

PYREOS

*Setting New Standards in NDIR Gas Sensing*

Jeff Wright CEO

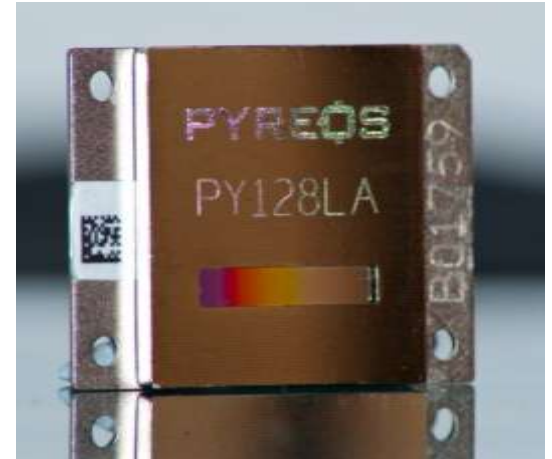
# Introducing Pyreos

## IP rich infra-red sensor products:

Siemens spin-out in Edinburgh UK

Outsourced manufacturing model

Experienced team backed by VCs



*Pyreos IR array sensor*

## Addressing our customers' needs for:

Reliable, small, accurate, low cost sensor solutions

Medical, industrial, environmental, consumer

## We create new opportunities in IR sensing:

Improved performance, more robust, lightweight, lower power

New low cost points for infrared systems

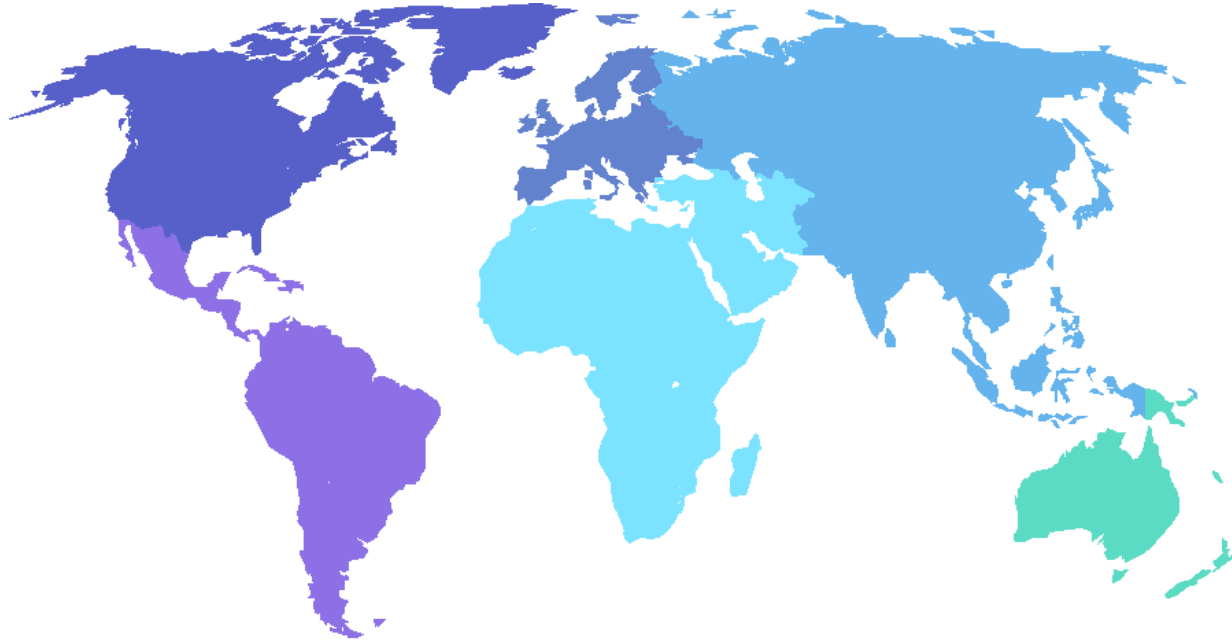
# Our Progress

- 2007 Pyreos incorporated & acquired technology from Siemens
- 2008 \$5 mn "A" round financing; Siemens, SE & Braveheart
- 2010 \$3 mn 1st close of "B" round; Seraphim new investor
- 2011 \$2 mn final "B" close; M-UFJ of Japan new investor
- 2012 \$8 mn investment April; Bosch new investor

Financially stable, 20 employees, strong sales growth

The logo for Siemens, featuring the word "SIEMENS" in a bold, teal, sans-serif font.

# Our Vision



Enabling unique innovation

Valued supplier to our customers

Setting new standards in IR sensing

# High Quality Outsourced Supply Chain

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## Edinburgh HQ

Sales & support  
Product design  
Key IP rich process



## MEMs wafer foundries

ISO qualified  
Dual sourcing -easy to scale  
Proven 3 years

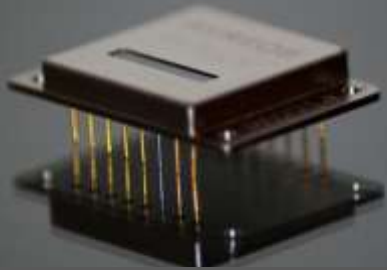


## Product Assembly

4 partners  
High capacity  
High quality

# Pyreos Sensor Product Lines

## Linear Line Array



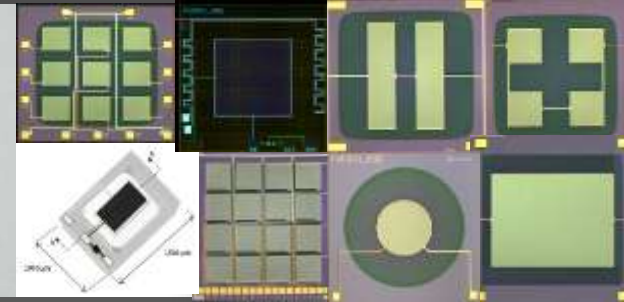
Four products

## TO Packaged Sensors



Singles, duals, quads,  
high frequency, 12 filter choices

## Unpackaged Sensor Die



Mini-arrays  
Customised solutions

**Medical**  
Industrial  
Environmental

**Medical**  
Industrial  
Environmental

**Consumer**  
Industrial  
Environmental

Evaluation kits suitable for all applications

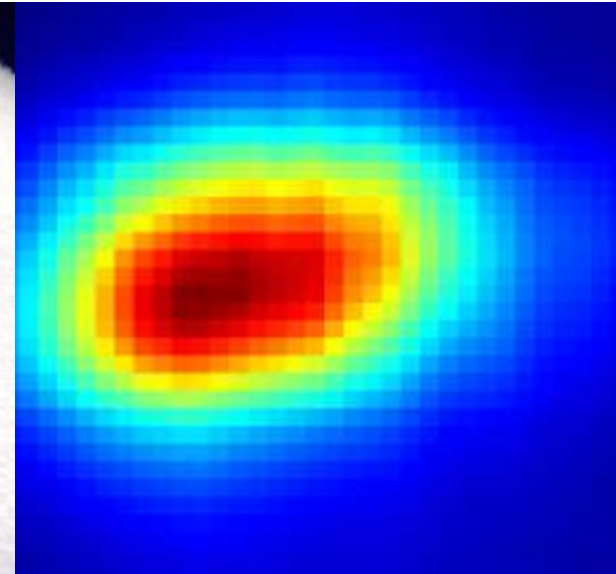
# Pyreos Sensors Are Enabling Pervasive IR Analysis



Anaesthesia



Non-invasive diabetes monitoring



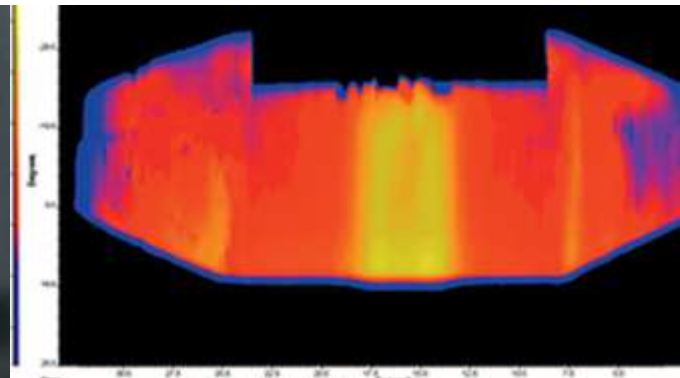
THz & Research



Inline Process Analysis



Mid IR Laser wavelength meters



Thermal line cameras

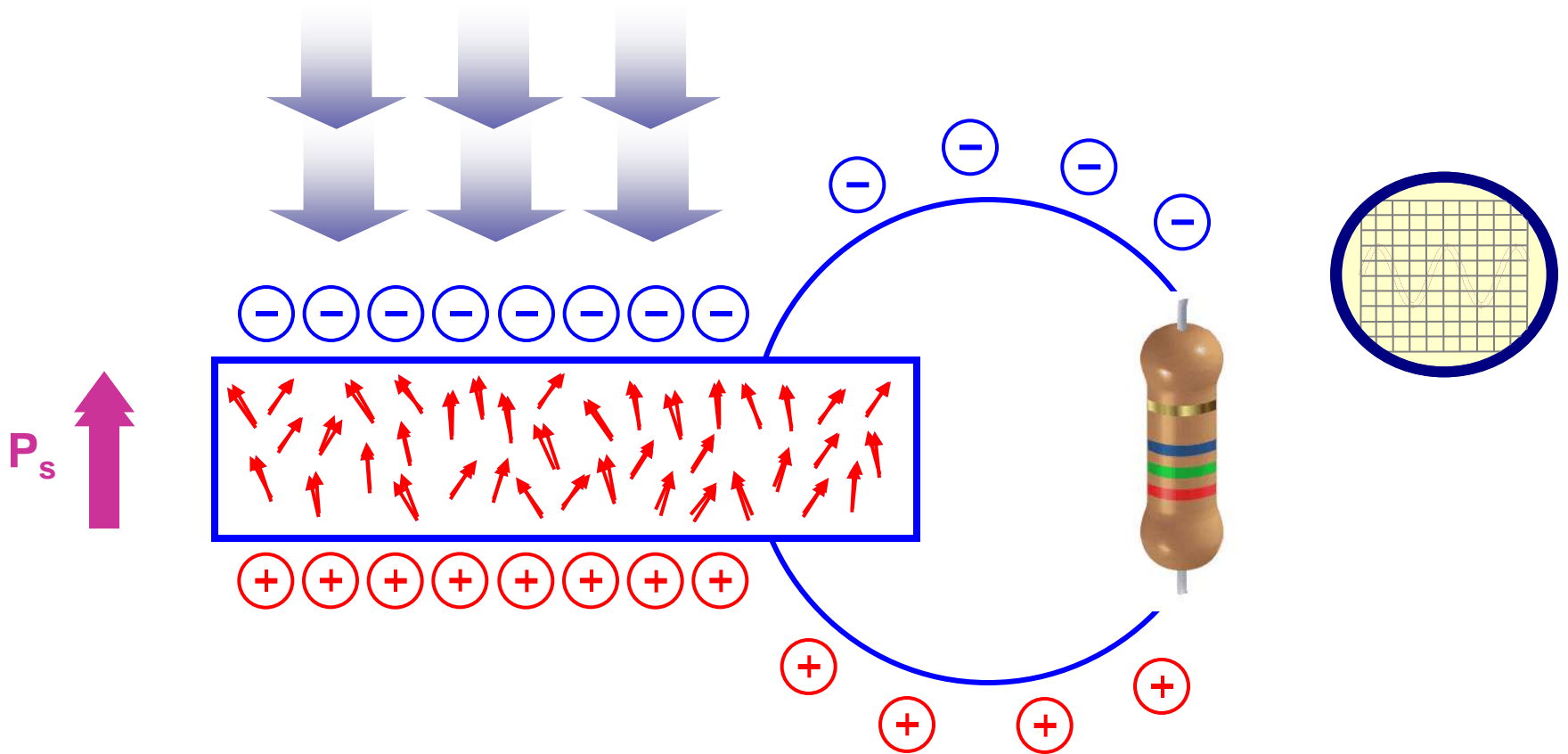


# Thin Film Pyroelectric Sensor Technology

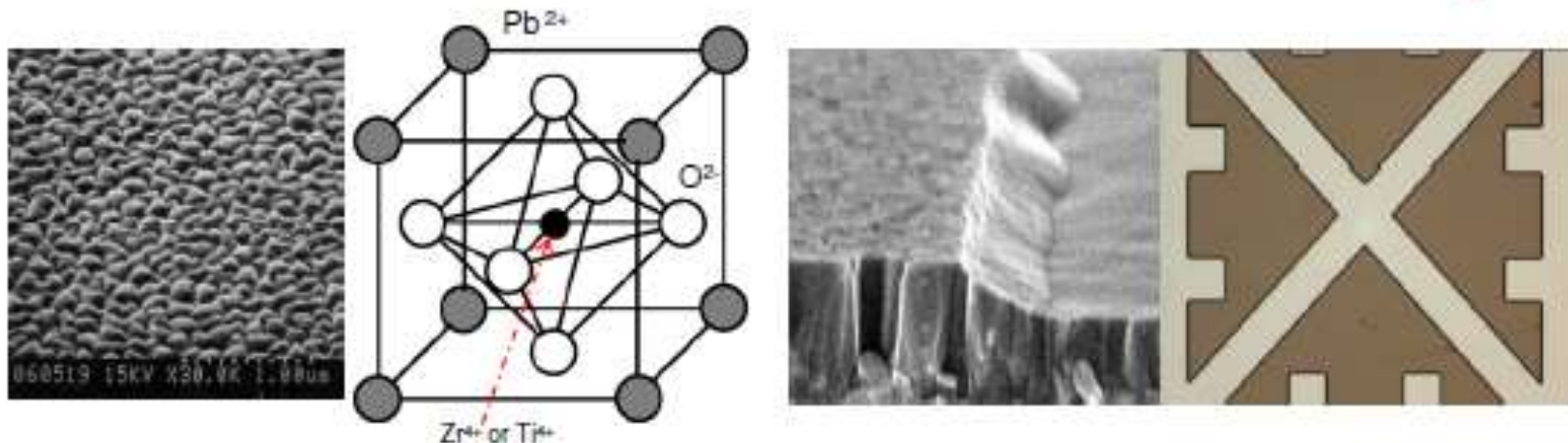


# Principle of Pyroelectric Sensors

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Pyroelectric effect = change in polarisation resulting from a temperature change



## Core Technology

- Sputtered 111 PZT thin film
- **Permanent polarization**
- >500C Curie point
- Low noise structure
- 15 years of R & D Siemens
- Stable mature technology

## Advantages

- Efficient sputter process
- Selectively etches- wet & dry
- Can be post processed
- Extremely stable material
- A low cost IR technology
- Unique to Pyreos

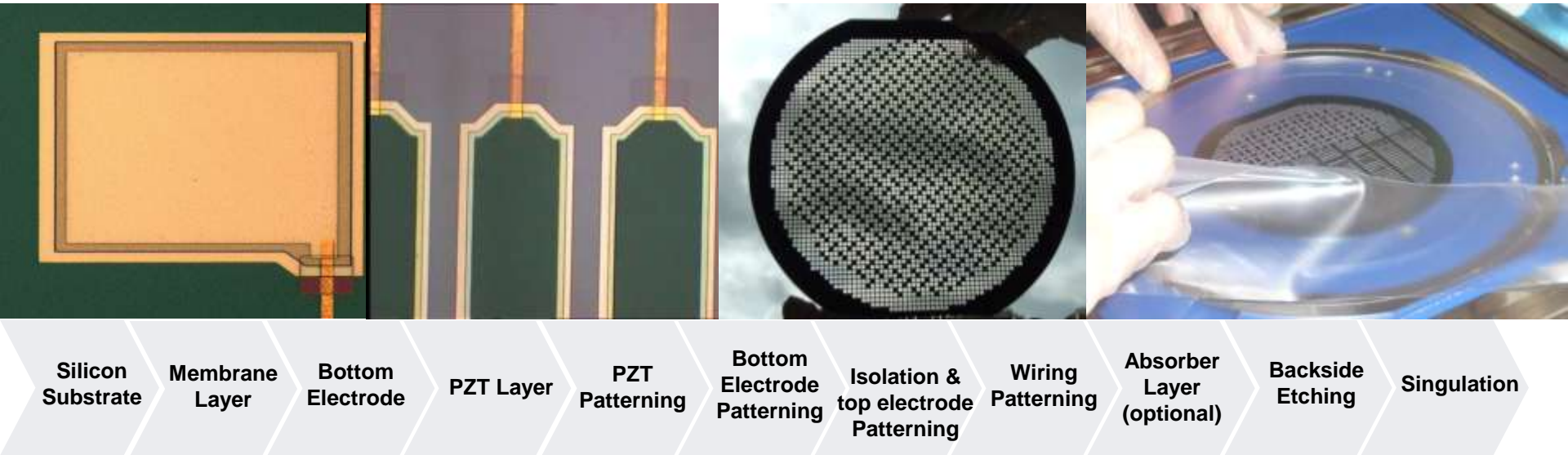
## IP Protection

- Many granted patents
- Further patent apps.
- Process know-how
- Bespoke equipment
- Design know-how
- Expanding IP portfolio

**Some of our customers tried and failed to achieve this technology  
Siemens succeeded and we acquired the patents and know-how**

# Efficient MEMs Thin Film Wafer Manufacturing

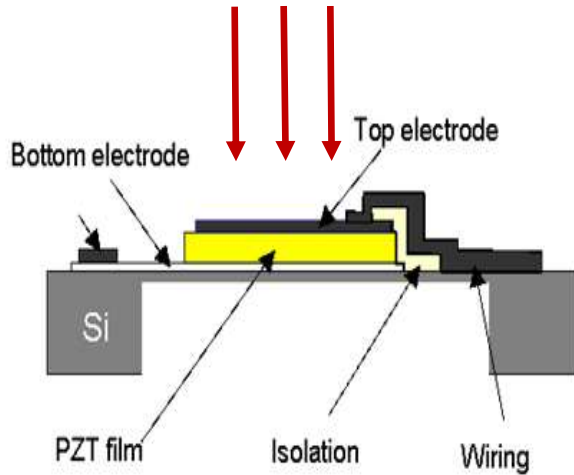
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- **Adaption of standard MEMs processes**
- **Standard tool-set for sputtering & etching processes**
- **100% wafer testing after each process**
- **High yield & economic processing**
- **Design flexibility for developing products**

**Our competitors do not have a highly controlled manufacturing process**

# Pyreos Unique IR Sensor Capability



## Solid-state Structure

Highly sensitive to mid IR  
 Robust, long lasting  
 Stable from -30 to +110 C

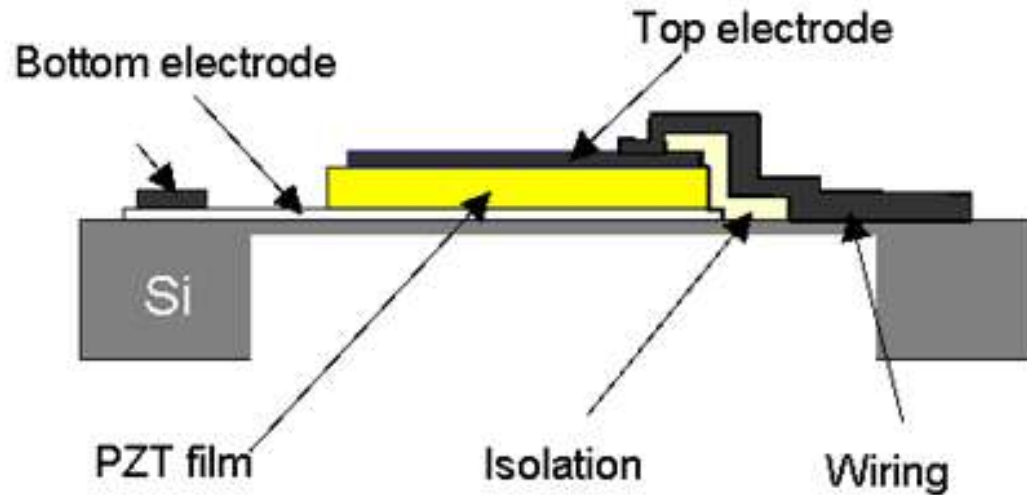
## Scalable Wafer Process

High yield & proven  
 Siemens €10m R & D  
 Sensor *array capability*

## 5 Layers of Protection

79 patents/ applications  
 15 families-13 granted  
 Further know-how

# Pyreos IR Sensor Device Structure & Advantages



**Stable from -30→+110C**

**Stable to vibration**

**No cooling required**

**No deterioration with time**

**Solid state & robust**

**Fast frequency sensor**

**Low power sensor**

**High SNR sensor**

**High sensitivity ( $D^*$ )**

**Broad wavelength range**

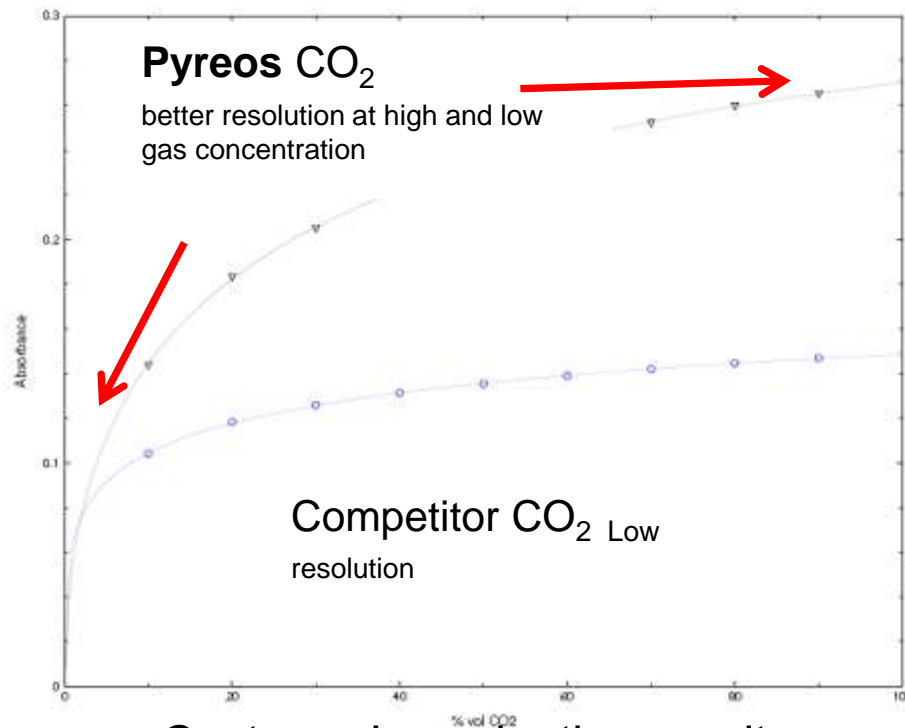
# Highly Stable Thin Film Devices

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$T_{Max}$	$\epsilon_{rel}$ (10kHz, 0.1 V level)	$\tan \delta$	$p_k / 10^{-4}C/(m^2K)$
as deposited	248	0.009	2.08
350°C	250	0.008	2.03
480°C	266	0.009	2.14
550°C	270	0.007	2.05
650°C	267	0.01	1.46

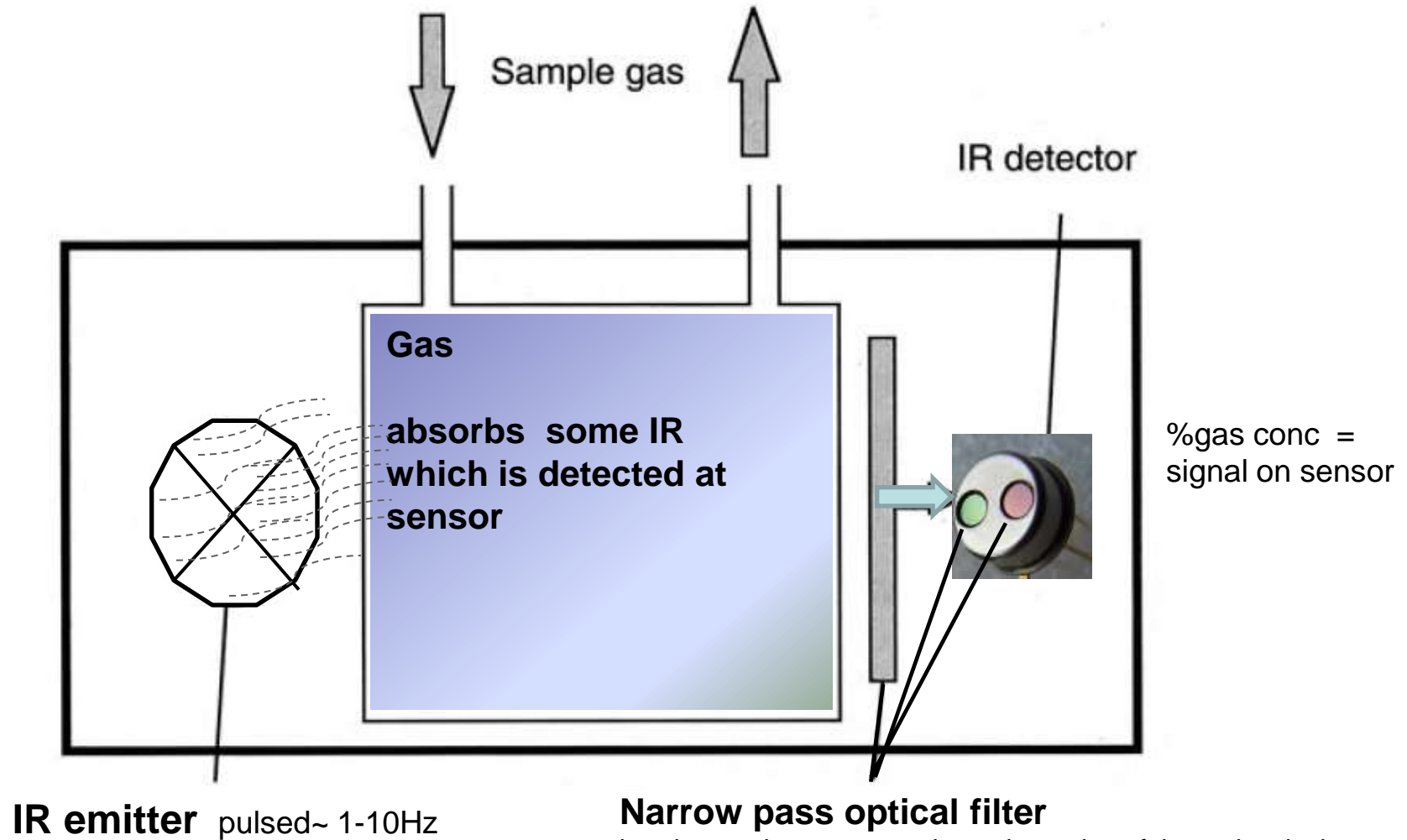
- Pyreos sensors withstand high temperatures
- Pyreos sensors are compatible with standard SMD technologies
  - Typically temperature of 300 C during SMD process
- Reduces assembly costs for customers

# NDIR Gas Sensing



## Customer's evaluation results

# Simple Principal of Non-Dispersive IR Gas Detection



band pass chosen to match an absorption of the molecule that is being monitored (2nd channel is a reference channel where no absorption will occur)



# Beer-Lambert Principle of NDIR Gas Detection

Beer-Lambert law :  $I / I_0 = e^{-CLG}$

$I$  is the light with gas at the IR sensor

$I_0$  is the light with no gas at IR sensor

$C$  is an absorbance coeff. - dependent on the absorption of the gas, & the optical filter

**L is the optical path length**

$G$  is the concentration of the gas

gas conc.  $G$  measurable logarithmically proportional to  $L$

For low level gas detection (single ppm levels)

Long path lengths are inconveniently large, require more gas ...

***Better to Achieve higher signal to noise by***

• *measuring at higher frequency* - **reduces 1/f noise**

• *Use a highly responsive sensor & fast emitter*

Leads to

*Reduced amplification* & reduced emitter noise pick-up

*All possible with Pyreos gas sensor & emitter products*

**High Performance, Fast, Reliable 1, 2 & 4 Channel Gas Sensors**

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**Unique Form Factors**

Surface mount sensors  
TO packaged sensors  
Miniaturised sensors

**Performance**

Wide frequency range  
>100,000 V/W  
Good S/N ratio

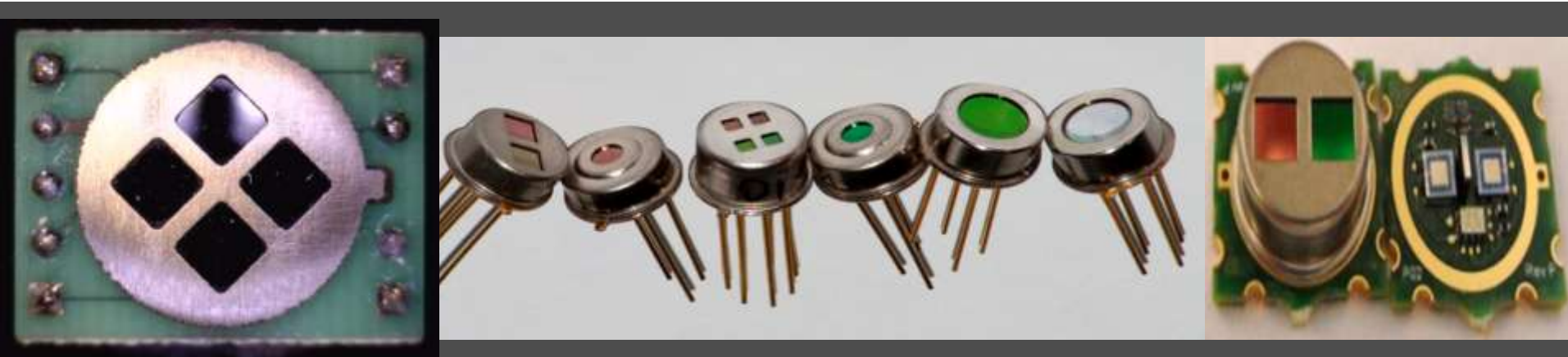
**Reliability**

Stable  
Low microphonics  
Easy to use

***New IR Emitters- Now Available From Pyreos***

**MEMs blackbody, fast switching & low cost**  
Surface mount & TO emitters, emitter arrays  
Miniaturised emitters with built in drive electronics

# Enabling New Opportunities in NDIR Gas Sensing



Pyreos fast frequency sensors and new MEMs IR blackbody emitters enable;

Fast frequency operation

reduce  $1/f$  noise, over-sample to improve measurement accuracy

rapid T90 measurement times, low power operation

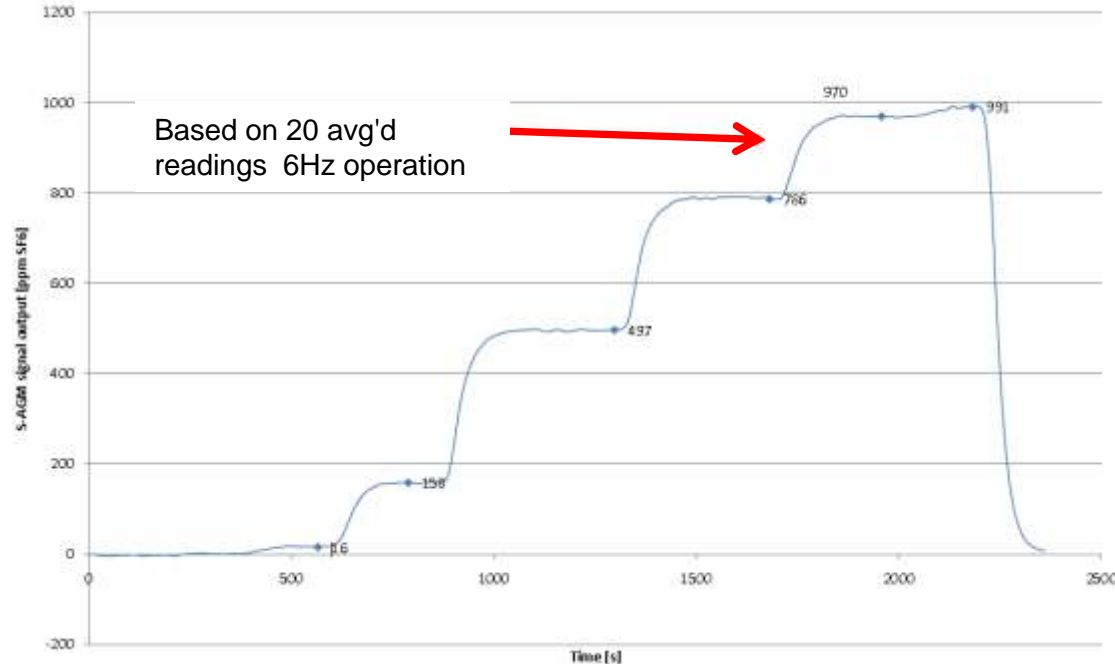
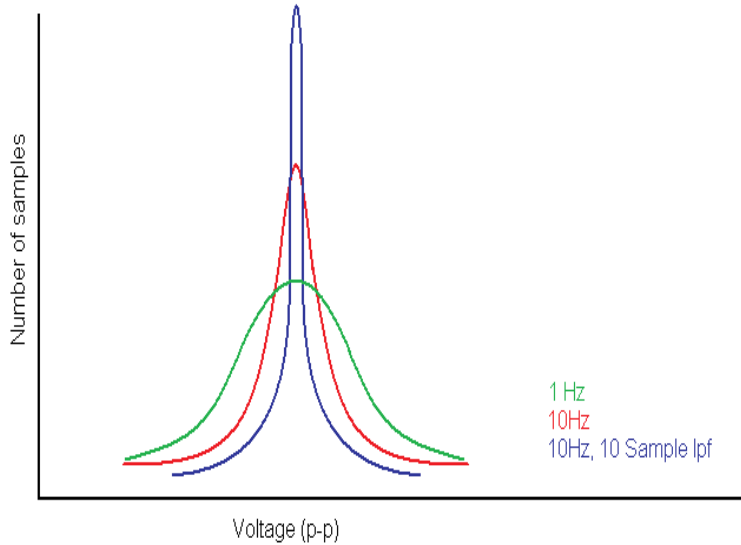
1-12 micron range -All gases & liquids can now be detected by NDIR

- SO<sub>x</sub> NO<sub>x</sub> SF<sub>6</sub> ,

Low cost multi-gas detection is now possible using several quads in a small device

# Breakthrough NDIR Performance e.g. for SF<sub>6</sub>

## 0-1000 ppm SF<sub>6</sub> measurement



Improved Signal-to-Noise

10 Hz operation with Pyreos components

Over-sampling further improves S/N

Now possible from 1-12 microns

Pyreos Excellent Sensitivity

Fast & stable linear response

Rapid measurement

Accurate low ppm detection level achieved

# Pyreos Advantages for NDIR Gas Detection

## Advantages

## Reason for Pyreos Advantage

Best Signal to noise (S/N)

high V/W, fast Hz operation, stable output

Easy to use

stable MEMs sensor & circuitry –low drift no ambient temp. problems, uniform performance

Low power operation

pulsed IR emitters, no 2<sup>nd</sup> stage gain needed

Low cost

Competitive pricing & no 2nd stage gain needed

Great product uniformity

Uniform MEMs wafer process technology

Surface mount compatible

Automated assembly – new small size products

Small size (mini quads)

High D \* sensitivity & thin-film low noise structure

Higher accuracy

Combination of the above

# Pyreos Gas Sensors Are Used Across Many Industries



**Multi-gas anaesthesia**



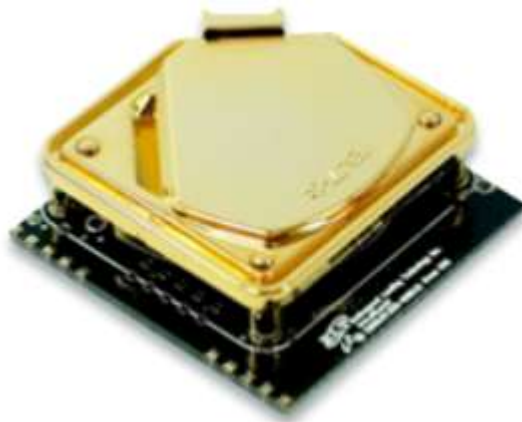
**NDIR pellistor replacement**



**Safety - flame detection**



**Inline Process Analysers**



**Air quality & ventilation systems**



**ATEX & explosion proof**

# THANK YOU

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[www.pyreos.com](http://www.pyreos.com)

see product videos on YouTube  
search for "Pyreos PIR"