



Progettazione e sviluppo di un sistema sensoriale per la misura di composti volatili e la identificazione di microorganismi di interesse occupazionale

Corrado Di Natale

Dipartimento di Ingegneria Elettronica
Università di Roma Tor Vergata

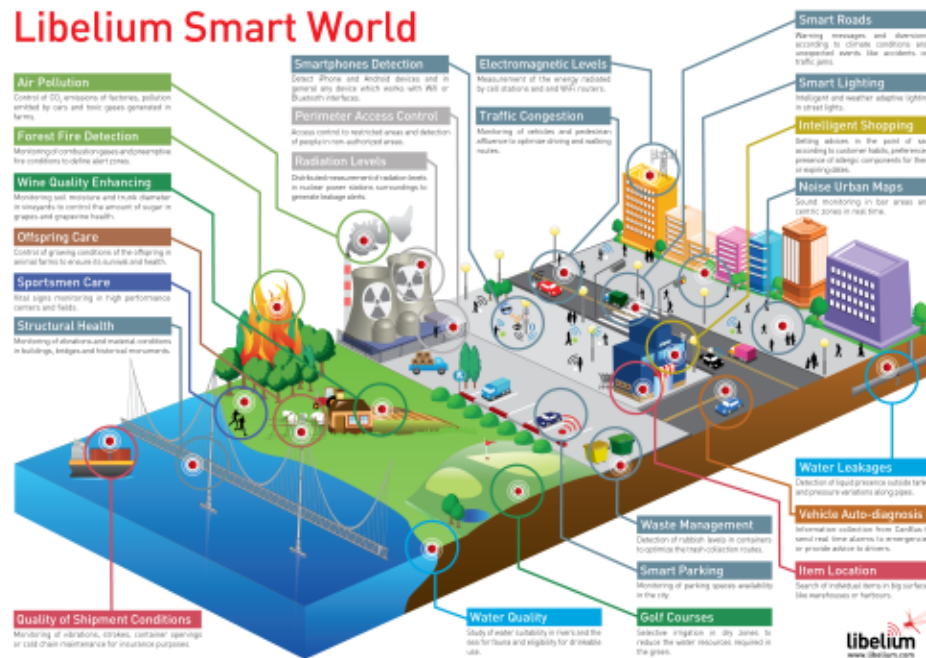
Sensorsgroup.uniroma2.it



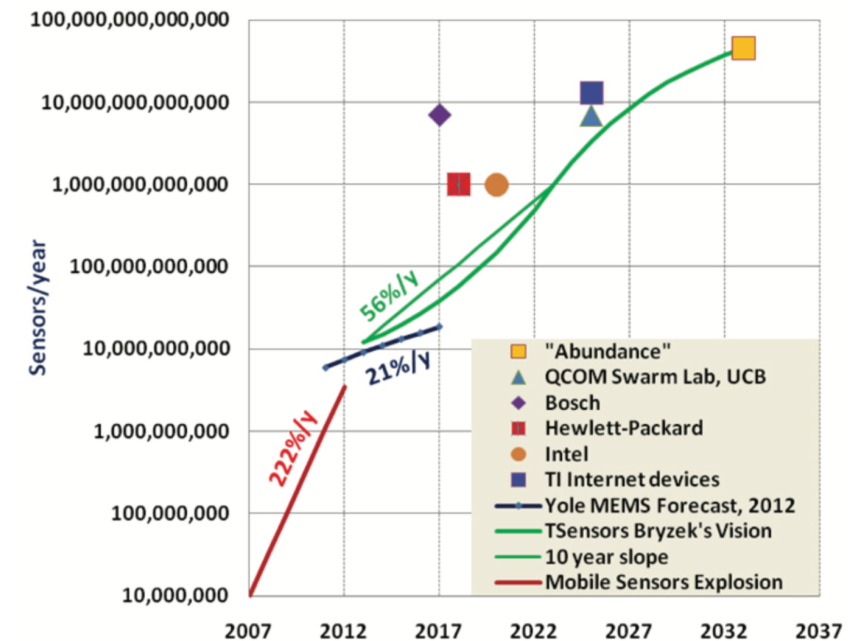
Sensori ovunque

- microelettronica
 - Capacità di calcolo distribuite
- Internet-of-things
 - Sensori per ciascuno e ovunque
- Data analysis

Libelium Smart World



Trillion Sensor Visions

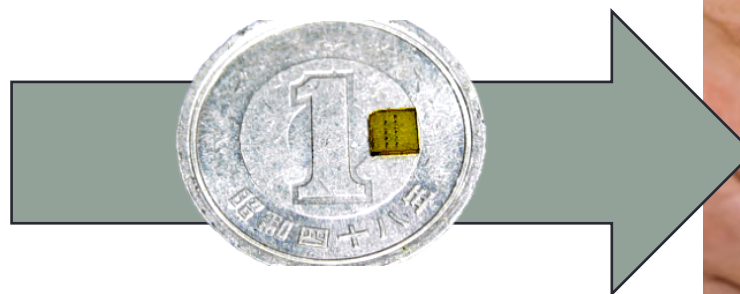


Sensori integrati negli smartphone:

- microfono
- 2 sensori di immagine
- 3D accelerometro
- 3D giroscopio
- sensore di pressione
- bussola 3D
- Sensore di luce ambiente
- sensore di prossimità
-
- **ma non ancora Sensori chimici e biosensori**

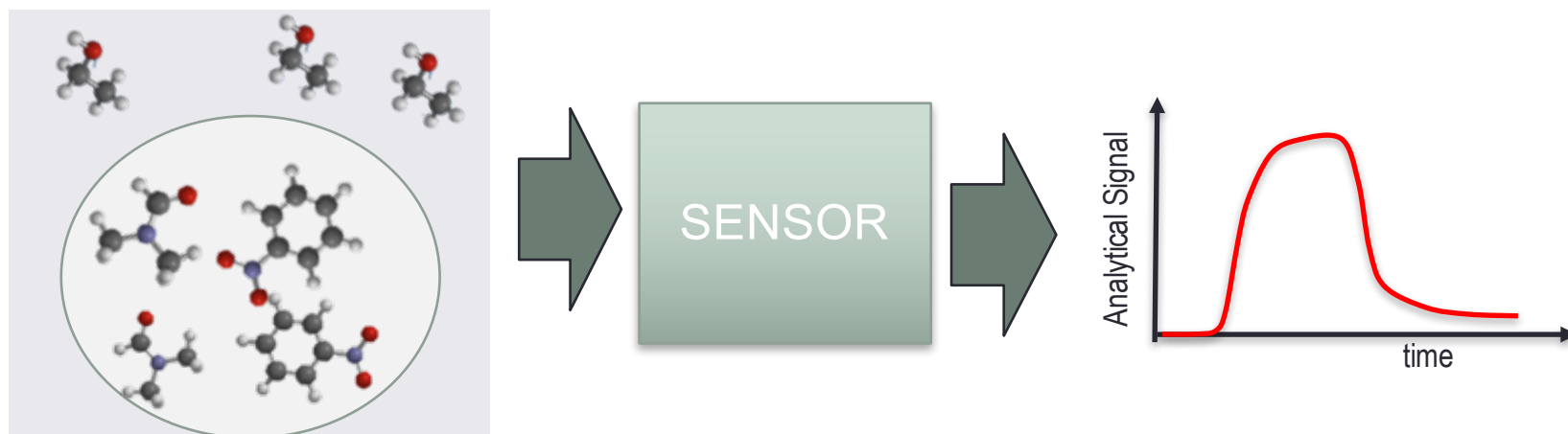


Chimica Analitica → Sensori

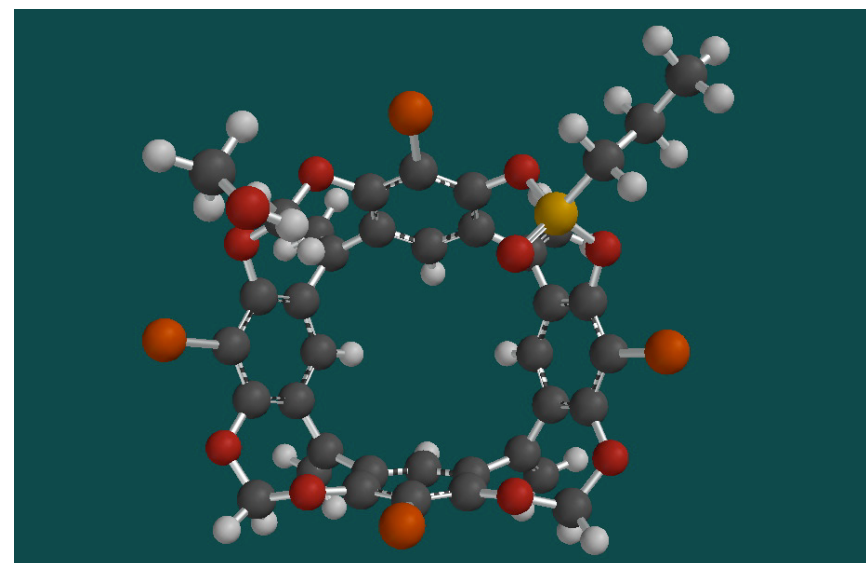
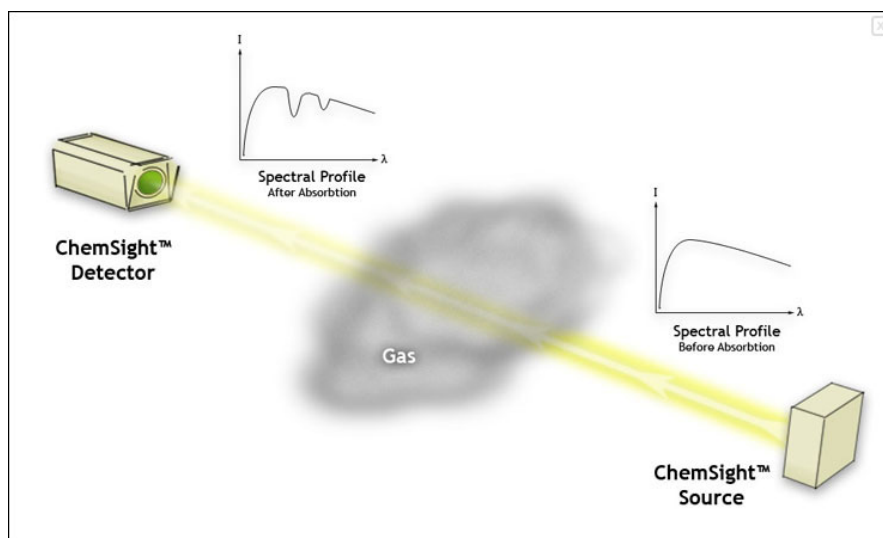




Principi dei sensori chimici

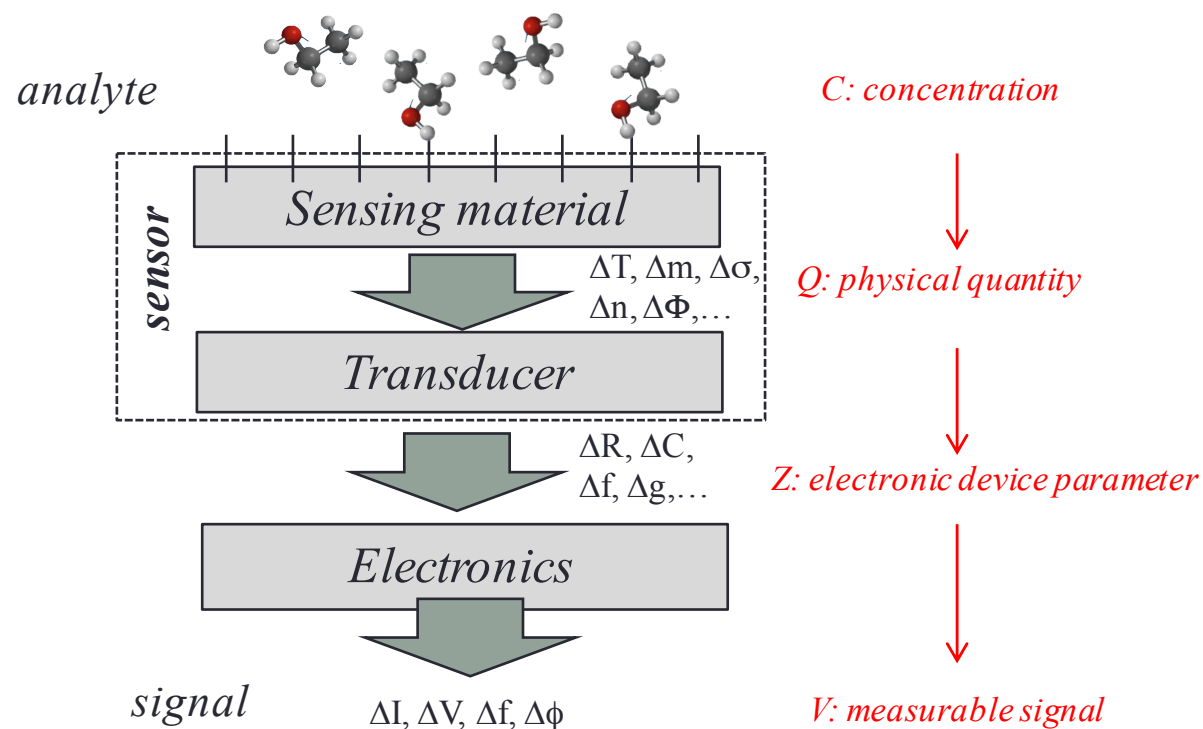


- Misura diretta attraverso una **proprietà intrinseca della molecola target** (tipicamente spettro ottico o IR)
- Misura mediata attraverso la **interazione della molecola target con un materiale sensibile**.

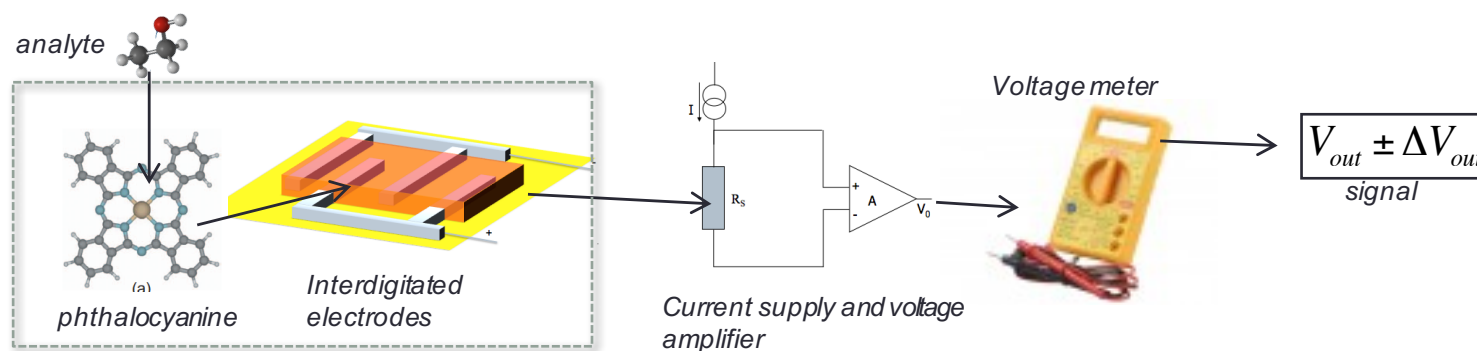




Schema generale di un sensore chimico a mediatore sensibile

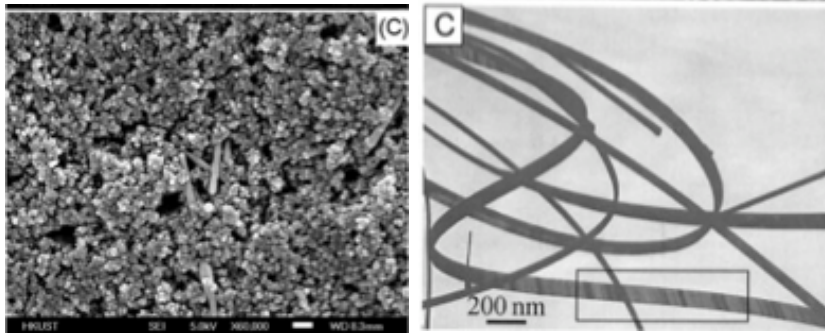


example:
phthalocyanine based
chemo-resistor

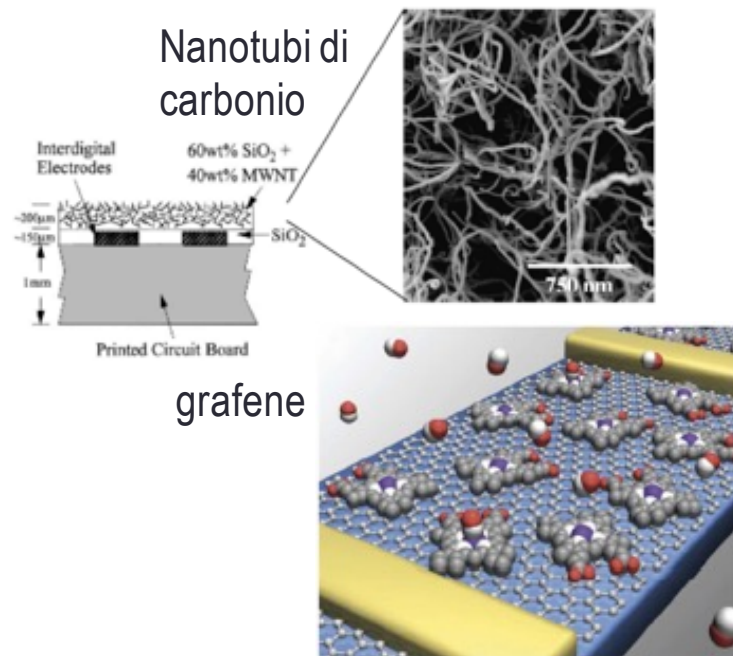


Materiali sensibili

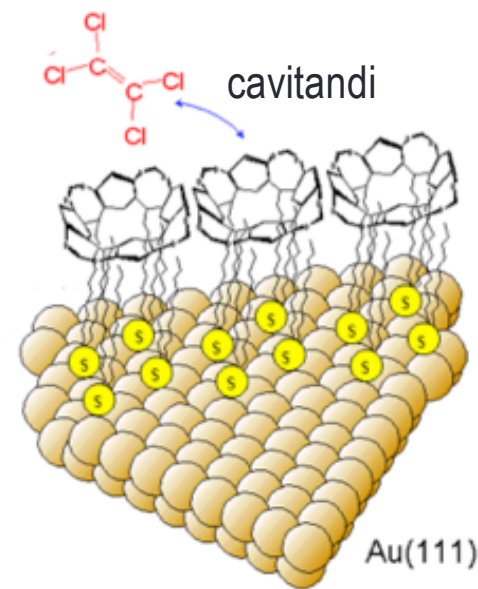
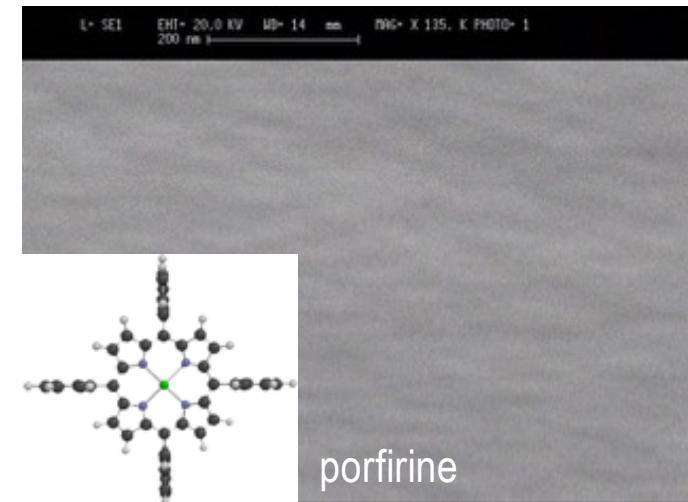
Materiali inorganici



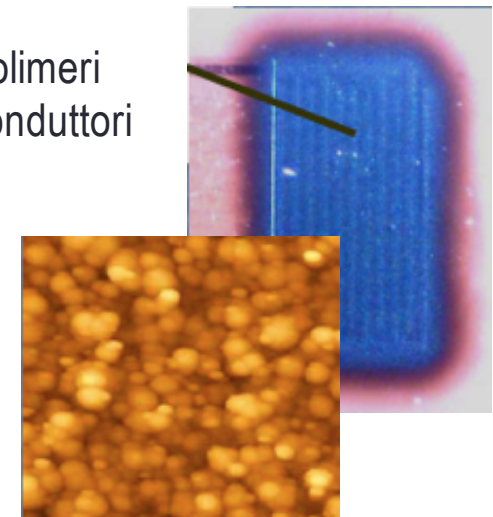
Ossidi metallici semiconduttori



Materiali organici

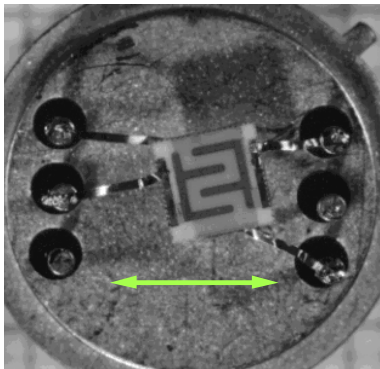


Polimeri conduttori



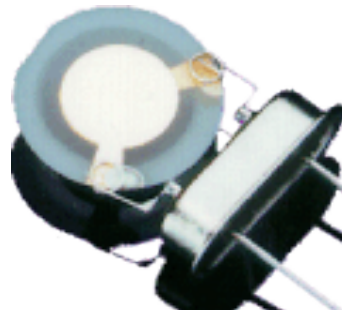
Trasduttori

Trasduttori di impedenza

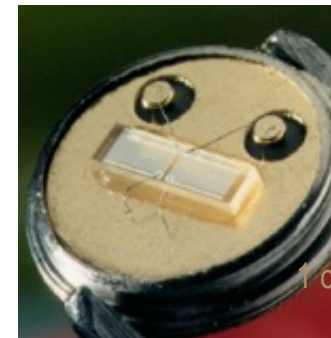


Elettrodi interdigitati

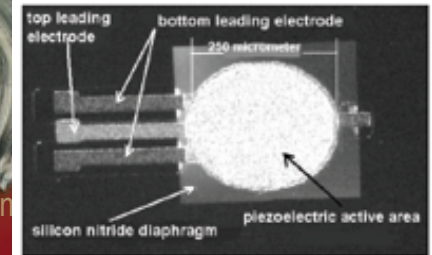
Trasduttori di massa



Microbilancia al quarzo

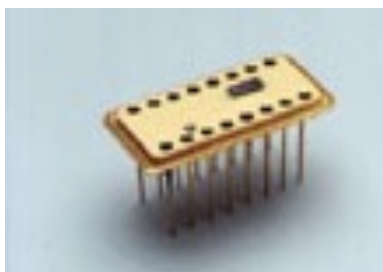


Surface acoustic wave

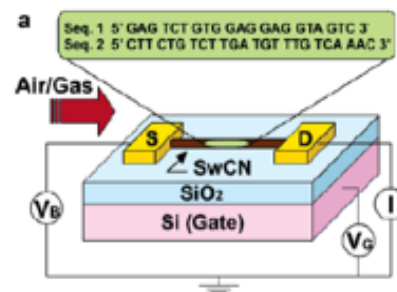


Risonatori a film sottile

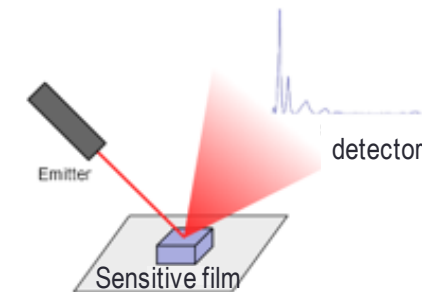
Dispositivi ad effetto di campo



ChemFET, FET organici, transistori a nanofili,...



Trasduttori ottici



Colorimetria, spettroscopia di assorbimento, fluorescenza, Raman, SERS, SPR...



Selettività: cosa possiamo imparare dalla Natura?

In living beings there are two main approaches to chemical sensing

specific receptors for few selected molecules

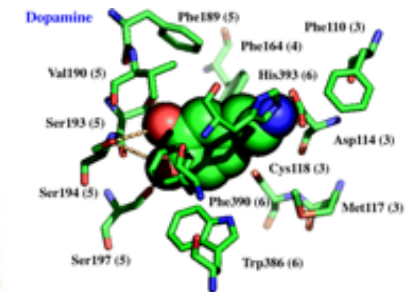
- receptors
- antibodies
- pheromones

non-specific receptors for unpredictable compounds

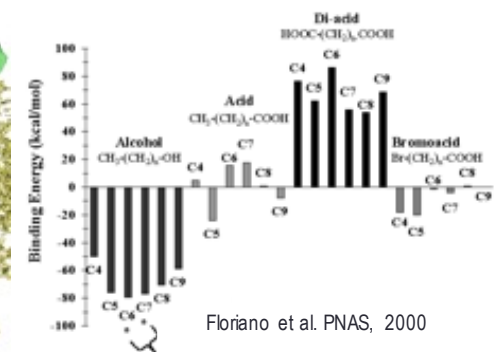
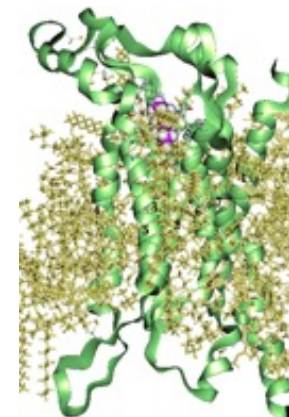
- in liquid: gustative receptors → tastes (clustered in five classes)
- in air: olfactive receptors → odors (millions)



Chien et al. Science, 2010



Kalani et al. PNAS, 2004



Floriano et al. PNAS, 2000



Combinatorial selectivity and the artificial olfaction conjecture

Array of olfactory neurons:

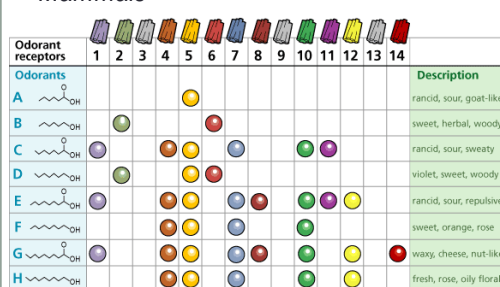
- Many ORNs each with a different pattern of sensitivity
- Protein chemistry offer a biologically efficient method to build different ORNs with the same building blocks

Array of gas sensors:

- Many sensors each with a different pattern of sensitivity
- Synthesis of organic and inorganic materials may provide the basis for the development of suitable sensors.

Combinatorial selectivity of OSN

Mammals



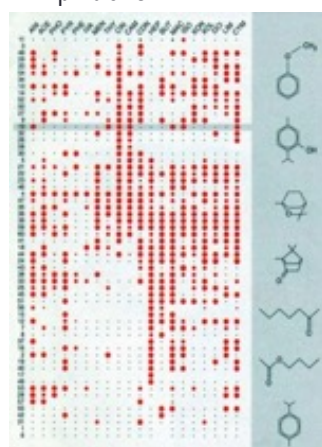
Malnic et al, Cell, 1999

Insects

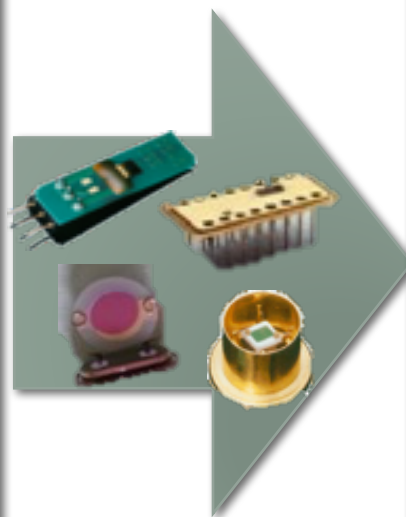


Hallam et al. Cell, 2004

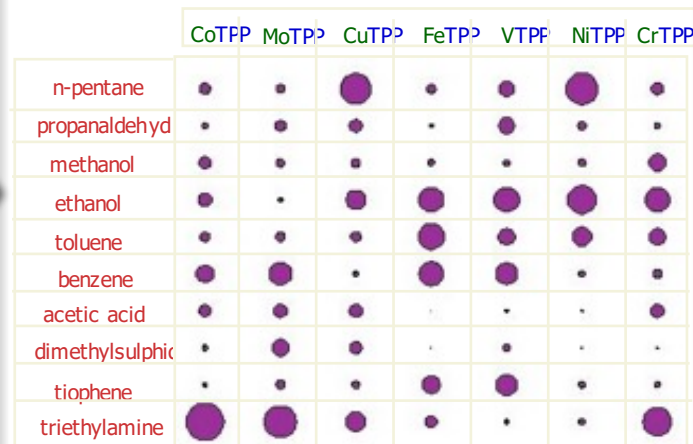
Amphibians



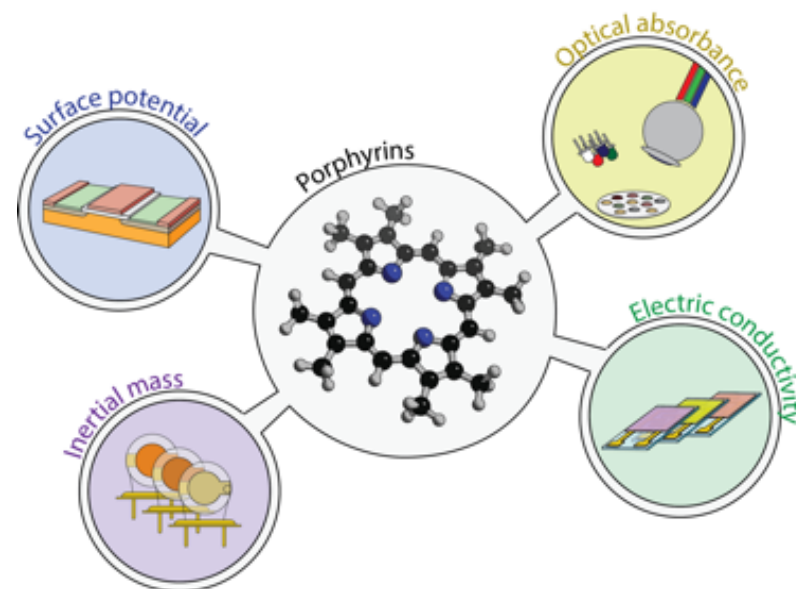
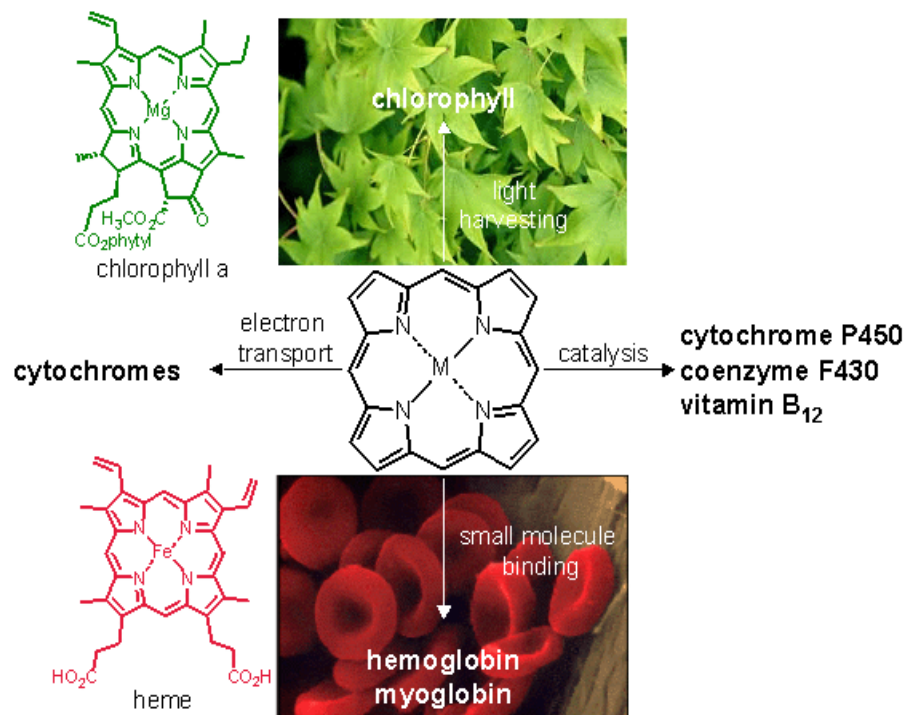
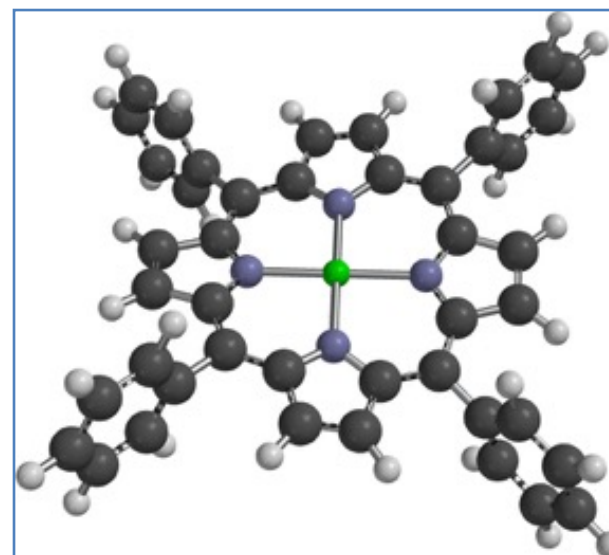
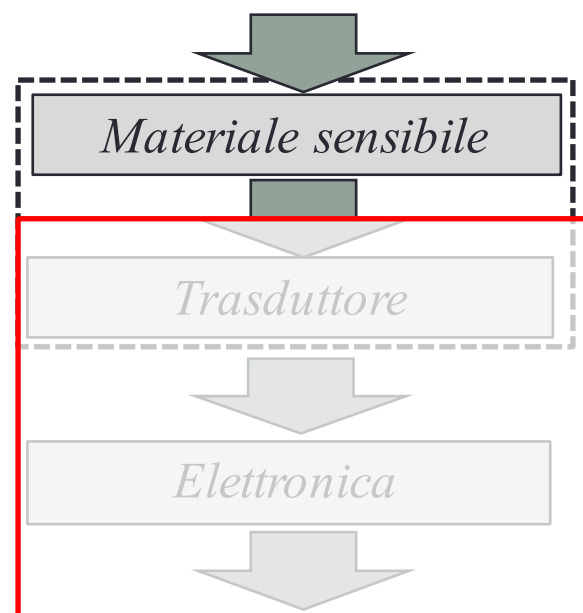
Sicard and Holley Brain Res., 1984



Sensor Array



C. Di Natale et al. Sens. Act. B 2007

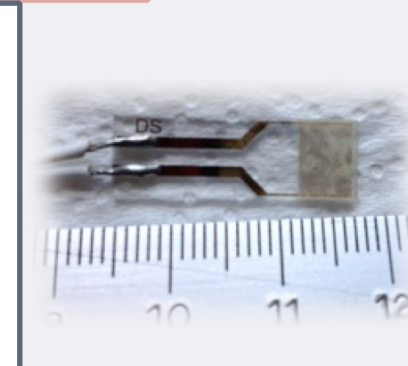
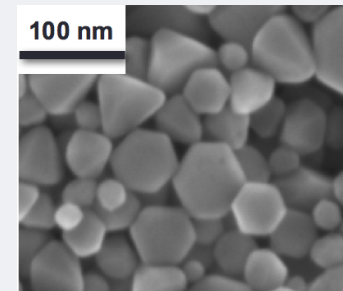
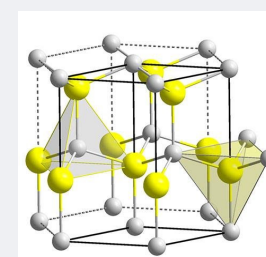
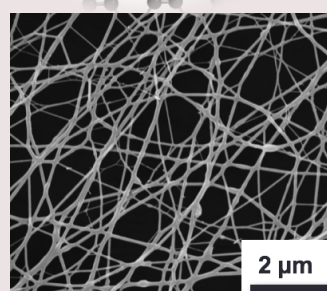
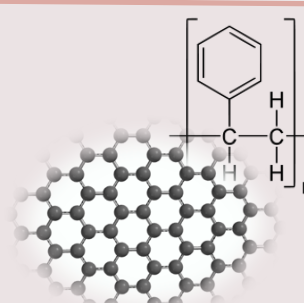
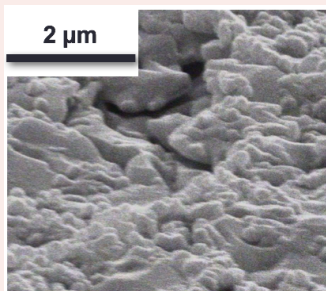
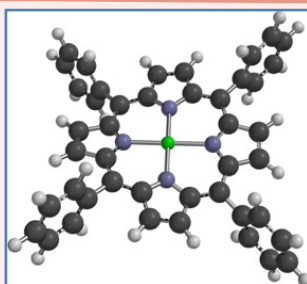
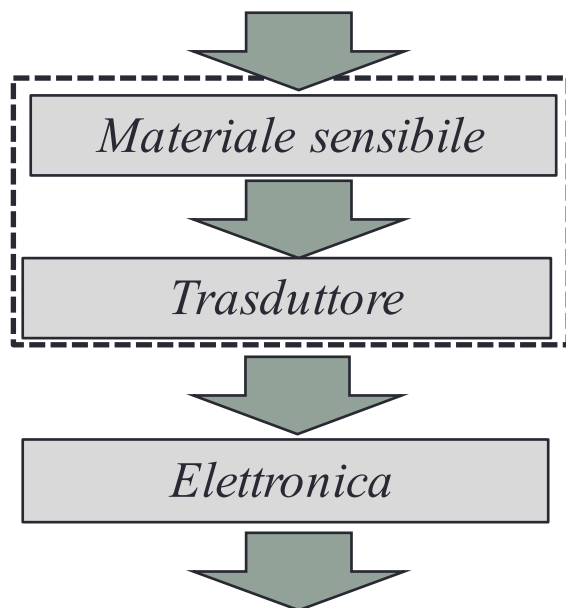


CHEMICAL
REVIEWS

Review
pubs.acs.org/CR

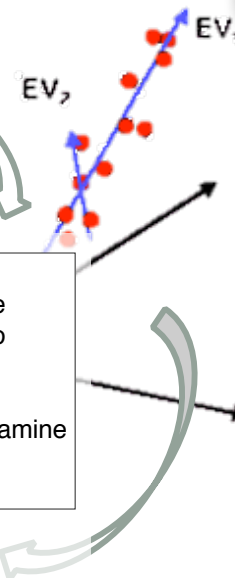
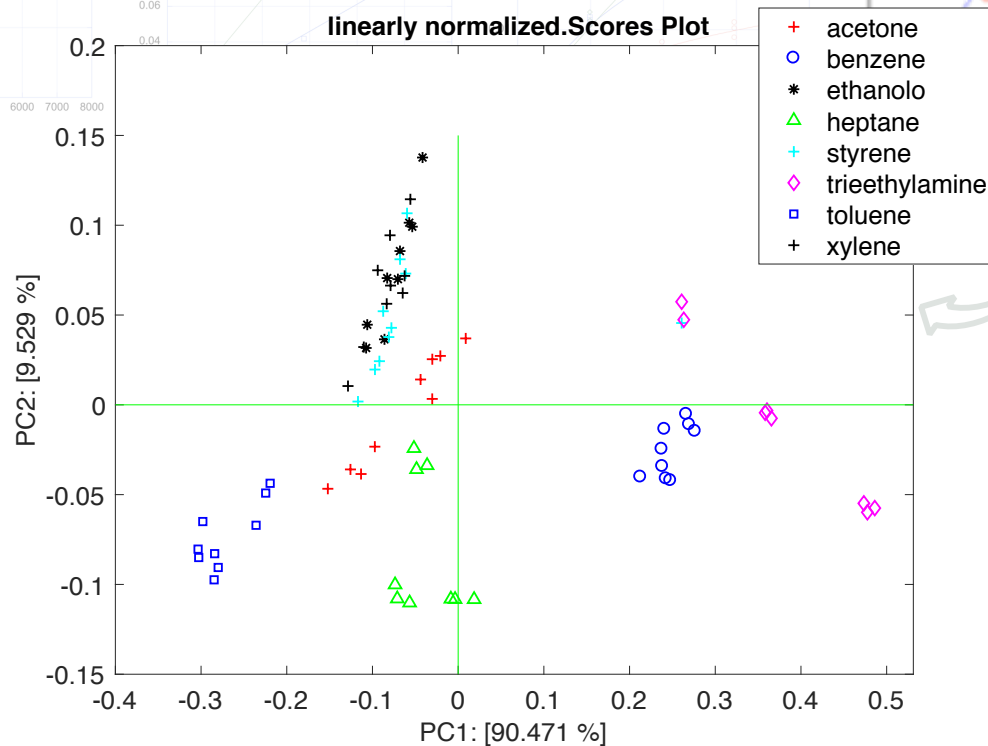
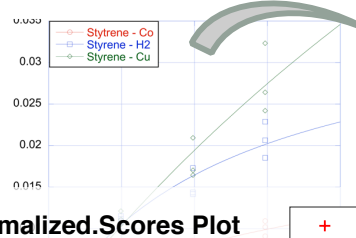
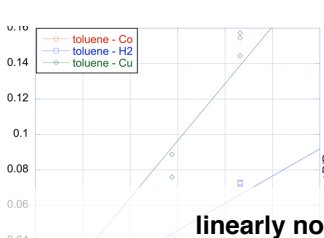
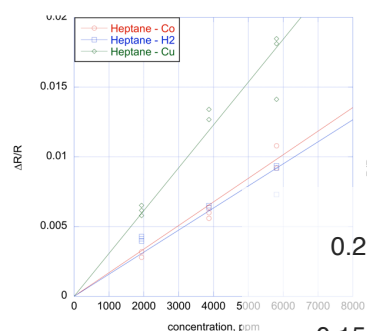
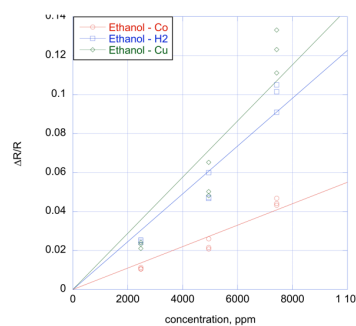
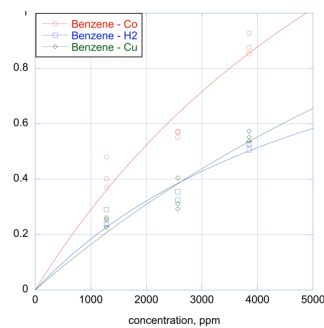
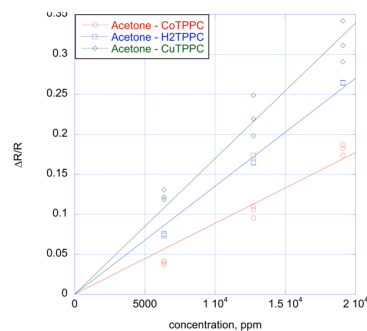
Porphyrinoids for Chemical Sensor Applications

Roberto Paolesse,^{*,†} Sara Nardis,[†] Donato Monti,[‡] Manuela Stefanelli,[‡] and Corrado Di Natale^{*,‡}





Selettività combinatoria: ZnO-TPP sensor array



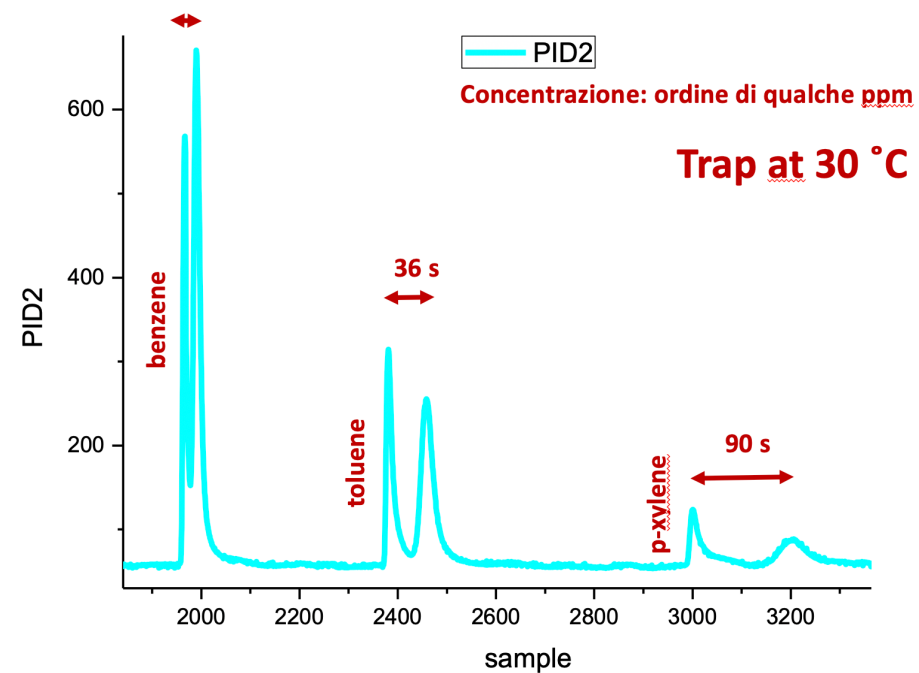
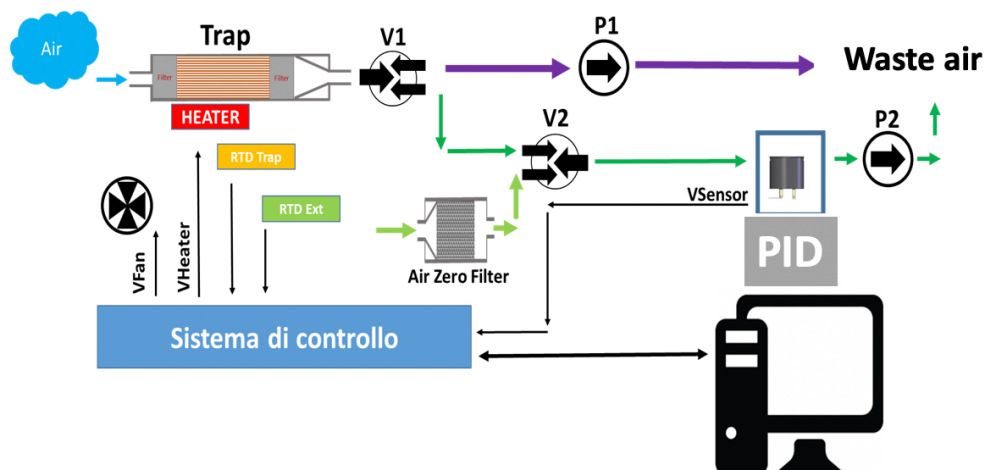
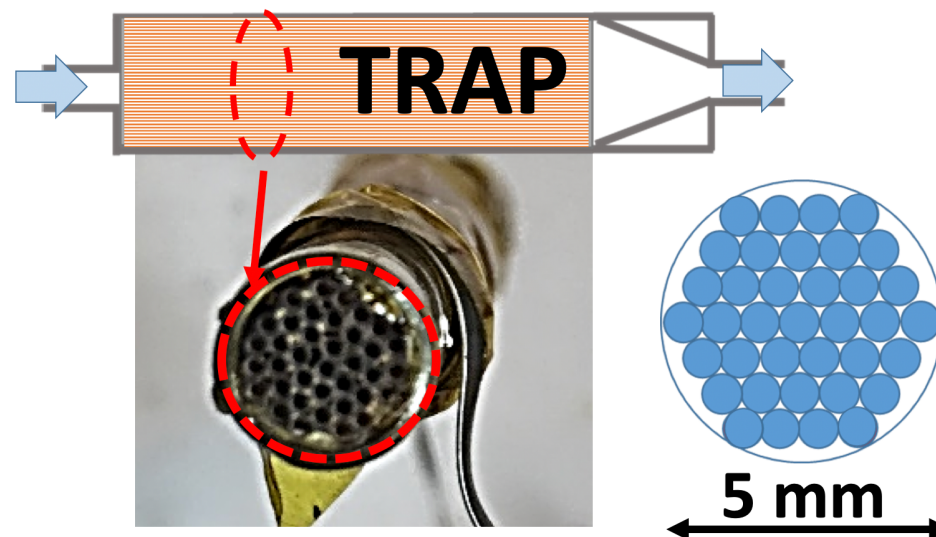


Pre-condizionamento

Materiale sensibile

Trasduttore

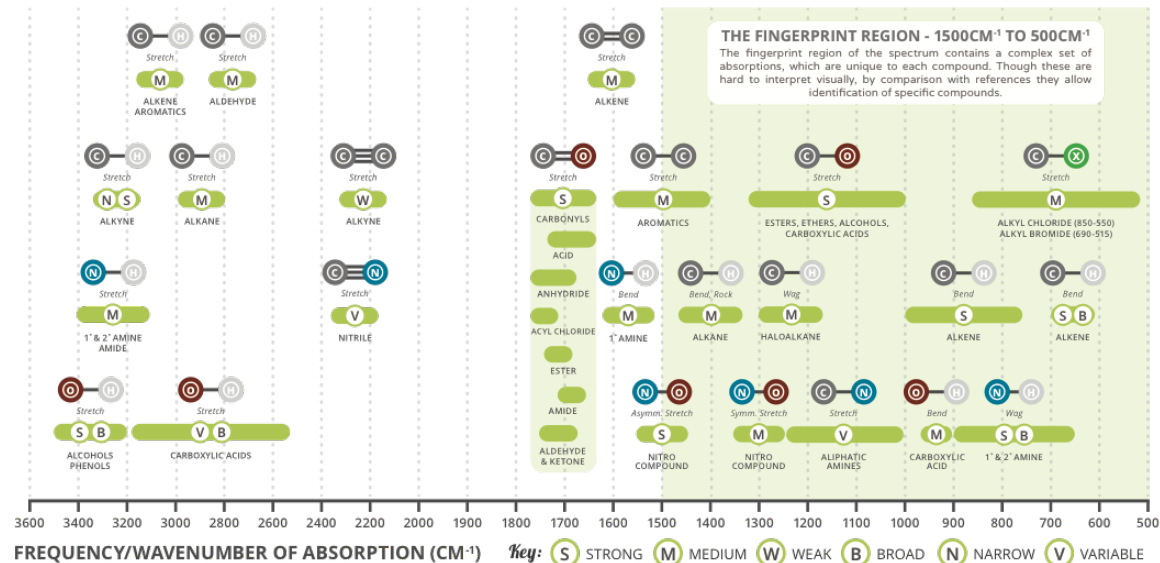
Elettronica



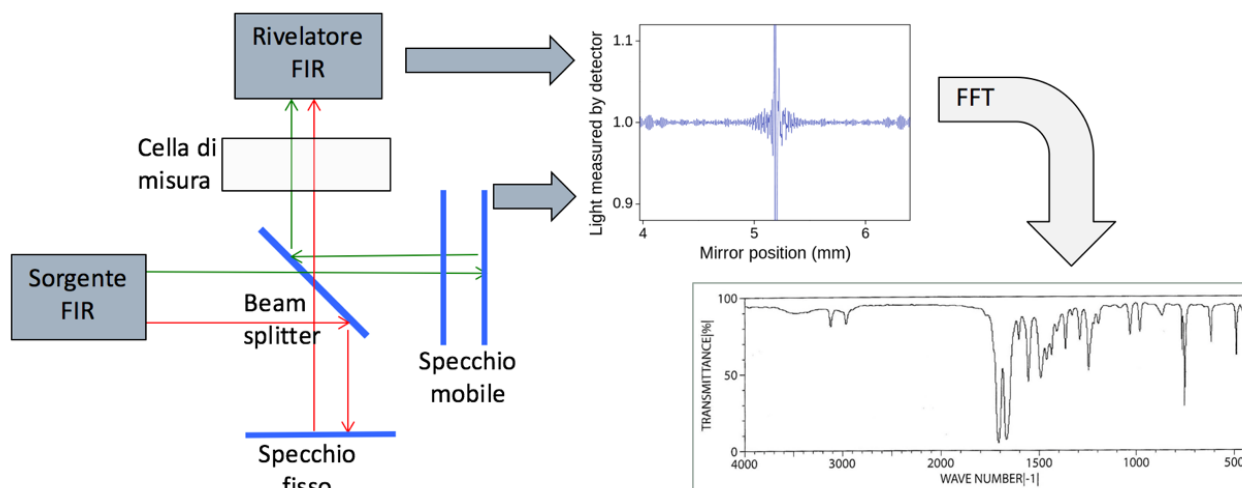
Spettroscopia IR

ANALYTICAL CHEMISTRY - INFRARED SPECTROSCOPY

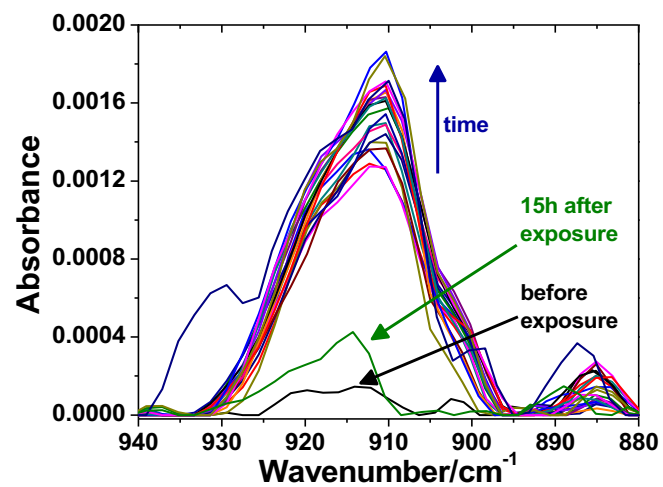
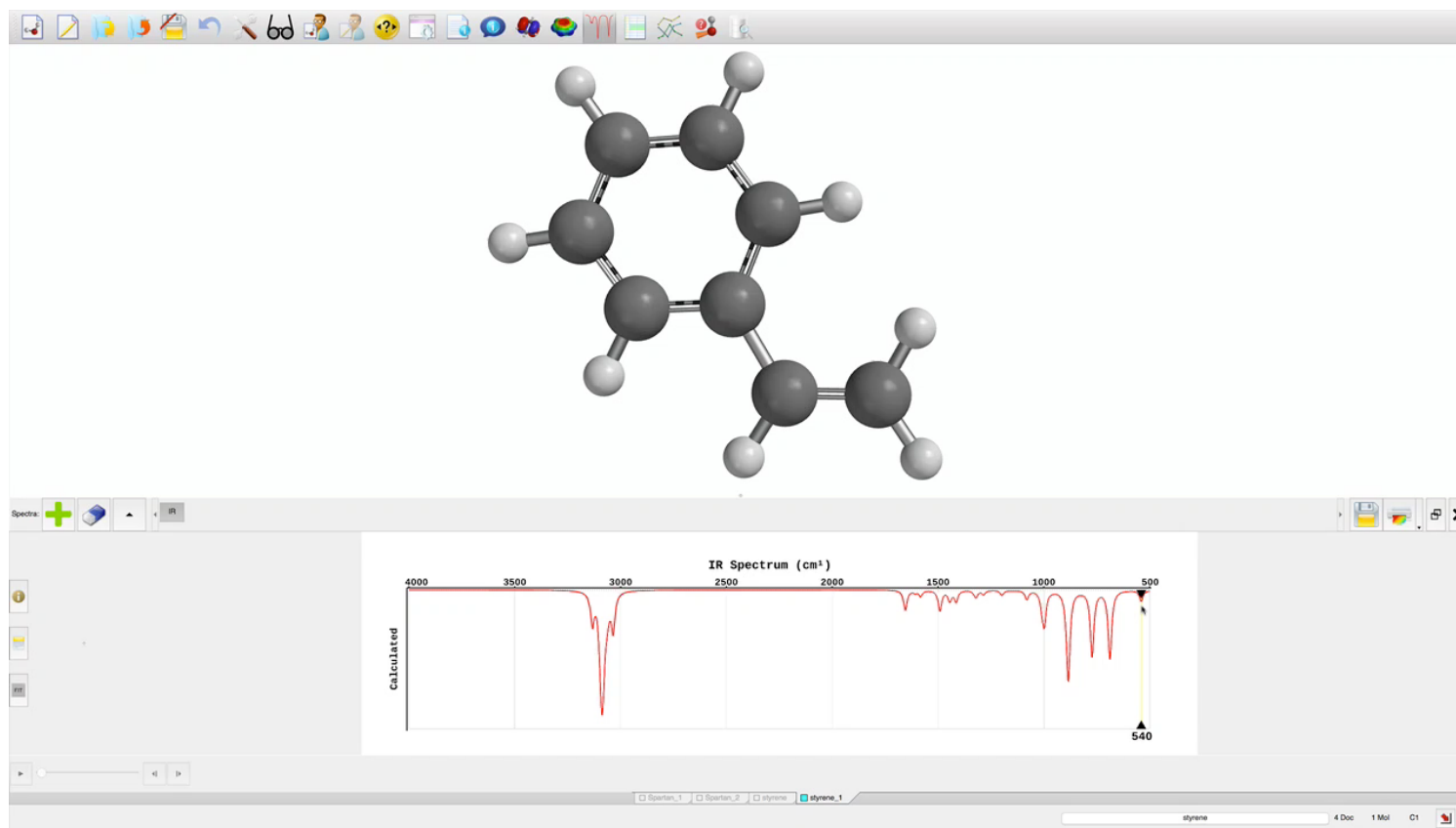
Commonly referred to as IR spectroscopy, this technique allows chemists to identify characteristic groups of atoms (functional groups) present in molecules.



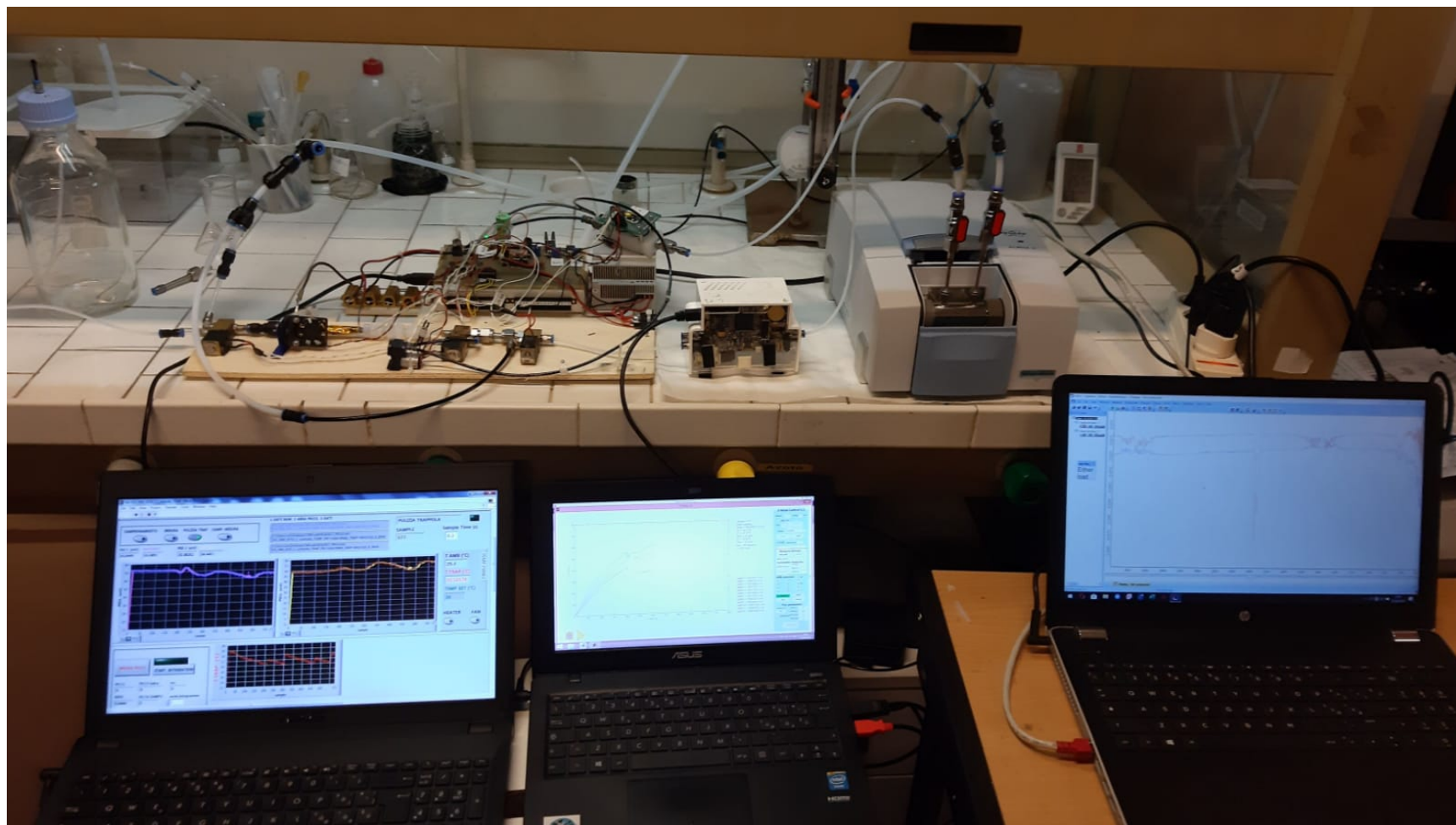
Infrared frequencies make up a portion of the electromagnetic spectrum. If a range of infrared frequencies are shone through an organic compound, some of the frequencies are absorbed by the chemical bonds within the compound. Different chemical bonds absorb different frequencies of infrared radiation. There are a number of characteristic absorptions which allow functional groups (the parts of a compound which give it its particular reactivity) to be identified. This graphic shows a number of these absorptions.



Spettroscopia IR: Styrene



Sistema Integrato



Conclusioni

- Risultati principali:
 - Sensori ottimizzati per la selettività combinatoria
 - Materiali sensibili ibridi
 - porfirine + polimeri + grafene
 - Porfirine + ossidi metallici
 - materiali nanostrutturati: incremento superficie/volume
 - Strutture elettrofilate, nanoparticelle e materiali mesoporosi
 - Realizzazione di array di sensori
 - Dimostrazione del principio della selettività combinatoria
 - Riconoscimento di analiti di interesse
 - Identificazione di microorganismi in laboratorio e in ambiente
 - Applicazione di tecnico spettrofotometriche alla analisi dei VOCs
 - Sistema portatile di arricchimento del campione gassoso e di separazione dei VOCs
 - Dimostrazione della integrabilità dei sistemi sviluppati
- Sviluppi futuri
 - Applicazione in un contesto reale
 - Integrazione con sistemi wireless mobili e indossabili
 - Implementazione di algoritmi di machine learning configurabili nei differenti scenari applicativi