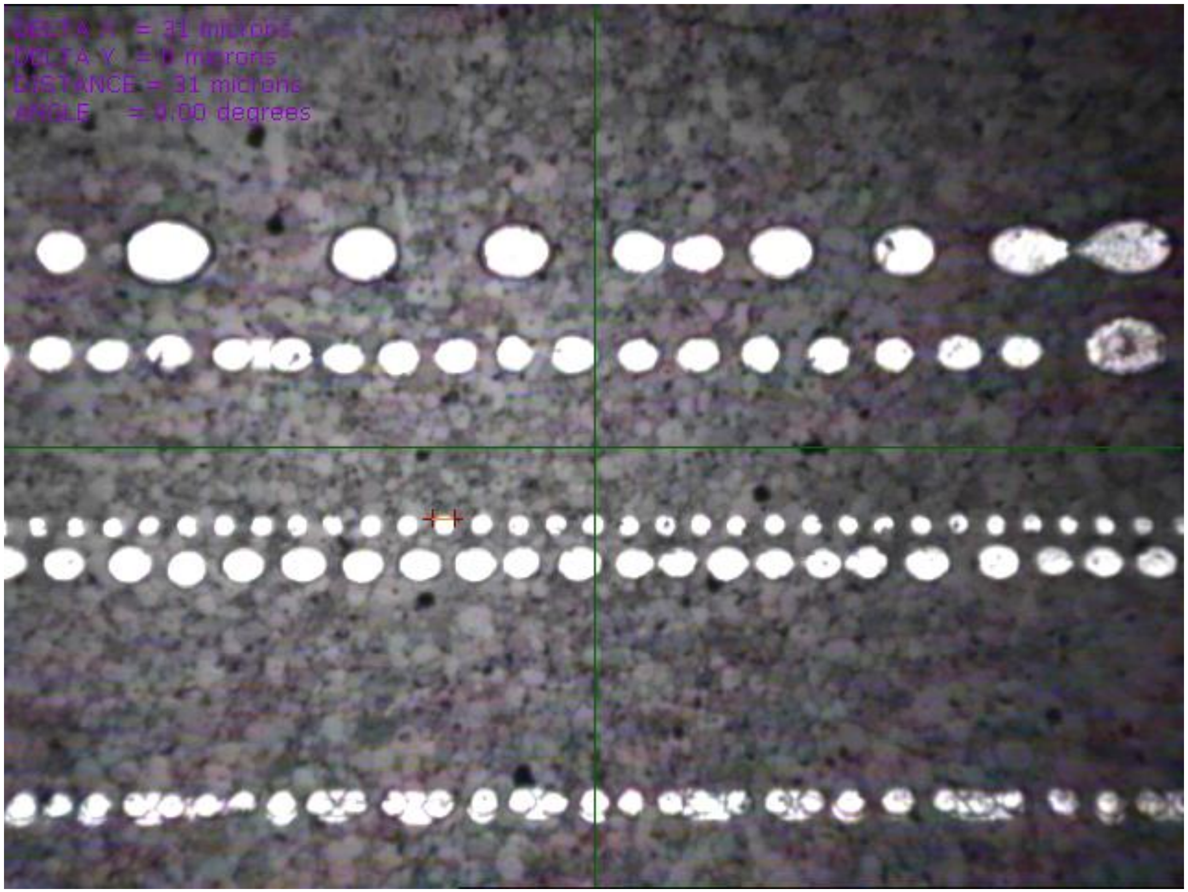
TEM Picture of Platinum nanoparticles from the Ink Usable for Printing





Particle size 3-8 nm without agglomerates.

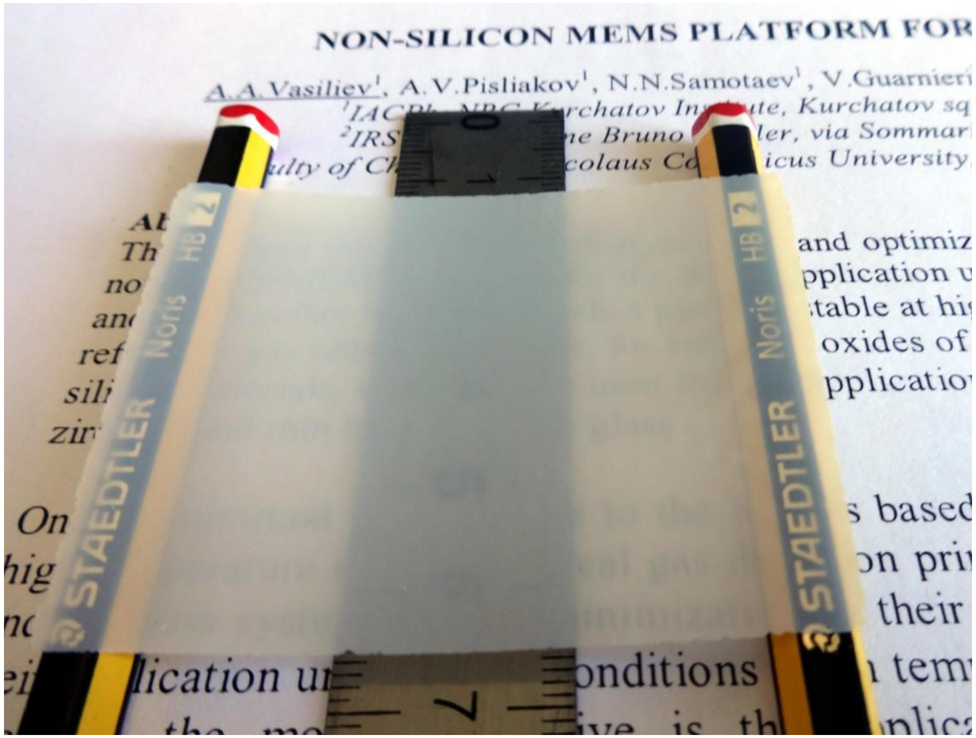
Ink-jet Printing on Polycrystalline Alumina Substrate



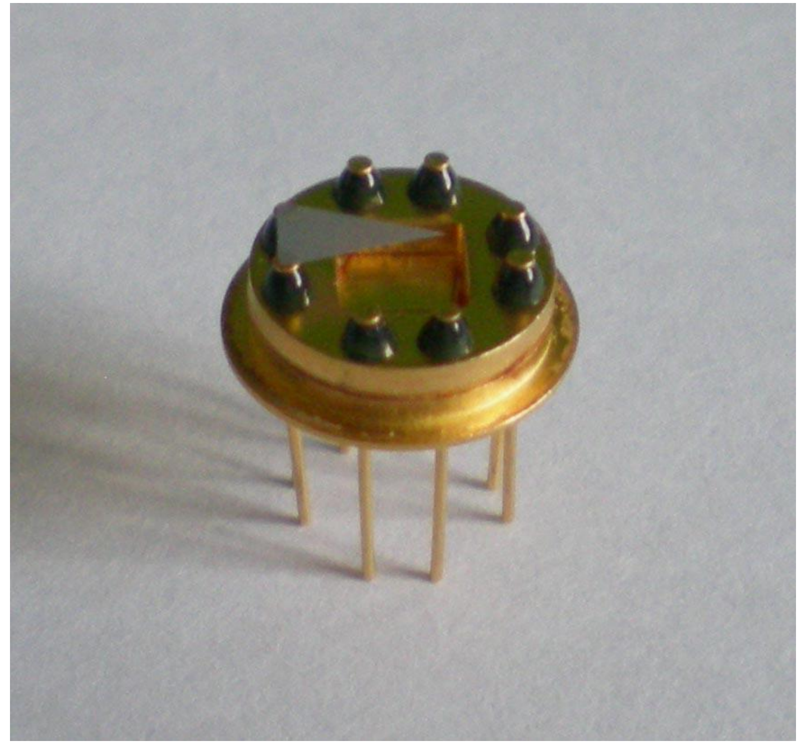
Ink-jet printer Dimatix DMP 2831.

Polycrystalline alumina substrate is hardly wetted by the ink based on organic vehicle (10 cPs) and 10-nm silver nanoparticles. Cleaning of the surface does not inprove printing very much.

Substrates Made by Anodic Oxidation of Aluminum Foil

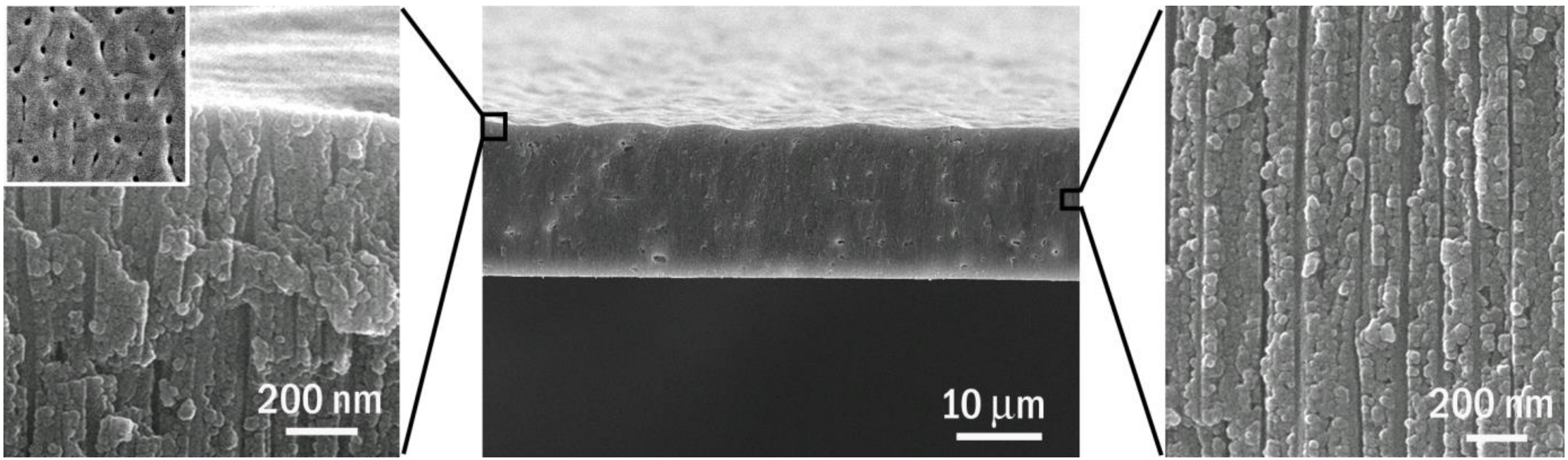


Alumina film (12 μm thick) prepared by anodic oxidation of aluminium followed by annealing at 800^{0}C. Membrane size is of 48x60 mm.

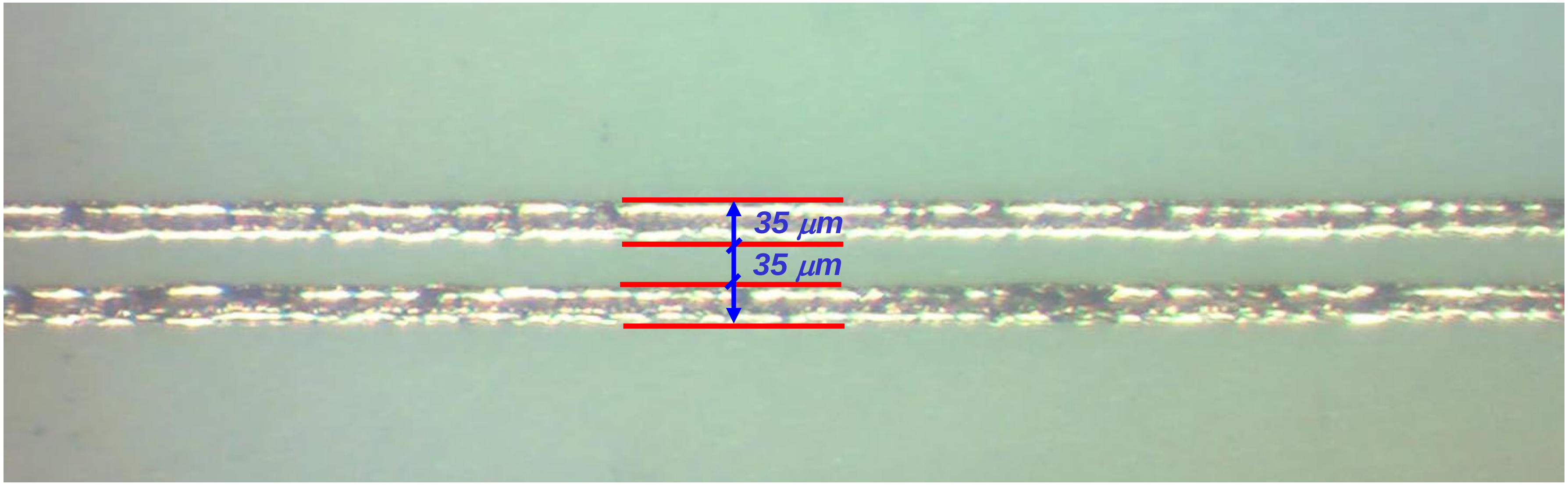


Alumina cantilever chip in TO8 package. Alumina film thickness is of 12 μm.

SEM Picture of Alumina Film Cross-Section

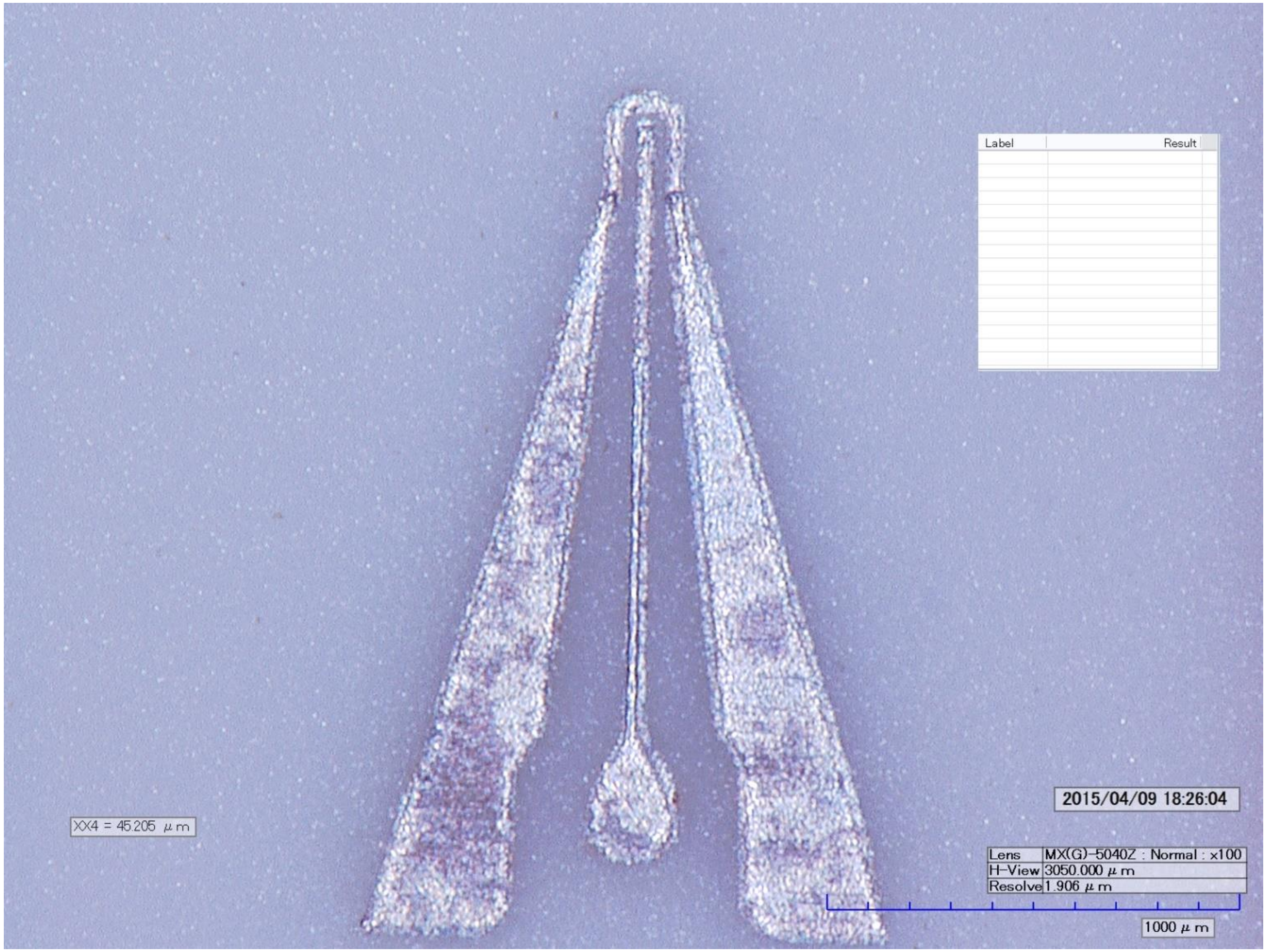


Printing with Dimatix DMP 2831 Ink-jet Printer



Printing with Ag ink (particle size of ~10 nm) in organic solvent with viscosity of 10 cPs. Annealing at 250^{0}C. Ag line sheet resistance is of ~ 2 Ohm/square.

Cantilever Sensor Layout Obtained Using Aerosol Jet Printer



Printing with Pt based ink of alumina substrate. Line width and gaps are of about 40 μm.

Conclusion

- *It is demonstrated that the application of aerosol and ink jet printing over thin alumina membrane fabricated by anodic oxidation of aluminum foil enables the manufacturing of microhotplates compatible by properties with Si MEMS.*
- *The combination of alumina thin membranes with additive technology of functional element deposition gives a possibility to produce gas sensors with high working (>600^0C) and technological (>1000^0C) treatment temperature.*
- *The suggested approach saves precious metals used for functional element formation and enables the fabrication of sensors with relatively simple equipment.*
- *The approach is very sutable for medium scale production of sensors. Existing aerosol printer is sufficient for the fabrication of ~2000 sensor chips per hour.*