



**Ceramics & Composites Laboratory (CCL)**  
**Department of Materials Science and Engineering**  
**Hierarchically Porous and Hybrid Materials Group,**

Michael A Karakassides

<http://www.materials.uoi.gr/ccl/>

## Hierarchically Porous and Hybrid Materials Group, (HPHM)

- Non-metals, Oxides, Glasses, Graphite, Carbides, minerals, cementitious, reinforced polymers

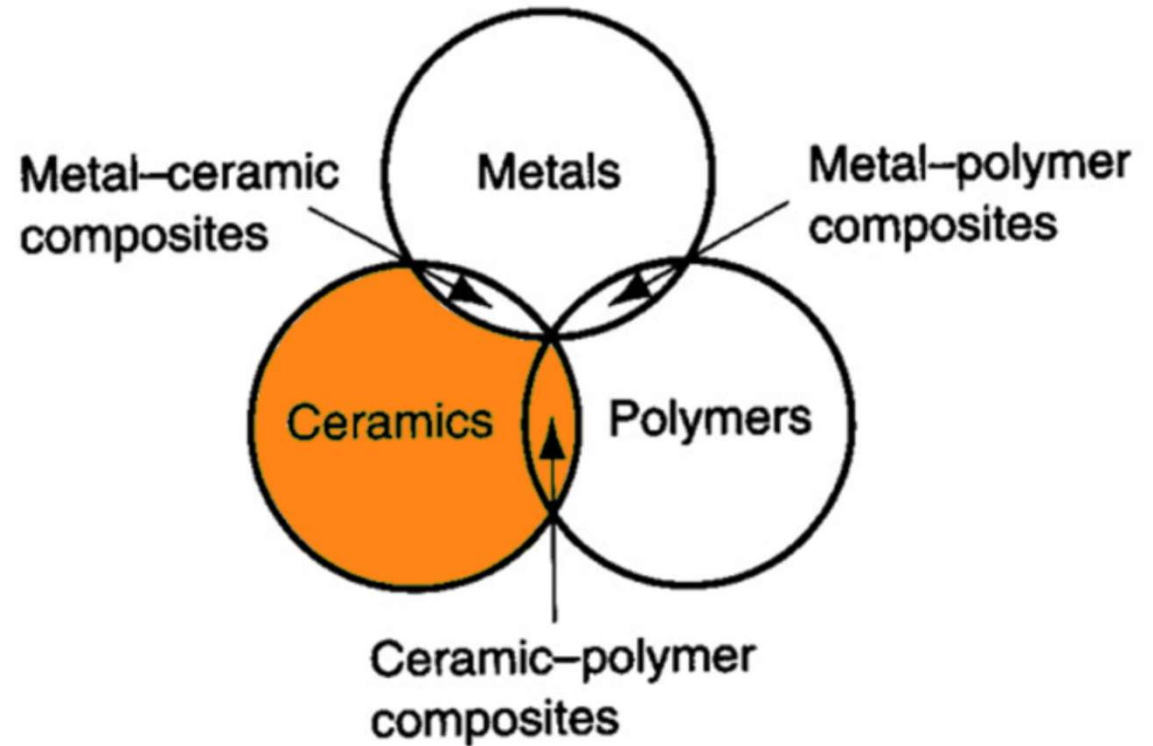
**High Temperature and Construction Materials**

**Layered and Nanoporous Materials**

**Biomaterials and Regenerative Medicine**

**X-ray spectroscopy for materials characterization**

**Process Engineering for Materials**





## Research Activities

- ❖ *ADVANCED AND TRADITIONAL CERAMICS & GLASSES*
- ❖ *COMPOSITE MATERIALS*
- ❖ *POROUS (MICRO-, MESO-, MACRO-) MATERIALS*
- ❖ *INORGANIC LAYERED MATERIALS*
- ❖ *CARBON-BASED NANOSTRUCTURED MATERIALS*

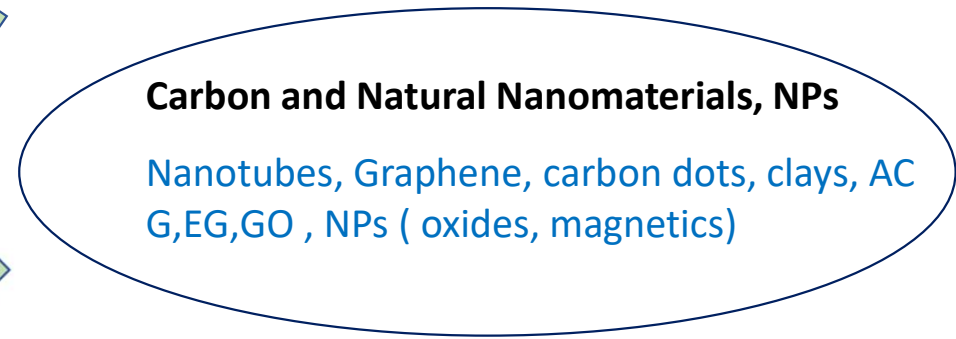


## Advanced Materials for Industrial applications

Aluminosilicate, Magnesite, Portland, Pozzolana cements, Gypsum, Cement Boards, Polymers

- Refractories
- Construction
- Flame retardants
- Remediation mortars & coatings

- ✓ Synthesis
- ✓ Functionalization
- ✓ Decoration



## Porous and Porous Hybrid materials

Molecular sieves (MCM-41, SBA-15, CMK-3, activated carbon and magnetic derivatives)

- Catalysis
- Energy storage technologies (Li-ion Batteries)
- Environmental Remediation

## Synthetic/Preparation methods



- Sol-gel Chemistry
- Coprecipitation reactions
- Microwave synthesis
- Hydrothermal synthesis
- Template synthesis (hard and soft)
- Wet impregnation/infiltration
- Chemical vapor deposition (CVD)
- Melt intercalation
- Pyrolysis/carbonization
- Chemical activation
- Designing of compositions
- Fabrication of ceramics and glasses and composites: hot pressing, castings, plastic forming techniques, sintering.
- Characterization and performance: Advanced spectroscopic characterization and thorough understanding of the materials' structure and the ways they are related to their fundamental properties are high-importance objectives of HPHM group.

### **Carbon & Natural**

**Nanomaterials:** *Nanotubes ( MWNTs) , Graphene (G) , Graphite Oxide (GO) Reduced GO (r-GO), dots, Expanded Graphite (EG), Expanded GO (EGO), Organo-clays, synthetic laponites, Layer Double hydroxides (LDHs)...*

**Nanoparticles:** *SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, ZrO<sub>2</sub>, TiO<sub>2</sub>, BaSO<sub>4</sub>, MgO , Mg(OH)<sub>2</sub>, Al(OH)<sub>3</sub>, γ-Fe<sub>2</sub>O<sub>3</sub>, Fe<sub>3</sub>O<sub>4</sub>, ZVI, SiC...*

**Porous structures:** *MCM-41, SBA-15, HMS, CMK-3, 3-DOM, AC, Starbons, Carbon Cages..*

**Compact structures:** *Oxide glasses (Borate, Silicate, Phosphates), polymer nanocomposites..*

# Advanced Materials for Industrial applications



❖ **Refractories**  
*NANOREFRAMAT*

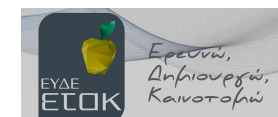
Advanced aluminosilicate and magnesia refractories  
of high efficiency using nanotechnology

Δράση "Ειδικές Δράσεις  
«ΥΔΑΤΟΚΑΛΛΙΕΡΓΕΙΕΣ» -  
«ΒΙΟΜΗΧΑΝΙΚΑ ΥΛΙΚΑ» - «ΑΝΟΙΧΤΗ  
ΚΑΙΝΟΤΟΜΙΑ ΣΤΟΝ ΠΟΛΙΤΙΣΜΟ»"



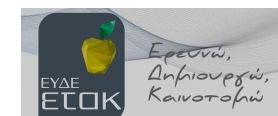
❖ **Construction**  
*SEMI-WEB*

Advanced Energy Upgrading Building Components Containing Phase  
Change Composites and/or Ceramic Foams with Electromagnetic  
Shielding Properties



❖ **Remediation  
mortars & coatings**  
*ΑΚΕΙΣΘΑΙ*

Self-Healing and Self-Sensing Nano-Composite Conservation Mortars



❖ **Flame retardants**

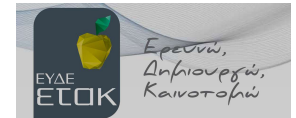
Development of Nanomaterials as additives masterbatches for polypropylene  
products





## Porous and Porous Hybrid Materials

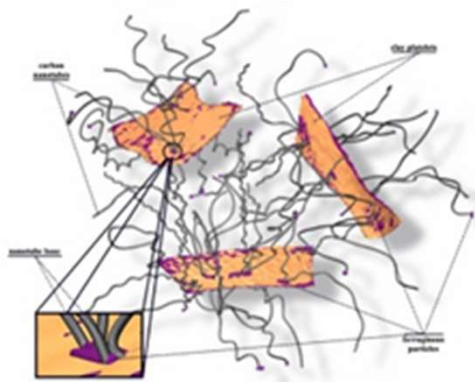
- ❖ **Catalysis/Industrial applications**  
**ECO-ETHYLENE**  
**A Novel Process for the Efficient and Eco-Friendly Valorization of Biogas and CO<sub>2</sub> Emissions: Complete Conversion to Ethylene**
- ❖ **Energy storage technologies**  
**CARBONBAT**  
**Porous Carbon Sulfur composites for Li-S Batteries**
- ❖ **Environmental Remediation**  
**Novel and highly efficient adsorbents for environmental applications**



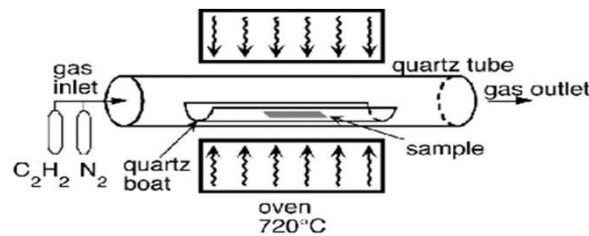
# Current research activities



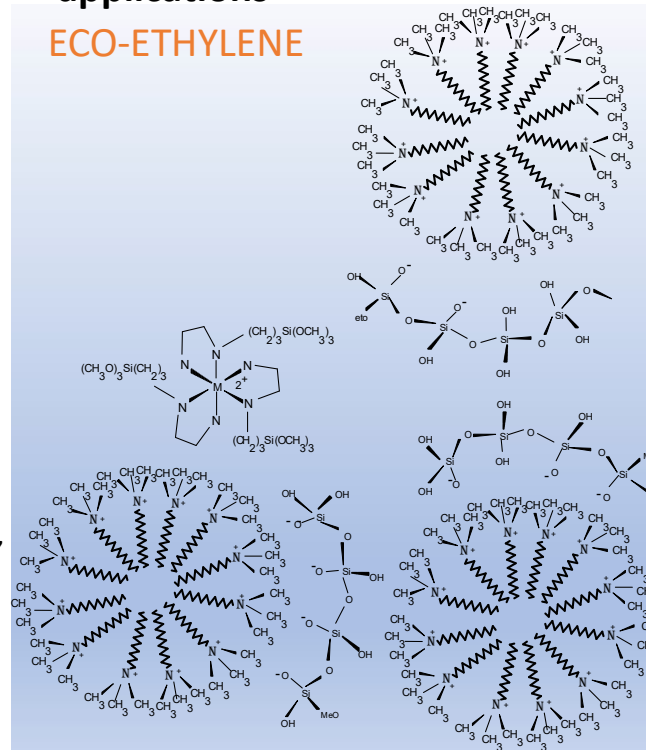
## ❖ Remediation mortars & coatings ΑΚΕΙΣΘΑΙ



Catalytic synthesis of carbon nanotubes on clay minerals, D Gournis, MA Karakassides, et al. Carbon 40 (14), 2641-2646, 2002

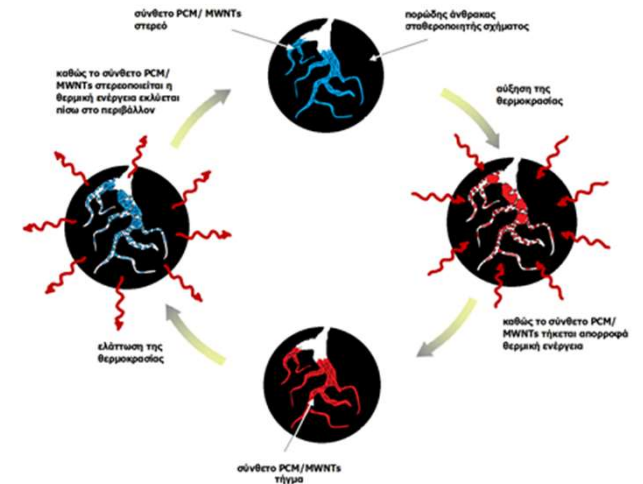


## ❖ Catalysis/Industrial applications ECO-ETHYLENE



Synthesis and characterization of copper containing mesoporous silicas, M.A. Karakassides, A Bourlinos et al, J. Mater. Chem., 10, 403-408, 2000

## ❖ Construction SEMI-WEB



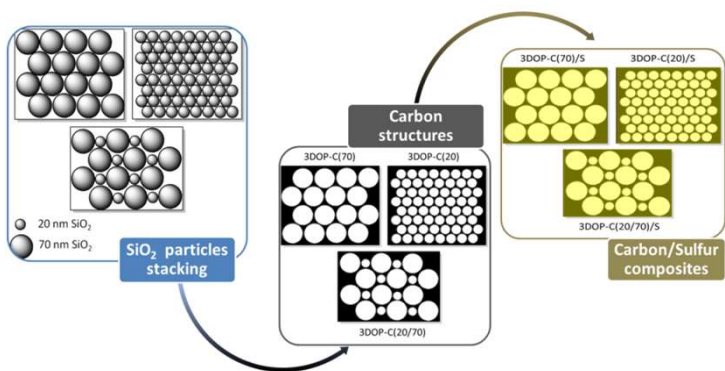
Pyrolytic formation of a carbonaceous solid for heavy metal adsorption, AB Bourlinos, MA Karakassides, P Stathi, Y Deligiannakis et al, Journal of Materials Science 46, 975-982, 2011



# Current research activities



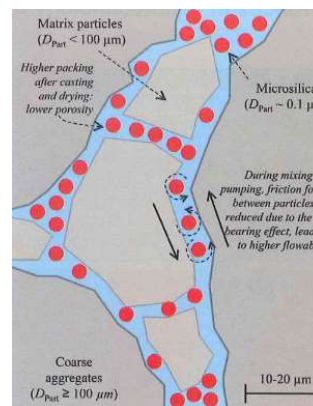
## ❖ Energy storage technologies CarbonBat



HPC carbons (~900 m<sup>2</sup>/g) ➔ up to 78% Sulfur

Synthesis and Characterization of  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub>/Carbon Hybrids and their Application in Removal of Hexavalent Chromium Ions from Aqueous Solutions, M.Baikousi et al., Langmuir 2012, 28, 8, 3918–3930

## ❖ Refractories NANOREFRAMAT



Lubricants,  
 Pore fillers,  
 Binders,  
 Improves the driving force for sintering,  
 Modifies microstructure  
 Improve mechanical properties  
 Improve corrosion resistance



## ❖ Flame retardants

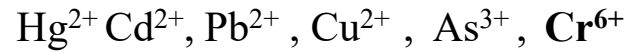


# Current research activities

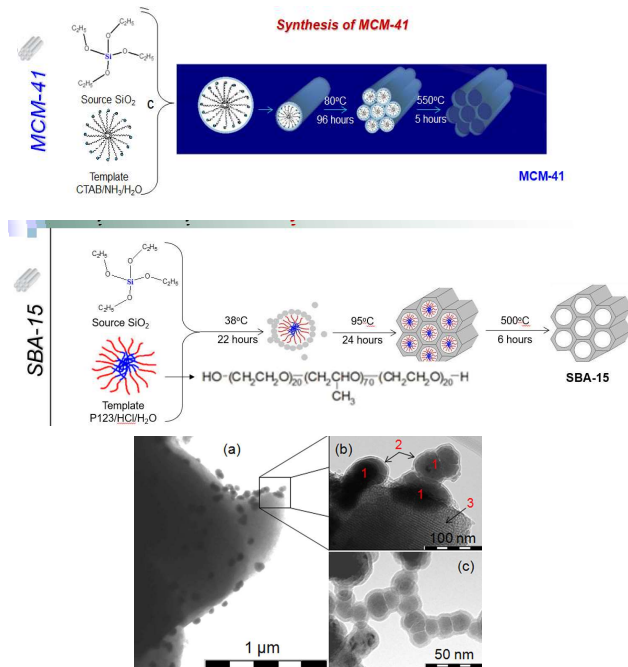


## ❖ Environmental Remediation

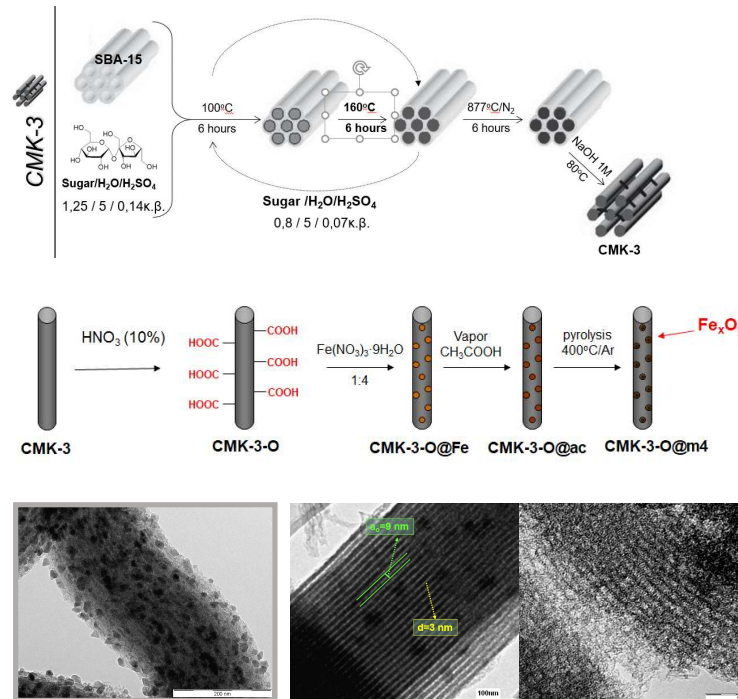
## Novel and highly efficient adsorbents for environmental applications



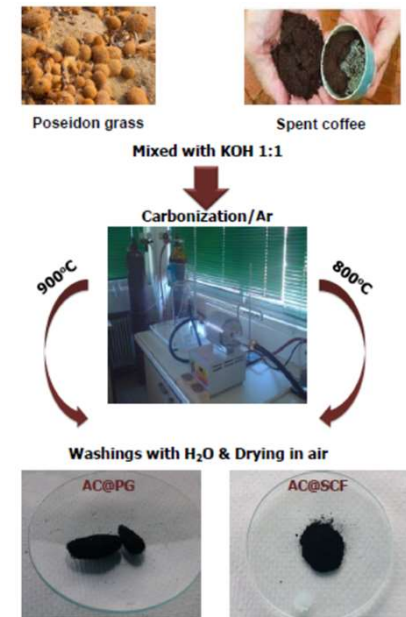
### MCM-41 & hybrids



### CMK-3 & hybrids



### Activated Carbons



Advanced Cr(VI) sorption properties of activated carbon produced via pyrolysis of the "Posidonia oceanica" seagrass

[Journal of Hazardous Materials](#), Available online 14 October 2020, 124274

## Experimental Facilities: Synthesis - Processing



### Two (2) fully equipped chemistry laboratories

#### Glassware

- Stirrers & hot plates
- Centrifuges
- pH-meters
- Drying ovens
- Ball mills
- Chemicals/Reagents/solvents/gases
- Ultra-Sonicators
- Water and oil baths
- Reflux and distillation apparatus
- Desiccators
- Balances
- Melting point apparatus
- Pumps



# Experimental Facilities: Synthesis - Processing

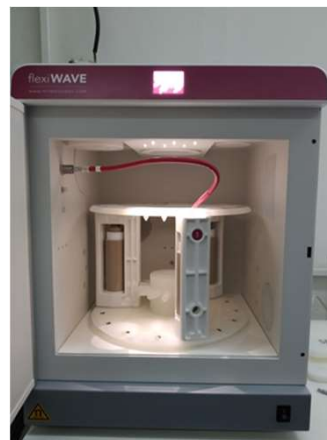
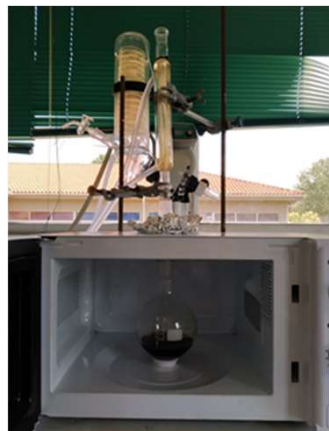


## Microwave synthesis system

(up to 300°C and pressures to 199 bar)

## Microwave Reactor for Reflux Condensation and Rotary evaporator)

(microwave synthesis)



## CCVD apparatus

(digital mass flow-meters, up to 1000 °C,  
various gases)

## Autoclave

(hydrothermal synthesis)





# Experimental Facilities: Synthesis - Processing



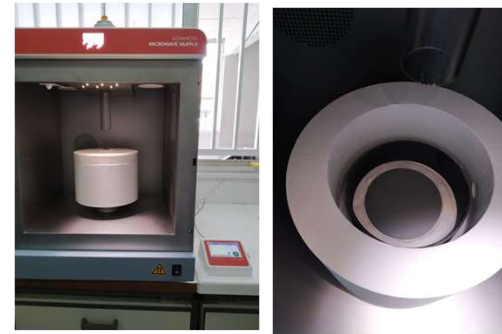
## Tube & box furnaces (5)

(Termolab, Thermoline, Carbolite, Abertherm etc. Temperatures up to 1750 °C)



## Microwave Furnace

Temperatures up to 1200 °C



## Bottom loading furnace

Bottom loading glass melting furnace  
(1700°C)



## Hot Press Graphite Furnace

High temperature uniaxial hot press  
(10kN 2000°C)



## Composite extrusion and pressing parts

(single screw extruder, heated platens, hydraulic press ,  
up to 300°C load bearing capacity up to 15 tons)





# Advanced Characterization Techniques

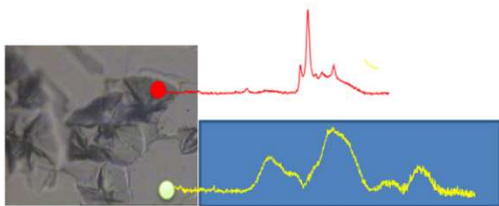
## μ-Raman

Renishaw 1000

(laser at 532 nm with optical microscope )



(χωρική διακριτική  
ικανότητα 1-2μm)



## FTIR/FT-Raman

JASCO FT-IR-6300 spectrometer  
system with Raman RFT-6000  
accessory

Raman: capability of micro- and macro-  
scopic measurements and mapping facility.  
Infrared: full vacuum system, wide range of  
measurements (mid and far infrared )



## Infrared microscope- FT-IR

JASCO IRT-5000, Infrared  
microscope-FT-IR 4000 system  
(Transmittance, reflectance and ATR  
measurement modes. Multi-point, line,  
area and ATR mapping)



## FT-IR

GX Shimadzu 4000

(Transmission, absorption, diffuse and  
specular reflectivity measurements,  
equipped with furnace for  
measurements from RT to 900 °C)



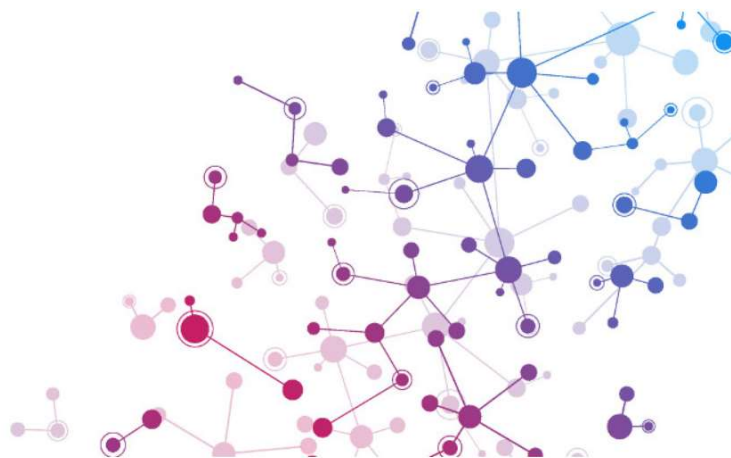
Vibrational spectroscopy

Vibrational spectroscopy



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Micro/Nanoelectronics



<https://innovation-el.net/>





# Advanced Characterization Techniques



Optical properties

## UV-Vis spectrophotometer

Shimadzu 1200PC

measurements of solids (integration sphere) or liquids



Agilent,  
Cary 5000  
(175–3300 nm)



## Specular reflectance measurements

Reflectivity, Refractive index, Absorption coefficient  
Real and imaginary parts of dielectric constant



## Density/Chemical Durability



Physical properties

## Thermal Conductivity

Solids: polymers, foams, ceramics



Morphological characterization

## AFM/MFM microscope

Veeco Multimode/Nanoscope 3D



## optical microscopes (3)

Equipped with digital cameras





# Advanced Characterization Techniques



## Surface area and Porosity analyzers

Sorptomatic 1990  
ThermoFinnigan  
(microporous – mesoporous)

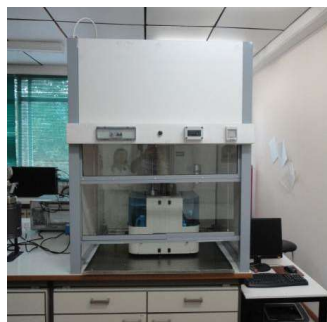


Autosorb iQ  
Quantachrome



## Mercury porosimeter

Quantachrome PoreMaster  
PM33GT-13  
(meso and macro-porous)

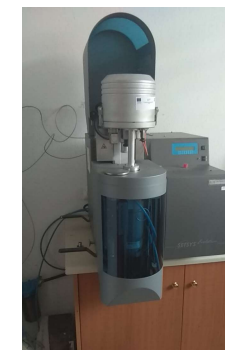


## Differential Thermal Analysis and Thermogravimetry (DTA/TGA)

Perkin-Elmer Pyris-Diamond  
(temperature range RT to 1500°C)



SETSYS Evolution-SETARAM  
(DTA/TGA/TMA (Thermomechanical analysis))



## Differential Scanning Calorimetry (DSC)

NETZSCH -  
DSC 214  
Polyma  
(Equipped with  
cryostat.  
Temperature  
range  
from -170 to  
600 °C)



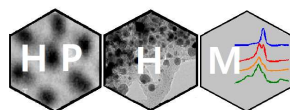
SETARAM DSC-131



Surface area & Porosity

Thermal Analysis

## Members of HPHM group



### Faculty members

- **Prof. M. A. Karakassides** (2001) – *Dipl. Physics, PhD Chemistry (UoA)*  
*Specialty: Ceramic, Porous & Composites*

### Post-doctoral fellows

- Dr. M. Baikousi - *Dipl. Mater. Sci, PhD Mater. Eng.*
- Dr. K. Vasilopoulos – *Dipl. Environ. Eng., PhD Mech.Eng. (AUTH)*

### PhD students

- C. Gioti (MSc) - *Dipl. Mater. Eng., MSc*
- G. Assimakopoulos (MSc) - *Dipl. Mater. Eng., MSc*
- S.Giouzel (MSc) – *Dipl. Physicist , MSc Mater. Eng.*
- A. Spyrou – *Dipl. Mater. Eng.*

### Master's students

- G. Kostakis (MSc) - *Dipl. Mater. Sci*

### Technical supporting staff

- Ms. S. Pappa (2001) – *Dipl Chem. Eng. (UoP)*

## CCL Faculty members



- **Prof. D. Gournis** (2005) – *Dipl. Chemistry, PhD Chem. Eng. (NTUA)*  
*Specialty: Chemistry of Layered Materials*
- **Prof. S. Agathopoulos** (2009) – *Dipl. Chemistry, PhD Chem Eng. (UoP), Specialty: Ceramics Engineering*
- **Assist. Prof. K. Salmas** (2018) – *Dipl. & PhD Chemical Engineer (NTUA), Specialty: Chemical Process*
- **Assoc. Prof. D. Anagnostopoulos** (2019) - *Dipl. & PhD Physics (Uoi)*  
*Specialty: X-ray spectroscopy*
- **A.Lekatou, I.Panagiotopoulos,**

### Close collaborators:

