

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*)

BENEFITS OF CMOS SENSORS FOR ENVIRONMENTAL MONITORING

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Function in the Action:

WG Member/WG4;

Technology Innovation Focus Group; ESSC

United Kingdom

CAMBRIDGE
CMOS
SENSORS



 **cost**
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY





Scientific context and objectives in the Action

Background / Problem statement:

- Environmental issue is a global problem
- Environmental monitoring is not just about Gas sensing
- It involves measuring many parameters such as temperature, humidity, pressure, flow, EM radiation, particles, GHG, liquids, air flow, nuclear radiation, vibration (earth quakes), bio-medical threats, etc.
- Monitoring all these parameters on a global scale is a costly business
- Systems are bulky – hence raw material wastages
- How can we address these issue?

Putting things into perspective

- Total area of Earth is ~500 million km square
- Need 500 million monitors if one sensor per km is sufficient
- Realistically need at least 100 monitors per km square thus need 50 billion monitors
- Out of which is 29% is land so minimum need 15 billion monitors
- With each monitors having multiple sensor, need $n \times$ number of monitors
- With energy harvested low power, with wireless, this need to be significantly more!
- Not physically possible using current discrete components solution!



Scientific context and objectives in the Action

Solutions:

- We need to make sensors widely available
- **We need to measure as many parameters as possible**
- We need to make the sensor as compact and low cost as possible
- We need to readily integrate sensors in everyday utilities and devices
- We need to make it ultra-low power
- To achieve this we need to exploit the following options:
 - Natural organic sensor
 - Printable electronics
 - Nanotechnology
 - Or CMOS sensing technology

Main Categories of Sensors

Question:

Can we use a single platform technology to measure all these parameters?



Answer:

Yes, and best option is to use CMOS

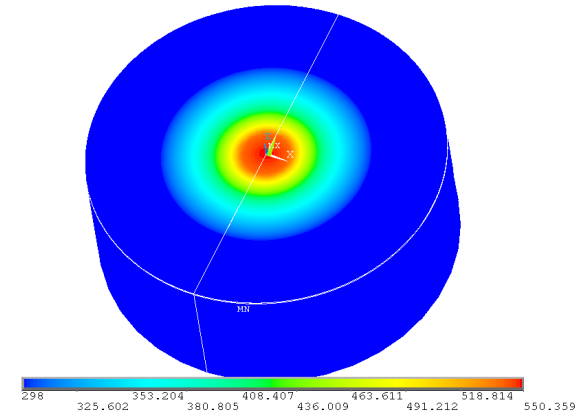
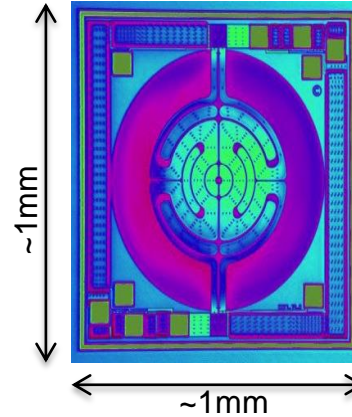
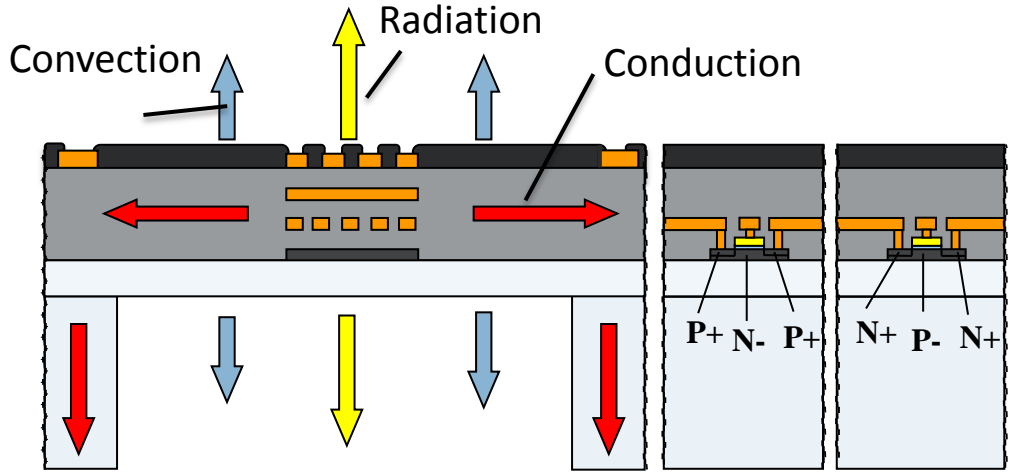
Parameters to be measured

With CMOS
all these
parameters
can be
measured on
the same
platform
because we
can ...



... we can
combine
natural,
printable and
nano-
technology
solution on
the same
CMOS
platform

Technology Breakthrough



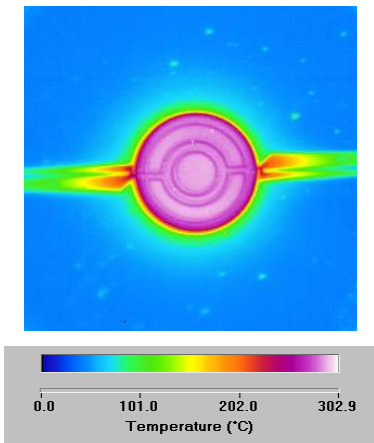
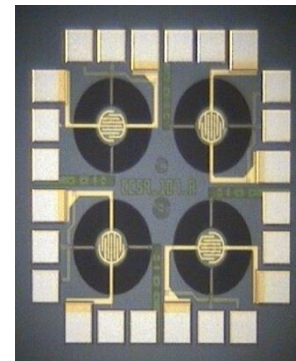
Only membrane is heated
silicon remains at ambient

**Micro-hotplates integrated on standard CMOS process
capable of:**

- High Temperature, High stability
- High reproducibility
- High reliability
- Miniature device 1mm x 1mm die

Platform for new generation of CMOS, MEMS

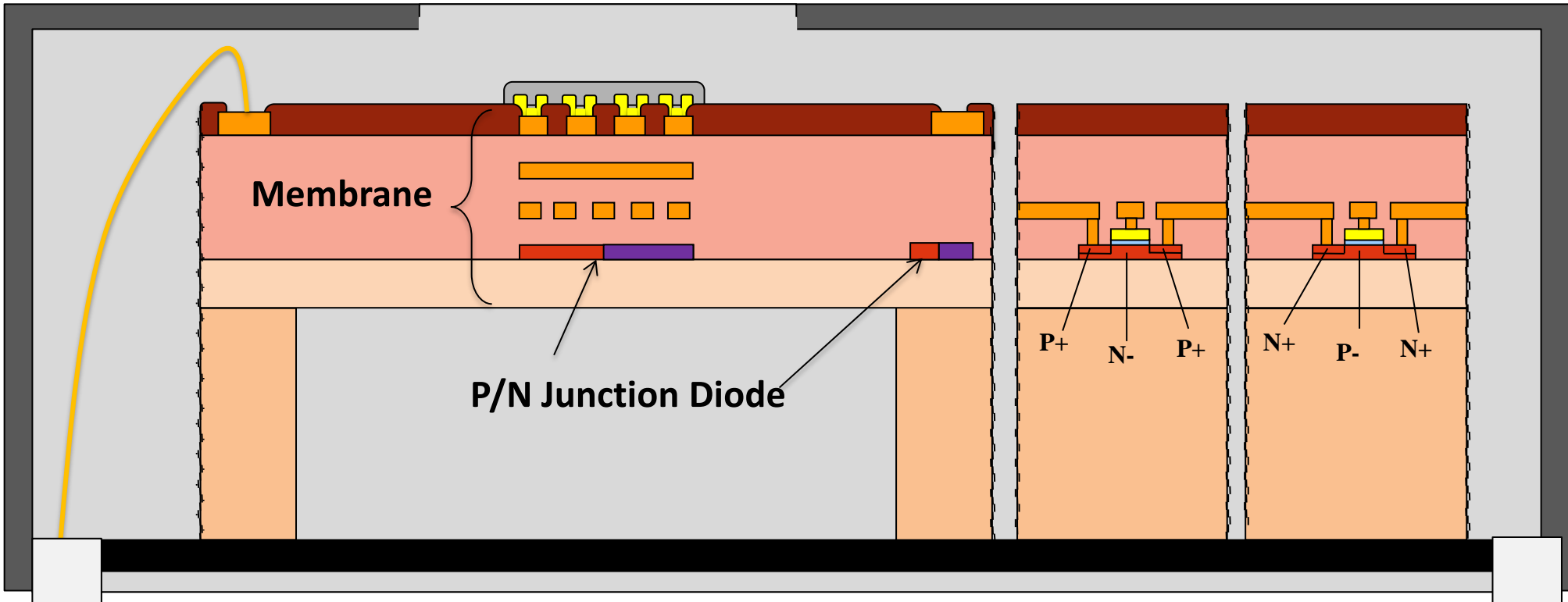
Gas sensors, IR source and Detectors



Array of 2 x 2 MHP on 1mm x 1mm die Good thermal uniformity

Parameters Measured by Sensors

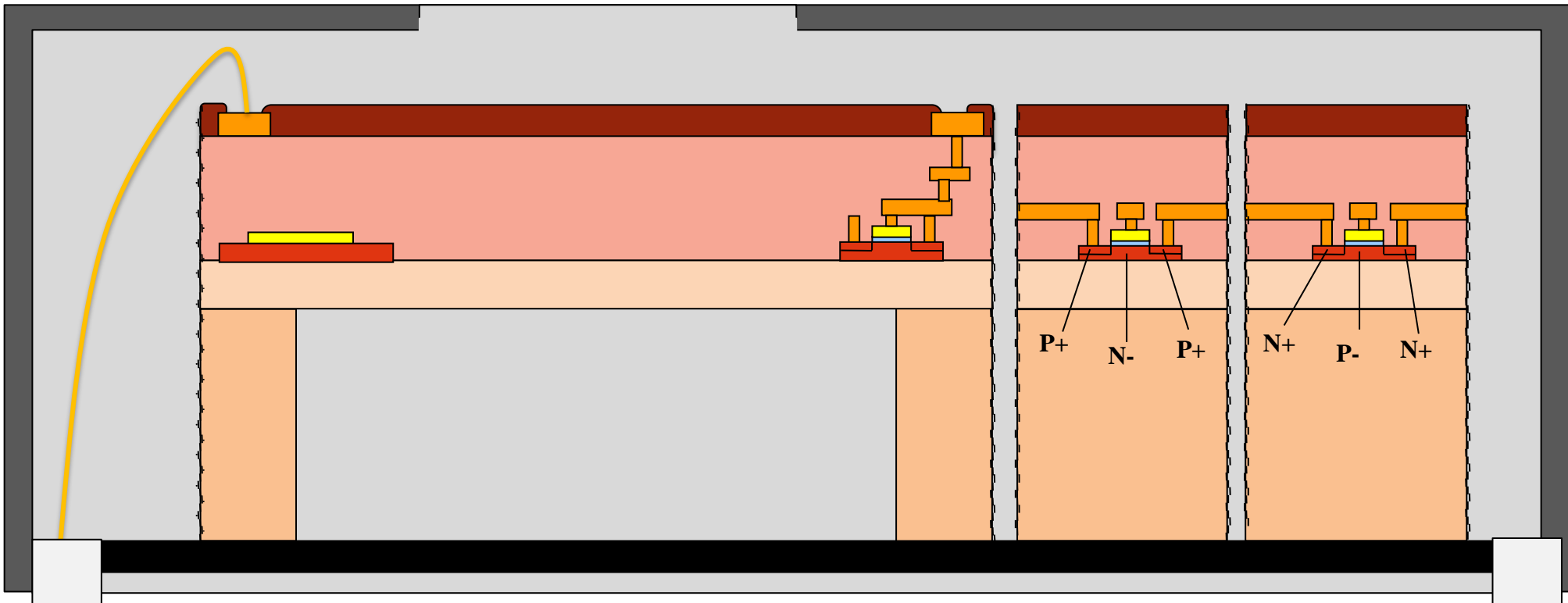
Physical: Temperature, Pressure, Flow, Humidity, Acoustic



Measure temperature: directly under sensing layer; ambient; stand-alone etc.

Parameters Measured by Sensors

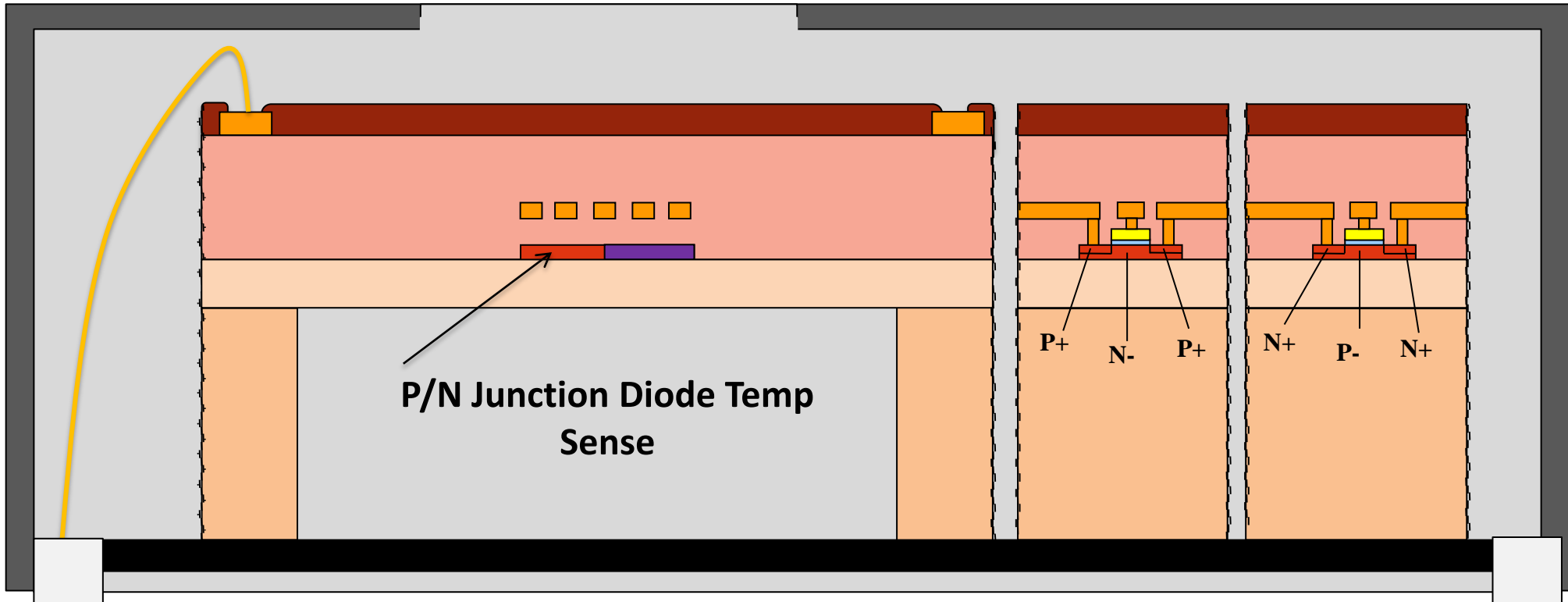
Physical: Temperature, Pressure, Flow, Humidity, Acoustic



Measure Pressure: Piezoresistive; active, etc.

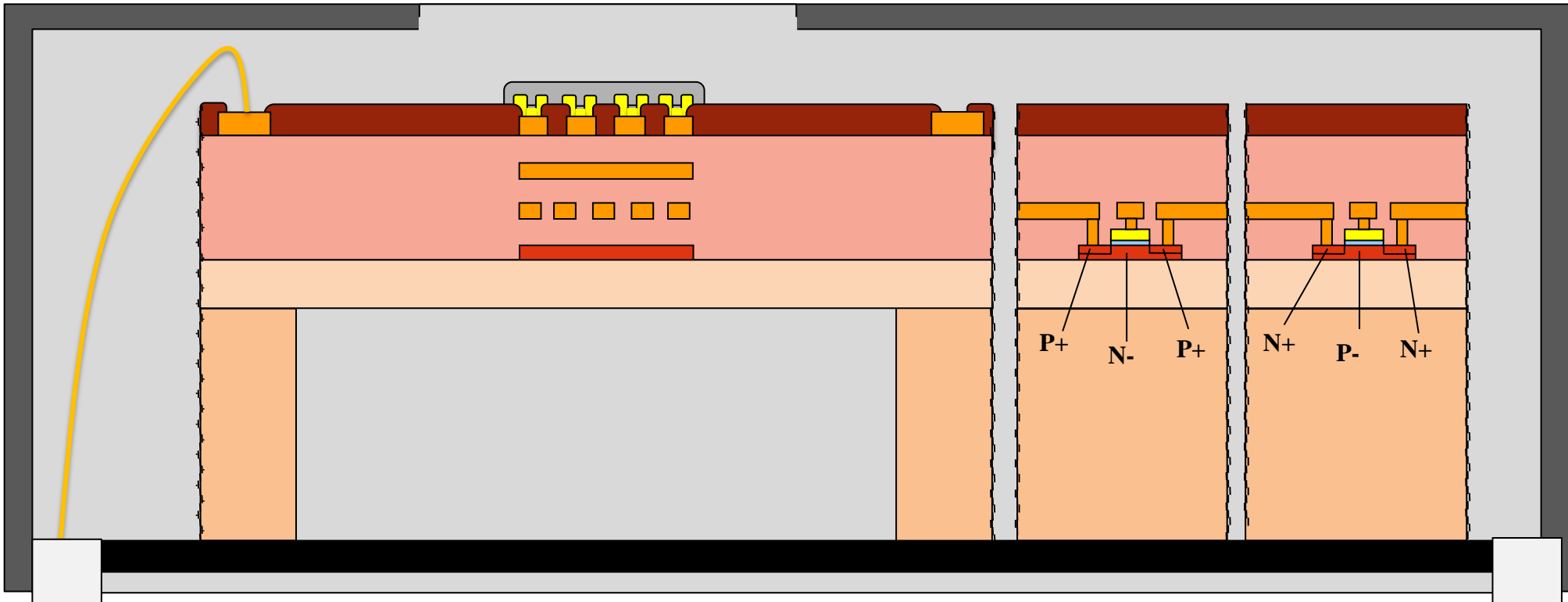
Parameters Measured by Sensors

Physical: Temperature, Pressure, **Flow**, Humidity, Acoustic



Parameters Measured by Sensors

Physical: Temperature, Pressure, Flow, **Humidity**, Acoustic

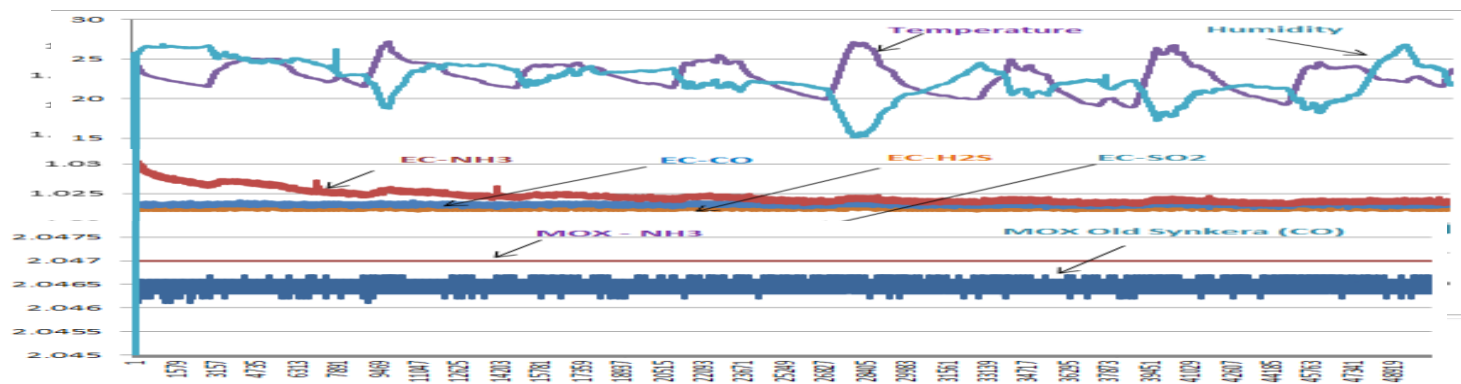


These are just some examples: Chemical; Mechanical; Electrical and Optical parameters can also be measured.

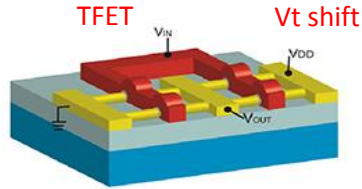
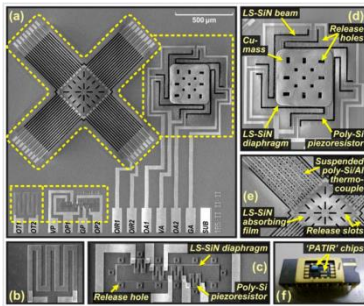
Multi-sensing on a PCB



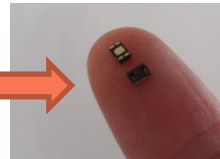
Figure 1. Example of sensor module: (a) Multi-parameter environmental sensing module; (b) Board with CMOS sensor modules providing same functionality (circled in red).]



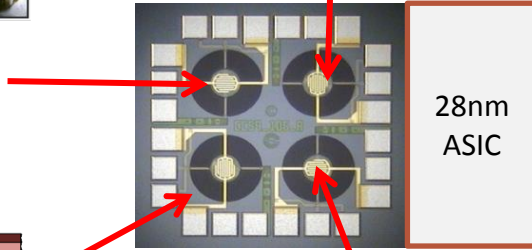
Multi-sensing on a single die



One of the smallest
Multi-gas sensors by CCS
Package 2 x 3mm

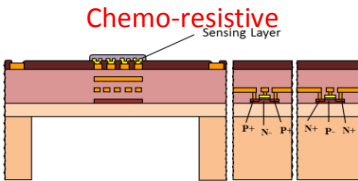


Temperature



1 x 1mm die

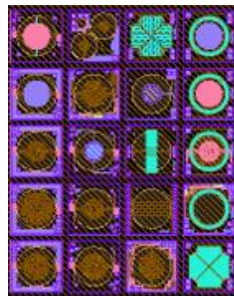
Humidity



SOI or CMOS (CCS)

Can measure:

- Gas
- Temperature
- Humidity
- etc



Key reasons for CMOS for Environmental Monitoring

1. The process perfected over more than 60 years
2. Proven to go beyond more than Moore's law
3. Billions of dollars invested in technology, methodologies and instrumentations
4. Billions of sensors already in production (microphone, accelerometer, hall etc.)
5. Technology offers true high volume production capabilities
6. Offers scalability for lasting product life cycle and for future innovations
7. Integrated solution to enable smart multi-sensing capabilities
8. Wafer-level processing for 3D, heterogeneous packaged solutions
9. Provides high yield, low cost, ultra-miniature, low power solution
10. Multi-sensing to enable system-on-a-chip solution!

Current research activities

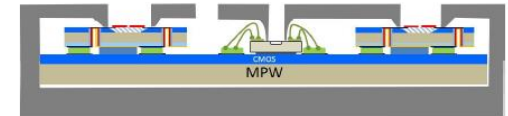
SOIHITS (Project ended Dec 2014):

- MHP enhancements for Harsh environment



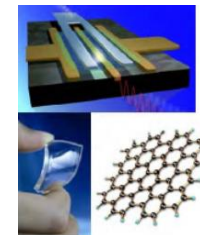
MSP:

Multi-sensing with wafer-level packaging with possibly TSV



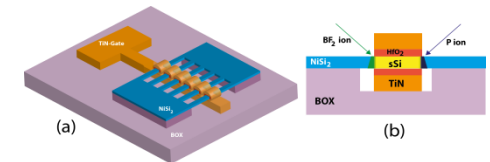
GRAFOL:

- Graphene-based low power NO₂ sensor and IR absorption enhancement



E2SWITCH:

- Low voltage, low power very simple circuits for sensing applications – (beyond CMOS)



Some of the Facilities Available at CCMOSS



Wafer probe station, ASL1000, batch tester designed for sensors, wire bonding machine



Gas test systems with MFC and fully automated control software

**Fabless company with 25+ staff
and Sales Offices in Taiwan, China, Korea and US**



Suggested **R&I Needs** for future research

- **Research directions as R&I NEEDS:**
- Combining bio, printable and nanotechnology on same silicon platform
- Develop and improve multi-sensing solutions for rapid deployment for affordable global environment monitoring
- Both to serve short-term and long-term requirements
- Energy-harvested ultra-low power solution

Awards and Acknowledgements



NMI 2014 Innovation Award Winner



Founders, Investors and Team at
Cambridge CMOS Sensors Limited.

EuNetAir
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