

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

COST Action TD1105

OPEN SESSION COST *EuNetAir* on

New Sensing Technologies for Air Quality Monitoring

CORE-GROUP MEETING at EUROSENSORS-2014 Conference

University of Brescia, Engineering Campus, Brescia, Italy, 10 September 2014

Smart Sensors in Mobile Phones for Environmental Monitoring

Julian Gardner

MC Member Substitute

J.W.Gardner@warwick.ac.uk

**Warwick University/UK & Cambridge CMOS
Sensors**

THE UNIVERSITY OF
WARWICK



Contents of Talk

- **Gas Sensors for New Devices – WHY?**
- **Potential Applications/Market for Gas sensors**
- **Smart Phones and Gas Sensors Today**
- **Conclusions and Challenges**

New Devices and the 2013 Market

- Consumer electronics is full of ASICS & also sensors/MEMS



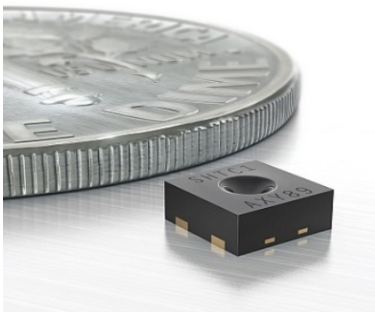
350 million computers sold in 2012



600 million phones sold



180 million tablets sold



Billions sensors sold



Samsung Gear



Nike Band

MEMS value proposition in mobile devices

High volume
Small production
Sampling / R&D

Better communication performances

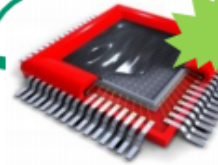
DelfMEMS switch



Wispry antenna tuner on cell phone board

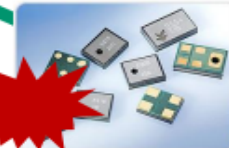


Sand 9 MEMS Oscillator



AudioPixel microspeaker

Sound quality

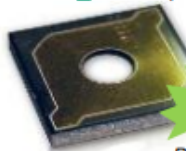


Knowles microphones



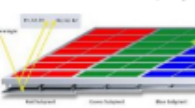
Scanning mirror from Lemoptix

Improved visual experience



Polight MEMS autofocus

Mirasol display



Increased battery lifetime



Nectar fuel cell

TI temperature sensor versus a competing thermopile sensor



Infrared sensing



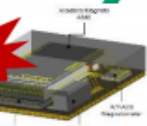
Thermal imager MuOptics

Navigation & environment sensing

Sensirion Humidity Sensor



Freescal pressure sensor



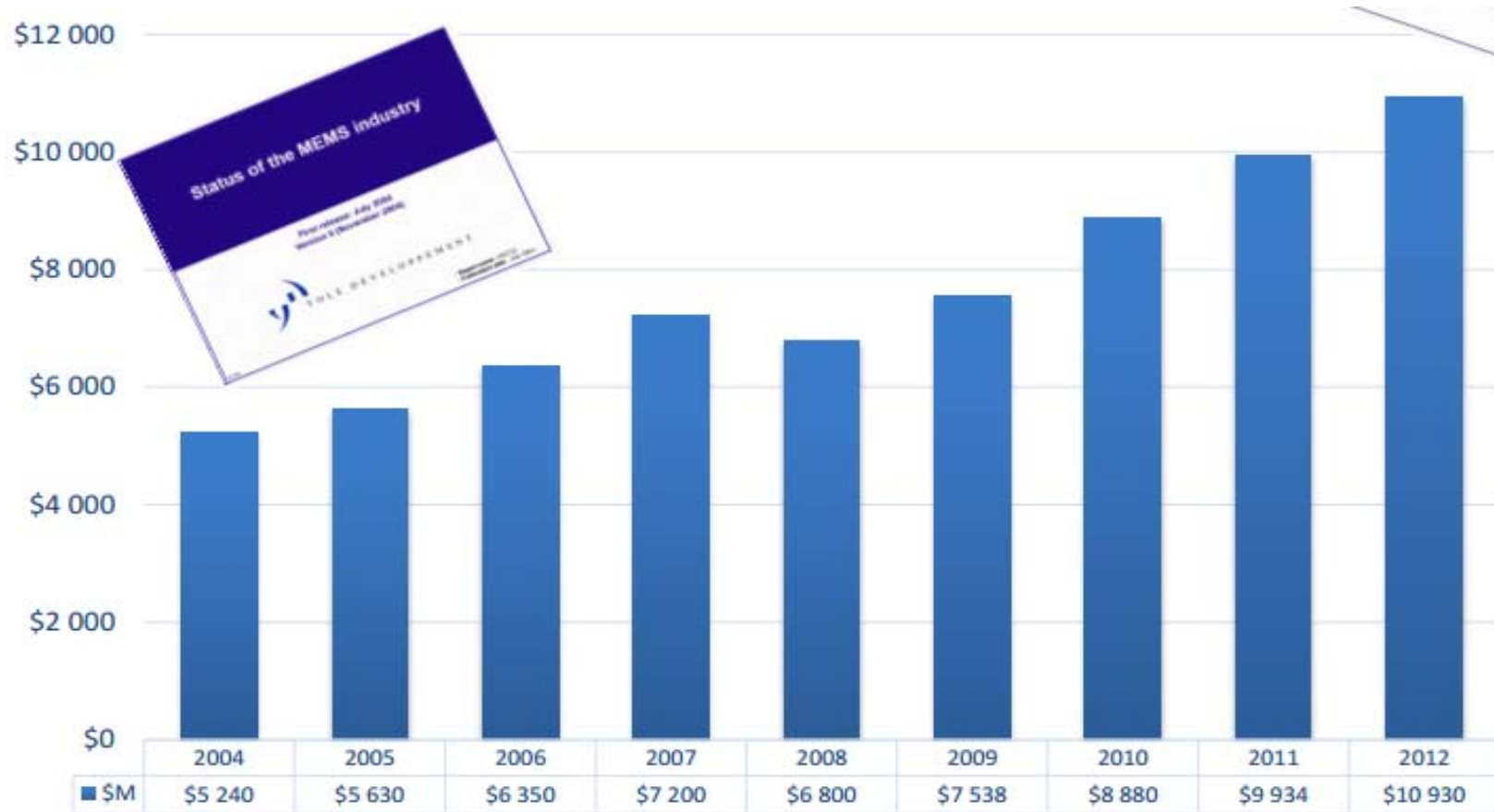
STM 9-axis

New tactile interface



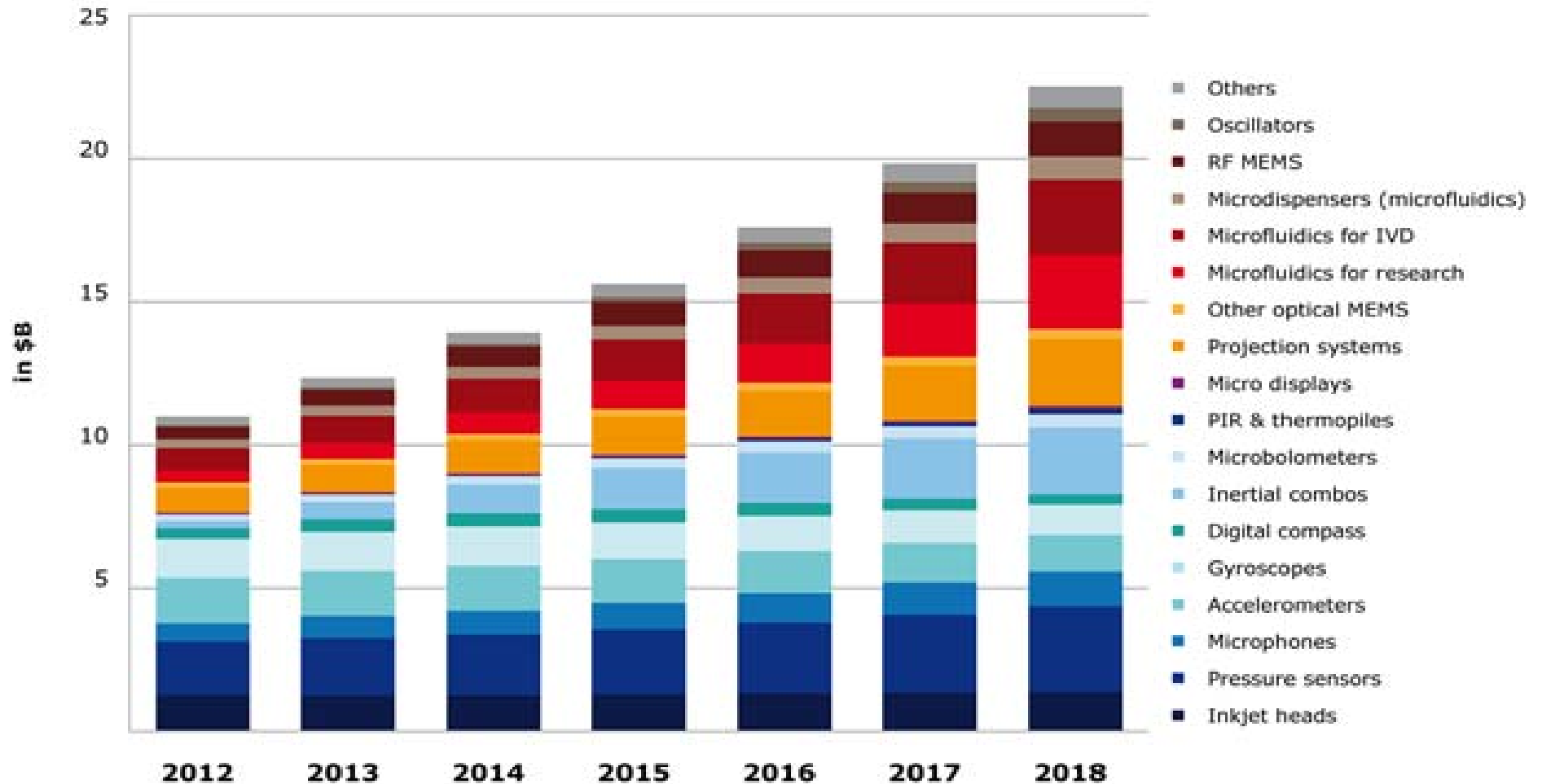
NextInput SoftTouch interface

MEMS Past Market in \$M 2004-2012



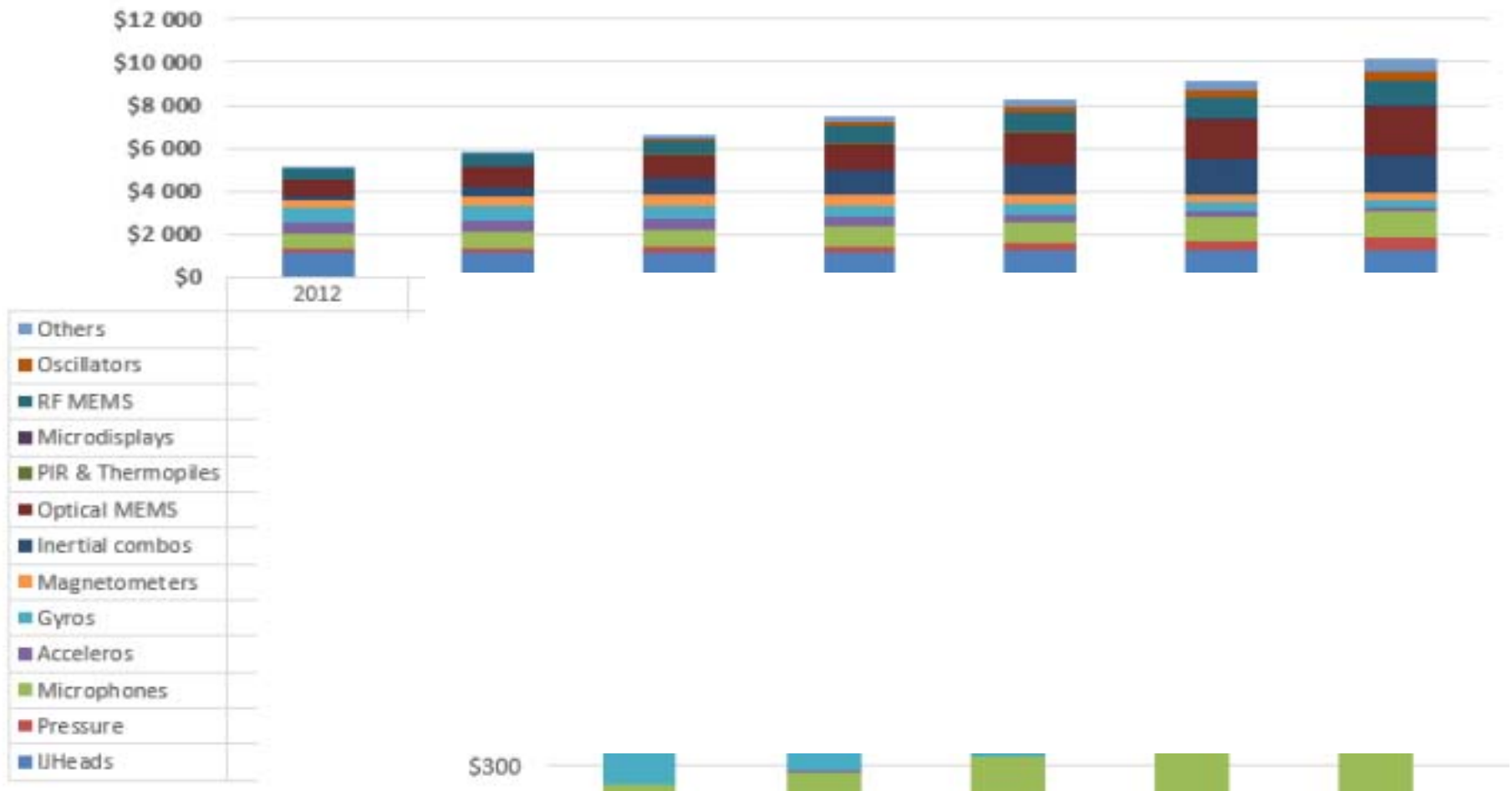
Source: Yole Status Report, July 2013

MEMS Market – Forecast by Device



Source: Yole Status Report, July 2013

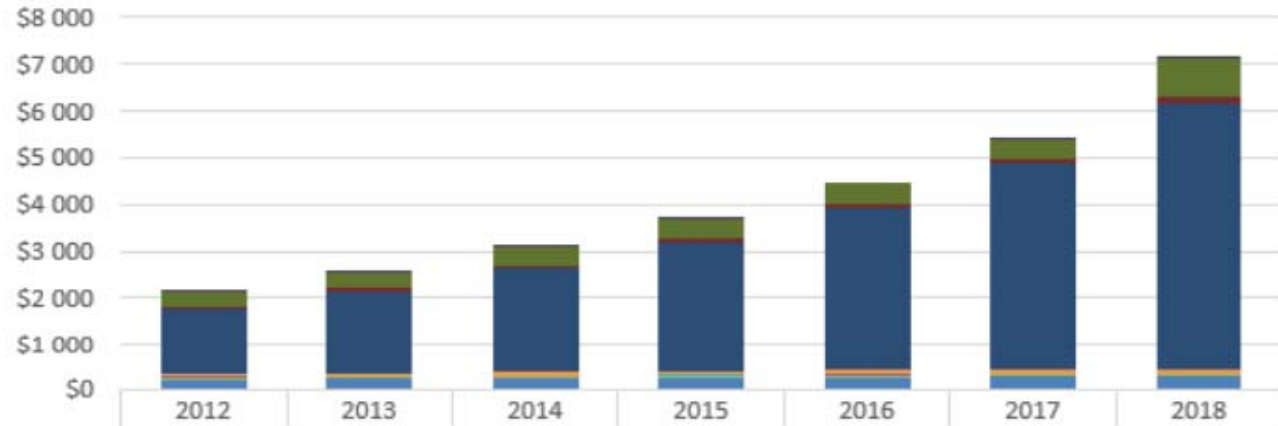
MEMS for Consumer in \$M – Future Outlook



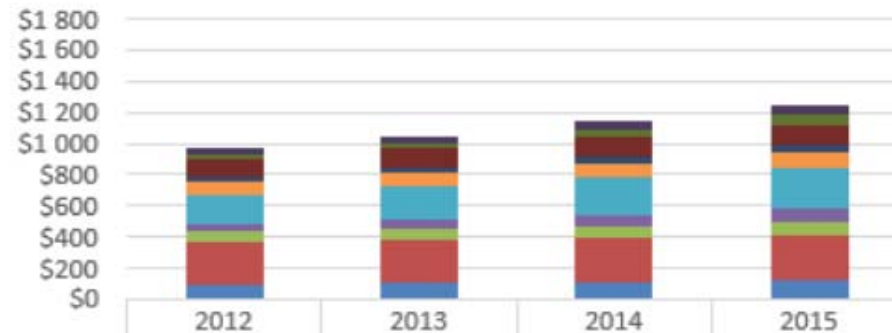
Source: Yole Status Report, July 2013

MEMS Market for Medical and Industry – Future Outlook

MEMS for Medical (US\$M)

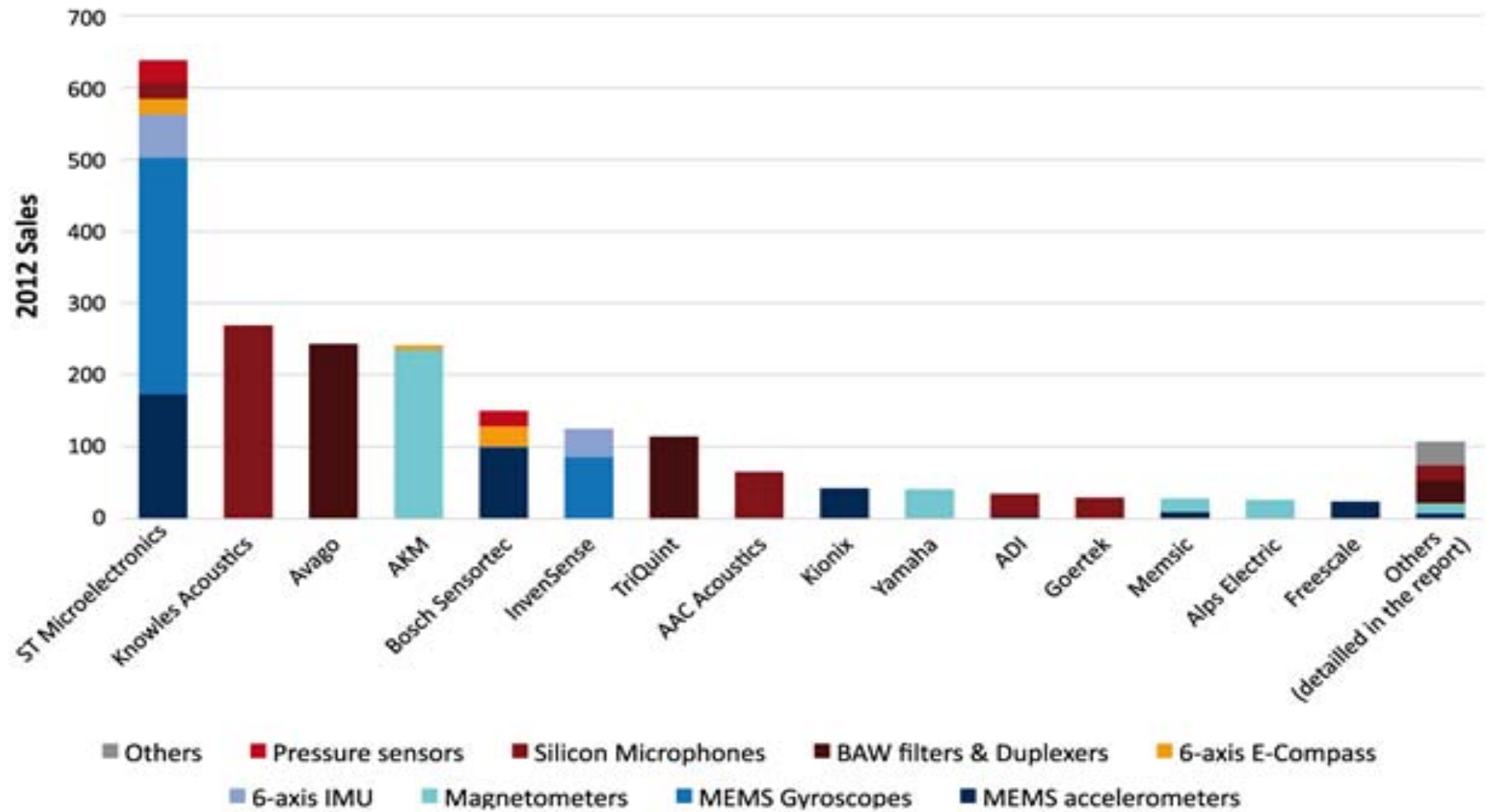


MEMS for Industry & Telecom



Source: Yole Status Report, July 2013

Top MEMS Suppliers in 2012 by Revenue (\$M) for Mobile Phones and Tablets



Source: Yole Status Report, July 2013

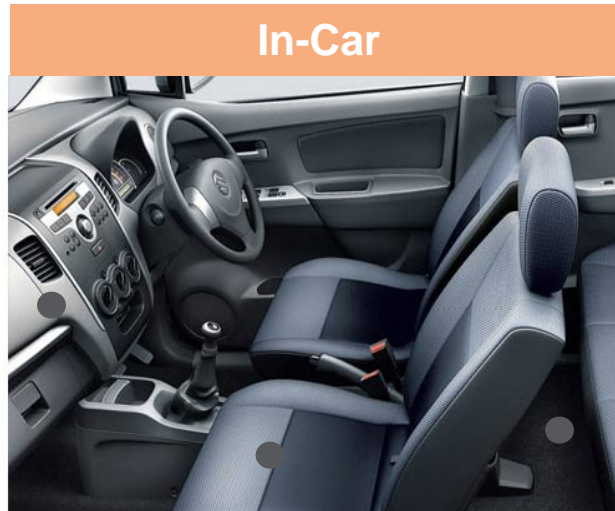
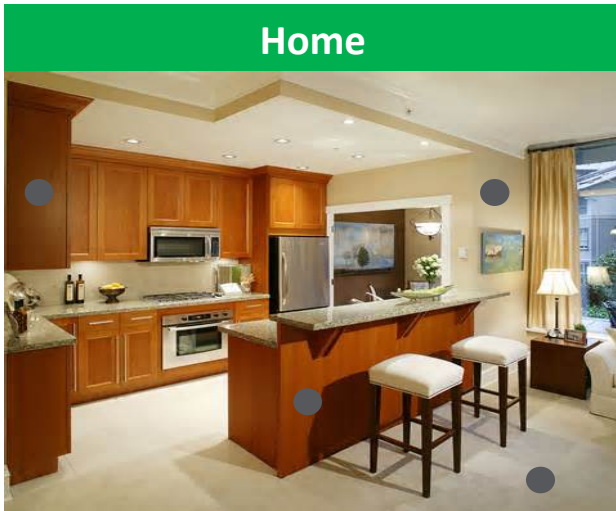
Environmental sources and gases

Contamination Source	Emission Source	VOCs
Building Materials	Adhesives, Carpets, Cement, Flooring, Solvents,	Formaldehyde, Alkanes, Alcohols, Aldehydes, Ketones
Combustion	Engines, Appliances, Smoke	Hydrocarbons, CO, CO ₂
Consumer Products	Household cleaning supplies	Acetone, alcohol, spirits
Furniture	Wood, Poly Vinyl Chloride (PVC), Glues	Toluene, Xylene, Decane
Human Being	Breath	Acetone, Ethanol, Isoprene, CO ₂
	Flatulence	Methane, Hydrogen
	Cosmetics	Limonence, Eucalyptol, Alcohols
Office Equipment	Printers, Copies, PCs	Benzene, Styrene, Phonole



Indoor Air Quality

- VOCs have been recognized as one of the principal trace constituents of poor Indoor air quality (IAQ) which can lead to a range of chronic adverse health effects such as throat / eye irritation, dizziness, headaches and tiredness (fatigue)
- Long term exposure to certain VOCs (like Formaldehyde) can harm the nervous system, aid development of cancers, and liver and kidney toxic effects



- Potential Sources of VOCs at home, in-car or office

From Cambridge CMOS Sensors Ltd

Environmental Gases & Smartphones

- **Humidity and Temperature sensing**
- Oxygen level
- CO₂ level for air quality
- VOCs – Ethanol, Formaldehyde
- Others: NO, Isoprene, NH₃

- **CHALLENGES FOR SMARTPHONE IMPLEMENTATION**
 - Manufacture in high volume with low CoV
 - Small size and power requirement
 - Low cost sensors (less than €10 per module)
 - Lifetime/Selectivity/Sensitivity

PHONE PLUG-INS HERE NOW

- Ethanol level
- Low power and digital
- iPhone plug in



TRAVEL EASY

**Elite Alcohol
Breath Tester**

TRAVEL EXCLUSIVE

A small device compatible with an iPhone 30-pin docking connector in order to check alcohol levels in the body. Operated by blowing into the device, where a reading of your blood alcohol level will then be shown.

The reading is not legally binding and cannot be used in a court of law. *iPhone not included.

£19

Nanobreak Plug-in Sensor from Nasa

The Product

The Nanobeak Sensor

- Plugs directly into an iPhone
- Collects and analyze chemical data in real time
- Senses chemicals in the air
 - using a “sample jet”
 - multi-channel silicon-based sensing chip



Nanobreak Inc.

FIRST IN PHONE – HUMIDITY SENSOR

- Sensirion chips for T and RH
- SHT21 & Later SHTC1
- Capacitive type
- +/- 2% RH +/- 0.3C
- Low power and digital I2C
- In Samsung Galaxy S4



The Smart Gas Sensor

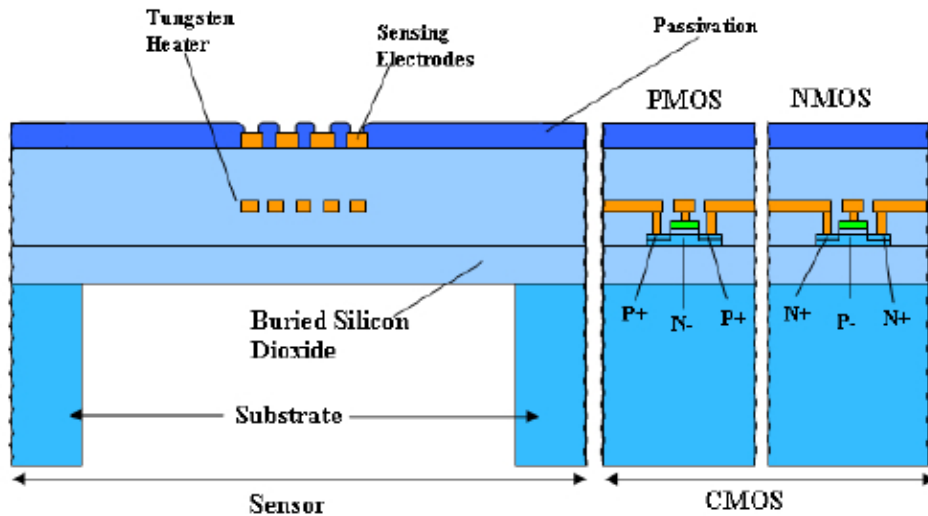
CCMOSS technology enables Air Quality monitoring through miniature multi-sensing devices!

- Indoor Air Quality (IAQ) monitor to detect a wide range of indoor air pollutants
- Toxic Gas Detector to alarm the user to dangerous levels of Carbon Monoxide (CO)
- Alcohol Breathalyser to provide ethanol levels on breath as indicator of Blood Alcohol Content (BAC)

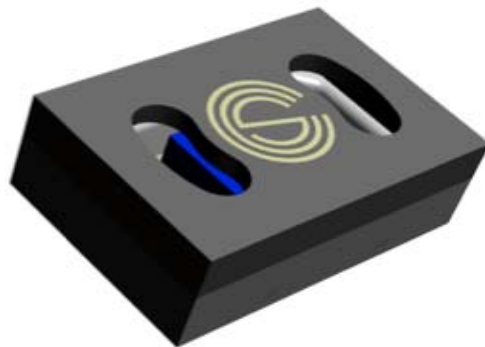


From Cambridge CMOS Sensors Ltd

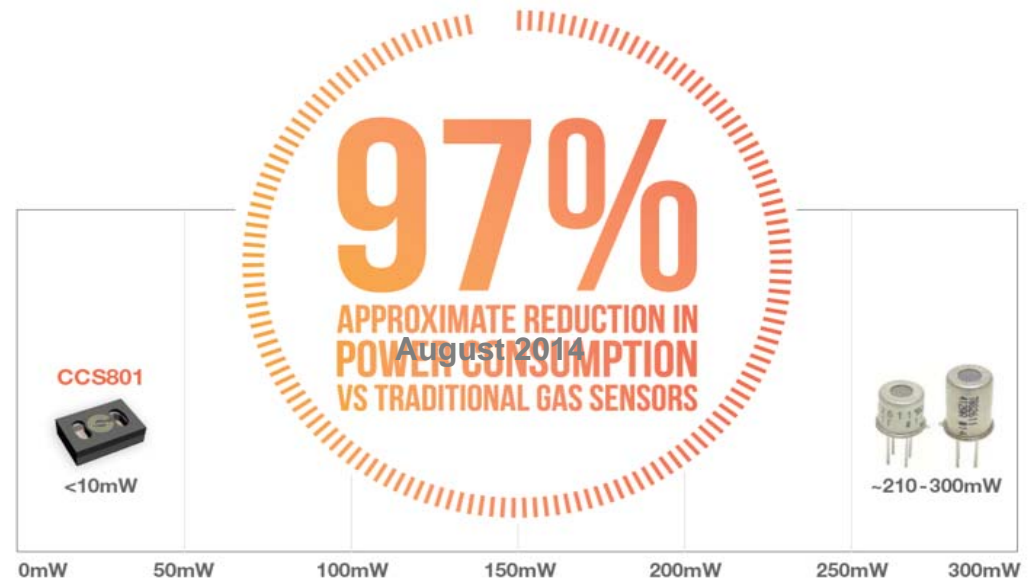
Small Low-Power Smart CMOS Gas Sensor (CCS800)



Sensor 1 mm by 1mm



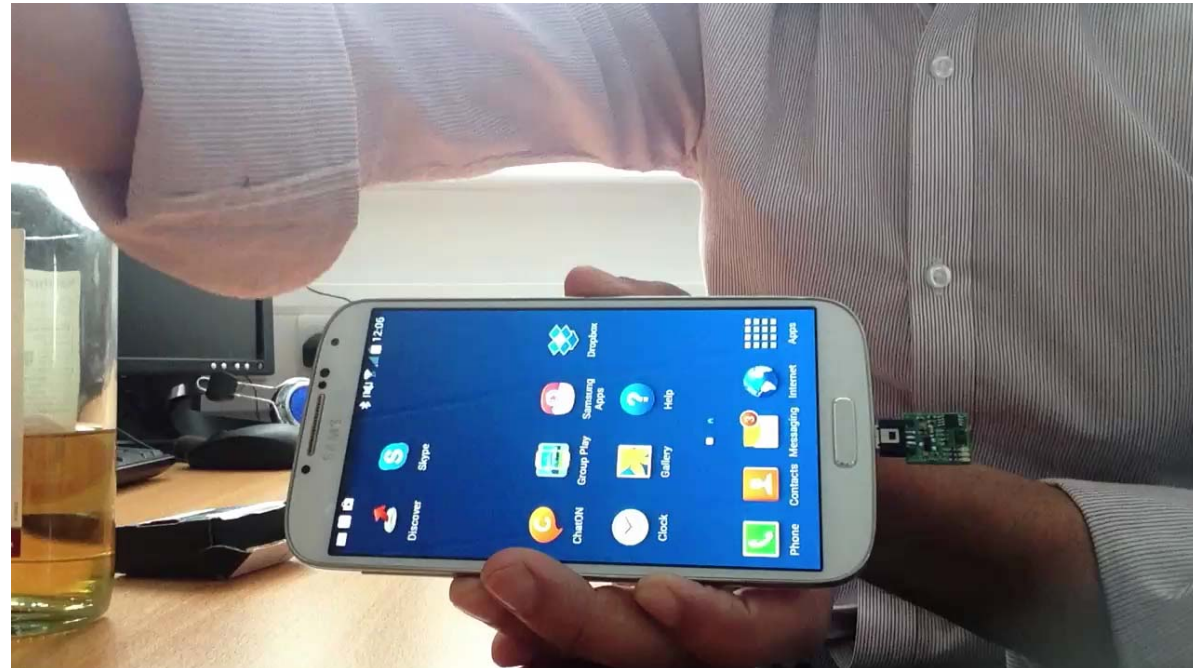
Package 2 mm by 3mm



Alcohol Breathalyser

- **CCS801 responds to Ethanol (ppm in Breath) is down to 10ppm within $\pm 25\%$ accuracy over temperature and humidity range ~ 4 s required for breath analysis**
- **Phone apps could be user activated or enabled while on call**
- **Smartphone apps monitors ppm level in breath. Rather than giving the user a PPM / BAC reading the app provides Low / Medium / High warning indication**
- **It is an alcohol indicator and not a certified sensor**

ppm in Breath	BAC	Note
52	0.02%	China legal driving limit
104	0.04%	Concentration impairment
208	0.08%	UK legal driving limit
520	0.20%	Severe motor impairment Loss of consciousness

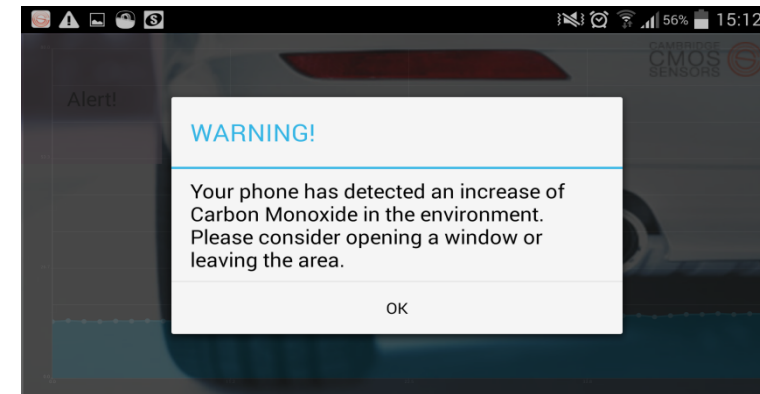


From Cambridge CMOS Sensors Ltd

CO – Toxic gas detection

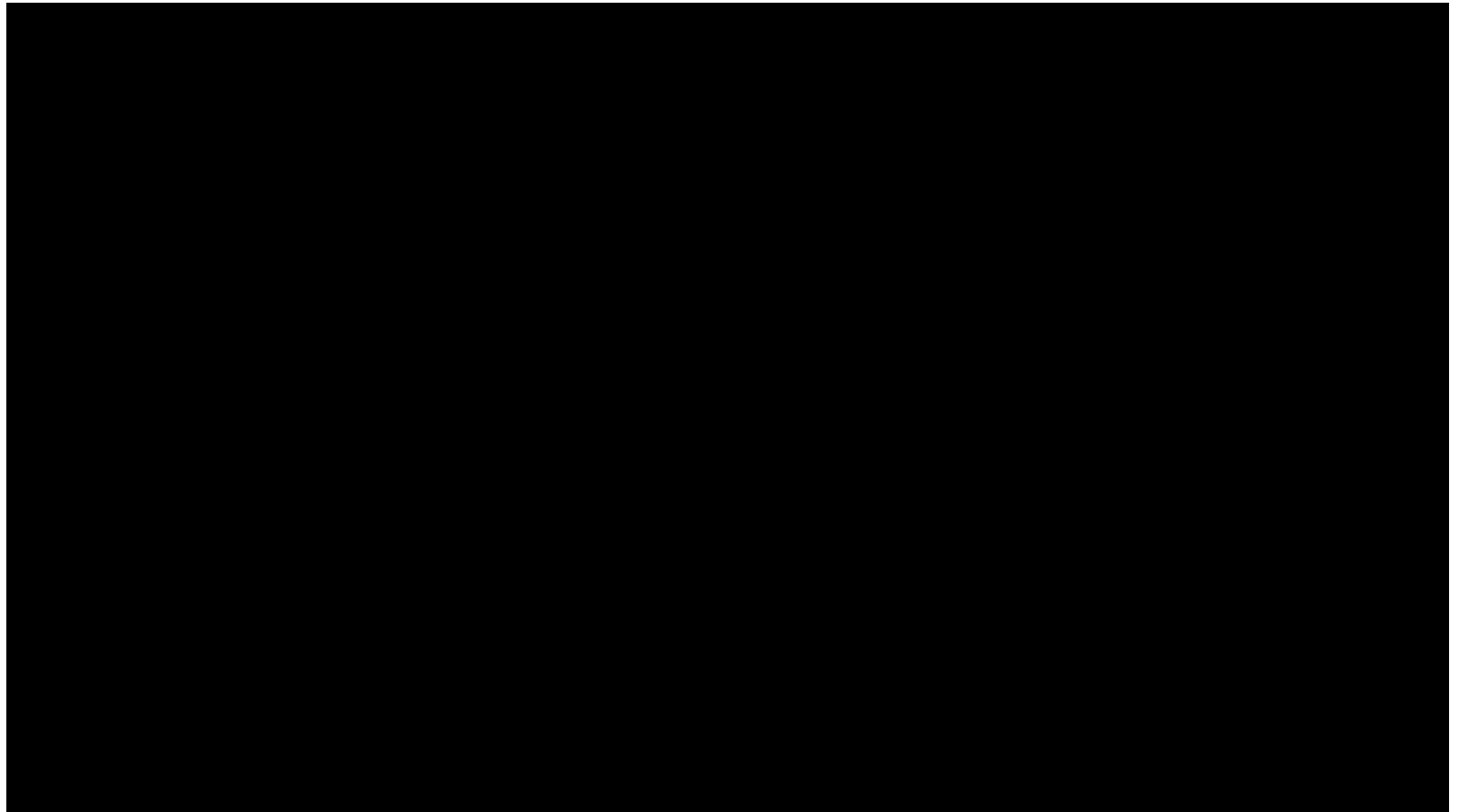
- **Carbon Monoxide (CO) is an odourless, tasteless and colourless gas, and exposure can be fatal!**
- **CCS801 responds to carbon monoxide down to 20ppm within $\pm 25\%$ accuracy over temperature and humidity range**
 - **-15°C -> +55°C Ambient temperature**
 - **Up to 95% relative Humidity**
- **Background apps on smartphone monitors CO levels every 30s (programmable) and provides Safe / Warning / Alert indication to the user about possible dangerous changes in their environment**
- **The phone should not be marketed as a life critical safety device to avoid legal/litigation issues.**

Concentration	Symptoms
35ppm (0.0035%)	Headache & dizziness within 6-8 hrs of constant exposure
100ppm (0.01%)	Slight headache in 2-3 hrs
200ppm (0.02%)	Slight headache within 2-3 hrs; loss of judgement
800ppm (0.08%)	Dizziness, nausea and convulsions within 45 mins; insensible within 2 hours



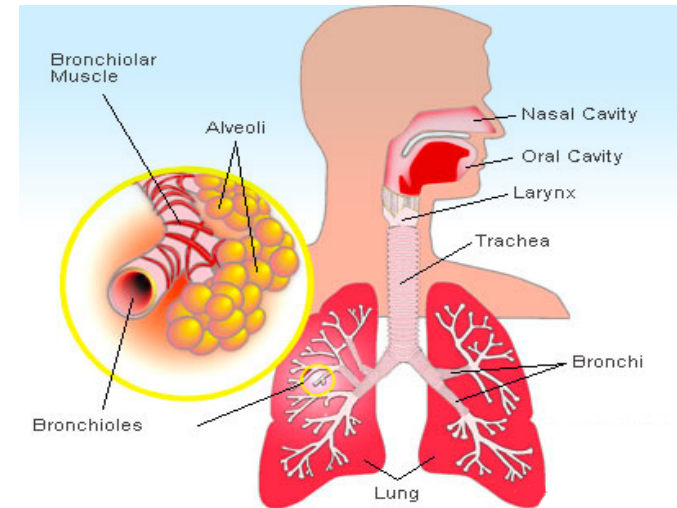
PHONE SENSORS

- Resistive type MOX
- CCS 2 mm by 3 mm package
- Low power and digital



Breath Analysis

- Concentrations of gases O_2 and CO_2 present in a sample of exhaled breath can provide a non-invasive insight into a person's health. VOCs are at PPB to Low PPM Levels
 - Acetone – Metabolism and Diabetes
 - Isoprene – Cholesterol
 - Ammonia – Liver condition
- End Exhaled gas, expired from the alveolar, presents a reflection of the gas exchanges occurring inside the lungs.
- Excellent (but expensive) breath monitors exist today and are in our hospital lab and used routinely.
- **Indirect Calorimetry** – considered the gold standard for energy expenditure (EE) assessment in clinical care, where volumes of oxygen consumed and carbon dioxide produced are measured.



PORTABLE Breath analysis: NEED FOR LOW COST Gas Sensors

- Sensors used for environmental gas monitoring often unsuitable for breath analysis
- Fast response time required for breath-by-breath measurements, when adult exhales 12x per minute.
- Nearly completely saturated, approximately body temperature ($\sim 36\text{ }^{\circ}\text{C}$)
- Flow sensor required for exhalation identification and volume calculation.
- O_2 required to a tolerance of 0.5%
- CO_2 to 1.2%



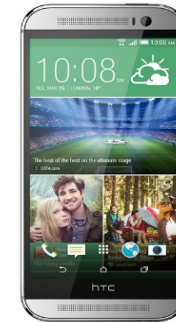
Alphasense: Electrochemical O_2 sensor



GSS SPRINTIR: NDIR CO_2 sensor

HOME BASED Breath ANALYSIS using SMARTPHONES

- Smartphones can wirelessly connect to gas sensor systems and provide intuitive monitoring interface.
- Potentially sensors to help monitor lifestyle can be included inside mobile devices.
- Bluetooth enabled microcontroller considered for remote breath sampling of patient's in UHCW respiratory chamber.
- Portable metabolic rate analyser could be used to log data, show metabolic rate variation over period of 1 day (e.g. after eating) and perhaps track progress over period of several weeks.



HTC One M8 phone, contains step counter fitness monitor, providing daily activity level.



Plug-in modules or wireless monitors available (<\$50) for smartphones display alcohol content from breath sample

Apple iPhone 6 with Barometer

- First phone with pressure sensor in
- MEMS type



Sensors: Barometer, three-axis gyro, Accelerometer, Proximity sensor, ambient light sensor.



CONCLUSIONS

- Few sensors can satisfy the demanding specification for phones
<€2, < 5 mW, < 3.0 V, 2 year life etc
- Low-cost silicon platforms possible (also plastic ones)
- **Life/stability issues of MOX films still an issue**
- Further cost/size/power reduction needed for smart watch market



New iWatch



Samsung



Addidas



ADIDAS



Nike

MULTI-GAS SENSORS – THE HOLY GRAIL

- Figaro MOX based (Japan) – Q4 2014?
- Sensirion MOX based (Switzerland) – Q1 2015?
- Cambridge CMOS Sensors – 2015?
- AMS/AppliedSensor MOXs?
- Others ...

- Technologies also coming:
 - RT MOX on Plastic
 - IR for CO₂
 - FBAR/Polymer VOCs
 - Nanowires/CNTs??

Sensirion preps multi-gas sensor 'nose' for smartphones

November 21, 2013 // Peter Clarke



Sensirion AG, a vendor of temperature and humidity sensors, has developed a multi-gas **sensor** that it is planning to sell to smartphone makers.

Page 1 of 3

The **sensor** platform will allow phones to act as alcohol breathalysers and monitor air quality, amongst other applications, as part of the next stage of smartphone evolution, the company reckons.

Moritz Lechner, co-CEO of Sensirion (Staeafa Zurich), said that the company has working examples of multi-

gas **sensors** and plans to ship samples to potential customers in the spring of 2014 with the aim of ramping production in 2015.



Acknowledgements

**Cambridge CMOS Sensors for
some slides/pictures and video clip**