Enmix A.I.S.B.L.

European Nanoporous Materials Institute of Excellence

Newsletter - N° 3, October 2012

In this issue:

Dear partners and friends of ENMIX,

Welcome to the third newsletter of the European Nanoporous Materials Institute of Excellence (ENMIX)!

ENMIX has steadily developed into a unique network of leading European research institutions covering all aspects of nanoporous materials. It consists of twelve partners from eight European countries (Belgium, Germany, Greece, Italy, The Netherlands, Norway, Slovenia, and Spain). Closely associated to the network is the Centre National de la Recherche Scientifique (CNRS) with four of its research laboratories in France.

Following the tradition of the previous ENMIX newsletters issued in November 2010 and April 2012, the present edition provides information concerning the structures and activities of two selected partners, viz. the CNRS with four of its laboratories in Montpellier, Marseille, Grenoble, and Orléans, and the Center for Research and Technology Hellas in Thessaloniki, Greece.

Already today, nanoporous materials have found widespread industrial applications, for example in heterogeneous catalysis, separation and purification technology, and environmental protection. Furthermore, novel applications are likely to emerge in the future. With the 3rd ENMIX workshop taking place in Hannover in 2013 the state of the art in synthesis and application of nanoporous materials will be summarized and future perspectives and innovations identified and discussed.

Taking the large commercial potential of materials like carbons, zeolites or metal-organic frameworks (MOFs) into account, ENMIX decided to strengthen its contacts with selected industrial companies in Europe that are active in the field. As a new feature of the newsletter, this issue contains a portrait of one of these companies, W.R. Grace & Co. located in Worms, Germany. We are grateful to Grace for having delivered this text for our newsletter.

Also introduced with this issue of the newsletter is a list of recent publications from the partner laboratories which is meant to provide quick information on some of their current research activities and fields of cooperation between the partners.

Jens Weitkamp

Elias Klemm

Announcement: 3rd ENMIX Workshop

Zeolites, MOFs, and Porous Carbons
- Advanced Preparation and Innovative Applications -

The workshop will take place on March 25-27, 2013 at Leibnizhaus in Hannover (belonging to the Leibniz University of Hannover) and will be organized by Juergen Caro (Leibniz University).

Four excellent keynote speakers will review recent developments in the field of nanoporous materials:

- Prof. Gabriele Centi, University of Messina:
  "Zeolites in catalysis – recent developments and perspectives"

- Prof. Stefan Kaskel, Technische Universität Dresden:
  "MOFs: Synthesis, adsorption and shaping"

- Prof. Francisco Rodríguez-Reinoso, Universidad de Alicante:
  "Novel nanoporous carbons for energy and environmental applications"

- Prof. Frederic Kapteijn, Delft University of Technology:
  "Catalysis with MOFs – opportunities and limitations"

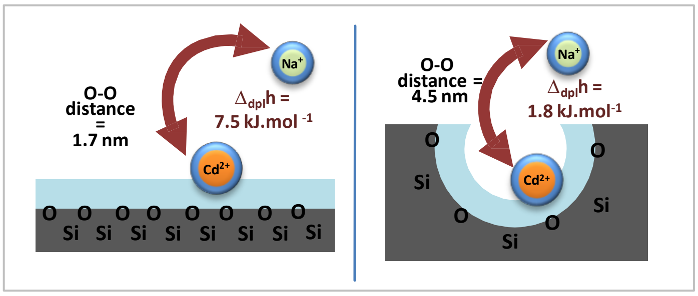
The traditional Leibnizhaus is located in the middle of Hannover within 5 minutes walking distance from Hotel Maritim, where the workshop participants will be accommodated. The Leibnizhaus was built in 1499 and named after the famous philosopher Gottfried Wilhelm Leibniz.

Centre National de la Recherche Scientifique (CNRS), F

The Centre National de la Recherche Scientifique (CNRS) in France comprises 4 groups at various locations throughout the country.

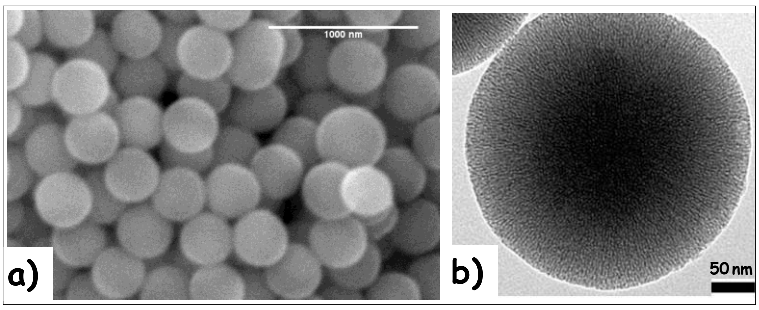
Institute for Molecular Chemistry and Materials, ICGM, Laboratory "Aggregates, Interfaces and Materials for Energy" (ICGM-AIME), Montpellier

Competence at ICGM-AIME in materials, electrochemistry and physical chemistry of interfaces has led to better understanding of sorption mechanisms, together with the conception and elaboration of materials with new properties for use, such as energy production, conversion and storage, catalysis or clean processes for the environment.



Interfacial phenomena in multi-component systems containing aqueous solutions of ionic surfactants, polymers, and heavy metals or radionuclides, are studied experimentally and modelled. The particularity of our approach lies in the use of probe fluids (gases, vapours, liquids, solutions) giving specific interactions with porous solids or nanoparticles.

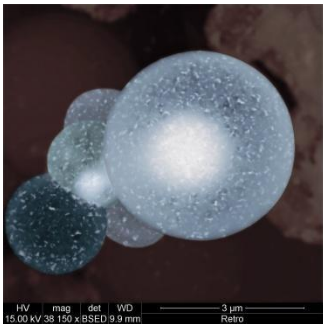
Competitive adsorption is studied by developing modern calorimetric techniques as powerful tools and then determining the main contributions to the enthalpy effect. At the solid-liquid interface, adsorption, desorption together with dehydration and hydration properties, are analyzed in correlation with the confinement effect (Prelot et al., J. Phys. Chem. C, 2011). At the solid-gas interface, the mean strength of surface acidity is characterized using gaseous ammonia adsorption onto doped mesoporous SBA-15, and combined to molecular modelling to evaluate the energy of molecular orbitals and LUMO energy levels (Szczodrowski et al., Micropor. Mesopor. Mater., 2009).

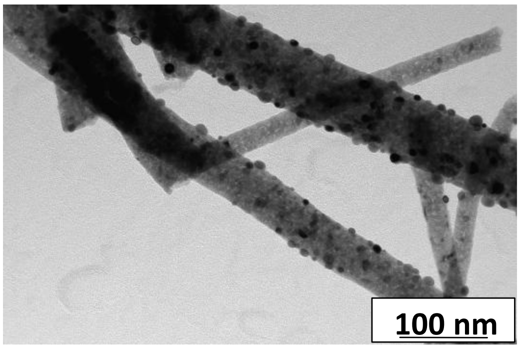


With the injection of concepts from Colloidal Science, new pre-shaped porous functionalised materials are designed, developed and tested to exploit their remarkable morphology and textural properties mostly based on high regularity of radially disposed pores and high monodispersity of particle sizes (Nyalosaso, J. Mater. Chem., 2012).

These mesoporous silica spheres have been replicated to prepare nanostructured Pt-carbon electrocatalysts for PEMFC, where nanosized Pt metal particles (around 4 nm) are dispersed in the carbon structure (G. Derrien, C. Charnay et al., Progress MEA 2008, Proceedings). Carbon can be oxidised in the fuel cell under the practical operation conditions of some applications, and there is great interest in more stable electrocatalyst support materials alternative to carbon.

In the development of low-dimensional fuel cell electrode materials showing high surface area and suitable porosity characteristics, as well as high electrical conductivity to ensure electron transfer, we have recently described a novel synthesis route leading to tungsten carbide microspheres comprising an outer shell and a compact kernel prepared by a simple hydrothermal method. The WC microspheres exhibit very high surface area promoting a high dispersion of platinum nanoparticles, and an exceptionally stable electrochemically active surface area to voltage cycling compared to the usual Pt/C electrocatalysts used for PEMFC application (J. Bernard d'Arbigny et al., ChemComm, 2011).





Conductive mesoporous titania nanofibres supporting Pt nanoparticles have been synthesised in a one-step method based on the electrospinning technique. The dimension of both the oxide fibres and platinum particles are tuneable, leading to versatile nanomaterials with application as fuel cell electrodes (S. Cavaliere et al., ChemComm, 2011).

Key personnel involved within ENMIX at the CNRS-Montpellier

Deborah Jones is CNRS full senior scientist, and leads the ICGM-AIME laboratory. Her interests have included ion and electron transfer and transport in insertion and intercalation materials, and proton conduction properties in solids ranging from soft matter to high temperature proton conducting ceramics, the development of porosity from layered solids and the use of supramolecular templating methods, and the development of catalyst materials for diesel fuel upgrading and for hydrogen generation from liquid fuels. Benedicte Prelot is Research Scientist at the CNRS. Her research is focussed on sorption phenomena and measurement of the surface reactivity via use of probe molecules at the surface-liquid and surface-gas interface (H^+/OH^-, NH_3, CO_2, ...), including the development of calorimetric measurements to better understand sorption mechanisms (environmental application and selective sorption of heavy metals, ...).

Jurek Zajac is Full Professor at the University of Montpellier 2. He leads a research group "Interfacial properties: Mechanisms, Interactions", dealing with thermodynamics and modeling of interfacial phenomena: adsorption, wetting, immersion, formation of Ionic Double Layer and the kindred phenomena, from physical chemistry of surfactants in solutions and at interfaces, to the conception and preparation of porous multifunctional materials for high-added-value applications, and mainly based on the use of calorimetry measurements.

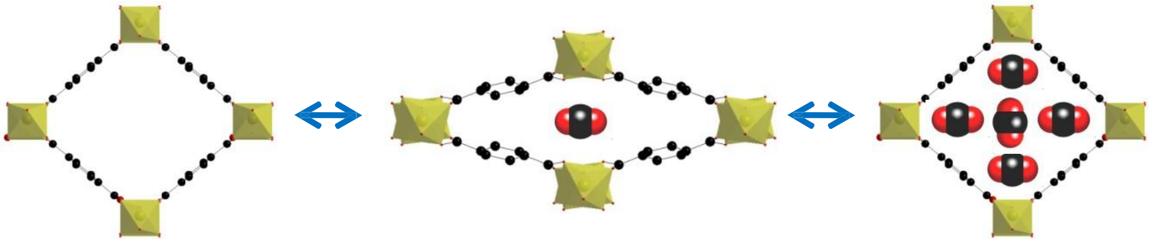
Clarence Charnay is Lecturer at the University of Montpellier 2. His research interests encompass advanced nanostructured materials for targeted applications, formulation and interfacial control of colloidal systems for morphological and textural tuning of porous particles. Louis-Charles de Menorval is Research Scientist at the CNRS, investigating adsorption phenomena mainly using NMR. From the various NMR measurements (mainly 1H, 129Xe), the objectives are to study accessibility in nanostructured porous networks, solubilization in micellar aggregates, or modification of conformation during adsorption.

Laboratory "Divided Materials, Interfaces, Reactivity, Electrochemistry" (MADIREL), Marseille

The MADIREL group in Marseilles is a joint CNRS – University de Provence research team which is made up from 10 university lecturers, 4 CNRS researchers and two technical engineers.

The aims of this research group are the advancement of the understanding of physicochemical phenomena that occur during the characterization or use of powders or porous solids. The applications currently concerned by this research include the capture and separation of gases, bioseparation of liquids and materials for energy. The group notably develops several original experimental methods to measure thermodynamic, kinetic and electrical properties of the materials under study.

Whilst the characterization of porous solids by adsorption is a well known strong point of the group, the group also couples standard adsorption methods with other techniques, notably microcalorimetry. These thermodynamic approaches are often completed with structural and spectroscopic and structural studies in collaboration with other groups. Adsorption from the gas phase is studied in the framework of problems such as the separation, purification and storage including current challenges in the energy (hydrogen storage), environmental (greenhouse gas capture – CO_2, CH_4) sectors. Adsorption at the liquid-solid interface is studied in the framework of separation, detergence, suspension stability, wetting and charge transfer. The study of such systems requires the determination of isotherms as well as complementary kinetic, electrical and structural parameters.



Some recent work has involved the study of flexibility during adsorption as schematically shown above for the Metal Organic Framework, MIL53. Our studies have included the adsorption of gases (CO_2, C_3H_6, C_3H_8) and vapours (water, methanol and ethanol) which have been aimed at various methods of gas or vapour separation. More recently, the group has looked at using just pressure to induce this flexibility and so use these systems as energy storage devices.

Key personnel involved within ENMIX at the CNRS-Marseille

Renaud Denoyel and Philip Llewellyn are both Research Directors with the CNRS. Renaud is interested in and has much of his research focused on the adsorption from the liquid phase as well as adsorption in disordered matrials. Philip concentrates his research on adsorption from the gas phase in ordered microporous materials.

Institut Néel, Grenoble

Most of the materials (bulk, thin films) under investigation in the group are of metallic character based on transition elements (d,f) and light interstitial species (p); thus the fundamental guideline of the team is the study of reactional and transitional mechanisms in intermetallics. Our expertise spans the entire range from synthesis and characterization (structural, physical) to processing and industrial transfer in prototypes or systems. Thermodynamics is also a concern of the group, in addition our investigations rely on and/or are accompanied by numerical simulation. In the recent past we focussed our interests in materials with applications for the conversion of energy (storage hydrides, magnetocaloric and thermoelectric materials). Due to its strong historical involvement in neutron diffraction (location of light interstitial elements in intermetallics, in situ reactional and sorption studies) the group is in charge of the CRG D1B at ILL since 2009.

Magnetocaloric materials

Magnetic refrigeration based on the magnetocaloric effect (MCE) is a serious alternative to traditional cooling because of its efficiency. The MCE (intrinsic to magnetic materials) is due to the coupling between magnetic sublattice and external magnetic field, which changes the magnetic contribution to the full entropy of the material.

Affordable and realistic innovative materials for magnetic refrigeration require high magnetization densities and thereby have to be of intermetallic type. Specific microstructure may be attained by the use of rapid cooling methods (atomization or melt spinning). A careful characterization involving direct measurement of the magnetocaloric effect requires dedicated and tailored calorimeters.

Subsequent modeling and electronic structure calculations are an asset and are therefore conducted. Finally, optimization of thermal exchange in the device or system requires a specific compounding of the magnetocaloric material (design, porosity, specific surface).

Hydrogen storage

Our research on new materials for hydrogen storage is driven by the following considerations: 1. stabilization of new phases or destabilization of very stable hydrides by means of very high pressure; 2. enhancement of sorption kinetics through nanostructuration or addition of activating and/or catalytic phases. The materials are then processed in order to optimize and handle thermal exchanges and finally tested in hydrogen storage instrumented tanks that are designed in the group. For this doing we rely on numerical simulation. The final goal is to insert the hydrogen storage tank in a chain for the conversion of energy. Our knowledge on MgH_2 has been patented and transferred to industry. Synthesis of novel and efficient materials for reversible hydrogen storage will be made possible by the use of specific techniques such as high pressure in order to stabilize new phases.

Two major routes are being investigated for the enhancement of sorption kinetics: nanostructuration (where refinement of the microstructure is attained through Severe Plastic Deformation methods) or addition of activating phases that may present either activating or catalytic properties. Processing and compounding of composite materials allows to handle the thermal exchanges that take place during hydrogen absorption (exothermic) or release (endothermic).

Phase transformations and electronic properties

In this rather wide topic we gathered materials of interest for their thermoelectric effect or shape memory effect. Such materials may be synthesized either in the bulk state or in deposited layers (plasma-assisted). Thermoelectric materials investigated in the group are of intermetallic type and belong to the following types : 1. ternary systems of Heusler type with early or late transition metals combined to metalloids or semi-metals (Ge, Sn, Sb, Bi…), 2. binary systems based on magnesium with the Laves phase structural type. The first materials are synthesized in the bulk state whereas the binary systems are more likely to be deposited as multilayers.

Research Centre for Divided Matter (CRMD), Orléans

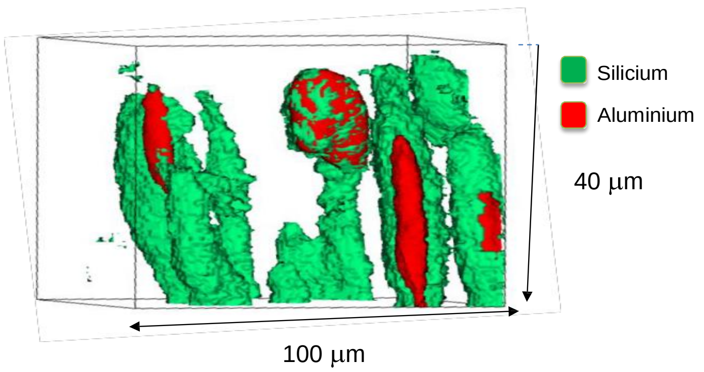
The CRMD - CNRS/University of Orléans inaugurated at the beginning of 2011 NanoScan, a platform for characterizing the surfaces of materials on the nanometre scale. NanoScan provides the scientific community with a full range of analytical techniques for studying the physicochemical properties of materials over a depth of several nanometres.

As the centrepiece of this platform, the Time-of-Flight Secondary IonMass Spectrometer(ToF-SIMS) is one of the most powerful instruments for comprehensive and precise analysis of the extreme surfaces of materials: organic, inorganic, biological and hybrid composite. The CRMD spectrometer is one of the few in France to have a C_{60} source, making it possible to study materials like those found in cells, soft matter and polymers.

This instrument complements an X-ray photoemission spectrometer (XPS) and an environmental atomic force microscope (AFM). The CRMD provides a comprehensive approach to the characterization needed to resolve problems arising in the research and the development of new materials. ToF-SIMS is particularly useful for identifying complex chemical species and/or components at low concentration distributed inhomogeneously in a material.

The main subjects in which this instrument is currently involved are the photo-oxidation of polymers, photovoltaic cells, materials for delivering drugs in chemotherapy and the identification of proteins involved in the mechanical properties and morphology of mouse tendons. The figure below illustrates the capability for measuring the distribution of chemical species in a rubber sample.

The NanoScan project results from a collaboration between TOTAL/ Hutchinson and the CRMD and is financially supported by the European Fund for Regional Development (FEDER), the CNRS, TOTAL/Hutchinson, the University of Orléans, the GREMI Laboratory and the General Council of the Loiret Department.



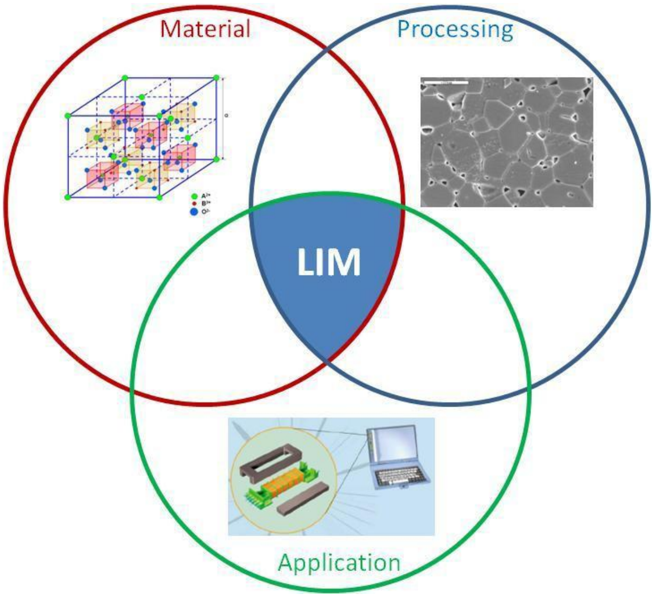
Distribution of chemical species in a rubber sample (Devant et al., private comm., 2011).

Center for Research and Technology Hellas (CERTH), GR

General

The Laboratory of Inorganic Materials (LIM) was founded in 2001 and is one of the five research laboratories of the Chemical Processes and Energy Resources Institute at CERTH.

A main Lab's goal is the achievement of excellence in the execution of focused research, primarily of applied but also of fundamental character. From the very broad field of materials, LIM concentrates its activities on metal oxides with emphasis on (amorphous or polycrystalline) ceramics.



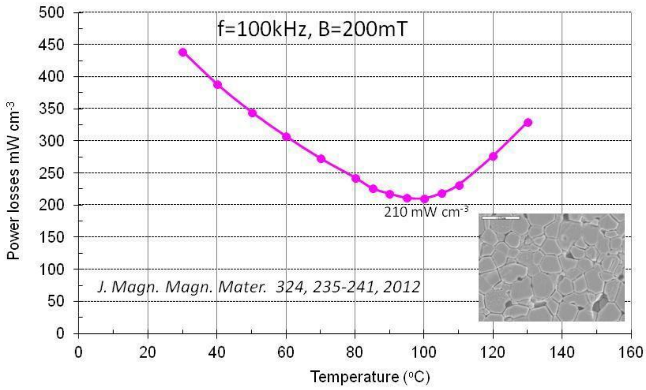
Recognizing the fact that materials have value only in relation to an application and a process technology by which they can be made at appropriate forms and microstructures, LIM utilizes a global approach and the research activities extend from material definition and synthesis processes, to characterization and application evaluation performance.

LIM has an average personnel of 15-20 people (including non-permanent scientific staff executing Ph.D. theses or other research), and an average annual budget of ca. 500,000 Euro of which 50% originate from industrial cooperations, 40% from the funding of national or European research projects and 10% from service activities. The average number of publications in peer reviewed journals amounts to 9-11 per year and the laboratory receives ca. 150 citations per year.

Research Activities

I) Magnetic Polycrystalline Ceramics - Energy

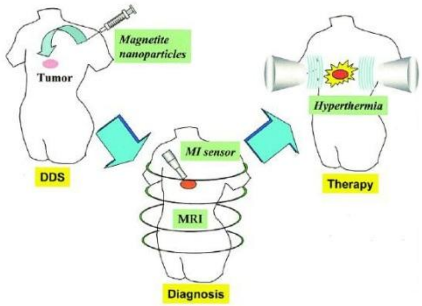
Within this research activity soft magnetic materials are being developed from the cubic/tetragonal spinel or the hexagonal structures. They are subsequently processed into polycrystalline specimens to form the cores of inductive components for a broad range of applications covering frequencies from ca. 50-100 kHz up to 90 GHz. Important current applications for renewable energy source inverters include materials and structures exhibiting as low as possible power losses when used as inductors (since there is no ideal process, a fraction of the energy sent to an inductor is not converted into useful magnetic energy but dissipated as heat over the body of the material). Optimized unit cell design in combination with nanoscale grain boundary engineering principles as well as innovations in the processing technology led to the development of MnZn-ferrite materials with energy losses among the lowest from those ever published in the open or patented literature.



Other material development directions include the development of materials with high saturation induction at high temperatures for applications in wireless electric car chargers or inductive cooking machines. Recently ferrite materials with a saturation flux density of 550 mT at 100 °C have been developed.

Among the lab's specialized and successful developments has been the development of the material used for the production of the magnetic rings used to focus the particle beam at the CERN synchrotron in Switzerland.

The experience gained in the lab with research on magnetic materials has triggered research activities towards the synthesis of magnetic nanoparticles by various wet chemical techniques such as co-precipitation or micro-emulsion. The surface of the nanoparticles is subsequently coated with silica and functionalized with specified organic groups



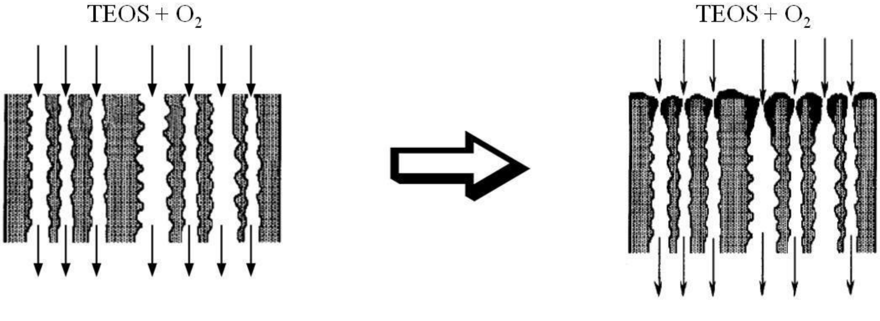
(proteins, antibodies etc.). Ultimate goal of this research is the development of functionalized magnetic nanoparticles that may find application in diagnostic or therapeutic medicine.

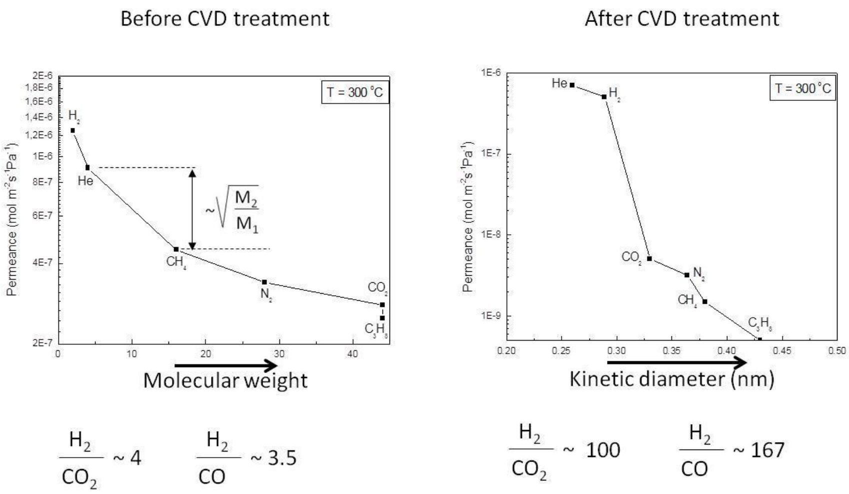
II) Porous membranes for water treatment

Within this research activity asymmetric multilayer porous ceramic membranes synthesized by the sol-gel technique are characterized and eventually in combination with other sorbents are used for the removal of toxic ions such as arsenic or cadmium from potable water (Journal of Membrane Science 367, 319-324, 2011). In a current project the sol-gel membrane tubes are used for a homogeneous and almost bubblelessj ozone introduction into the water stream, towards the development of a more efficient and cost- effective ozonation process.

III) Porous membranes for gas separation

The structural demands of gas separation membranes are quite stronger than those corresponding to membranes for liquid treatment. To this end, a low temperature (300 ^oC) CVD technique using TEOS as silica precursor and oxygen as oxidizing agent has been developed for pore narrowing, eventual defect repairing and in general gas separation performance improvement of the primary sol gel membranes.

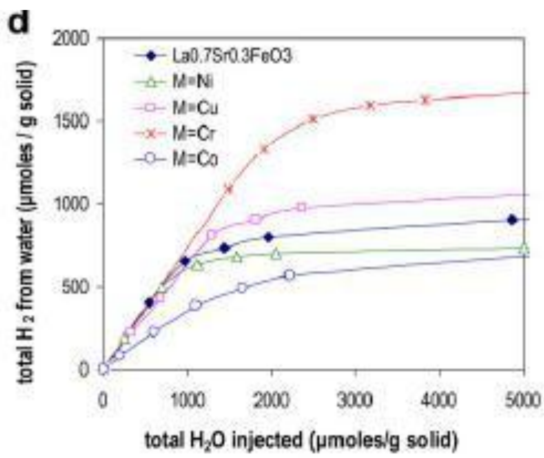




Intern. J. Hydrogen Energy (2012)-available on Internet

As indicated in the figure above, gas permeability measurements of several gases before and after the previous CVD treatment led to great permeselectivity improvement and indicated the synthesis of membranes suitable for important industrial separations.

IV) RedOx processes of environmental or energetic importance



The effect of B-site doping of the $La_{0.7}Sr_{0.3}M_{0.05}Fe_{0.95}O_3$ perovskite on its ability to decompose water towards hydrogen production (Int. J. Hydr. Energy 36, 6657, 2011)

Within this research activity spinel-ferrites and perovskite materials are being investigated in relation to their potential as redox materials in various processes. During such a process the vacancy containing material is initially oxidized (i.e. the oxygen vacancies are filled) with oxygen or some oxygen containing compound (e.g. air, H_2O, CO_2). In a subsequent step, the material is reduced either at elevated temperatures and inert atmospheres or by the use of a reductant such as CH_4 or CO. This process represents the basis of the so-called “chemical looping process” where total or partial oxidation of natural gas occurs with pure oxygen absorbed from air. The advantage is the production of exhaust gases containing only carbon dioxide and can therefore easily be directed to a storage process. Moreover, the usage of H_2O as oxidizing agent delivers as product pure hydrogen which is a valuable fuel. The same concept was utilized for the construction of a membrane reactor using dense oxygen conducting membranes from the previous materials. The two reactions could then be carried out in parallel in each of the reactor compartments.

LIM developed (in the frame of its obligations as partner) the cubic inverse spinel structured redox “catalysts” employed in the European “HYDROSOL” project (thermochemical decomposition of water using solar energy) that has been awarded with the 2006 Descartes research prize by the European Commission.

Infrastructure

For the execution of its research activities the laboratory possesses a quite broad spectrum of material characterization and testing instrumentation. Among this is equipment for the chemical (XRF, UV, ICP), thermal (TGA, DTA, TPR, TPO, TMA)), structural (XRD) morphological (BET, N_2 ads./des.), electromagnetic characterization of solids as a function of temperature and frequency and a series of optical-, SEM and HRTEM microscopes. For special solids processing, the laboratory possesses freeze-drying technology, CVD technology with integrated permporometry, (inductive) plasma treatment units and special computerized furnaces able to sinter under programmable temperature and oxygen partial pressure profiles. For application testing, there are membrane liquid purification and gas separation units and a catalytic unit with quadrupole mass spectrometer.

Services

The laboratory uses its infrastructure for the provision of services to external customers. Those may include chemical analysis of liquid samples or solid specimens, various specimen characterizations and consultancy. In addition the lab offers the service of in situ measurement of electromagnetic radiation originated either from components of the electricity distribution system or from high frequency sources such as mobile telecommunication networks. All laboratory services provided to external customers are covered with ISO 9001:2000 quality certificates.

ENMIX Key Personnel

Prof. dr. ir. Vassilis Zaspalis received in 1986 his diploma in Chemical Engineering from the University of Patras – Greece and his Ph.D. degree in 1990 from the Chemical Technology Department of the University of Twente – the Netherlands. Subsequently he joined the Philips Forschungslaboratorien in Aachen – Germany where he stayed until 2001 having obtained the degree of Senior Scientist. During this period he spent several months in materials production plans in Europe and Asia Pacific. In 2001 he joined the Chemical Process and Energy Resources Institute at CERTH, Thessaloniki-Greece, where he founded and directed the laboratory which is briefly described in the previous pages. In 2010 he was appointed Full Professor on Materials Science and Technology at the Chemical Engineering Department of the Aristotle University of Thessaloniki. Prof. Zaspalis is the author or co-author of 70 publications in peer reviewed journals, 30 International or World Patents, more than 100 publications in the proceedings of International Conferences and 4 publications of chapters in multiauthored books. Prof. Zaspalis is Member of the Board of Directors and holds currently the function of the Secretary of ENMIX.

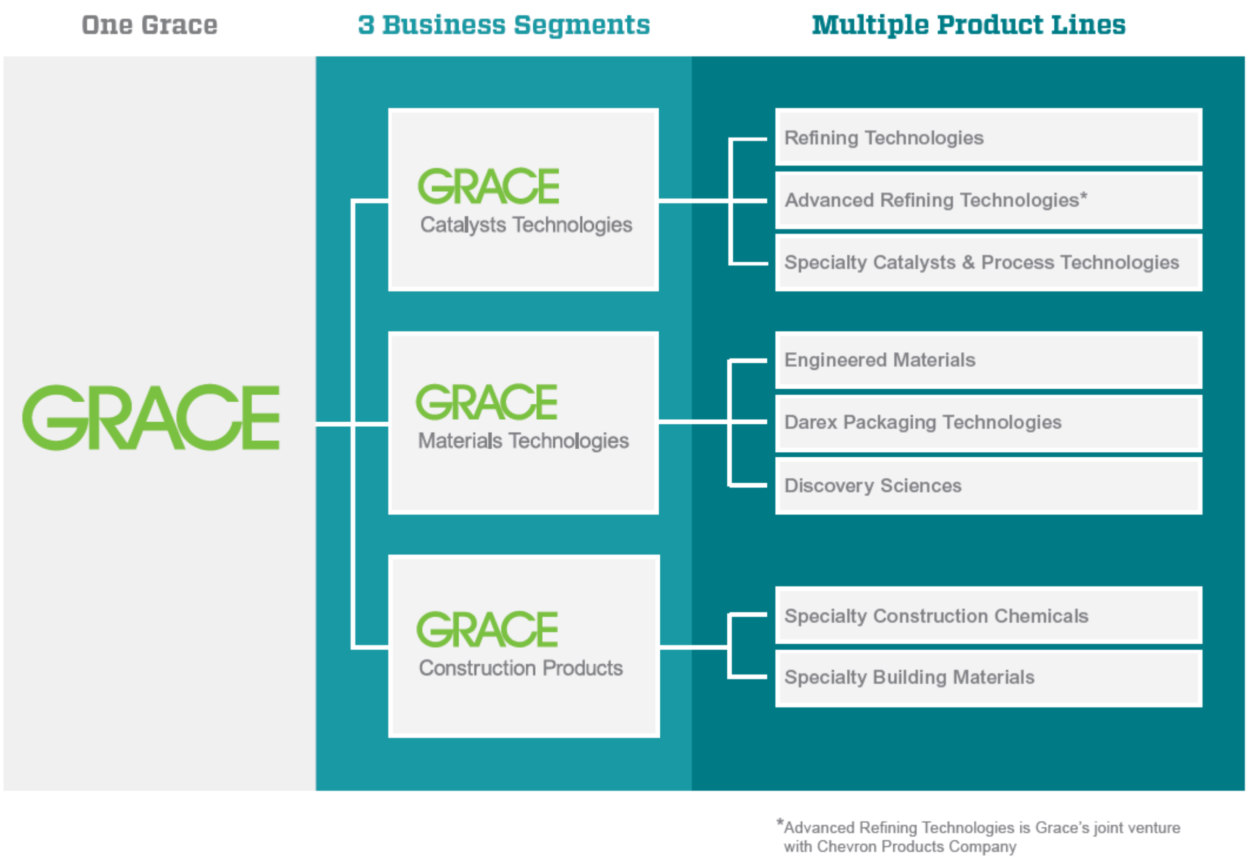
V.T. Zaspalis, E-mail: zaspalis@cperi.certh.gr or zaspalis@auth.gr

W. R. GRACE & Co.

Grace's history began in 1854 when William Russell Grace founds W. R. Grace & Co. in Peru. In the year 1865, W. R. Grace & Co. relocates to New York City and begins triangular trade with South America and Europe. Grace acquires Davison Chemical Company (founded in Baltimore by William T. Davison in 1834) and Dewey & Almy Chemical Company, establishing the basis for the Company's catalysts, packaging, silicas and construction product lines in 1954. It is the second longest continually operating chemical company in the United States.

Nowadays, Grace is a leading global supplier of catalysts and other products to petroleum refiners; catalysts for the manufacture of plastics; silica-based engineered and specialty materials for a wide range of industrial applications; sealants and coatings for food and beverage packaging, specialty chemicals and additives and building materials for commercial and residential construction. Grace employs approximately 6,000 people in over 40 countries and had 2011 net sales of $3.2 billion. The company's three industry-leading business segments — **Grace Catalysts Technologies**, **Grace Materials Technologies** and **Grace Construction Products** — provide innovative products, technologies and services that enhance the quality of life.

GRACE's Multiple Production Lines



GRACE Catalysts Technologies

We manufacture specialty catalysts and related products used in chemical manufacturing applications. Our products include petroleum refining catalysts and additives, and catalyst systems that support the petrochemical industry.

Refining Technologies

Grace is the global leader of FCC catalysts and additives, offering solution-oriented approaches backed by a broad, highly differentiated portfolio and industry-leading technical service. FCC catalysts and chemical additives used by petroleum refiners that help ‘‘crack’’ the hydrocarbon chain in distilled crude oil to produce transportation fuels and other petroleum-based products. Additives used to reduce sulfur in gasoline and reduce emissions. Grace’s research leadership and flexible manufacturing system support value-added technology tailored to meet customers' current and future needs.

Advanced Refining Technologies

We sell hydroprocessing catalysts through Advanced Refining Technologies, our joint venture with Chevron Products Company. Hydroprocessing catalysts are used by petroleum refiners to upgrade heavy oils into lighter, more useful products by removing impurities such as nitrogen, sulfur and heavy metals.

Specialty Catalysts & Process Technologies

We provide catalyst systems and supports to the polyolefins industry for a variety of polyethylene and polypropylene process technologies.

GRACE Materials Technologies

We manufacture value-added, materials-based specialty products for a variety of industrial, consumer, food/beverage, pharmaceutical and packaging uses.

Engineered Materials & Darex Packaging Technologies

Engineered materials used in industrial markets, such as plastics and rubber; in consumer applications, such as food products, toothpaste, pharmaceutical and personal care products, and the processing of edible oils and beverages; and in digital media coatings for ink jet paper.

Packaging technologies that seal and enhance the shelf life of can and bottle contents, prevent metal corrosion and protect package contents.

In addition to packaging technologies, the "MPT" product line markets and produces silica-based and silica-alumina-based functional additives and process aids, such as silica gel, colloidal silica, zeolitic adsorbents, precipitated silica and silica-aluminas, for a wide variety of uses.

Discovery Sciences

Our products enable scientists to identify and separate mixtures of molecules into their various constituents. Silica-based materials and chromatography columns, instruments, consumables and accessories used in life and analytical sciences applications.

GRACE Construction Products

Grace Construction Products was formed through a series of acquisitions in 1954 and is today a global industry leader.

Construction Products

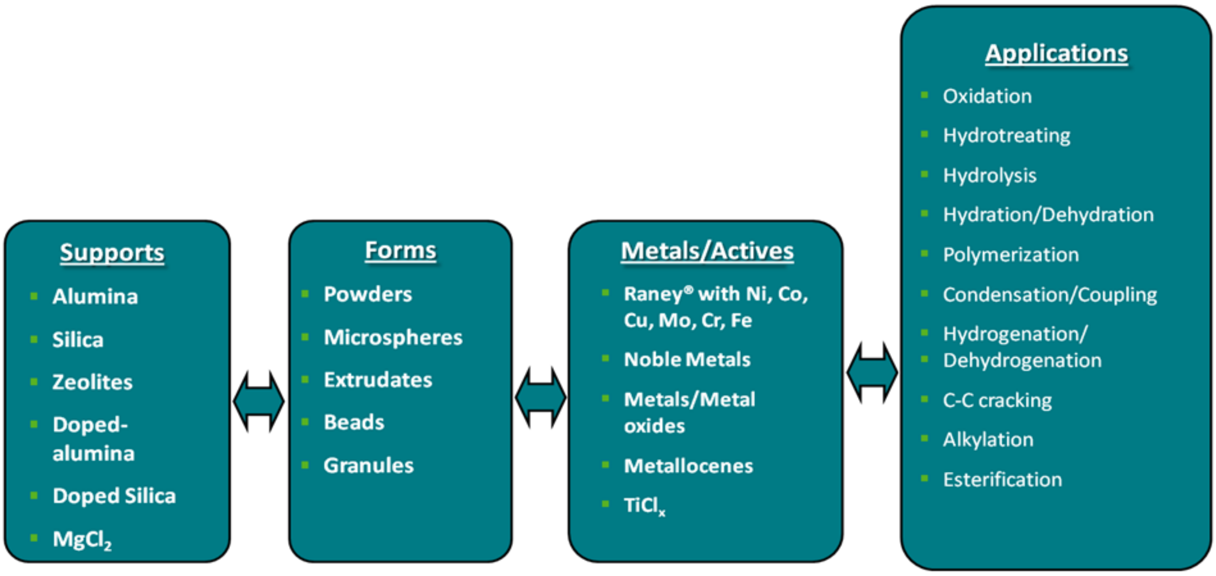
Grace Construction Products offers a wide range of innovative specialty construction chemicals and materials that includes: concrete admixtures and fibers, liquid pigments for colored concrete, cement processing additives, concrete masonry products, air and vapor barriers, roofing underlayments, self-adhered window, door and deck flashings, structural waterproofing systems and fire protection products. As a worldwide leader in the construction products industry, Grace products are specified by architects and engineers and are used by contractors, ready mix, precast and block producers, cement manufacturers to enhance the durability, strength and appearance of structures found in many major construction projects. Many of the world's most challenging building problems have been solved by Grace's premium construction chemicals and building materials.

Specialty Building Materials

We help homeowners protect their house and property with building materials that include roofing underlayments, deck protectors and flashing solutions. Additives used in cement processing to improve energy efficiency and enhance the characteristics of finished cement. Waterproofing materials used in commercial and residential construction and renovation to protect buildings from water penetration. Fireproofing materials used to protect buildings from structural failure in the event of fire.

GRACE Technologies – Supports to Catalysts

Grace's world is dealing with highly specialized aluminas, silicas and magnesium chloride as well as products prepared from these ingredients.



Recent publications:

National Institute of Chemistry, SLO – Laboratory for Inorganic Chemistry and Technology

M. Rangus, M. Mazaj, I. Arčon, G. Mali, V. Kaučič,
Spectroscopic investigation of Ti-modified aluminum-free zeolite-beta crystallization.
Chem. Mater. 2011, *23*, 1337-1346.

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