sensichips

learning **microsensors**

Single chip embedded Electrochemical Impedance Spectroscopy and on-line safety monitoring

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ARESCOSMO
DEFENCE AND SPACE

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OSC

Smart Cable Air
Smart Cable Water

SDM

Drone

3D


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GUI


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SDM Team Leader


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Software Engineer

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Software Engineer

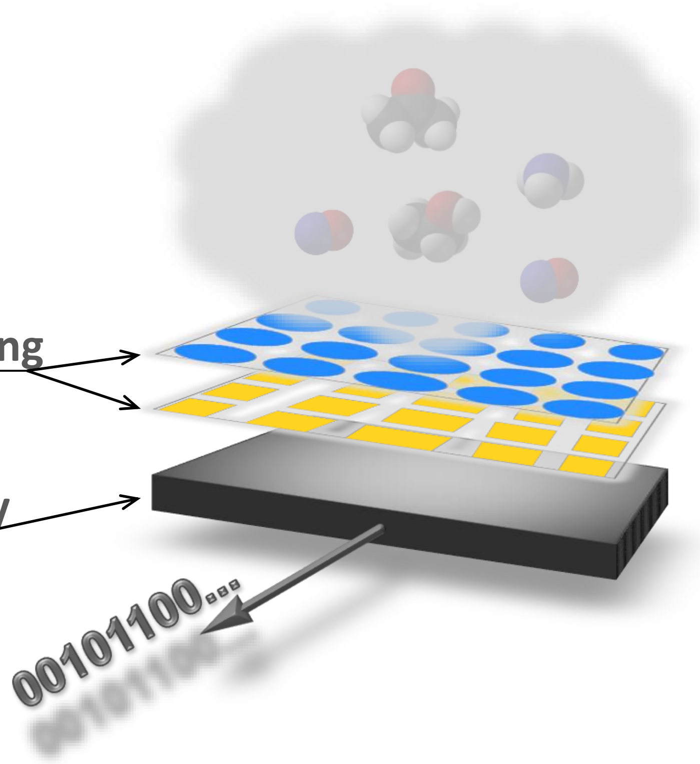
Luca Gerevini
Firmware Engineer

Single Chip

Learning Sensors + Microelectronics

Sensichips Manufacturing

Standard CMOS Factory



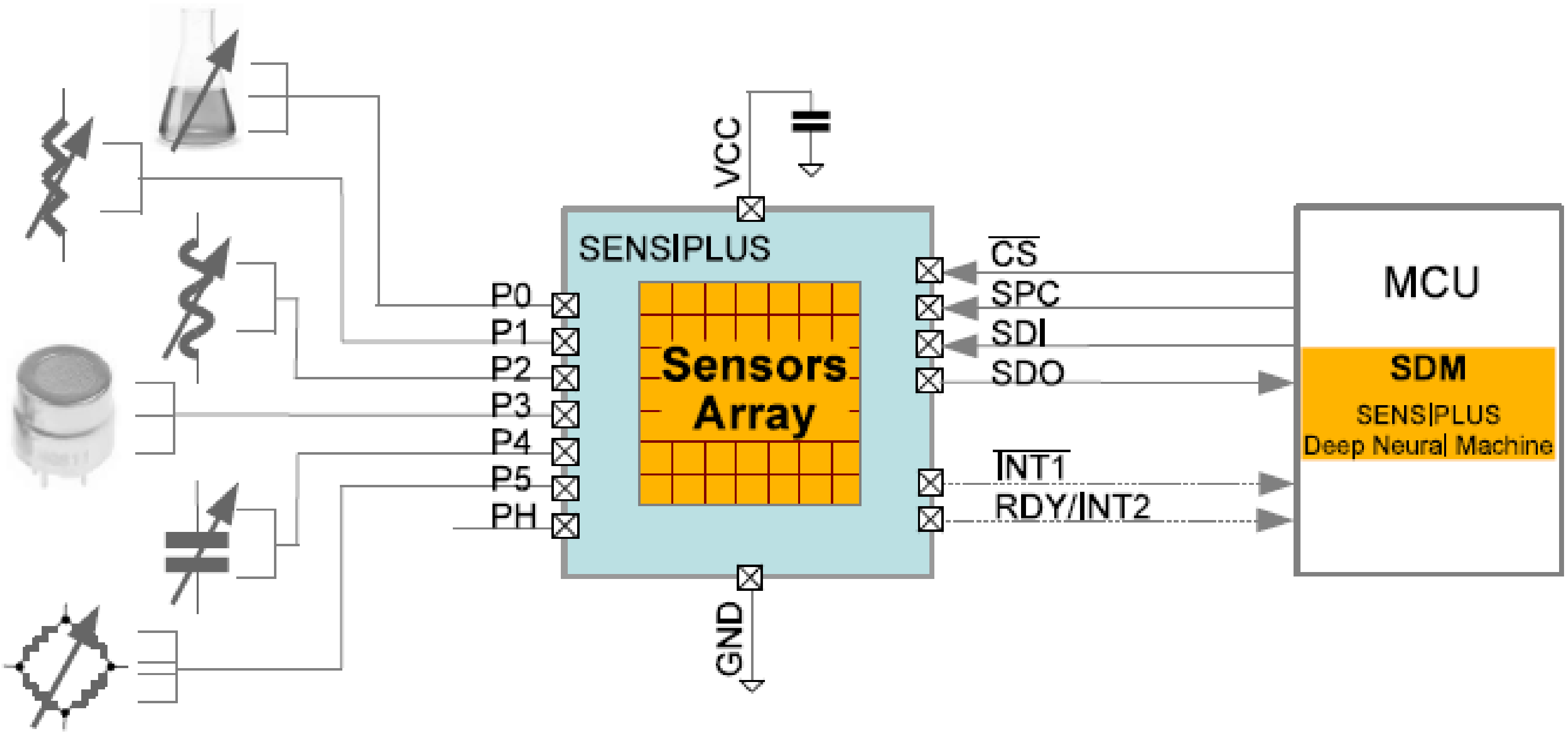
Sensors

Post-CMOS processing

CMOS microelectronics

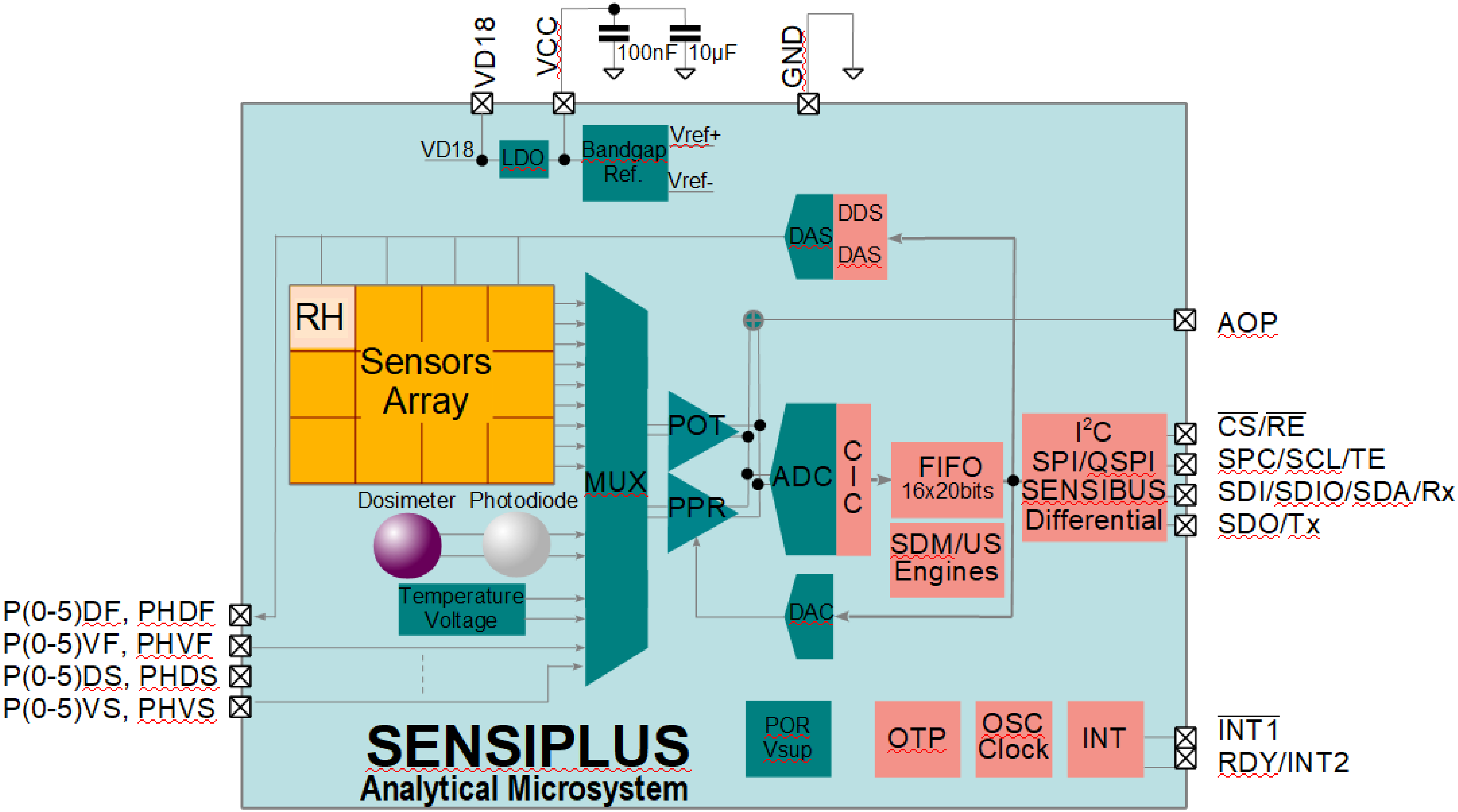
Chemical / Physical to digital conversion

Application Diagram



- Up to 16 on-chip sensors
- Up to 7 or 14 external sensors

Block Diagram



2x2mm
<1.5mW

SENSIPLUS RUN5

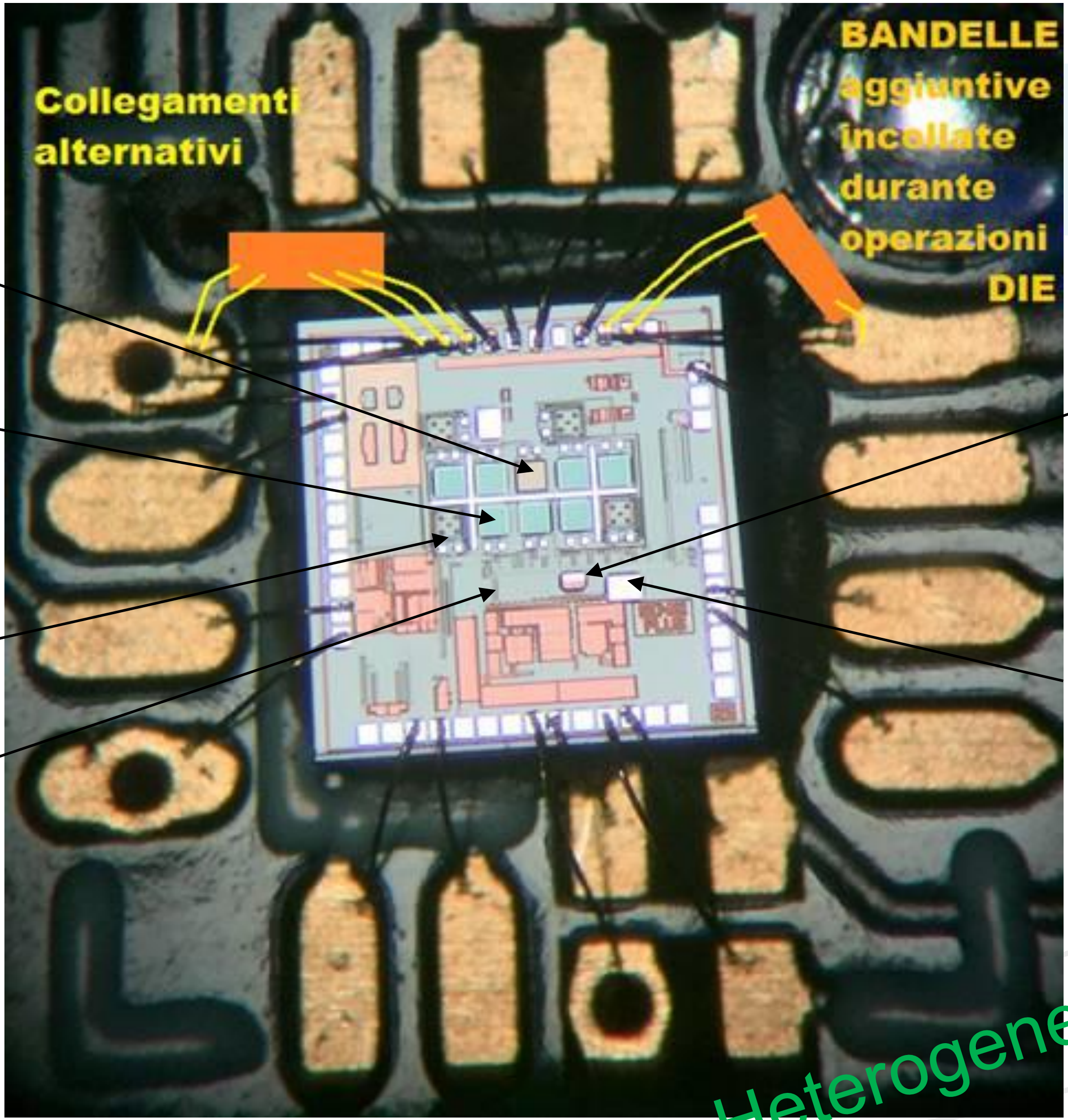
First CBRNe microsensor

Polyimide sensor

Al_2O_3 MOX sensors

Ionization Gas Sensor (?)

Temperature sensor
< 0.1°C precision
(for thermodynamic sensor)

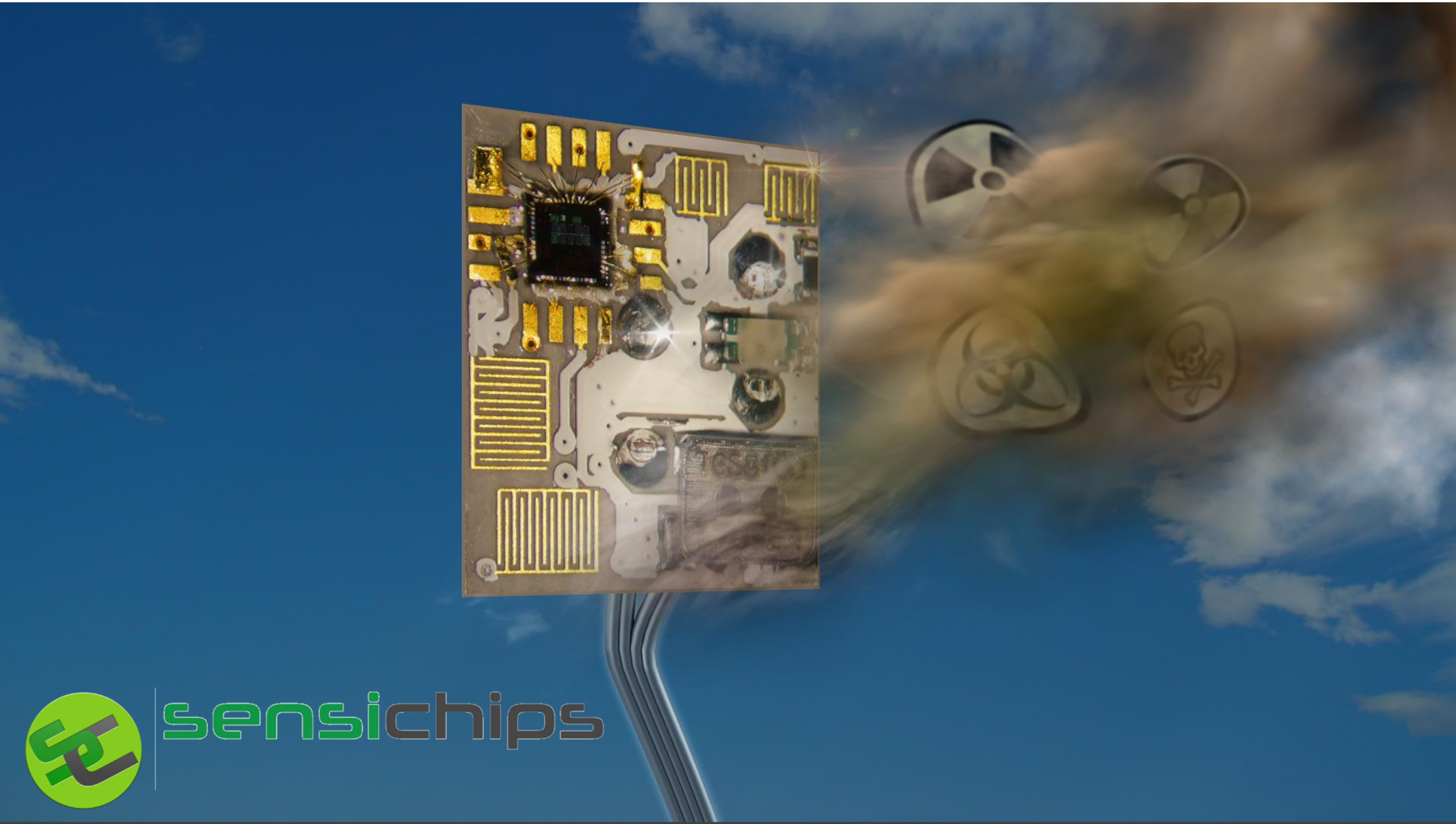


Photodiode

FG CMOS Ionizing Radiation Dosimeter (α, β, γ rays) & Deep UV sensor

Heterogeneous sensors

Smart Cable Air

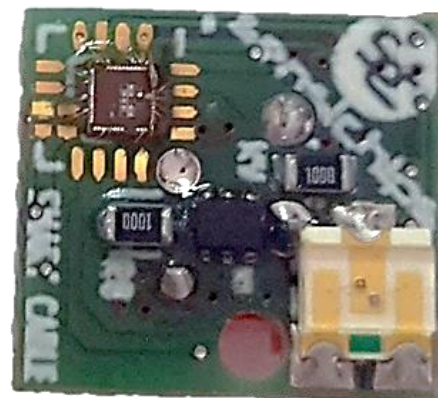


Smart Cable Air

RUN4

RUN5

9.87mm

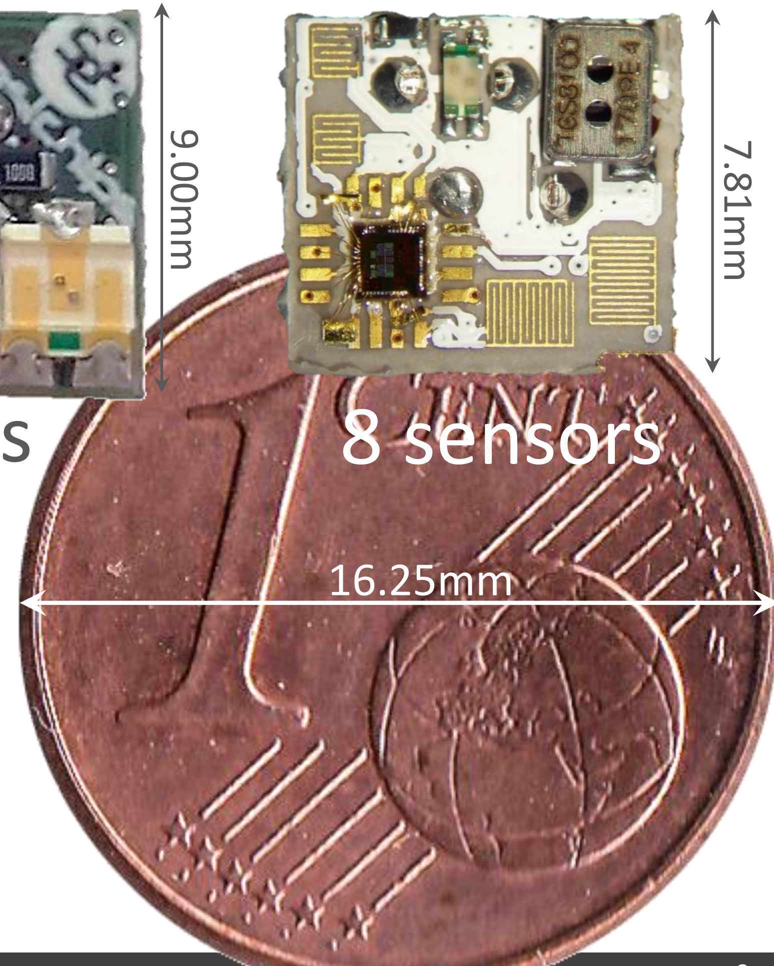


9.00mm

3 sensors

RUN6

8.63mm



Air Sensors

Temperature *bandgap CMOS sensor*

Polyaniline *chemisorption sensor with EIS (RH, NH_3)*

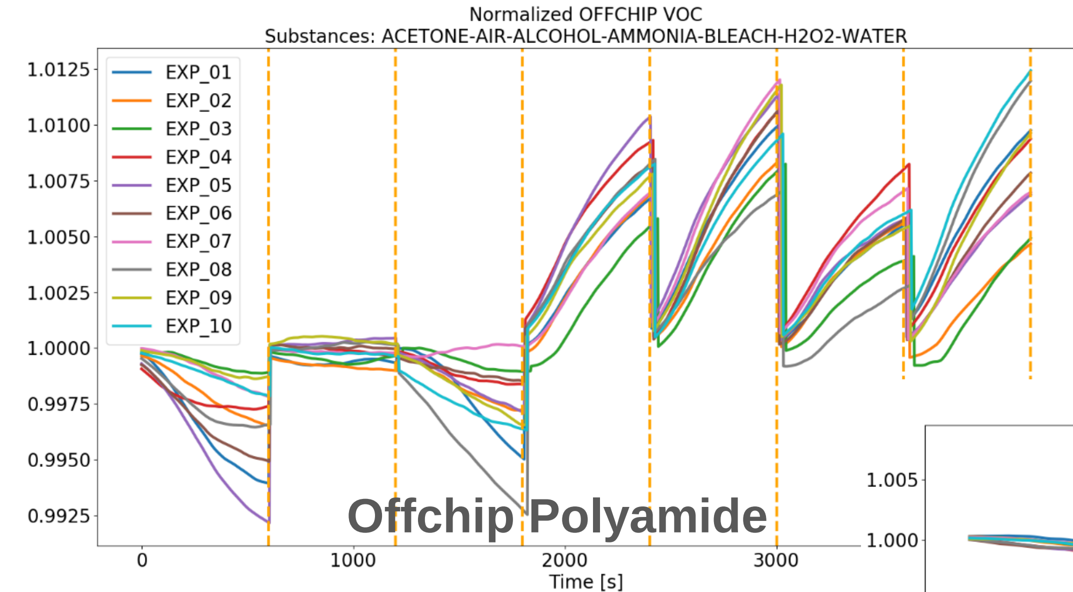
Aluminum Oxide *chemisorption sensor with EIS (Ammonium)*

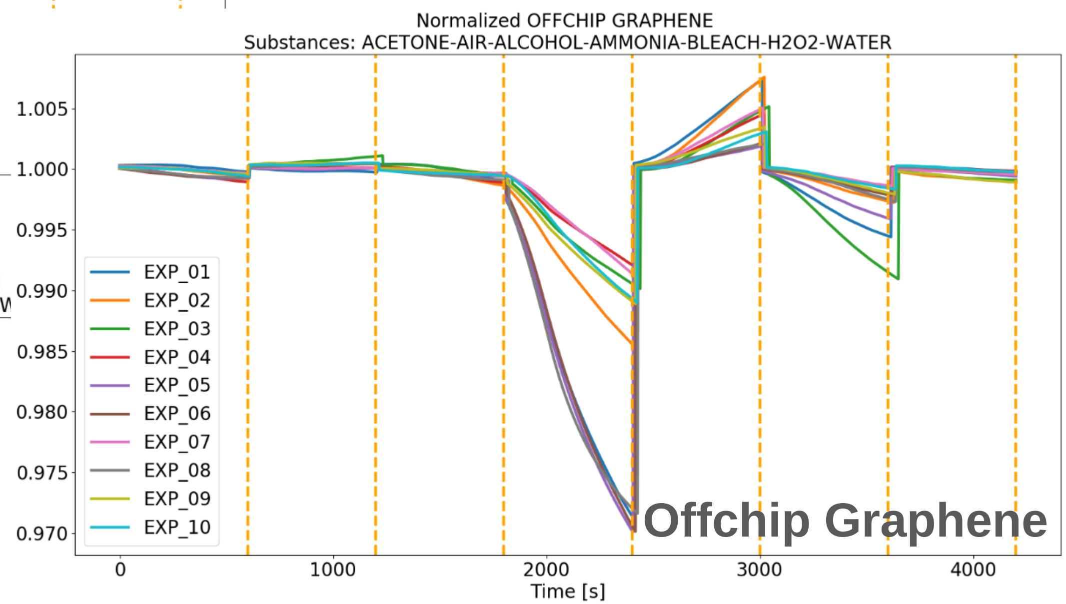
Heated Tin Oxide *RedOx sensor for hydrocarbons, solvents, VOCs*

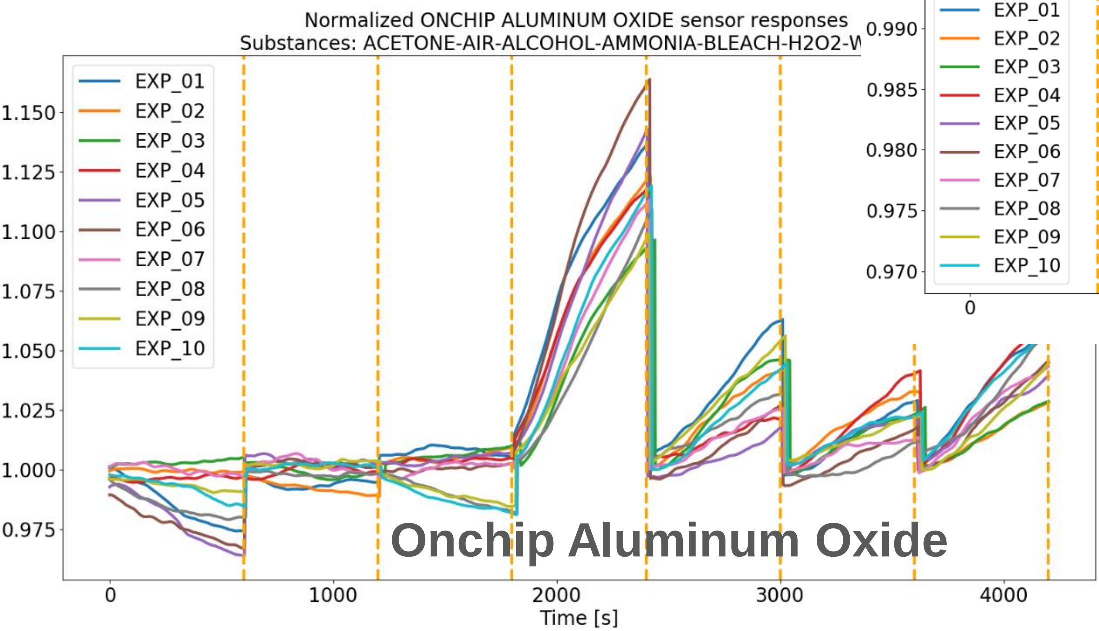
Graphene *RedOx sensor highly selective to NO_2, O_3*

Photodiode *350nm to 1100nm*

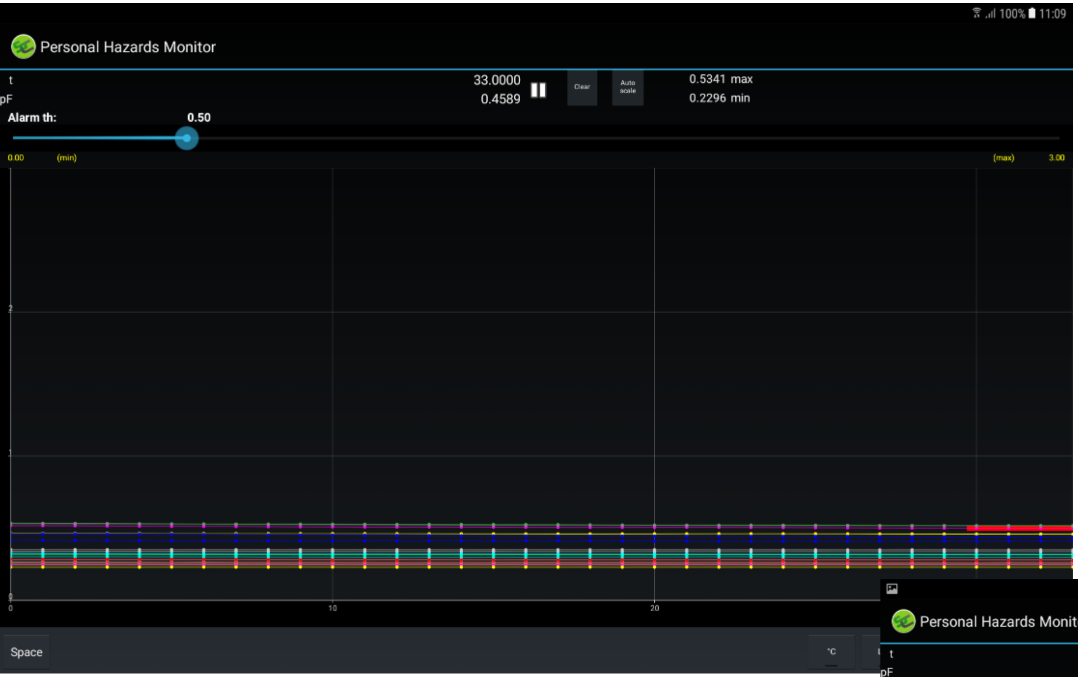
Measurements for 10 distinct experiments for substance







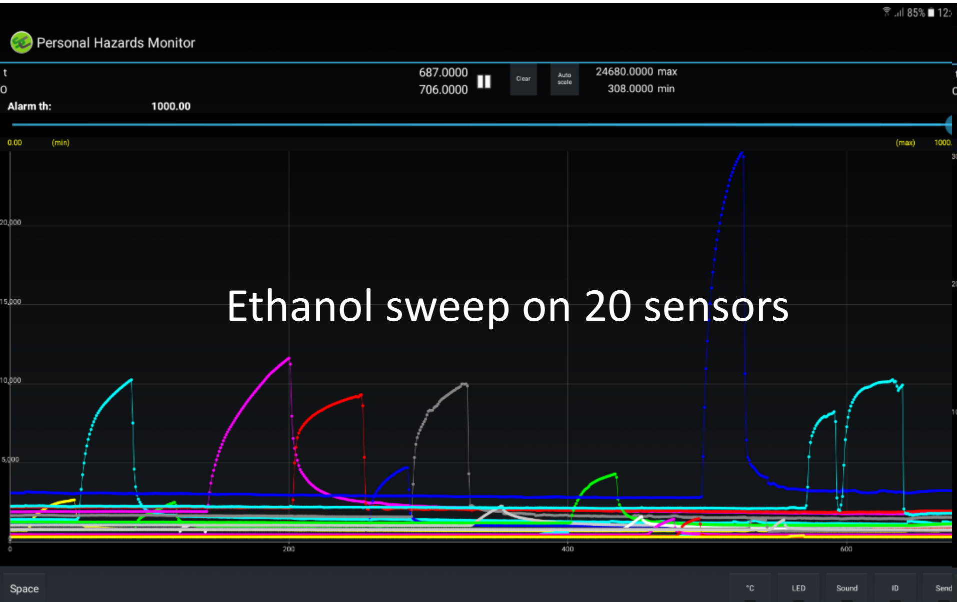
Smart Cable Air – RUN5

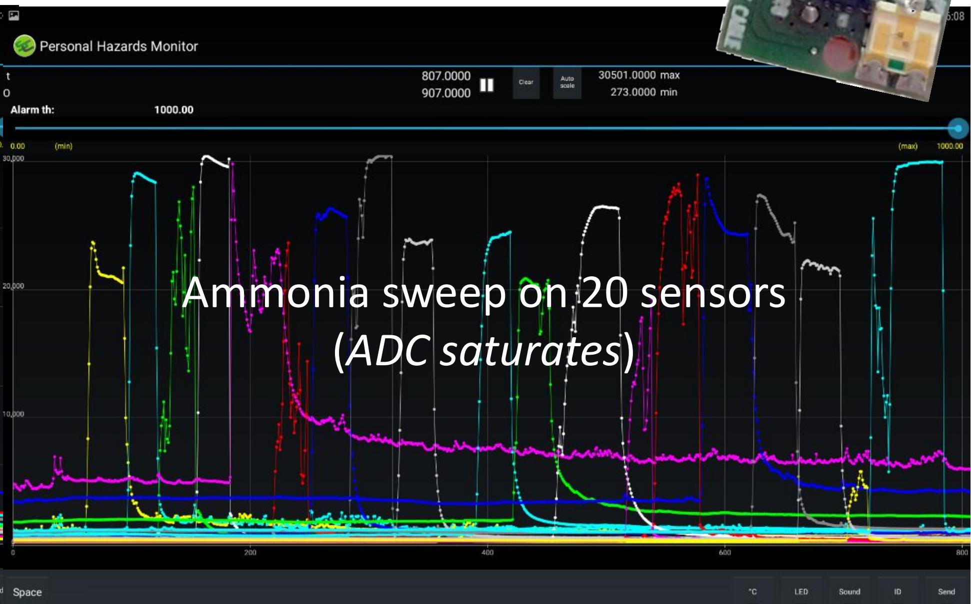


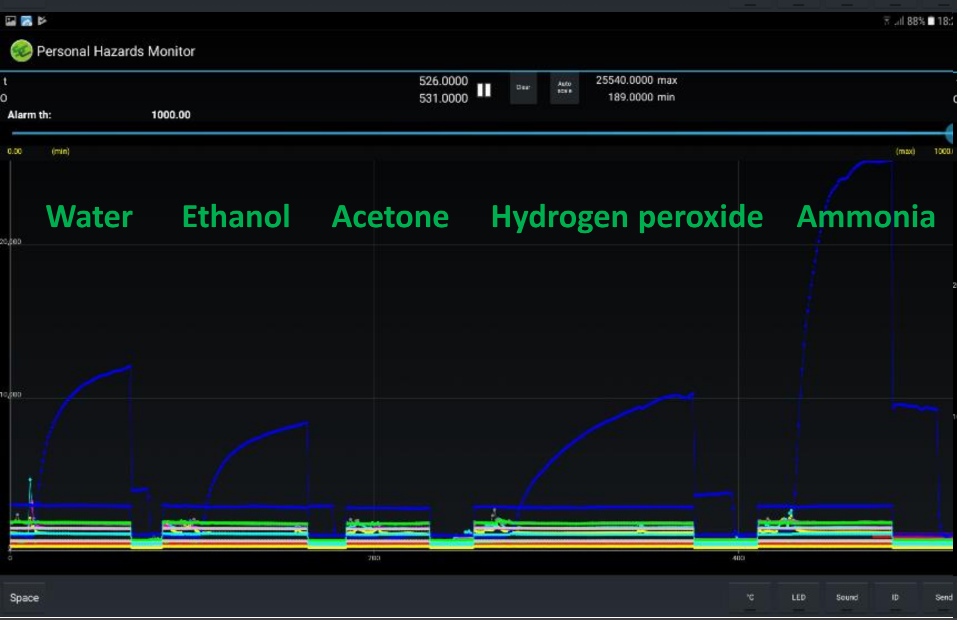
Environmental baseline

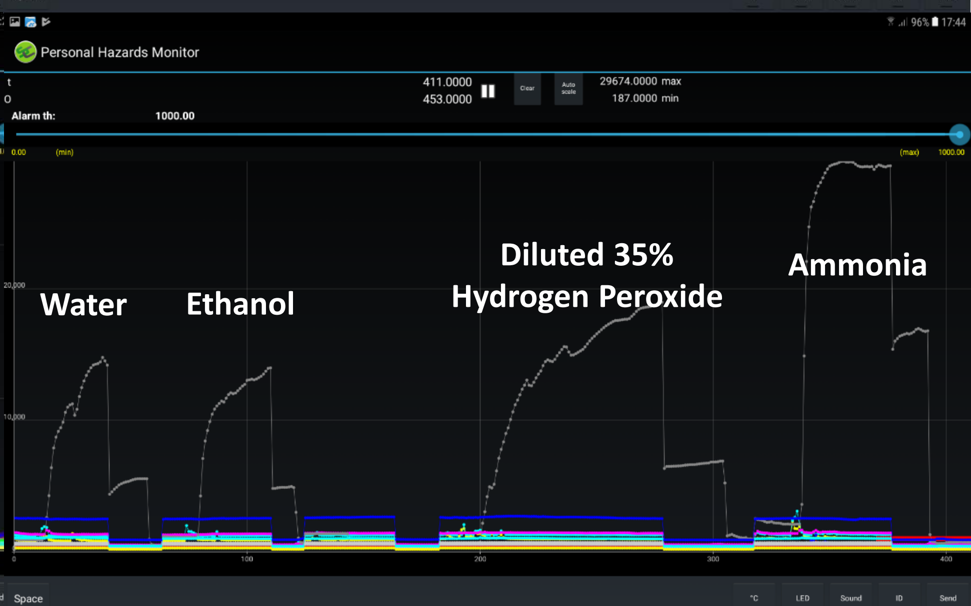
Uncalibrated baseline offset on 20 chips

Smart Cable Air – RUN5

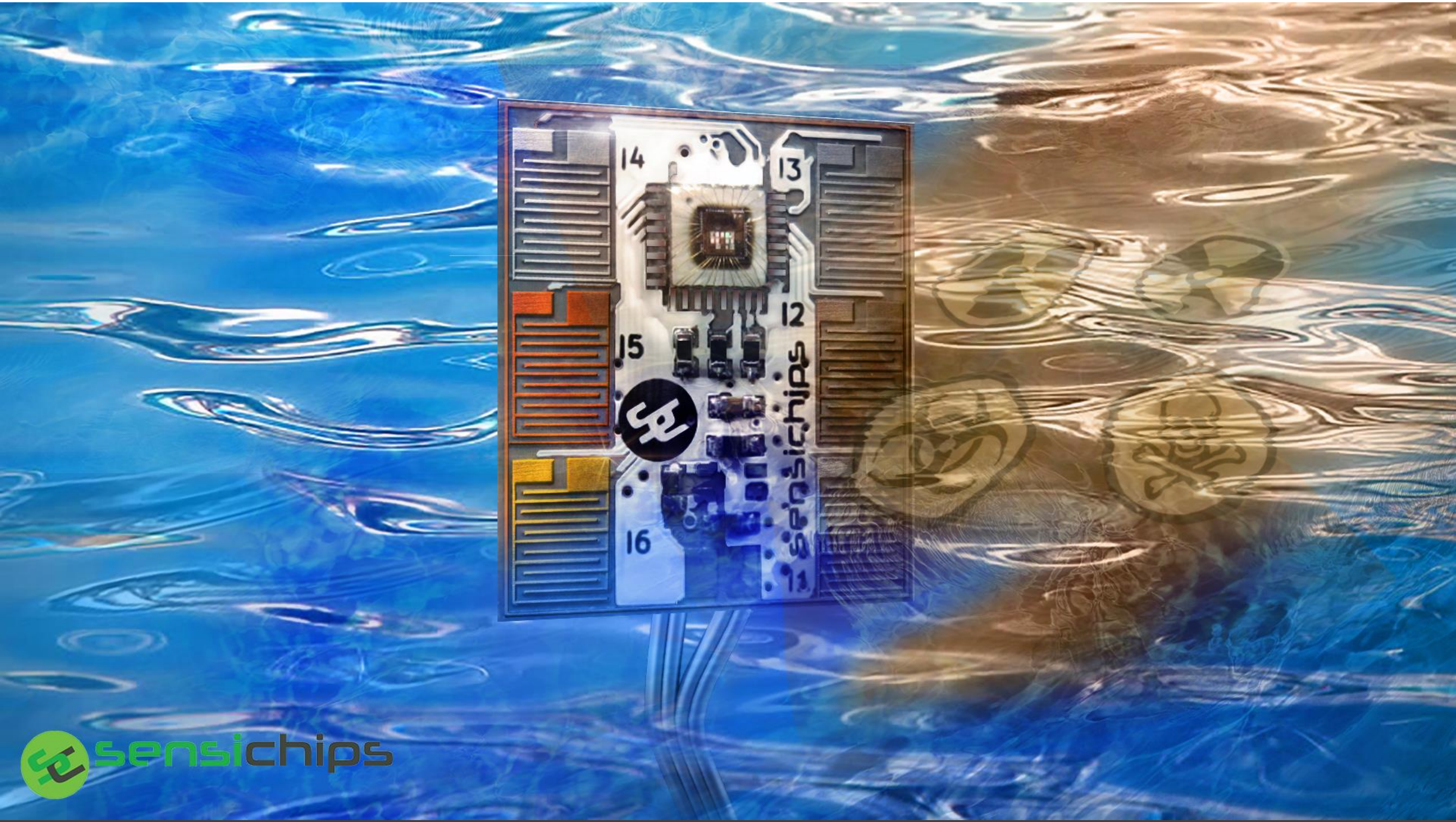








Smart Cable Water



pH/ORP
€250

Dissolved O_2
€350

Salinity
€150

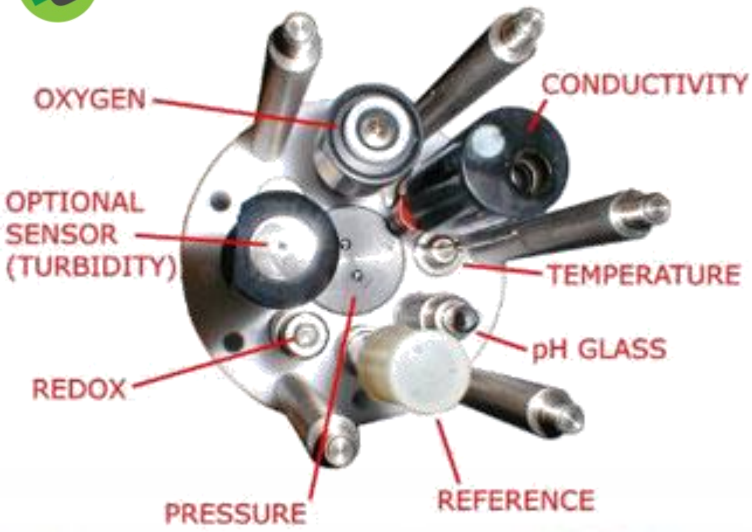
Light/PAR
€300

Temperature
€30

Nitrogen
€250

Moisture
€150

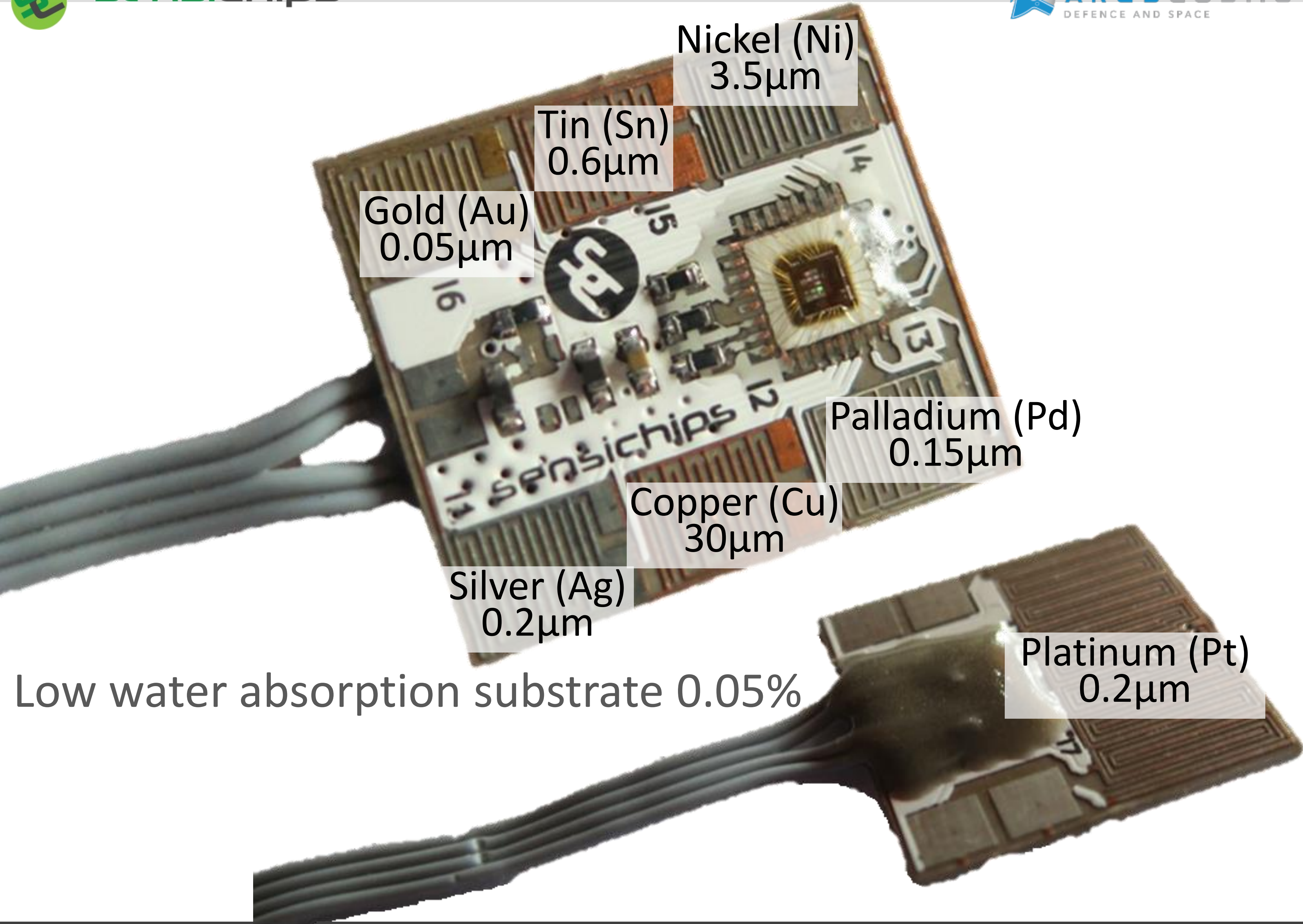
Conductivity/TDS
€250



Multi-parametric
€7500

Optical DO
Specific EC
Absolute EC
pH
ORP
Depth
TDS
Resistivity
Salinity
SSG
Temperature

1350gr
440mm x 77mm



Low water absorption substrate 0.05%

Electrochemical Methods

pH *measures potential of Platinum vs Cl_{ads}-Platinum electrode*

ORP *measures oxidation and reduction potentials*

RedOx *measures reduction and oxidation activity/current (free chlorine, hardness)*

Anodic Stripping Voltammetry *measures heavy metals*

Electro-catalysis *functional IDE measures current specifically*

Thermodynamics *calorimetry, enthalpy, exo/endothermic*

Impedance Methods

Impedance Spectroscopy measures:

- Conductivity in the frequency domain
  (resistivity, salinity, EC, TDS)

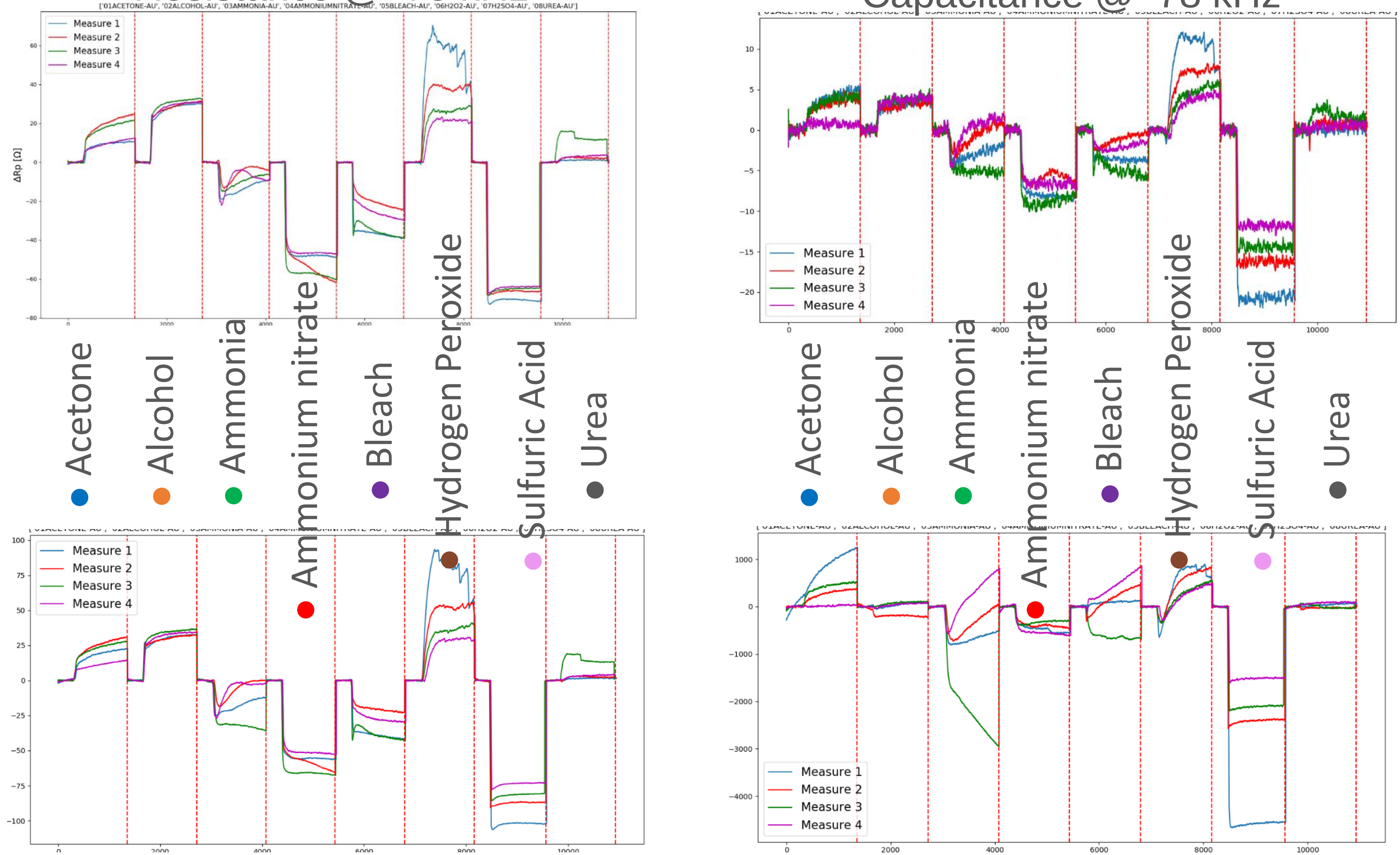
- Dielectric spectroscopy
  (turbidity, SS, biomass total or active)

- Absorption dynamics

Results - Gold Sensor

Resistance @ 78 kHz

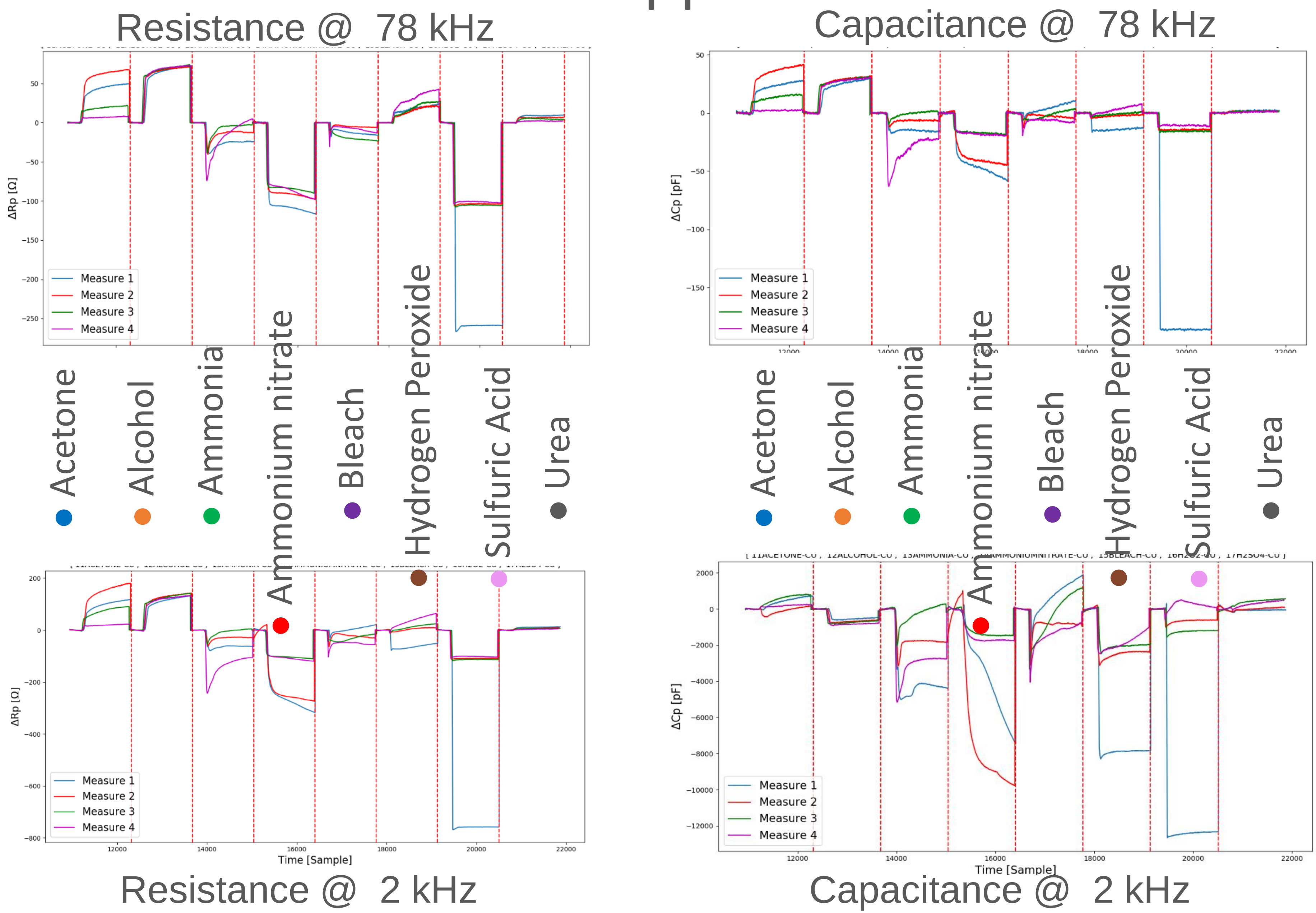
Capacitance @ 78 kHz



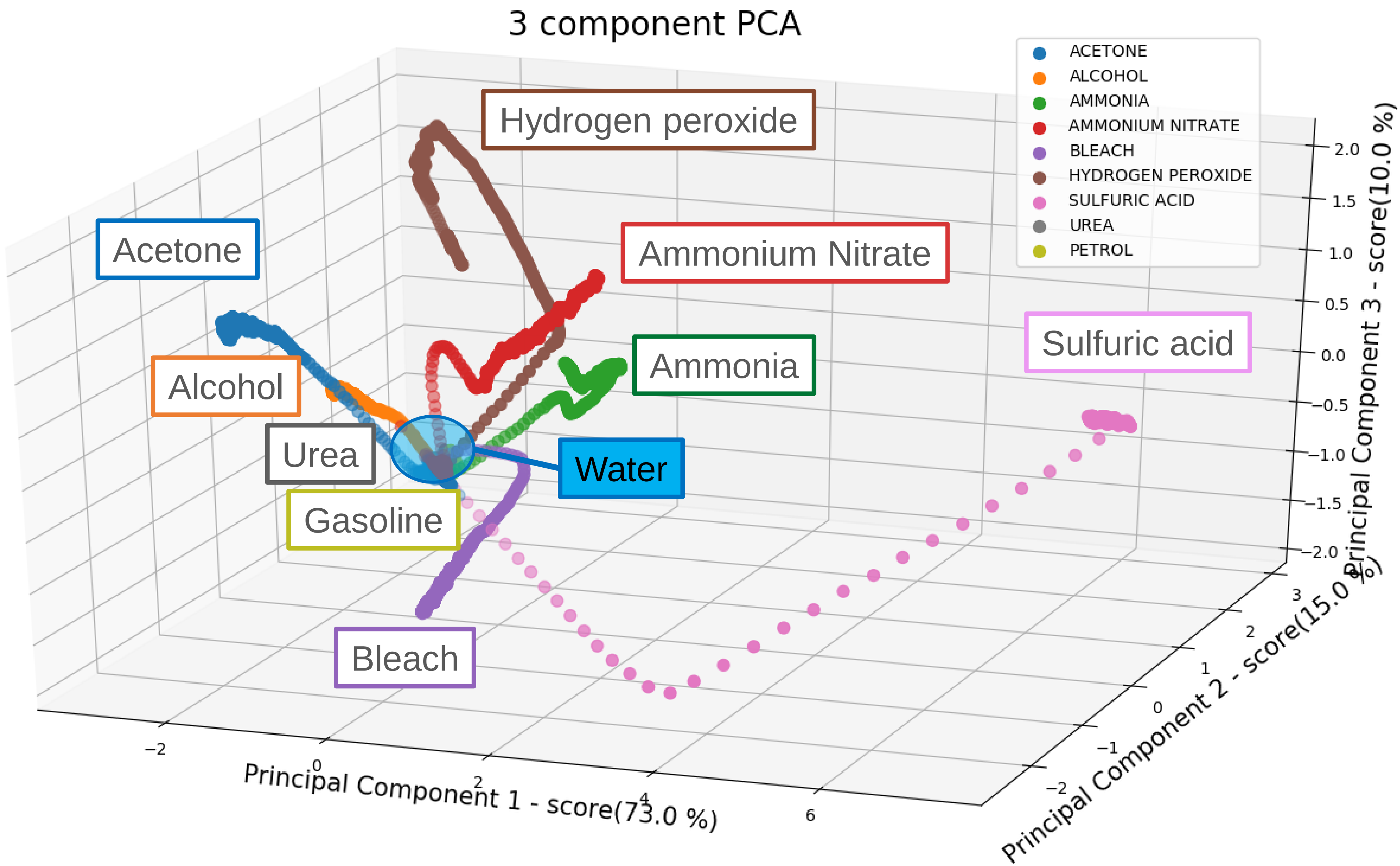
Resistance @ 2 kHz

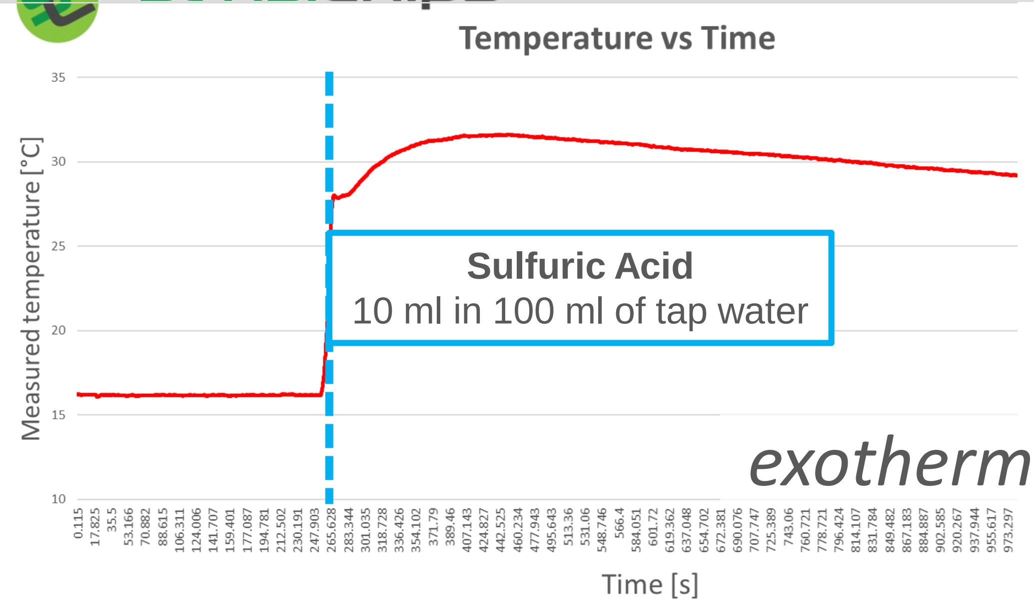
Capacitance @ 2 kHz

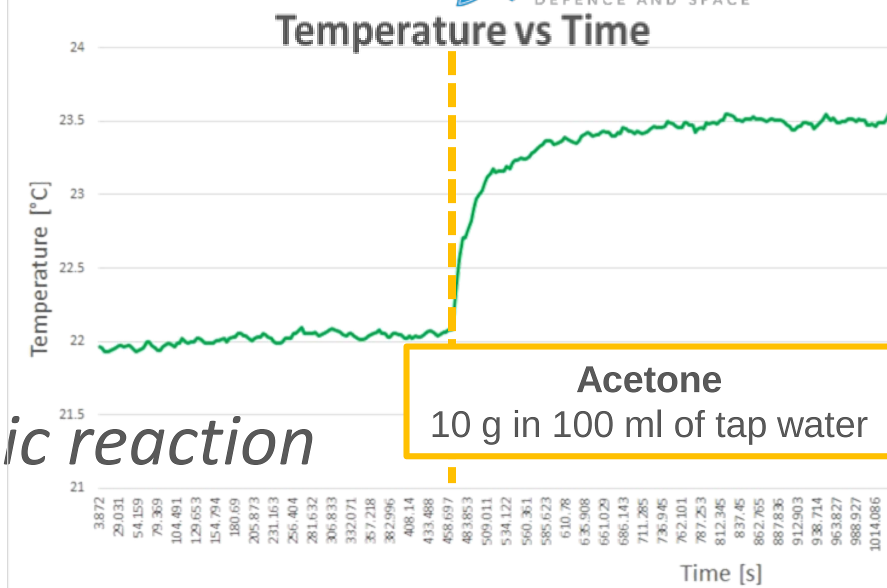
Results - Copper Sensor



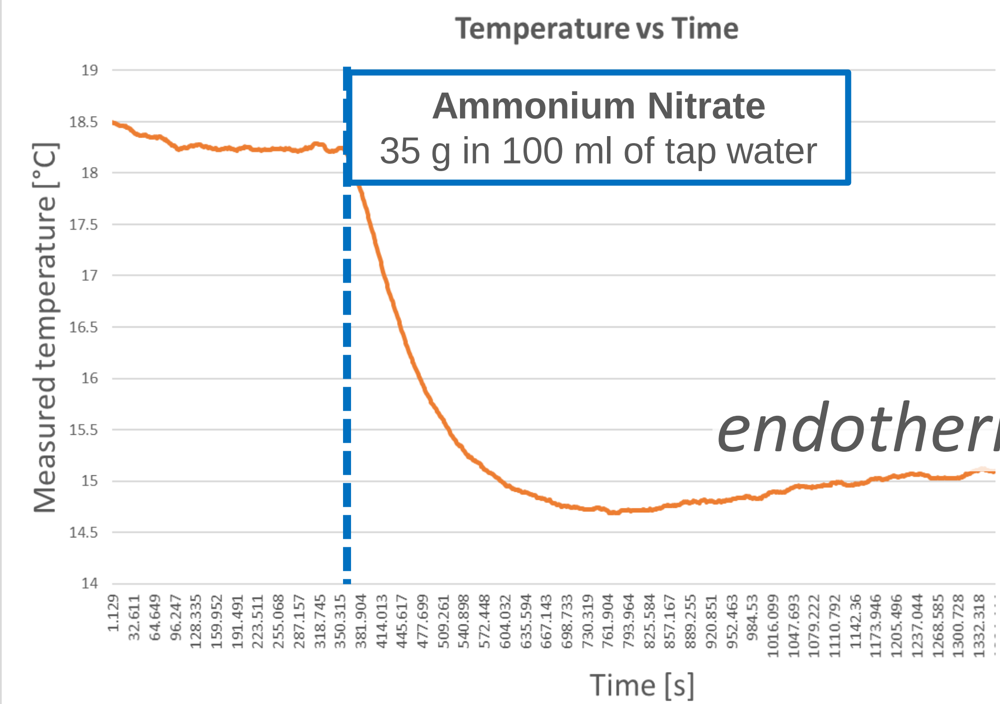
Results – P.C.A. - 3 dimensions

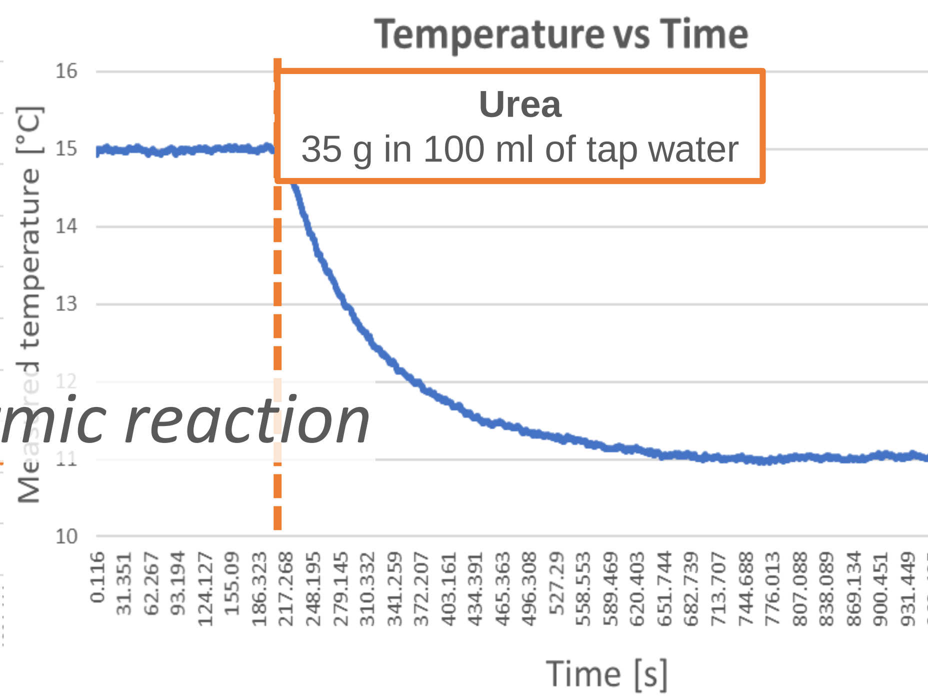






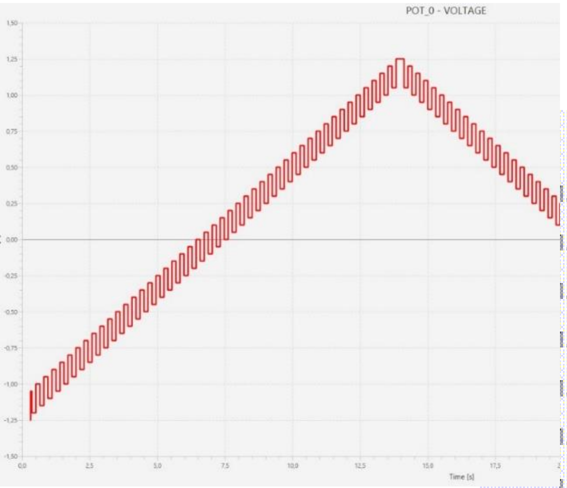
exothermic reaction



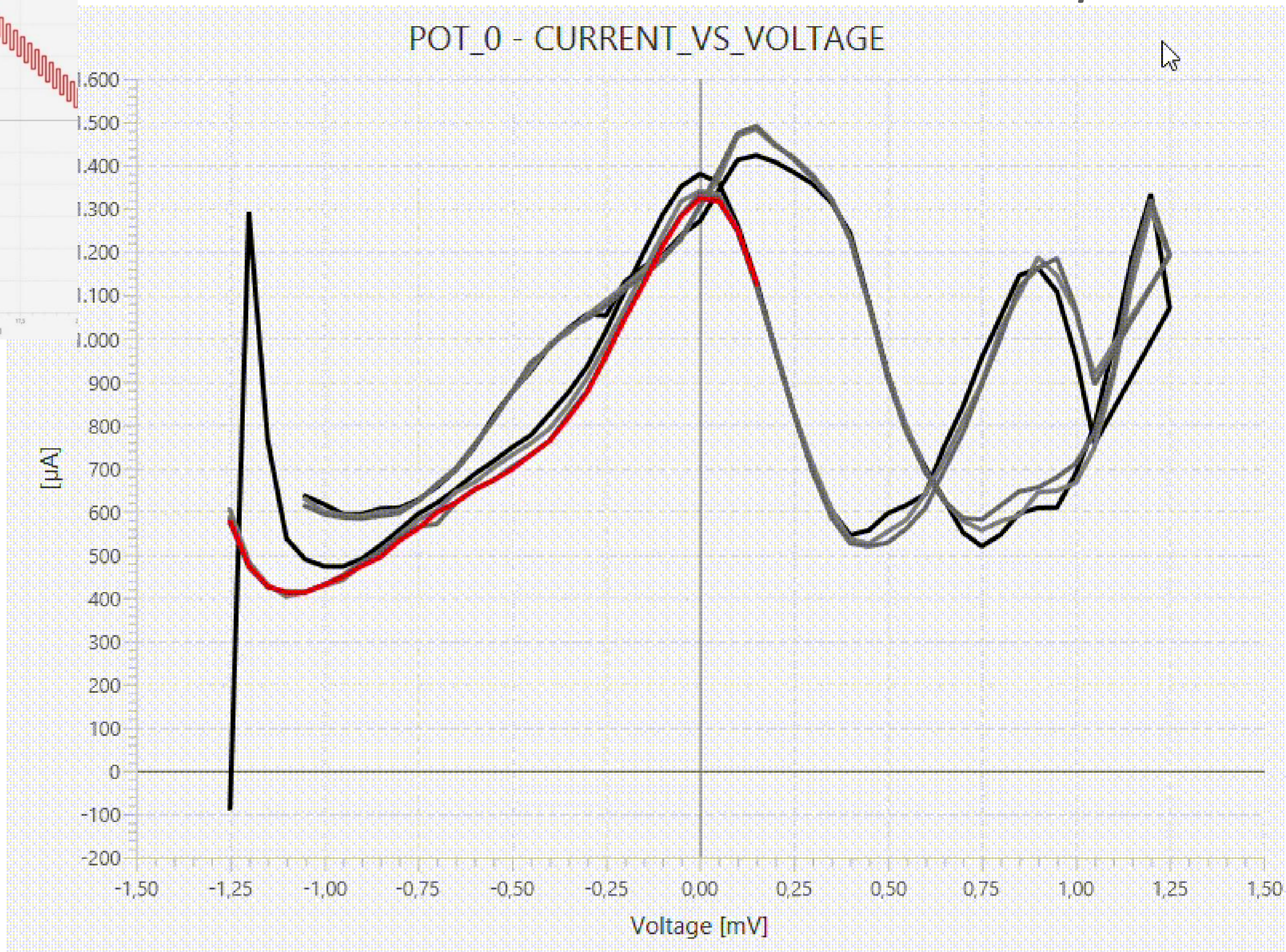


endothermic reaction

Hydrogen Peroxide peaks DPV on Platinum



tap water



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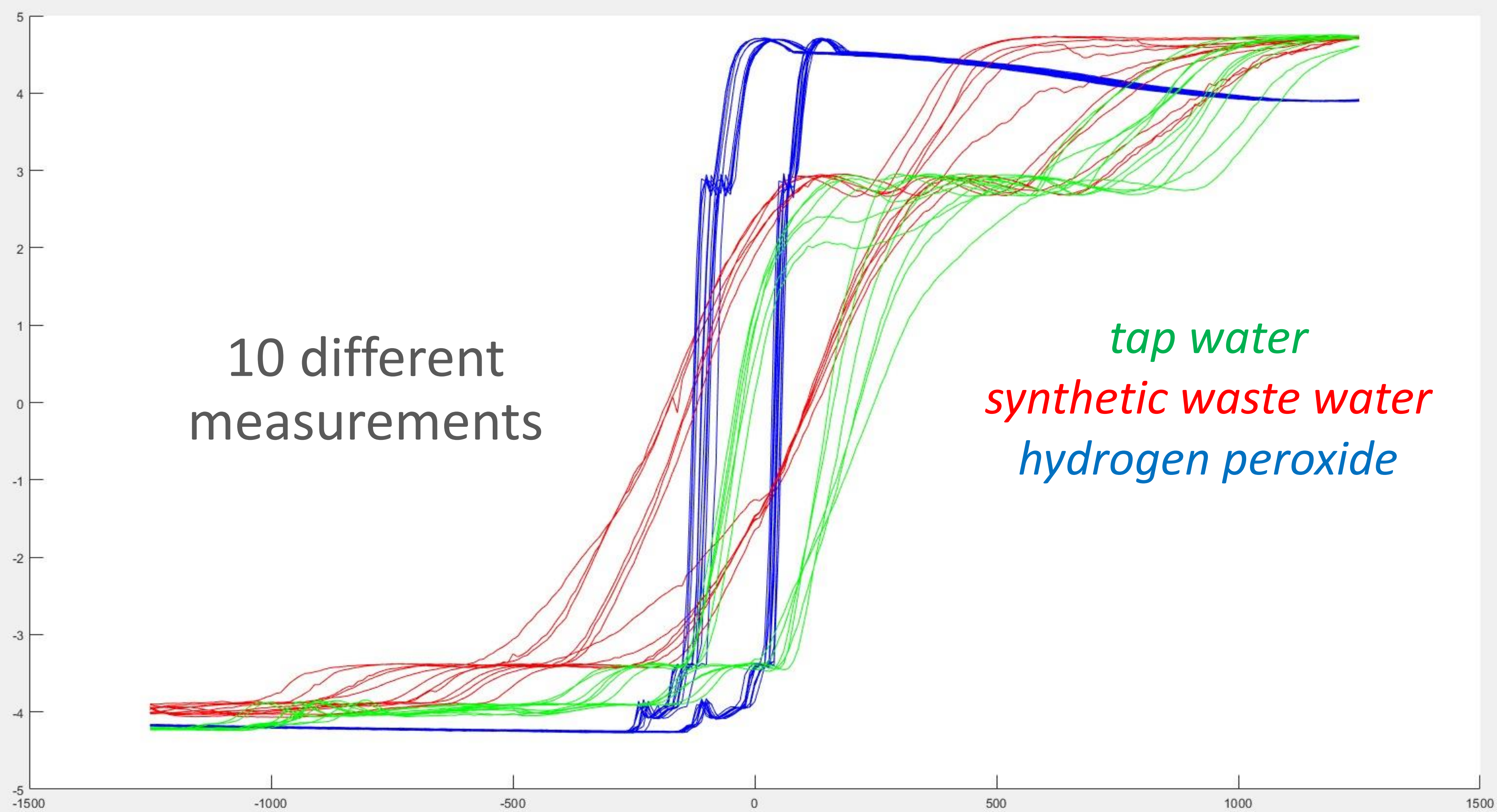
Hydrogen Peroxide CV on Platinum



Applications

Water quality: *river, sea, wastewater, aquaculture*

Precision farming: *pH, moisture, nutrients, contaminants*

Hydroponics, greenhouses: “

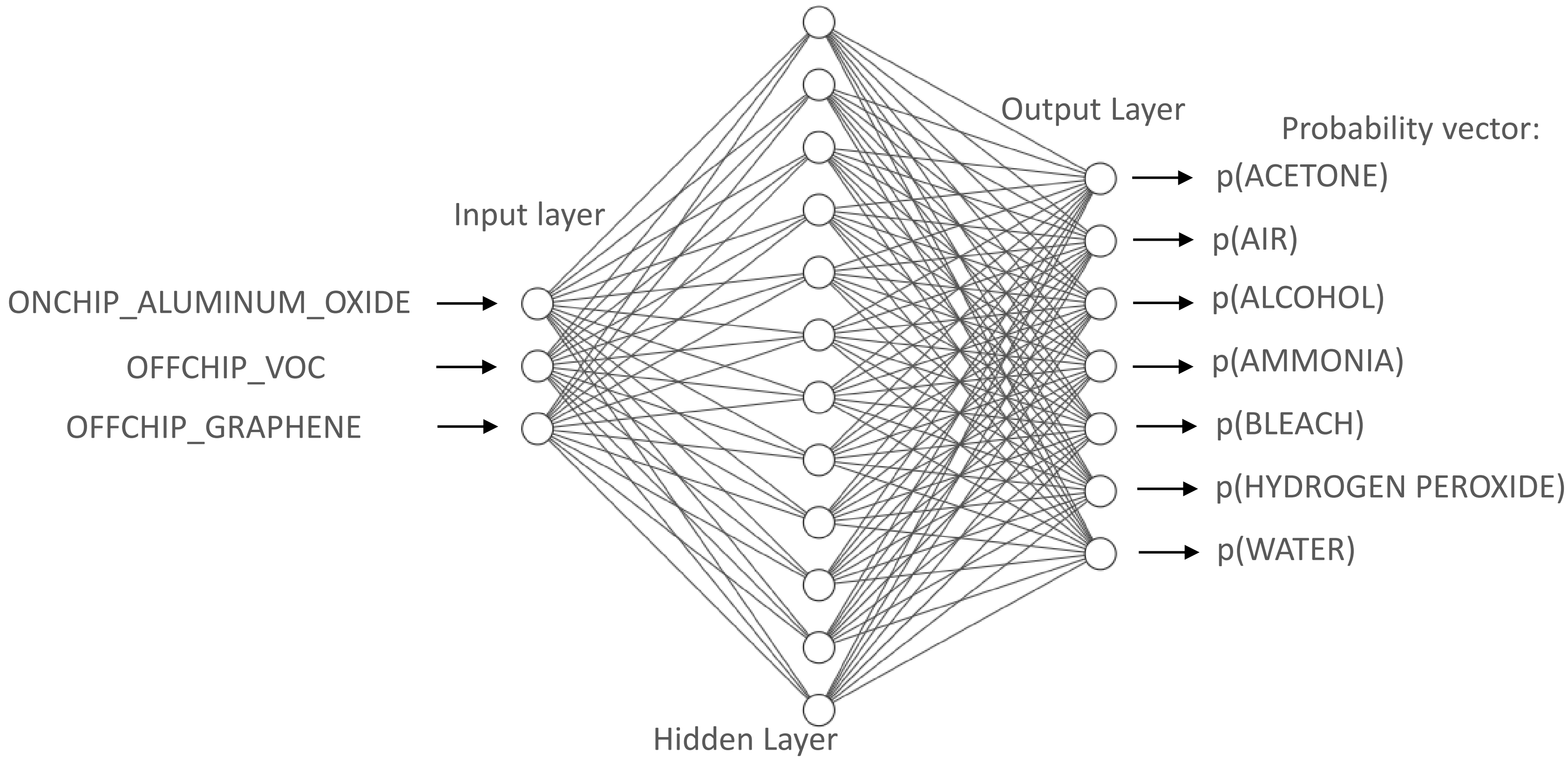
Production process: *wine, an/alcoholic beverages, milk*

Food safety: *spoilage, temperature, humidity*

SENSIPLUS Deep Neural Machine

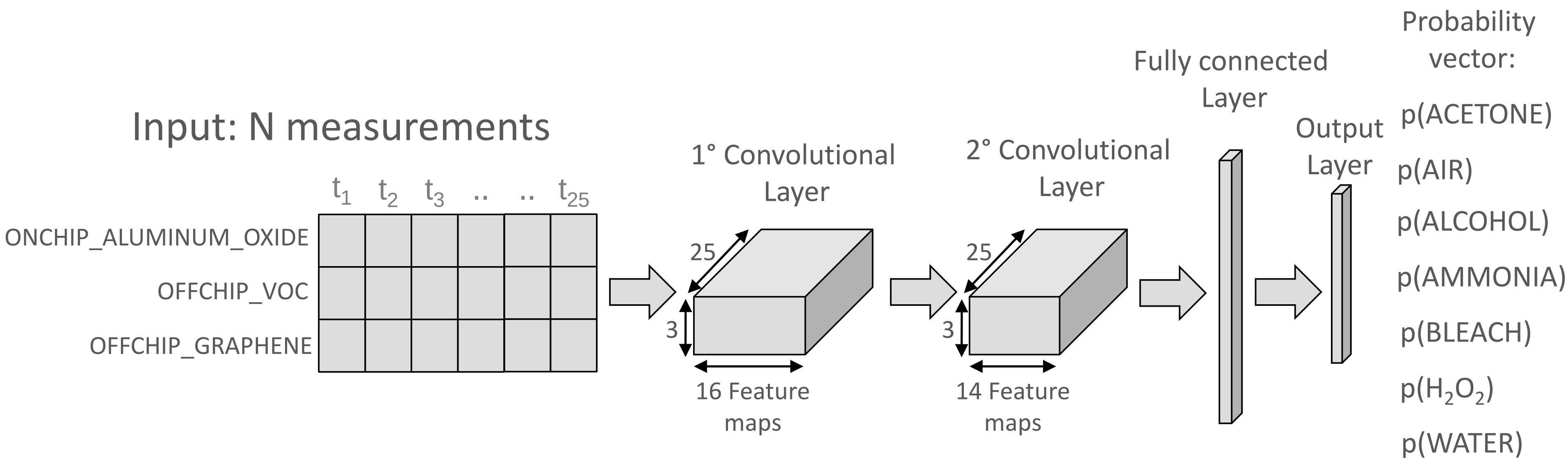
SDM-Light, SDM

SDM-L: Artificial Neural Network (ANN)



- Input: ONE SAMPLE (no latency)
- Lightweight
- Suitable for embedded MCU

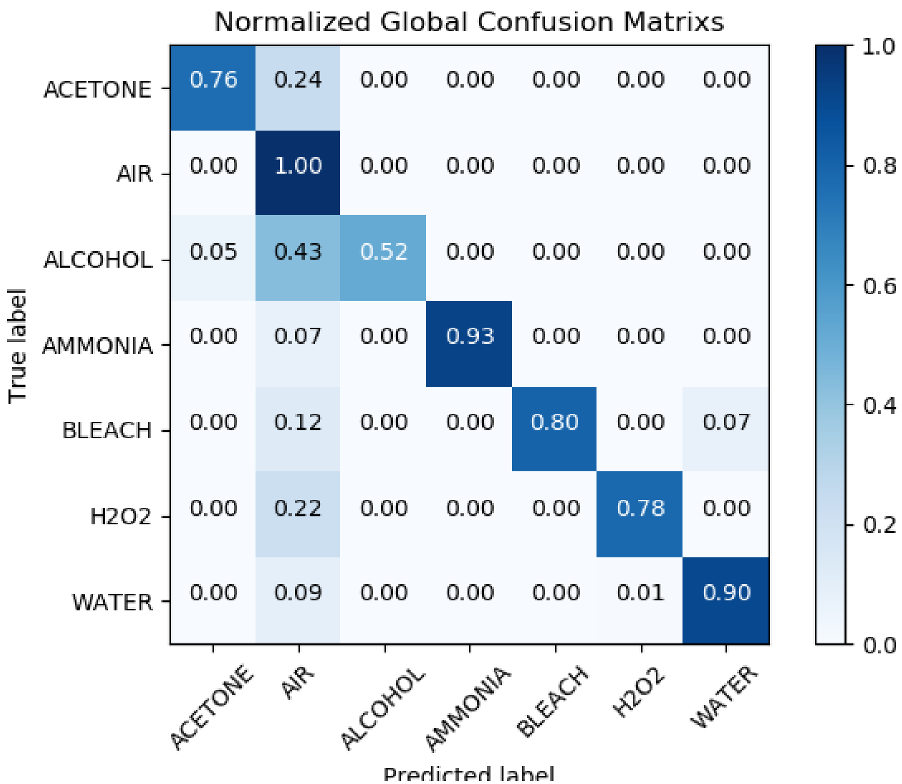
SDM: Convolutional Neural Network (CNN) Deep Learning



- Input: SEVERAL SAMPLES (latency)
- Deep architecture with convolutions
- Automatic feature extraction

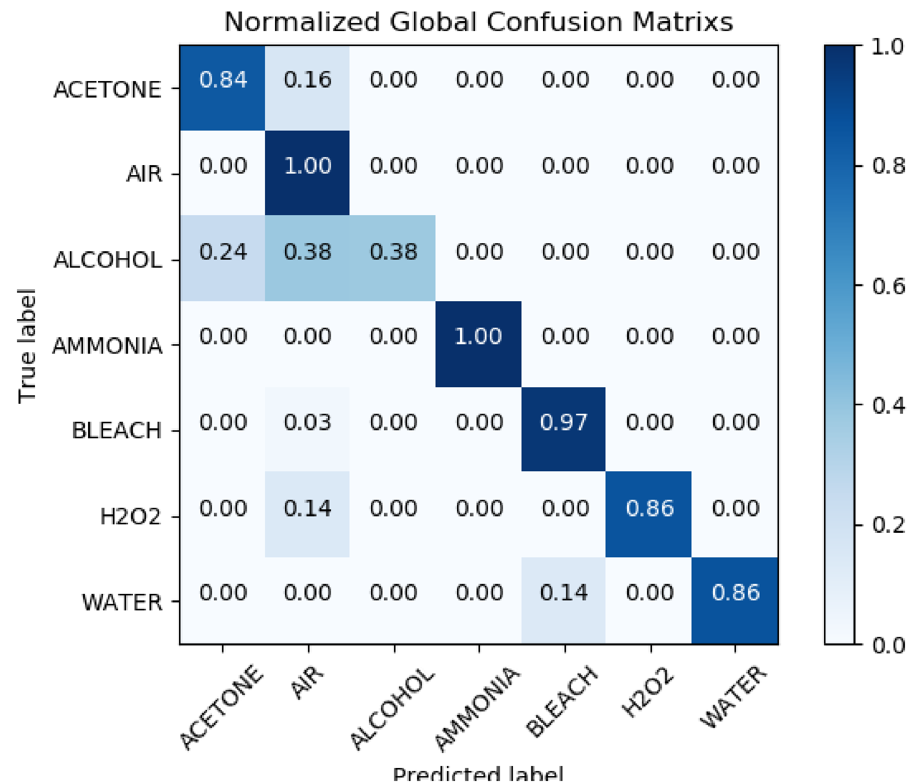
SDM-L vs SDM confusion matrix

SDM-L Artificial Neural Network (ANN)



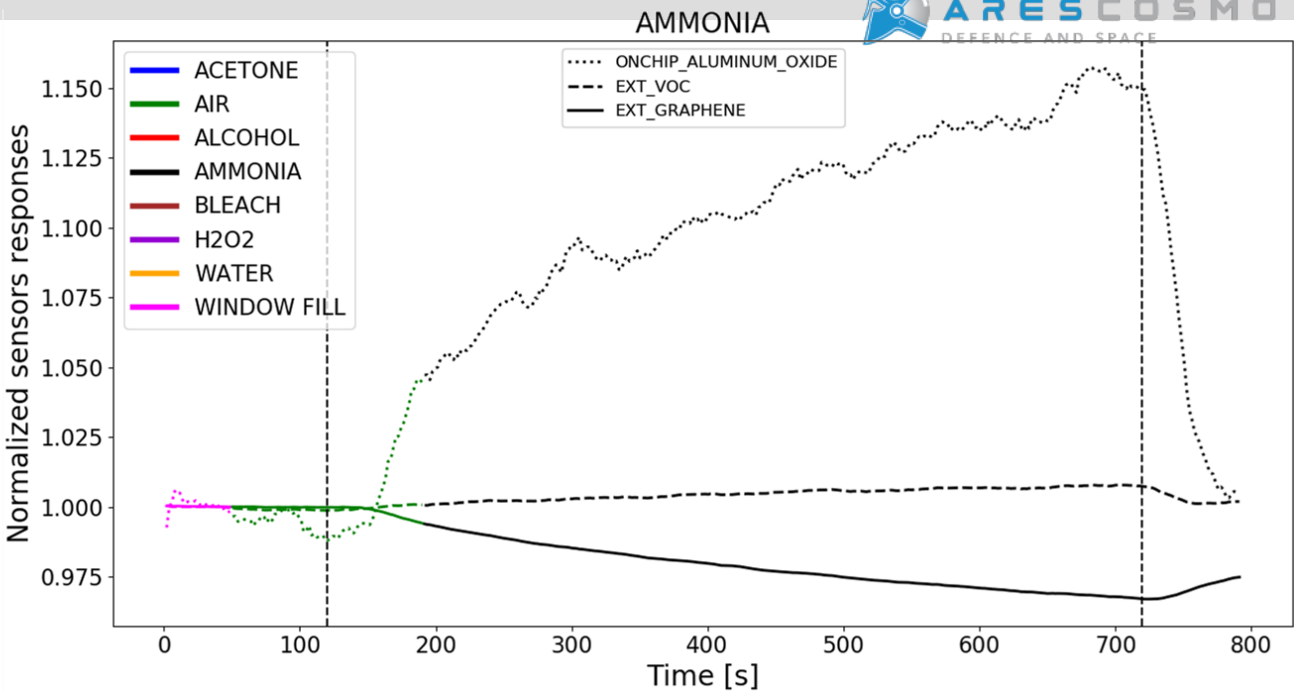
Mean accuracy = 81.35 %

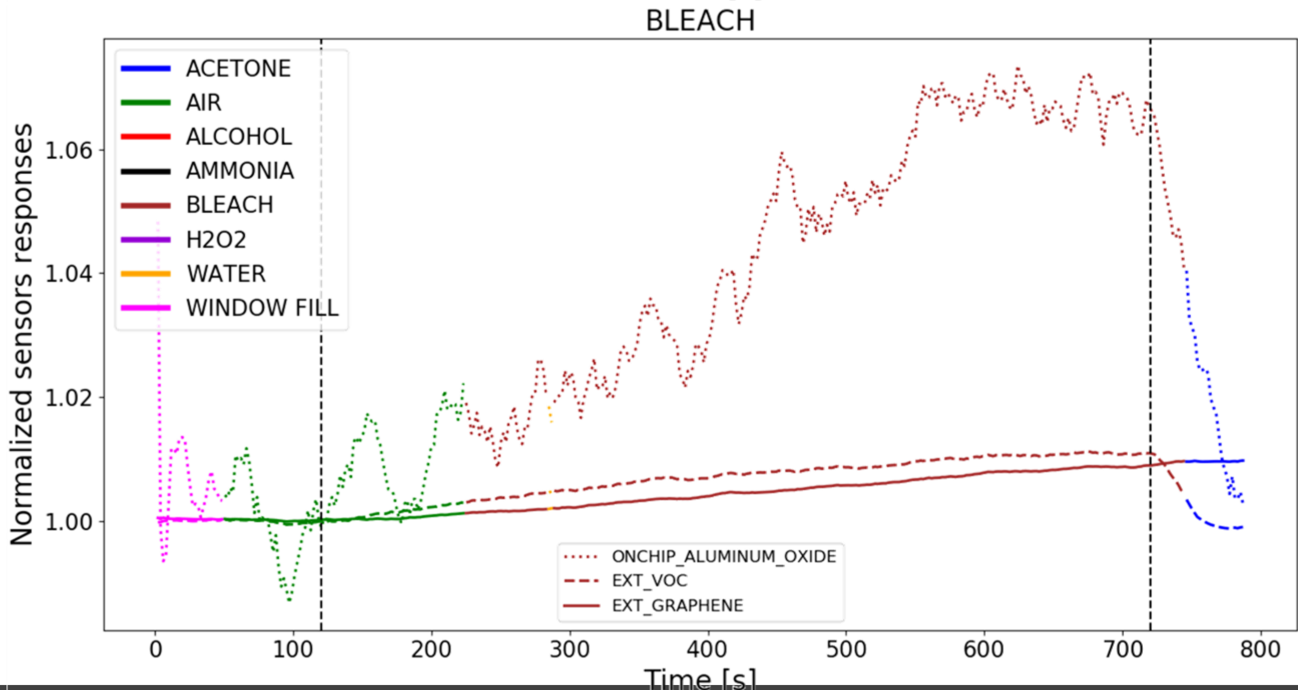
SDM Deep Learning Convolutional Neural Network (CNN)



Mean accuracy = 84.42 %

CNN classification at work (SDM)





SDM output from each measure

	Relative Concentration	Confidence Vector	Variance Vector
Background	YBpct	0.PB	0.VB
Everything-else	YEpct	0.PE	N/A
Compound1	Y1pct	0.P1	0.V1
Compound2	Y2pct	0.P2	0.V2
Compound3	Y3pct	0.P3	0.V3
Compound4	Y4pct	0.P4	0.V4
:	:	:	:
CompoundN	YNpct	0.PN	0.VN

Adds to 1

- SDM monitors for the presence of only those N Compounds
- Confidence and Variance among the trained compounds only
- One measure every 10seconds (user definable)

Single Chip

Battery, Supercapacitors, Fuel Cells

Cell Management Unit (CMU)

SoX, safety, graceful degradation and self-healing

Resilient Battery Components

A Resilient Battery meets four key criteria:

- **Most efficient use**
- High reliability with safety features
- Graceful degradation
- Self-healing

Requires advanced analytics that looks at phenomena inside each battery cell, during in field operation.

CMU External Sensors

In order to “look & measure” the internal state of a single cell, the Cell Management Unit implements external sensors.

EXTERNAL SENSORS

V : voltage

I : current

Z(jω): cell impedance (EIS)

(Electrical Impedance Spectroscopy)

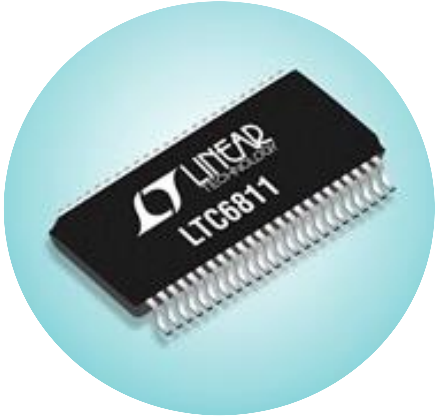
T : external temperature

LL : liquid leakage

GL : gas leakage

MS : mechanical strain

State of the Art



Linear Technologies Inc. CMU chip used in the i3 from BMW

EXTERNAL SENSORS

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(Electrical Impedance Spectroscopy)

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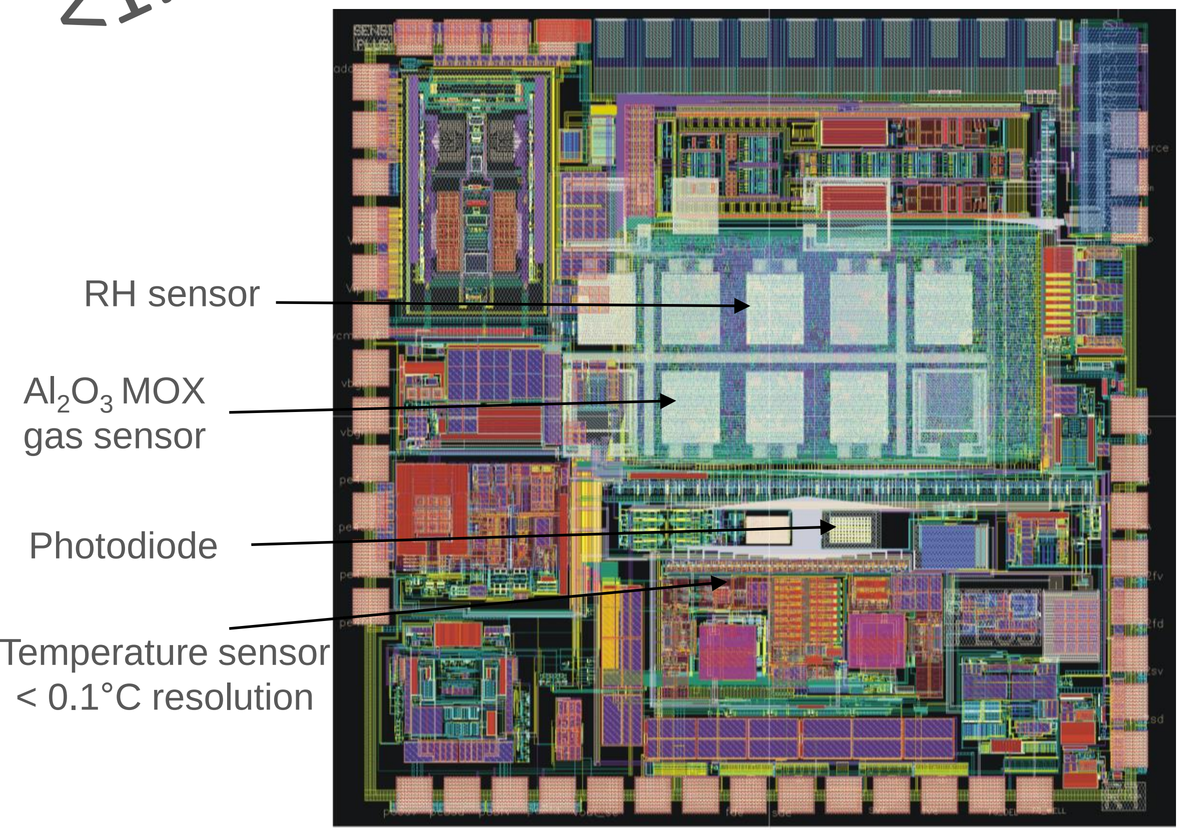
SENSIPLUS single chip battery CMU

2x2mm
<1.5mW



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(Electrical Impedance Spectroscopy)

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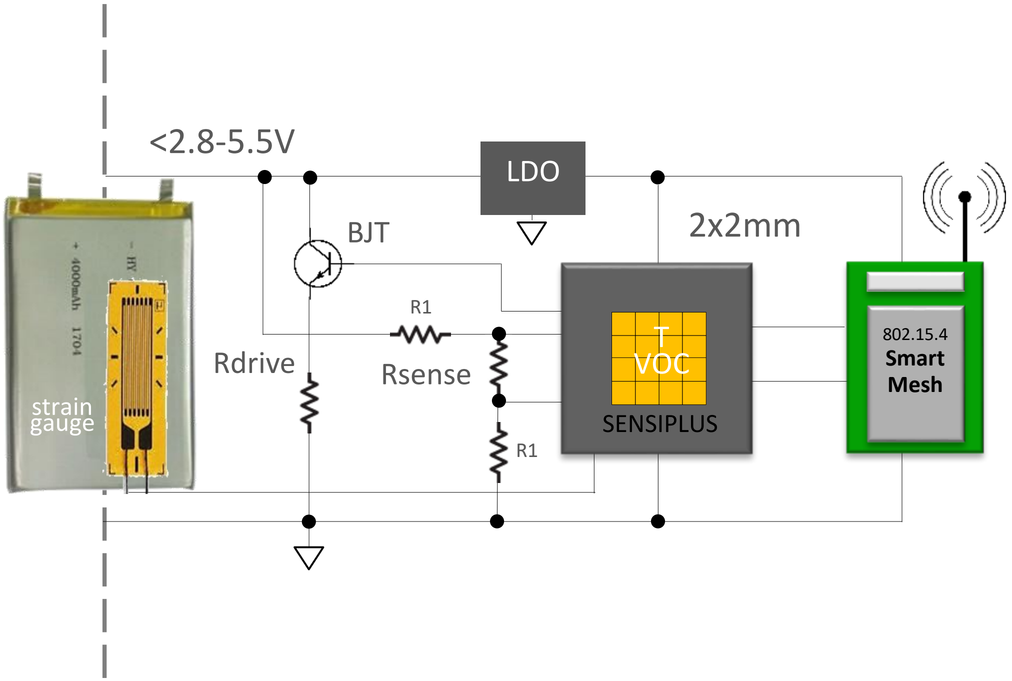
MS : mechanical strain

+

Thermodynamics

Safety sensors

SENSIPLUS single chip battery CMU



- Single cell
- Cluster of cells (reduce costs)
- Smart cell balancing

Wireless Smart Mesh or

Multi-drop HV isolated bus

Roadmap to inside cell sensing

SENSIPLUS Single Chip CMU

Chemistry independent analytics, for any type of electrochemical cell

- Battery, supercapacitors, fuel cells
- Determines State of Charge/Health/Function/Power (SoX)
- External sensors far safety
- One miniature chip 2x2mm

BATTERY 2030+

https://battery2030.eu/

sensichips

learning **microsensors**

Thank you for your attention

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