



Wearable Sensing Application- Carbon Dioxide Monitoring for Emergency Personnel Using Wearable Sensors

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Proetex project- Advanced e-textiles for firefighters and civilian victims

-Developing textile and fibre based integrated smart wearables for emergency disaster intervention personnel with a goal of improving their safety, coordination and efficiency

-EU funded FP6 project
-2004-2010
-23 European project partners


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Consortium partners

1 National Institute of Physics of Matter	Italy
2 Technical University of Lodz	Poland
3 University of Ghent	Belgium
4 Smartex s.r.l.	Italy
5 Millor s.p.a	Italy
6 Sofletta s.p.a.	France
7 Thuasene France	France
8 University of Pisa	Italy
9 Dublin City University	Ireland
10 Commissariat a l'Energie Atomique	France
11 Centre Suisse de Electronique et de Microtechnique SA	Switzerland
12 Sensor Technology and Devices Ltd.	United Kingdom
13 Steiger	Switzerland
14 Philips Research	Germany
15 Ciba Specialty Chemicals	Switzerland
16 Diadora/Invicta Group	Italy
17 Xacient Ltd.	United Kingdom
18 Zarlink Semiconductor	United Kingdom
19 Brunet-Lion	France
20 Brigade de Sapeurs-Pompiers de Paris	France
21 INSA-Lyon-CNRS	France
22 EUCENTRE - Protezione Civile	Italy
23 Department de la Defense et de la Securite Civile	France


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Advanced E-Textile systems can bring together sensors, connections, transmission systems, power management. The emergency disaster personnel smart garments will progressively enhance and integrate such textile systems to enable the following functions:

- Continuous monitoring of life signs (biopotentials, breathing movement, cardiac sounds);
- Continuous monitoring biosensors (sweat, dehydration, electrolytes, stress indicators);
- Pose and activity monitoring;
- Low power local wireless communications, including integrated textile antennae;
- Internal temperature monitoring using textile sensors;
- External chemical detection, including toxic gases and vapours;
- Power generation - photovoltaic and thermoelectric and energy storage;
- Longer term e-textile technologies including further sensors, light emission and logic on fibre.

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The PROeTEX Concept

Inner Garment Wearable:

- Life signs monitoring
- Temperature, internal
- Biochemicals sensing
- Posture and activity
- Power generation and storage
- Low power local communications

Outer Garment Wearable:

- External chemicals sensing
- Posture and activity
- Visibility enhancement
- Power generation and storage
- Low power local communications

Civilian Monitoring Jerkin: (or chest band)

- Life signs monitoring
- Temperature, internal
- Biochemicals sensing
- Posture and activity
- Power generation and storage
- Low power local communications


Portable Communications Units:

- 6 axis INS, GPS,
- External temperature
- Additional sensors
- On board battery storage
- Low power local communication
- Long range communications
- Data input ; Display and audio, alarms

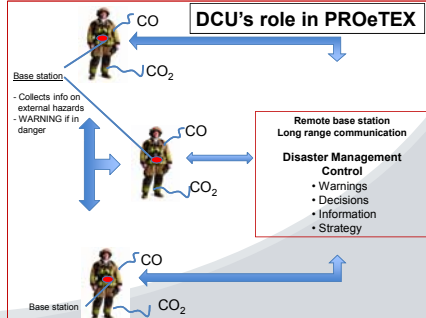
Ambient Environment:

- Communications
- Planning
- Coordination
- Monitoring
- Prediction
- Situation awareness

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DCU's role in PROeTEX



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Targeted gasses

Carbon monoxide- CO

- Colorless, odorless, tasteless, toxic gas
- Produced by the incomplete combustion of the fossil fuels

Concentration of CO in air	Inhalation time and toxic developed
50 ppm	Safety level as specified by the Health and Safety Executive
200 ppm	Slight headache within 1-2 hours
400 ppm	Frontal headache within 1-2 hours
800 ppm	Dizziness, nausea, convulsions within 45 minutes, insensible in 2 hours

Carbon dioxide- CO₂

- Present in atmosphere as a trace gas, in conc. of 350-400 ppm
- Colourless, odourless, non-combustible gas
- Combustion of fossil fuels and deforestation
- High concentrations may occur in closed spaces


Concentration of CO in air	Inhalation time and toxic developed
10000 ppm	Drowsiness
>20000 ppm	More frequent, deeper respiration
30000 ppm	Breathing rate doubles
50000 ppm	Serious oxygen deprivation resulting in permanent brain damage, coma and even death.

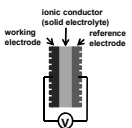
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CO₂ sensor characteristics

- Sensor supplier- Alphasense UK
- 3-pin sensors
- 14.5 mm diameter, 12.5 mm height (including pins)
- CO₂ sensor electrodes: reference, working





Principle of a Potentiometric Sensor for Gases The signal is measured as the potential difference (voltage) between the working electrode and the reference electrode. The working electrode's potential depends on the concentration of the CO₂ in the gas phase

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Sensor integration



CO₂ sensor

CO₂ gas is more dense than air it tends to accumulate in low height, the CO₂ sensor has been integrated in to a specially designed **boot pocket**

The less dense CO gas tends to rise and therefore CO sensor was integrated in **the jacket collar** close to the breathing height.




CO sensor


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CO₂ wireless sensing module



mini-B USB connection




Nickel hydride rechargeable battery



2.4 GHz Zigbee module with an integrated ceramic antenna- Jennic JN5139-001-M00 802.15.4 RF Module

Module dimensions: 5.5x4x1.5 cm

Signal captured using a base station, connected to a PC and monitored using HyperTerminal



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CO₂ module protective casing and testing chamber

Protective casing

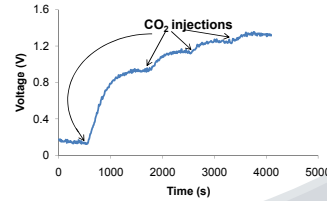




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CO₂ sensor response

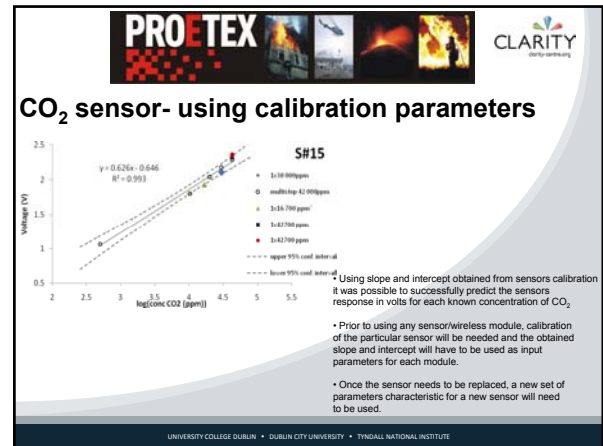
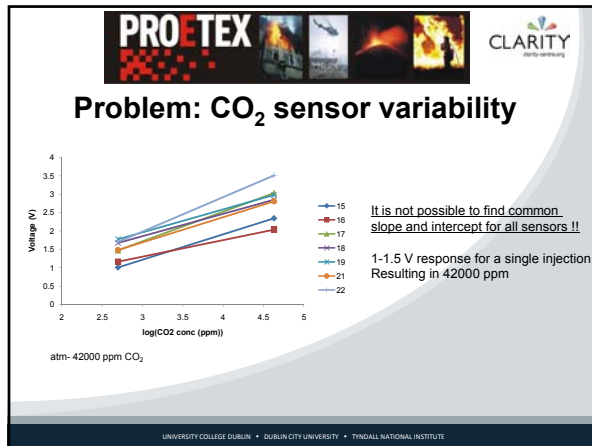


CO₂ concentrations

- atmospheric (initial base line)
- 9750 ppm,
- 19500 ppm,
- 29300 ppm,
- 42800 ppm

Wirelessly transmitted signal from CO₂ sensor calibration (range atmospheric to 42800 ppm CO₂). Sensor was enclosed in an airtight chamber and CO₂ was injected.

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- ### Future activities
- Re-programming the modules to account for calibration factors
 - Full integration of CO/CO₂ sensors into the garment
 - Wireless transmission: communication of on-body base station and the remote station
 - Evaluation of prototypes in laboratory conditions
 - Evaluation of prototypes in-field conditions
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