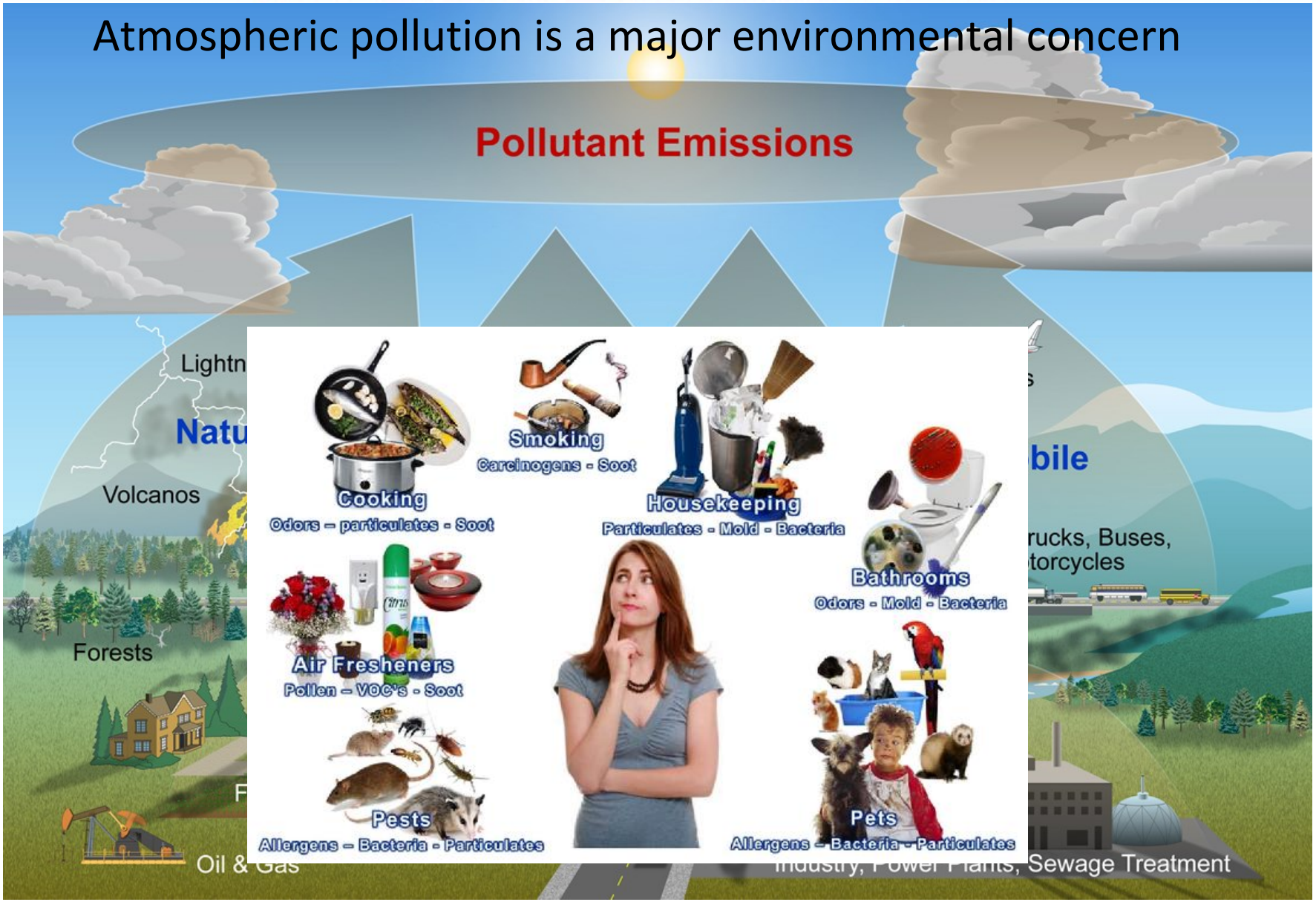
FTIR spectroscopy as a tool for quantitative evaluation of volatile organic compounds (VOCs) in air

Giancarlo Della Ventura[1,2*], Francesco Radica[1], Plinio Innocenzi[3], Luca Malfatti[3], Augusto Marcelli[2,4]

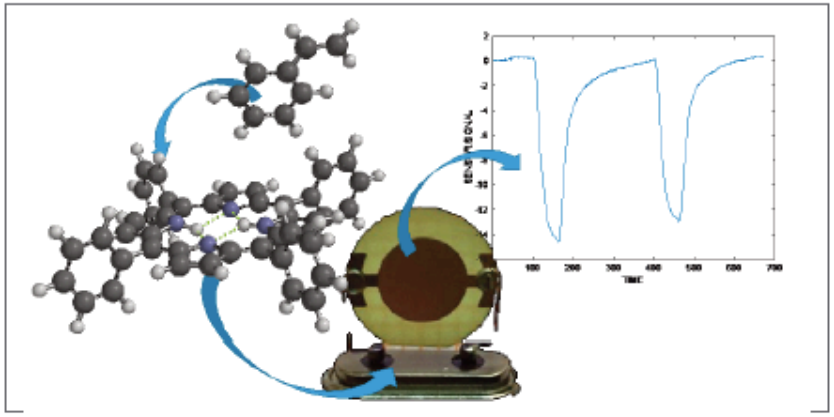
[1]Department of Science, University of Roma Tre, Largo San L. Murialdo 1, 00146 Rome (Italy)
[2]INFN Laboratori Nazionali di Frascati, Via E. Fermi 40, 00044 Frascati, Italy
[3]Institute of Material Science and Nanotechnology, Sassari, Italy
[4]RICMASS, Via dei Sabelli 119A, 00185 Rome, Italy

Atmospheric pollution is a major environmental concern



Indoor pollution in work places

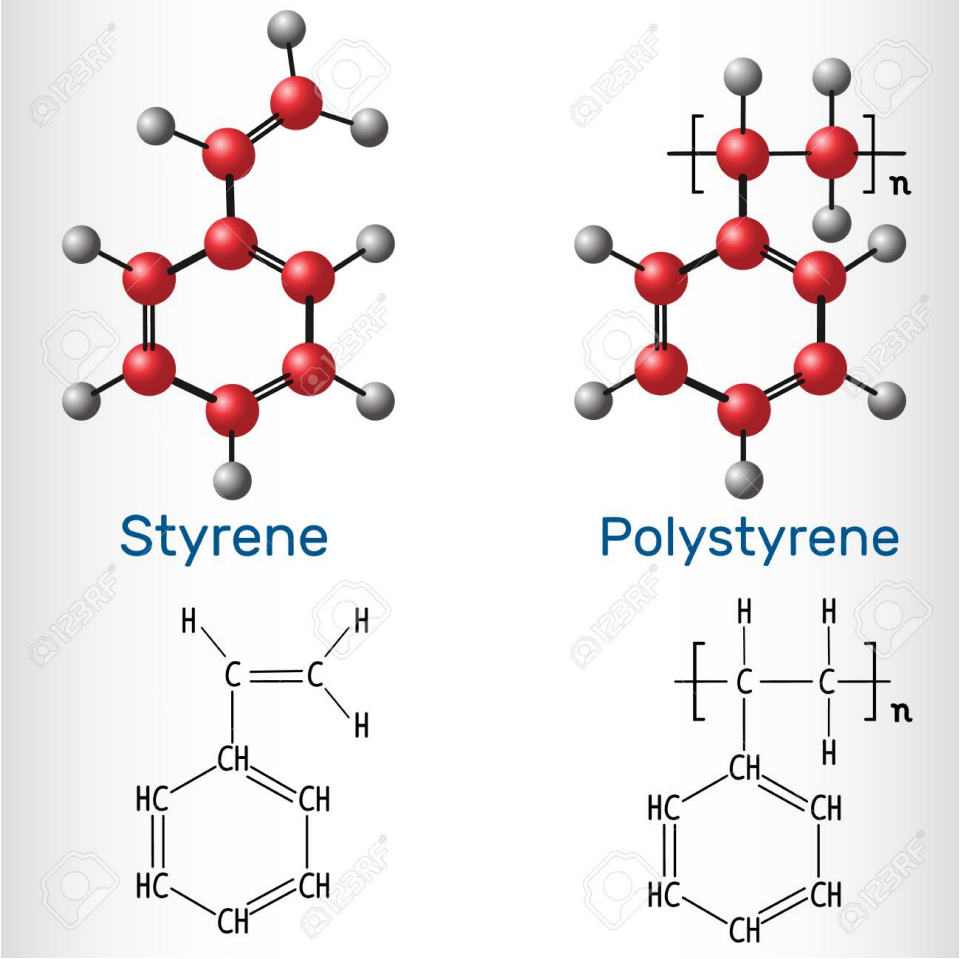
Sensor systems for volatile compounds and micro-organisms in working sites



edited by
Giancarlo Della Ventura - Corrado Di Natale - Antonella Macagnano

Our project

Università di Roma Tor Vergata
ROMA TRE UNIVERSITÀ DEGLI STUDI
INAIL ISTITUTO NAZIONALE PER L'ASSICURAZIONE CONTRO GLI INFORTUNI SUL LAVORO
INFN Istituto Nazionale di Fisica Nucleare
CNR-IIA



What is it? Under normal conditions is a colourless to pale yellow liquid that evaporates quickly

What is used for? Large amounts are produced to make important materials, inluding rubber, resins, fiberglass, food-packaging, colours etc.

How may it affect human health? Styrene may enter the body by inhalation, contaminated water or food, dermal contact. Adverse effects include problems to the central nervous system (depression, headache, loss of concentration, fatigue, nausea etc. but also irritation to eyes, skin etc.

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Global styrene oligomers monitoring as new chemical contamination from polystyrene plastic marine pollution

Bum Gun Kwon[a,*], Koshiro Koizumi[b], Seon-Yong Chung[c], Yoichi Kodera[d], Jong-Oh Kim[e], Katsuhiko Saido[d,**]

[a] Department of Bioenvironmental & Chemical Engineering, Chosun College of Science & Technology, 309-1 Pilmundae-ro, Dong-gu, Gwangju 501-744, Republic of Korea
[b] Department of Chemistry, College of Science and Technology, Nihon University, 7-24-1, Narashinodai, Funabashi-shi, Chiba 274-8501, Japan
[c] Department of Environment and Energy Engineering, College of Engineering, Chonnam National University, 77 Yongbong-ro, Buk-gu, Gwangju 500-757, Republic of Korea
[d] National Institute of Advanced Industrial Science and Technology (AIST), 16-1 Onogawa Tsukuba, Ibaraki 305-8569, Japan
[e] Department of Civil and Environmental Engineering, College of Engineering, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 133-791, Republic of Korea

HIGHLIGHTS

- This study reports styrene oligomers (SOs) as a new global pollutant.
- SOs can be leached from the weathering of polystyrene (PS) plastic.
- The high levels of SOs in sandy beaches around the world present the PS plastic pollution.

GRAPHICAL ABSTRACT

ARTICLE INFO

Article history:
Received 13 February 2015
Received in revised form 16 June 2015
Accepted 10 July 2015
Available online 18 July 2015

Keywords:
Styrene oligomers
Polystyrene
Plastic pollution
Leaching
Persistent

ABSTRACT

Polystyrene (PS) plastic marine pollution is an environmental concern. However, a reliable and objective assessment of the scope of this problem, which can lead to persistent organic contaminants, has yet to be performed. Here, we show that anthropogenic styrene oligomers (SOs), a possible indicator of PS pollution in the ocean, are found globally at concentrations that are higher than those expected based on the stability of PS. SOs appear to persist to varying degrees in the seawater and sand samples collected from beaches around the world. The most persistent forms are styrene monomer, styrene dimer, and styrene trimer. Sand samples from beaches, which are commonly recreation sites, are particularly polluted with these high SOs concentrations. This finding is of interest from both scientific and public perspectives because SOs may pose potential long-term risks to the environment in combination with other endocrine disrupting chemicals. From SOs monitoring results, this study proposes a flow diagram for SOs leaching from PS cycle. Using this flow diagram, we conclude that SOs are global contaminants in sandy beaches around the world due to their broad spatial distribution.

http://dx.doi.org/10.1016/j.jhazmat.2015.07.039
0304-3894/

The European UP/VE Resin Association Safe Handling Guide No. 2:

Occupational Exposure to Styrene

The occupational exposure to styrene is considered highly hazardous

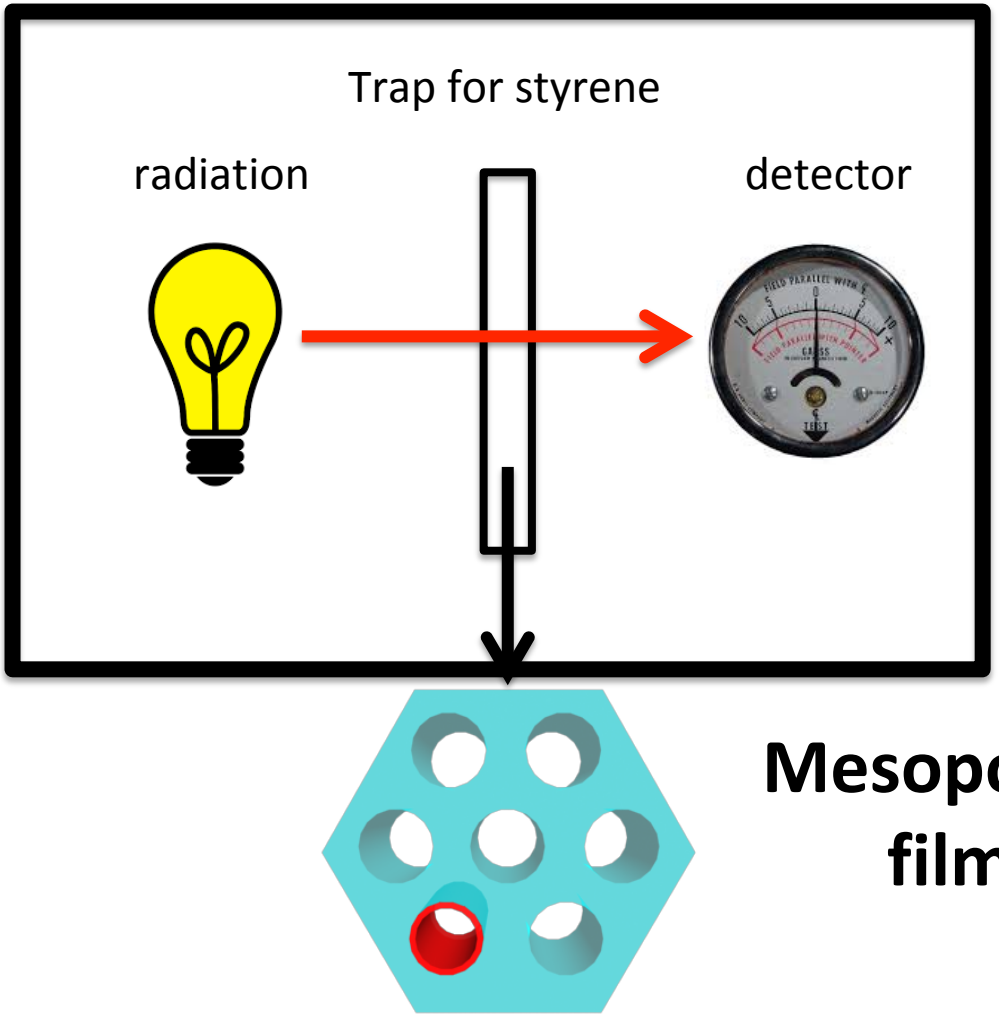
It has been recognized as **carcirogenic** by WHO and included in group 2B substances

Methods for monitoring exposure to styrene

Badge monitoring and data analysis system for recording workplace styrene

Combined Photo-Ionisation Detection (PID) and gas monitoring system.

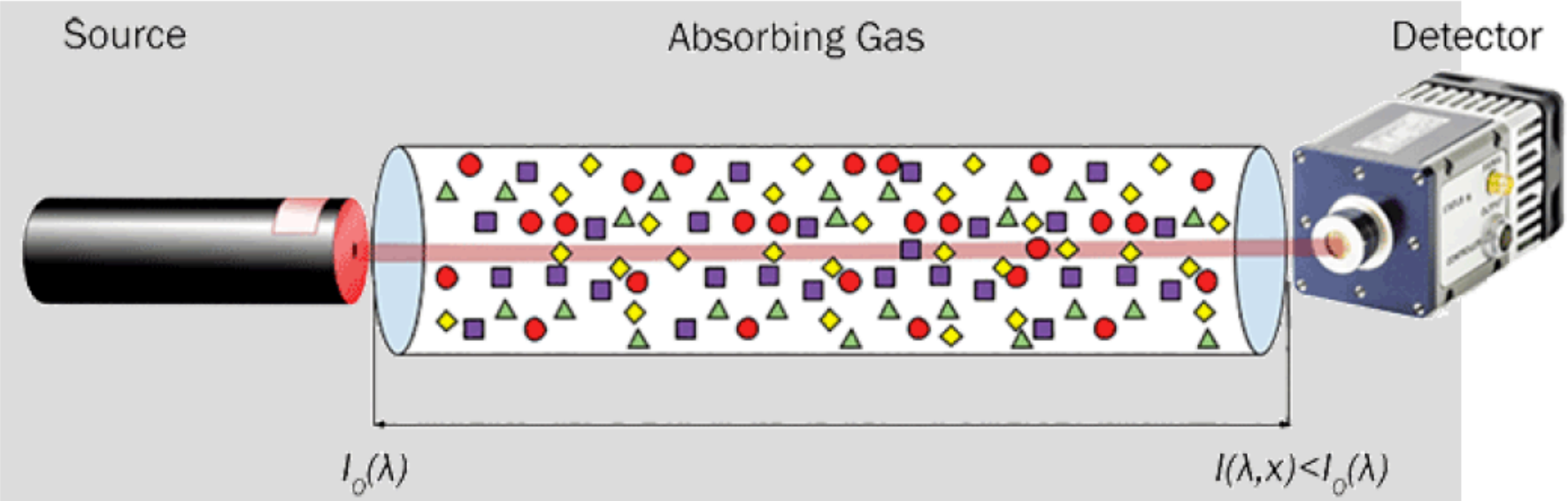
We studied two routes for developing a novel sensor for styrene: gas trapping and detection



Mesoporous films

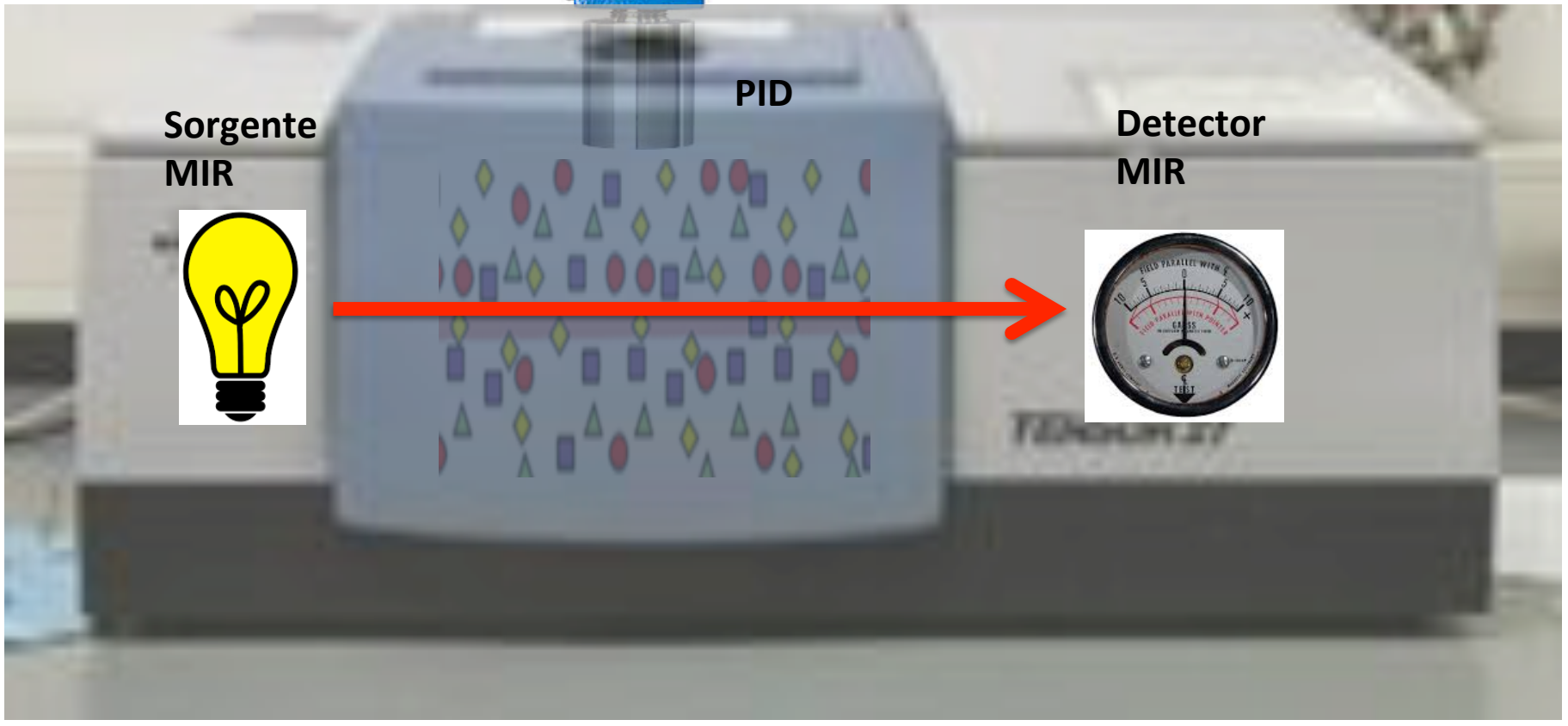
Detection system for rela-time monitoring via MIR spettroscopy

Goal: design and test of a compact and (relatively) low-cost device

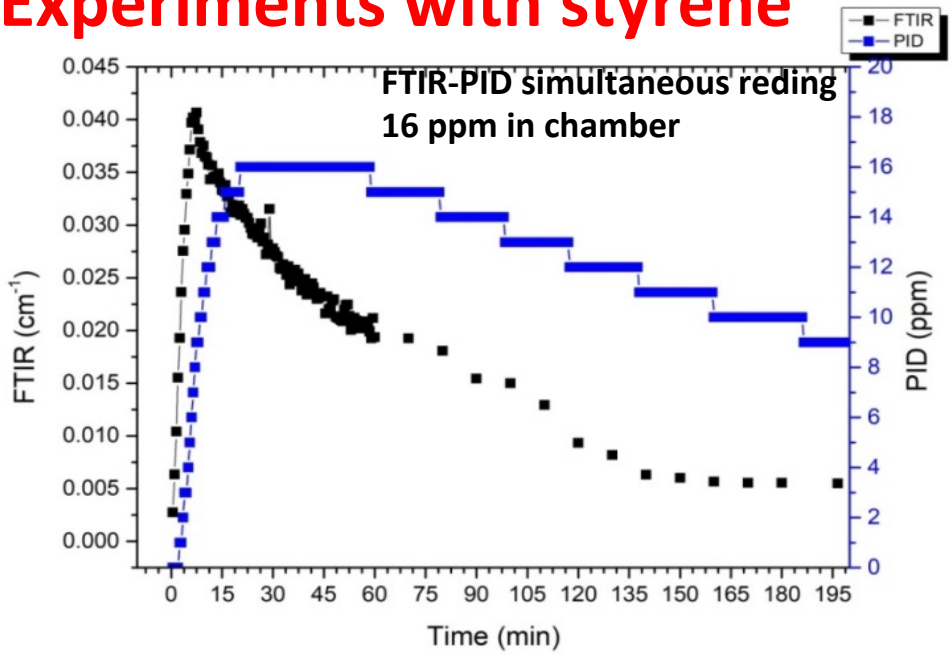


Depiction of a typical gas analyzer arrangement.

Schematic layout of the lab

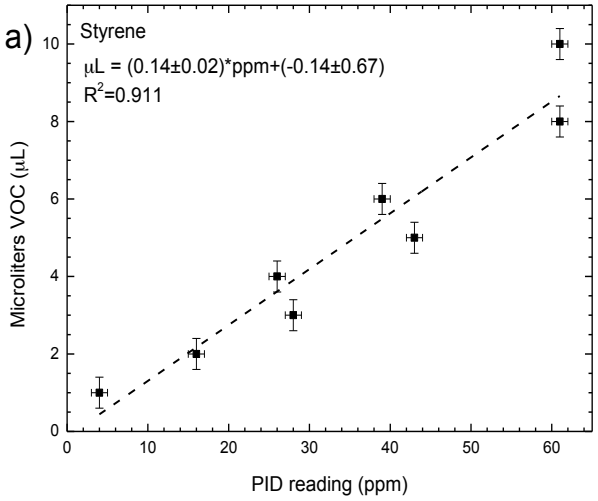


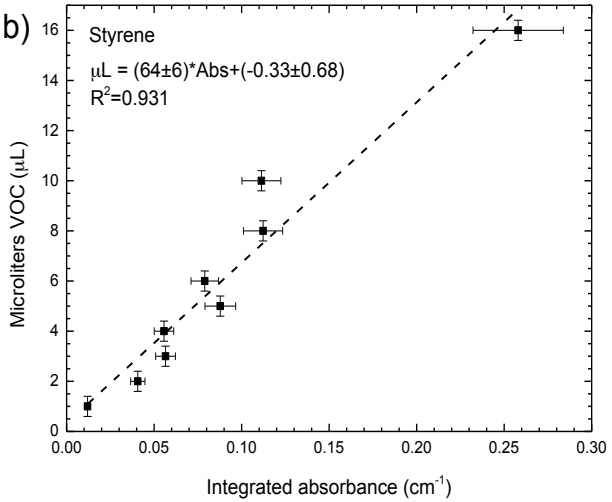
Experiments with styrene

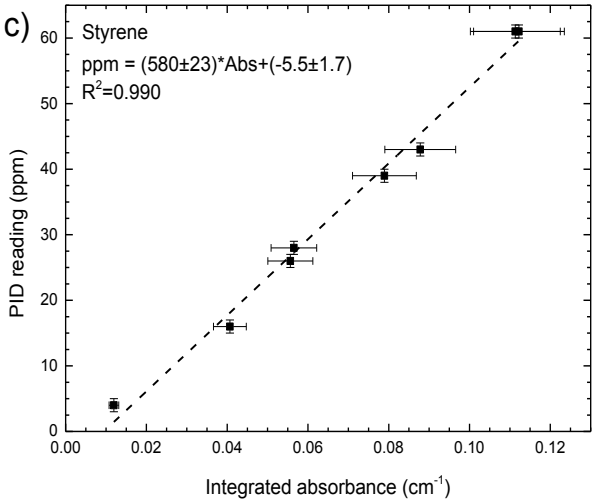


stirene (µL)	FTIR Abs (cm^{-1})	PID (ppm)
1	0.012	4
2	0.041	16
3	0.057	28
4	0.056	26
5	0.088	43
6	0.079	39
8	0.112	61
10	0.111	61
16	0.258	>100

FTIR calibration curve for styrene



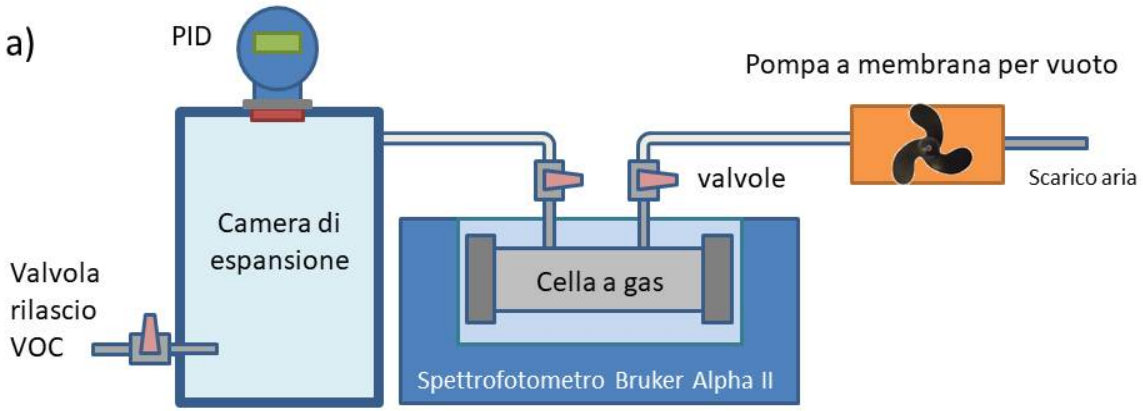


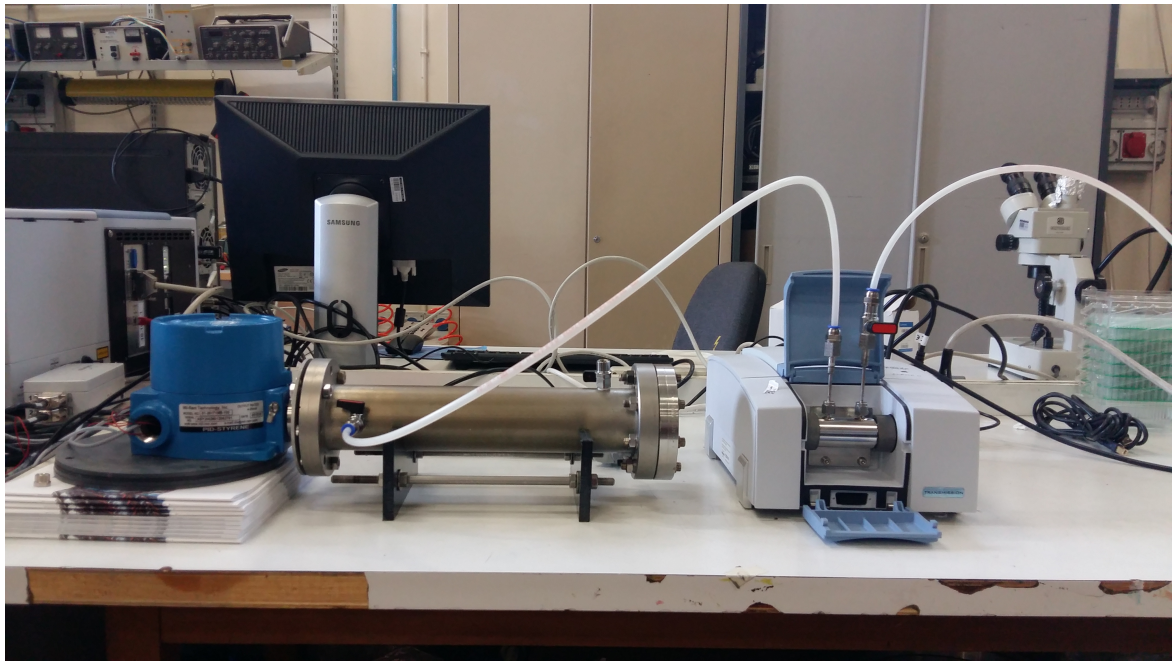


Toward a portable FTIR system

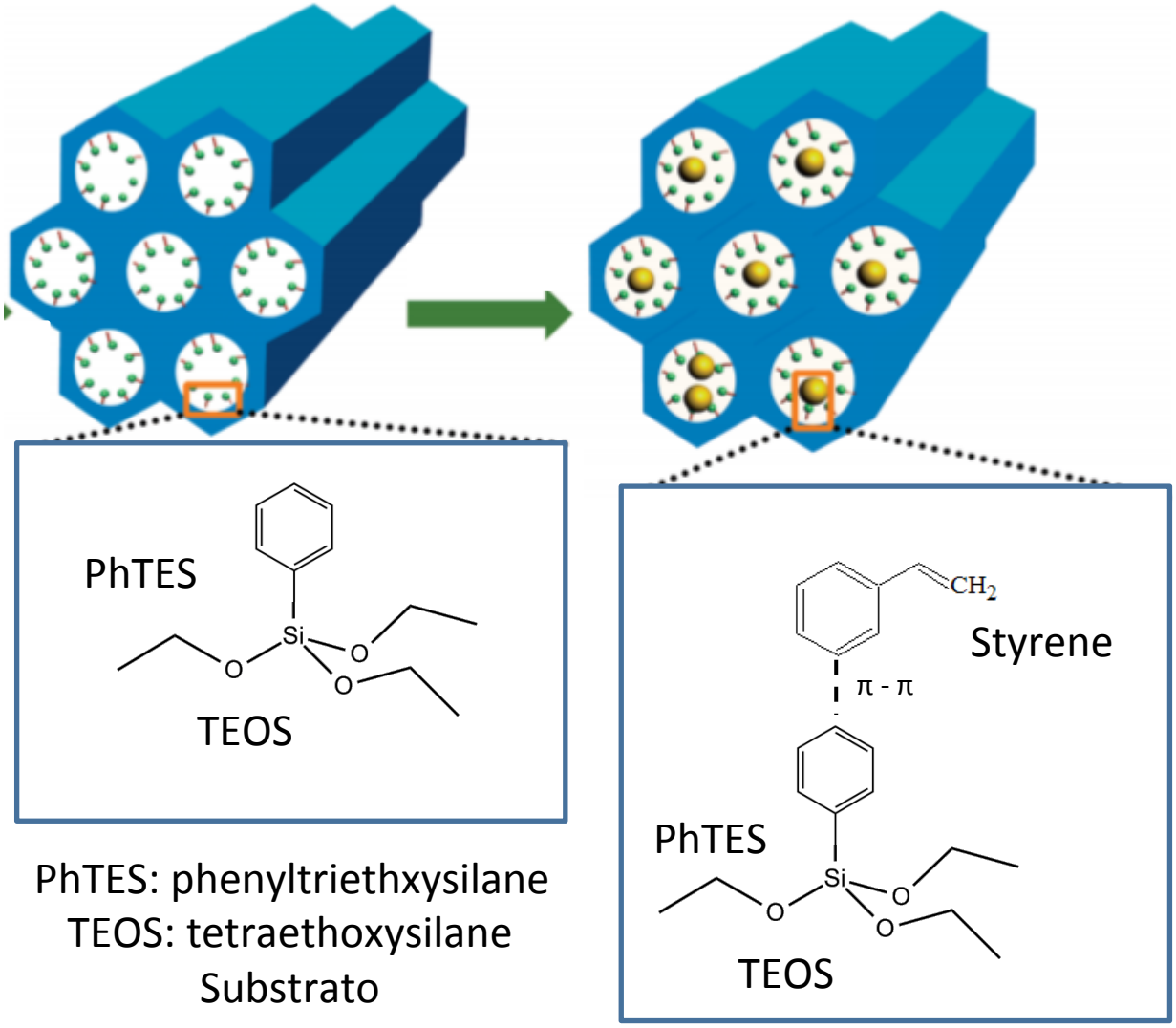
QuickSnap Modules for gas analysis

Different dedicated sampling modules with integrated gas cell allow the measurement of gases and gaseous mixtures by transmission IR spectroscopy. The ALPHA sampling module with 7 cm gas cell is characterized by a minimized cell volume that requires little sample amounts and allows fast gas exchange. The module with 4.8 m gas cell provides the sensitivity to detect low concentrations. Heating options prevent condensation of gases in the cell.


a)
PID
Pompa a membrana per vuoto
valvole
Scarico aria
Camera di espansione
Valvola rilascio VOC
Cella a gas
Spettrofotometro Bruker Alpha II



Design and test of mesoporous hybrid PhTES/TEOS silica films



PhTES: phenyltriethxysilane
TEOS: tetraethoxysilane
Substrato

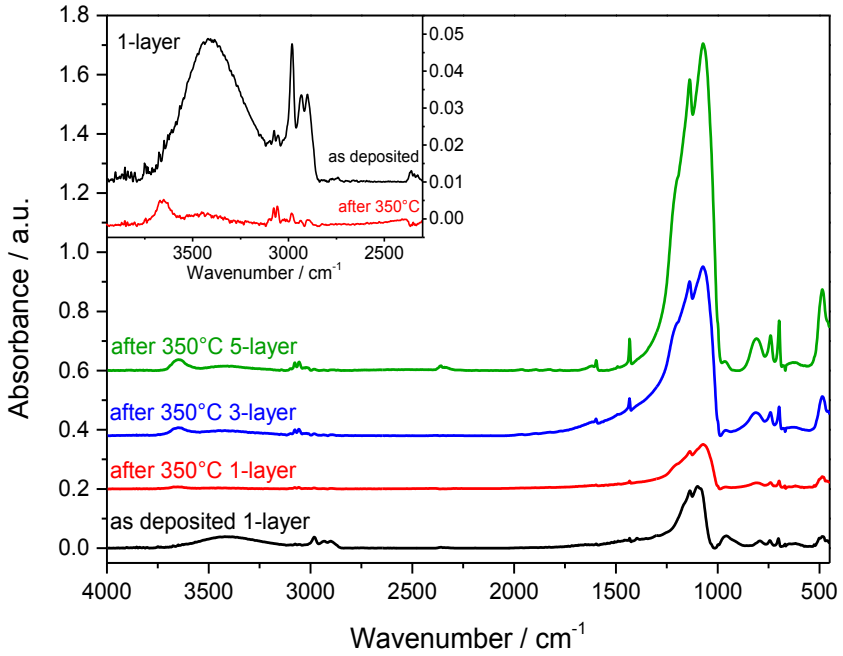
Weak bond with the aromatic group of styrene

We tested different strategies for the nanofilm deposition

PhTES/TEOS Ratio	0.25:1	0.5:1	1:1
F127 (tensiattivo)	138 mg	138 mg	138 mg
TEOS	1 ml	1 ml	1 ml
PhTOS	0.27 ml	0.54 ml	1.08 ml
ETOH (etanolo)	8.405 ml	8.135 ml	7.595 ml
H2O	0.3 ml	0.3 ml	0.3 ml
HCl 2N	0.025 ml	0.025 ml	0.025 ml
Totale	10 ml	10 ml	10 ml

- Different solutions with different PhTES:TEOS
- Best choice 0.5:1

- Different layer number
- 2 thermal treatments to eliminate reaction chemicals
- Products studied with FTIR



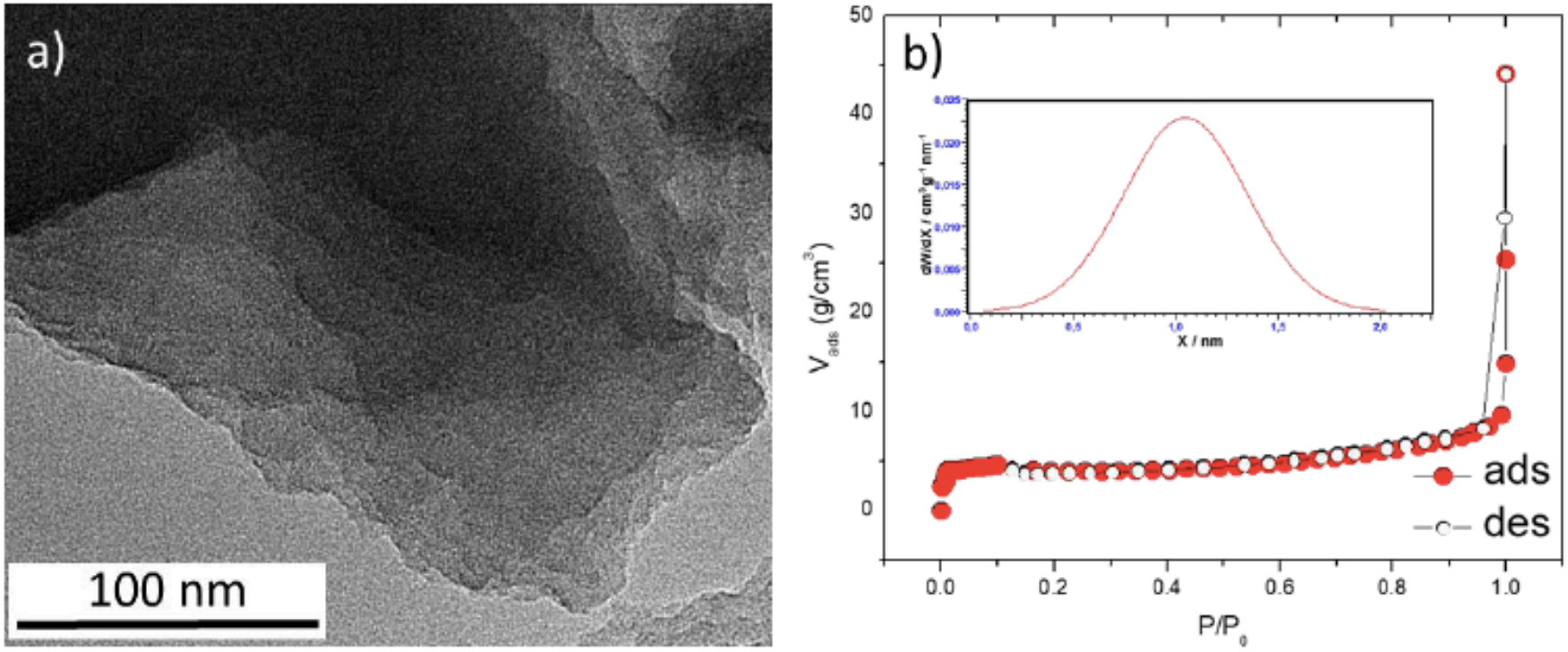
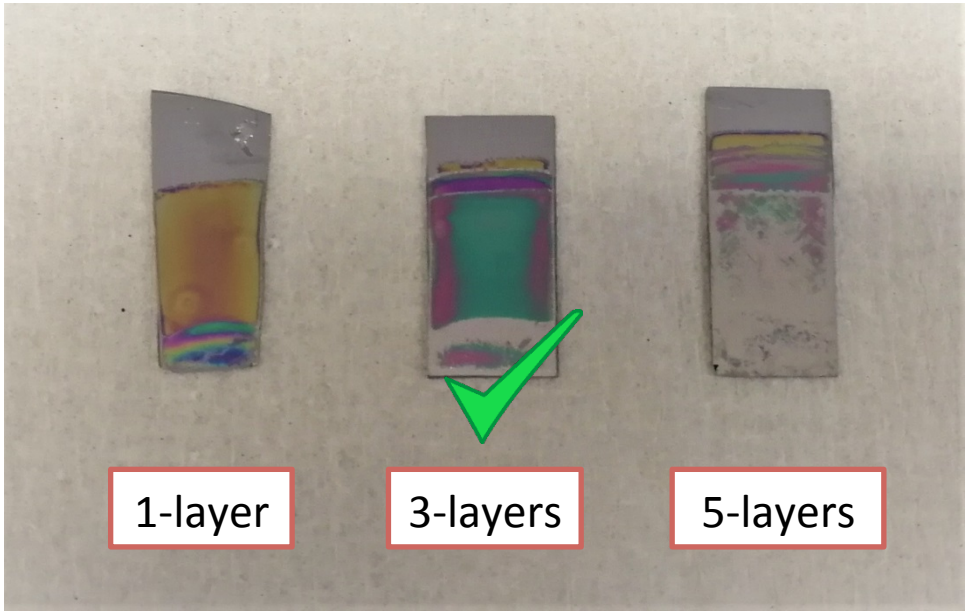


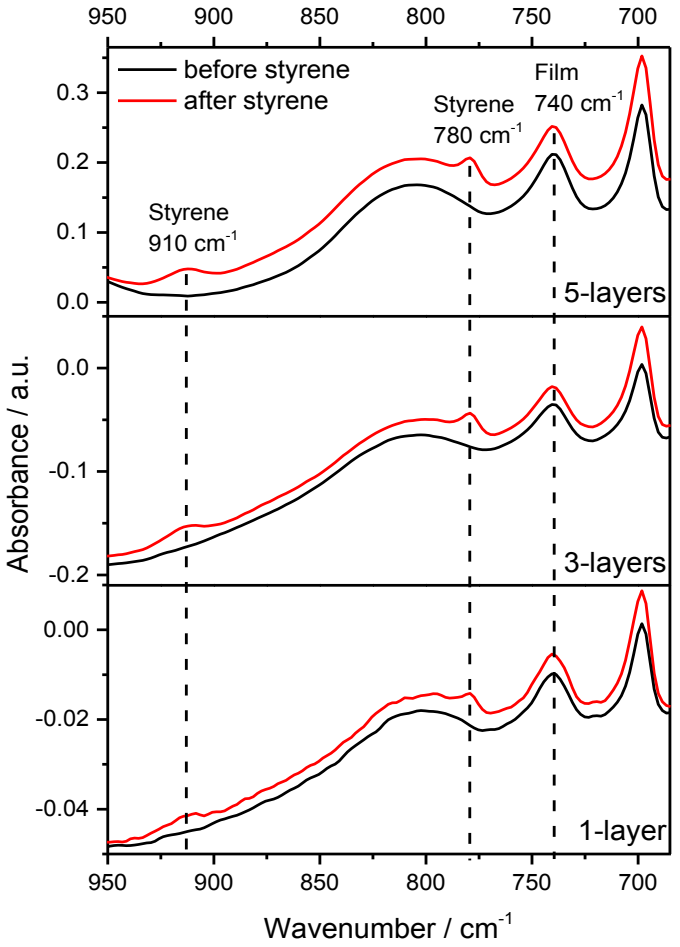
Figure 3. a) Representative TEM image of the 1-layer film after thermal treatment. b) Nitrogen sorption isotherms of the hybrid materials, obtained from the sol used for film deposition, after treatment at 350°C. The inset shows the Dubinin Stoeckli fit of the curve.

From ellipsometry:

- One layer: 250 nm
- Three layers 740 nm

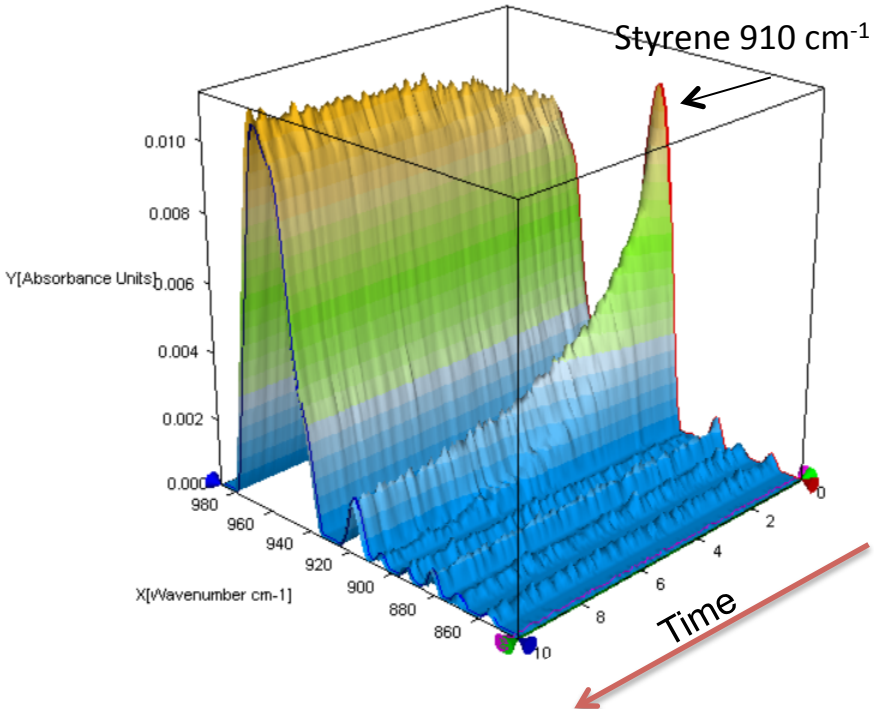


60 min in 70 ppm styrene atmosphere



Desorption experiments

The film is exposed for 1 hour to a styrene atmosphere and than measured every 30 sec for one hrs



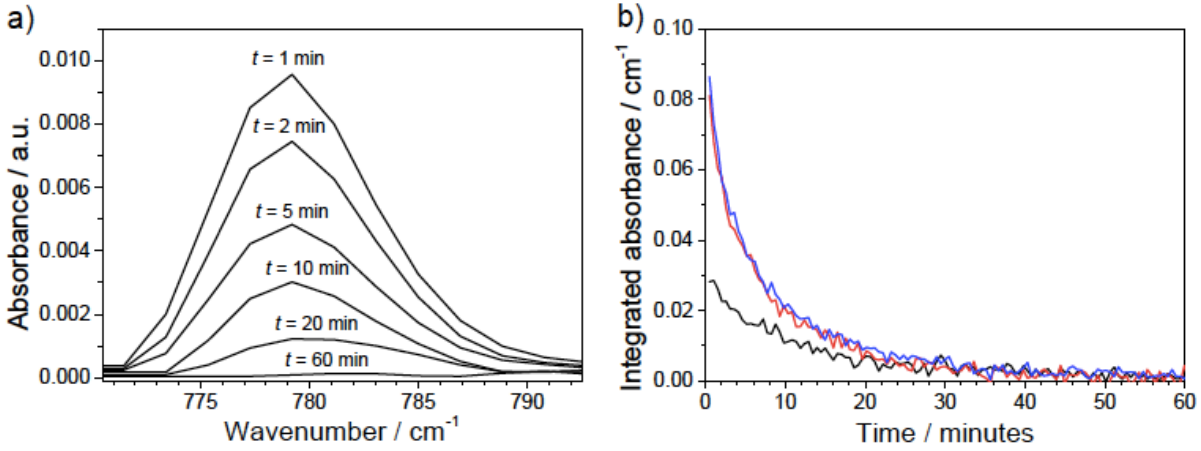
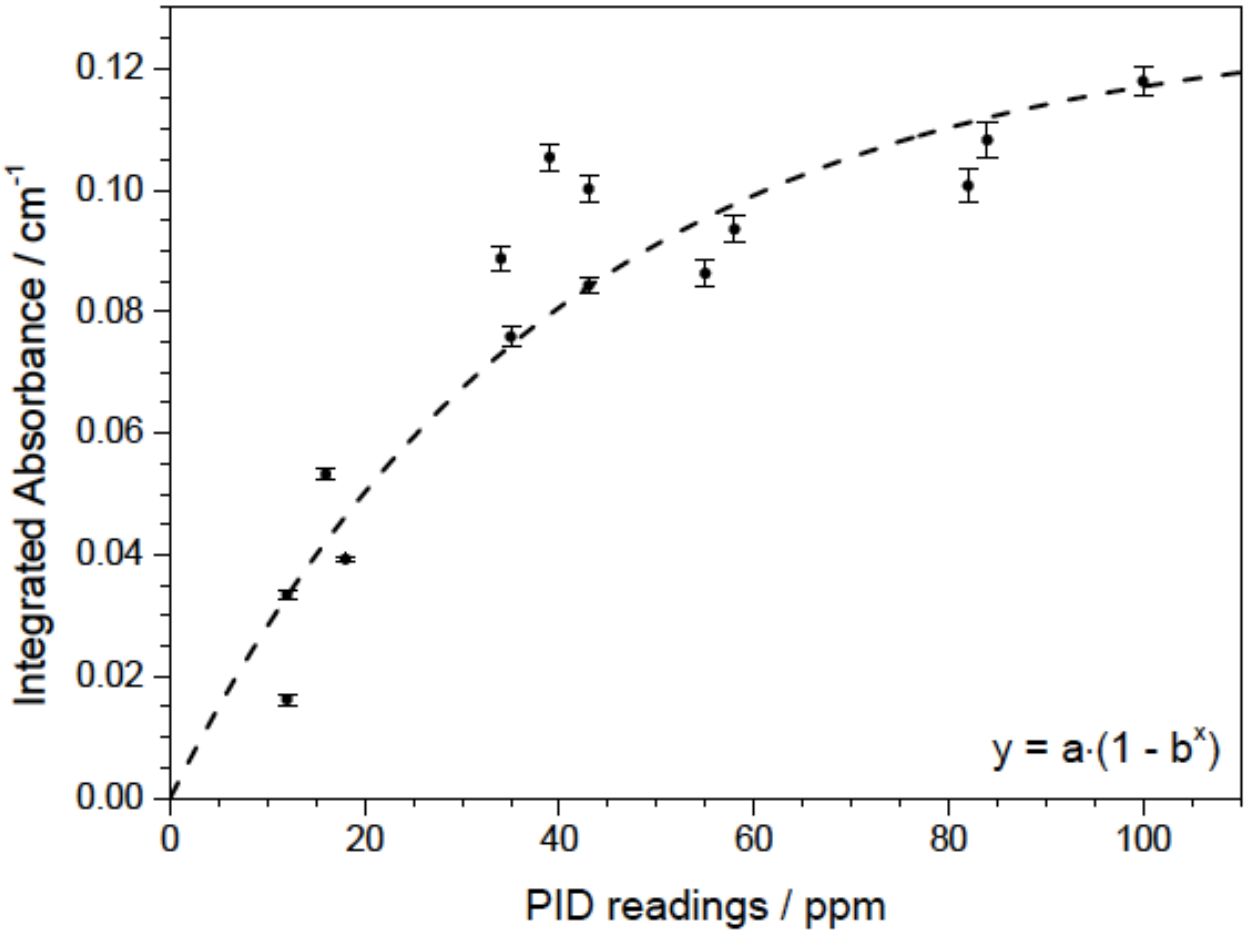


Figure 5. Selected FTIR spectra of the 780 cm^{-1} styrene absorption band at different desorption times, background correction is applied (a). Desorption curves for the 780 cm^{-1} styrene band as a function of time. The experiments have been performed on the same film (sample 1) exposed each time to a different styrene concentration (12 ppm black line, 34 ppm red line and 58 ppm blue line) (b).

Styrene uptake at different concentrations




Thanks for your attention