4.2.1 - Italian approach

Many of the stakeholders that have promoted IT-SusChem have already clearly defined their position and priorities in the different fields linked to this Platform. These inputs had to be considered in the preparation of this Vision document. In particular, the following initiatives had to have been taken into consideration:

- Federchimica research priorities[1]
- Federchimica – CNR agreement[2]
- PNR (FIRB, FISR, COFIN, Centres of Excellence)[3]
- CNR-INSTM agreement
- ENEA priorities on materials technology
- Technological Districts and Parks
- Regional Research Plans and Innovative Projects
- European Networks of Excellence
- Other Technological Platforms

The position of Federchimica with respect to Materials Technology has been defined within its Research, Development and Innovative Committee, by means of setting up a specific Working Group to analyse the impact of Nanotechnology on industry and territory in Italy. The Working Group is preparing a document, "P.I.N.C.: A Programme on Chemical Nanotechnology: how to ensure the co-leadership of a Country in Europe" and the aim thereof is to evaluate the situation of Nanotechnology in Italy, including by means of a comparison with the European context. Furthermore, the text proposes a definition of the technology used and application markets.

Within the Working Group, a limited Participant Group has been formed, whose members include Research and Development Institutions, Universities, Venture Capitalists (including Finlombarda SRG, Pino Partecipazioni S.p.A. and Fort Business Advisor S.r.l.) and actors, like the Lazio Region and the Industrial Union of the Savona Province and which is aimed at creating a large-scale group with a critical mass.

The objective thereof is to create a network of contacts that are useful in setting up R&D projects on Nanotechnology. In particular, Federchimica is following the legislative *iter* of the VII Framework Programme, which will commence on 1 January 2007, to support Associated Enterprises in the participation of calls for tenders and intends participating in the CORNET Programme of the European Community. With regards thereto, IPI (the Institute for Industrial Promotion) has been contacted for a call that should be issued in Spring 2007 and which Federchimica intends participating in with a project on Nanotechnology. For these purposes, it would be appropriate for the Ministry of Economic Development to finance the Programme with an amount equal to €1 million.

Agreements have been entered into at an international level as well: the VNCI (the Chemical Enterprises of Netherlands Federation) has been contacted in order to collaborate in a Research Project and likewise the Embassies of certain countries, who are very interested in collaborating (in particular, the Dutch and British Embassies in Italy and the Italian Embassy in Israel) therewith. Regarding contacts in Israel, Federchimica is entering into agreements for the promotion and formation of Italian-Israeli joint Venture Capital Funds.

Moreover, Federchimica intends intensifying contacts with the European Investment Bank, who has already declared that it is open to co-financing the creation of Territorial Venture Capital Funds on Nanotechnology. In particular, a €10 million Fund has been considered, of which €5 million is to be provided by the Ministry for Economic Development and €5 million is to be made available by the Participants of the "P.I.N.C." Programme.

One of the initiatives provided for by Federchimica, within the framework of the "P.I.N.C." Programme, at the beginning of 2007, is to organise the "First National Conference on Chemical Nanotechnology", which will include the participation of Officers of the European Commission.

Parallel to the Working Group, a "Nanoscience" Task Force has been activated, which is evaluating the risks and opportunities related to nanomaterials, including the security thereof in working environments.

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[1] *See for example: The Chemical Industry in Italy, Federchimica (http://www2.federchimica.it)*

[2] *Accordo Quadro CNR–Federchimica, May 2005 (http://www.cnr.it/cnr/events/CnrEventi?IDn=683)*

[3] *Programma Nazionale di Ricerca - PNR 2005-2007 (http://www.miur.it/0003Ricerc/0141Temi/index_cf3.htm)*

With respect to the technology transfer referred to in Materials Technology and other industrial sectors, Federchimica has developed specific contacts with CNR to develop specific strategies. Firstly, Federchimica analysed certain successful models of technology transfer structures in European and non European countries (for example, the Canadian model, the ISIS model of Oxford University, the Fraunhofer-Gesellschaft model or Regional Competence Centres of the Campania Region). Thereafter, Federchimica reached the conclusion that the key point for chemical enterprises in Italy is to be able to count on one or more existing technology transfer structures that will provide them with applied research results, placing them in a position where they are able to do industrial research on that which they have demonstrated that they know how to operate successfully. On the basis thereof, Federchimica proposes that CNR, in the role of technology transfer, is a suitable interface for the needs of the enterprises.

Federchimica therefore decided to enter into a Framework Agreement with CNR (signed on 6 May 2005), in order to supply SMEs with a valid instrument and to trigger a virtual research and innovative process, placing them at the forefront and making them competitive on the global market. In this way, the SMEs could make use of CNR's competencies and of their research structures, thereby overcoming their dimensional limitations.

In fact, the Framework Agreement between Federchimica and CNR provides the following:

- Jointly elaborated specific projects, with shared objectives between CNR and Enterprises;
- Planned and controlled research with a responsible project-manager who is adequately professional and experienced;
- CNR is to assume the costs and risks related to applied research activities;
- The Enterprises are to guarantee the use of their results and assume the relative costs of industrialisation and entrepreneurial risks;
- Penalties in the event of non-fulfilment in order to guarantee the seriousness of the Agreement and the duties undertaken;
- The discipline of industrial property rights;
- Give royalties to CNR in terms of a licence for the use of the results.

In terms of the "CNR – Federchimica Framework Agreement", specific actions aimed at the presentation of the CNR offer to Associate Enterprises and the clarification thereof, with the involvement of SMEs in particular, are provided for. These meetings can favour the creation of concrete collaboration between Enterprises and CNR.

Furthermore, Federchimica transmitted the "Sustainable Chemistry" project to CNR, which was positively evaluated by the Director of the Molecular Designs Department, Prof. Viticoli and will become one of the inter-departmental projects provided for in CNR's new statutes.

4.2.2 - Description of the Materials Technology Sector

Material and material development have been fundamental for the development of our civilization and continue to be one of the most important factors and objectives of industrial development, thereby contributing in solving some emerging societal needs and to increase the quality of life. As the 21st century unfolds, it is becoming more apparent that the next technological frontier will be opened, not through a better understanding and application of a particular material, but rather by understanding and optimising material combinations and their synergistic function, hence blurring the distinction between a material and a functional device comprised of distinct materials[4]

Materials science deals with the design and manufacture of materials, an area in which chemistry plays the central role; there is also considerable overlapping in the chemical engineering, biotechnology and physics fields. Discovery of new materials with tailored properties and the ability to process them are one of the main constraints of industrial development. The demands of tomorrow's technology translate directly into increasingly stringent demands on the chemicals and materials involved: their intrinsic properties, their cost, their processing and fabrication, benign health and environmental attributes and their recycle-ability, focussing on eco-efficiency. This requires doing a complete life cycle analysis on the new developed products and considering both the ecological as well as the economic components. Converging with the various performance demands are a suite of new technologies and approaches that offer more rapid new materials discovery, better characterisation, more direct molecular-level control of their properties and more reliable design and simulation.

The ***Materials Technology*** section of SusChem focuses on materials for mankind's future surroundings, which will be designed to enhance the quality of life while at the same time minimising the use of resources and limiting environmental impact. These materials will make life simpler, easier, safer, better and more importantly, place mankind at the centre of technology. The role of nanoscience and related nanotechnology will be one of the important factors in providing the knowledge necessary for innovative products and process methods.

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[4] *The vision for 2025 and beyond: A European Technology Platform for Sustainable Chemistry, EU-SusChem Vision Document, March 2005 (http://www.suschem.org)*

Materials science has made substantial contributions to many fields including: modern plastics, paints, textiles and electronic materials but there are greater opportunities and challenges for the future. Materials chemistry is vital in all areas of science and technology as well as in the needs of society respecting energy, information and communications technology (ICT), healthcare, quality of life, transportation and citizen protection. Furthermore, materials science will play an important role in contributing to solutions for some emerging societal needs and in increasing the quality of life of European citizens.

The vision of the European SusChem Platform on Materials Technology is[1]:

1. To make Europe the world's leading supplier of advanced materials.

2. Innovation in materials technology driven by societal needs and contributing to improving the quality of life of European citizens.

3. Accelerated identification of opportunities, in close co-operation with partner industries down the value chain, leading to materials with new and improved properties.

4. The ability to rationally design materials with tailored macroscopic properties, based on their molecular structure.

5. Products based on integrated complex systems made available by improving and combining the benefits of traditional materials and nanomaterials.

6. Convergence of market demand and technology development, creating many opportunities for new enterprises in the materials sector (e.g. SMEs).

The SUSCHEM platform, should contemplate in its priorities different aspects of materials research, and integrate them:

- *Multifunctional materials* by design: polymer and organic semiconductors, polymer and organic dielectrics, conjugated liquid crystals, molecular actuators, coordination compounds and clusters; nanoparticles, nanotubes, nanopowders, nanostructured surfaces
- *Bio-functional materials*: bio-compatible and bio-degradable materials with tailored properties which include thin films and surface coatings, medical prosthetics, materials for therapeutic and diagnostic applications, formulation technologies for drugs, agrochemicals, nutrition, cosmetic and personal care products and bio-nanocomposites using, amongst others, nanotechnological and biomimetic material concepts. In this area, links to the technology section of industrial biotechnology are to be found and concerted activities will be necessary;
- *Intelligent materials* with tailored electrical (e.g. superconducting), optical, mechanical and magnetic properties for applications in electronic devices, such as, displays or sensors for the development of organic electronics;
- *Materials for new sustainable technologies* in the areas of energy creation, storage, transport and conversion, covering areas ranging from renewable energy sources, such as, solar and fuel cell technologies to nanoporous materials for insulation; nanomaterials and nanopowders able to degrade contaminants and remediate the environment.
- *Development of new methods for the controlled synthesis* of rational designed materials including novel polymerisation techniques and catalytic processes, giving access to yet unknown materials. Activities in this area will be linked to activities in the other two sections: Reaction & Process Design and Industrial Biotechnology, seeking the most eco-efficient process possible.
- *Hybrid materials:* conventional materials (polymers, co-polymers, glass, fibres) integrated with a functional or multifunctional material; systems for hybrid technologies (e.g. organic spintronics)
- *Organization, assembling and self-assembling*: growth of thin films and nanostructures; cooperativity; wetting/dewetting; capillary forces in nano- and mesoscopic channels; self-assembly; self-organisation; kinetics vs thermodynamics; structure of organic/metal and organic/dielectric interfaces; interfaces between multifunctional materials and magnetic conductors; length scales of organisation; study of spatial correlations and length scales
- *Fabrication and processes*: Advanced materials technologies based on new and optimized traditional processes. Key words include intercalation, exfoliation, dispersion, covalent and non covalent interactions, molecular and multiphase distribution and orientation, unconventional lithographies, etc.
- *Properties:* charge and energy transport; charge injection; exciton dissociation; magnetism; spin transport; actuation; intermolecular and surface forces; scaling behaviour of relevant properties
- *Tools and techniques:* for growth and characterisation. It is important to increase the use of nanoscale microscopy techniques in chemistry (scanning probes above all, still rather limited with respect to the potential), and diffraction techniques to nanostructures. Scanning probes should be strengthened not only for the morphological information, but also for the investigation of length scale dependent properties as electrostatic potential, magnetism, viscoelastic properties. Electron spectroscopy, nanoscale optical probes, micro-Raman also surface (SERS) and tip-enhanced (TERS), electron microscopy.

- *Devices:* these are crucial for the demonstration that the sustainable chemistry and fabrication approaches paves the way for a technological platform. Electronic and optoelectronic devices, photonics, sensing, memories made of one or more integrated components; microfludic systems, and their integration with other solid state devices (hybrid liquid-solid state technology). Nanotags with high information content and integrated sensitivity (e.g. time temperature integrators; security: identification)

Nanotechnology: *Nanotechnology is the design, characterisation, production and application of structures, devices and systems by controlling shape and size on a the nanometre scale.* Application areas include construction, cosmetics, polymer additives, functional surfaces, vehicles, the aerospace industry, sensors and biosensors, molecular electronics, targeted drug release and manufacturing. Although there is nothing like a single discipline called "nanotechnology", the ability to design and control the materials' properties through size, shape, dimensionality, positioning and inter connectivity, at all length scales will nevertheless be crucial for most high-value applications. So, Nanotechnology must be considered as being a horizontal enabling technology supporting innovation in all areas of Materials Technology. This requires the integration of different fields of chemistry and the other disciplines like physics, engineering, biology and medicine. From the cultural point of view, this is an important challenge for chemists, which traditionally operate within the disciplinary boundaries of their specialty and often experience difficulties in interfacing with researchers from other disciplines or fields, especially for device applications. In most of the chemistry curricula, the integration of the different disciplines is often weak. It turns out that traditional research approaches emerge more natural. This is a barrier for the further evolution of the chemist towards more complex and ambitious research activities. In order to boost high impact research, the programs envisioned in the platform must promote cross-disciplinary activities.

Among the fields where multidisciplinary approach in the research at the state-of-the-art is normally applied, multifunctional materials designed for electronic and optical properties, recognition and sensing, actuation, catalysis, occupy a central role. Multifunctional materials are paradigm of nanotechnology, since they combine relevant properties for applications together with the ability to give rise to precisely defined architectures, in size and connectivity, by sustainable fabrication processes. These materials are of great interest for many technological fields, from intelligent packaging, to smart textiles, to consumer's electronics, information storage media, sensors, displays.

The fabrication technology with control at all length scales is a central issue for research on multifunctional materials. In the platform, it is important that activities aimed to explore fabrication comply to several requirements:

- must be based on convergence of top-down and bottom-up approaches to ensure the control across length scales;
- must be sustainable;
- must be scalable:
- must be as versatile as possible.

Therefore, it is important to contemplate research activities not exclusively aimed to prototyping, which can be easily made by serial approaches, as for instance scanning probe lithography and manipulation, but instead put an effort towards scalable approaches which are suitable for large area and/or high throughput fabrication. Indeed, the shortcoming of many "nanotechnology" projects is that they stop at the material synthesis and characterisation, else at the proof of concept, without envisioning an evolution towards up-scaling and real applications. The integration of both "proofs of concept" and up-scaling is the effective way to direct research towards goals which are ambitious from the fundamental research point of view, but also become attractive for industry. An example is soft lithography, where the phenomenon of self-assembly at surfaces has evolved towards a patterning technology with applications in many different tech, from technological fields, from microelectronics, to micro-electromechanics, optics, photonics, biodiagnostics, printing, information storage. The impact is huge, from consumers' electronics, to health, safety and traceability of food and pharmaceuticals, and smart packaging. These industries are end-users of materials and technology developed within this frame. Therefore, it is crucial that the chemical industry increases its awareness to the fabrication aspects, and catches these new market opportunities for fine chemicals and for traditional materials which can be endowed with new properties by suitable fabrication.

The attractive feature of multifunctional materials is that they can be patterned into nanostructures of well defined size and a variety of controlled shapes, such as lines, dots, meshes, nets, etc. by exploiting sustainable approaches, as for instance self-organisation from solutions in confined environments. The control on the smaller length scales is intrinsic to the self-organisation process, whereas the larger length scales are imposed by the external agency. The control on the size and dimensionality of the material can be enforced by merging the emergence of characteristic length-scales (at the nanometer-mesoscopic scale) of self-organisation phenomena with the larger length scales, from tens of nanometers to microns, that are imposed by an external agency, either stamps, microfluidics with meso- and nanoscopic channels, or nanofabricated templates, or simply the interplay with capillary and hydrodynamic forces.

This converging approach requires a thorough knowledge not only on the materials properties and intermolecular interactions by design, but also on interfacial and surface interactions, competing interactions, nucleation and growth phenomena, capillary and viscous forces, hydrodynamic effects. Therefore, it is important to establish broad research programs where synthesis and molecular design interact with physical chemistry, polymer chemistry and engineering, theory of the condensed and soft matter, surface physics, characterisation at the nanoscale with local microscopy and spectroscopic techniques, multiscale simulation of phenomena in meso- and microscopic systems. These programs should contemplate device and bio-diagnostics demonstrators of the materials and the processing technology. As examples, fabrication of memory storage elements, field effect transistors, biosensors where the active component is made of nanostructures exactly defined in terms of size, shape and position, would make projects much more coherent and convincing for long term exploitation. The development should be in the hand of engineers, with e.g. the simulation of the circuitry and the logic boards, or the up-scaling of the patterning technique to large area or roll-to-roll processing. This may be a strong contact point between chemistry and industry.

4.2.3 - Interaction with other Technology Platforms[5]

On a European level, close interaction between SusChem and other technology platforms is of utmost importance, as chemistry and biotechnology are enabling technologies, delivering solutions and materials for a wide range of other areas like the consumer care industry, information technology or transport.

SusChem has identified several technology platforms which either promise significant synergy with SusChem activities and/or cover important technology for chemistry and biotechnology along the value chain. Bi- and multilateral consultations with these platforms will be continued or organised in the future.

The technology platforms essential for SusChem are:

- Biofuels
- Construction
- EuMaT
- Forestry
- Hydrogen and Fuel Cells
- Industrial Safety
- Manufuture
- Nanomedicine
- Photovoltaics
- Plants for the Future
- Textiles
- WSSTP
- Zero Emission Fossil Fuel Power Plants

4.2.4 - Main R&D priorities for Materials Technology in Italy

This chapter synthesizes the information provided by stakeholders on the priorities, needs and expertise on Materials Technology provided by Italian industries and public and private research centres.

As expressed above, the information will be analysed and classified according to the priorities already identified at a European level[3]. However, it is obvious that the Italian Platform should also define and propose new priorities, not previously identified, that will enhance the Italian contribution and presence in the EU-SusChem Platform.

Considering Italy's socio-economical priorities, its international position, R&D industrial needs and expertise already available in Italy, future R&D national efforts in the area of Materials Technology should be addressed to implement and boost the development of:

a) *Nanosciences and nanotechnology:* Nanosciences and nanotechnology are widely seen as a multi-disciplinary and integrative RTD approach, having the huge potential to improve the competitiveness and sustainable development of materials technology across a wide range of industrial sectors.
b) *Development of new materials with higher knowledge content:* Materials with new functionalities and improved performance must be developed in order to increase industrial competitiveness and sustainable development.
c) *New manufacturing processes:* efficient processing of new materials with tailored properties, from a resource intensive to a sustainable knowledge-based industrial development.
d) *Materials with higher knowledge content* and innovative manufacturing approach for specific industrial sectors
e) The LCA approach: a selection criterion of defining eco-materials based on their environmental performance

4.2.4.1: Priority a) - Nanosciences and Nanotechnology

The main objective is the study of the fundamental phenomena and the manipulation of matter at a nanoscale, in order to promote long-term innovation by enabling the manufacturing of new nanotechnology-based products with

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[5] European Technological Platforms (http://cordis.europa.eu/technologyplaforms/ home_en.html)

superior performance across a range of applications, while minimising any potentially adverse environmental and health impacts. Interdisciplinarity and the integration of theoretical and experimental approaches are required.

Main research themes for the Italian community include:

Development of self-assembled nanostructured materials and surfaces

Molecular self-assembly is a strategy for nanofabrication that involves molecule designing and supramolecular entities so that shape-complementarity causes them to aggregate into desired structures. Self-assembly has a number of advantages as a strategy: it carries out many of the most difficult steps in nanofabrication--that involve the atomic-level modification of structures, using the very highly developed techniques of synthetic chemistry. Secondly, it draws from the enormous wealth of examples in biology for inspiration: self-assembly is one of the most important strategies used in biology for the development of complex functional structures. Moreover, it can incorporate biological structures as components directly in the final systems. Finally, because it requires target structures that are thermodynamically the most stable ones open to the system, it tends to produce structures that are relatively defect-free and self-healing. The long term objective should be to take advantage of self-organization processes to develop nanostructured materials with specific and controlled physical-chemical structures and with predictable and controllable properties. Bottom-up self-assembling and self-organisation should be used in order to generate structures with new functionalities. Computer modelling should be used to help understand the fundamental aspects of self organisation and multi-scale development.

In this topic the appealing features of the DNA molecule should be considered in bottom-up nanobiotechnology. Its excellent stability and powerful molecular-recognition properties can be used to direct the assembly of highly structured material with specific nanoscale features. In fact, this biomolecule plays an outstanding role in the development of artificial biomolecular hybrid elements, since the specificity of simple A-T and G-C base pairing as well as its robust physicochemical nature allows for the fabrication of nanostructured molecular scaffolding and surface architecture, and to selectively position proteins, inorganic colloidal components, carbohydrates, organometallics, and reactive chemical compounds on the nanometer length scale.

Also in this topic mesostructured templated silicates and zeolites are considered to provide stable frameworks whose surface can be respectively modified by functonalization and ionic exchange. By this way, the properties of a single framework can be tailored according to the specific field of application for which the usage of a nanostructured material is required.

Italian research lines of interest:

- nanoscale integrated processing of self-organizing multifunctional organic molecules and polymers
- self assembly of metallic nanocrystals and functionalized semiconductors in nano-patterned 2/3 D structures for optoelectronics and sensors
- organic conjugated systems for electronic and optical applications
- development of carbon based nano and micro structures
- modelling electro active conjugated materials at a multiscale level
- self-organization of polymer blends and block copolymers
- development of self-assembled nanostructured hybrid surfaces and thin films
- systematic exploration of DNA molecules and analogues to expand and improve their self-assembly properties
- modelling and characterisation of liquid crystals for nano-organised structures
- real-time characterization and computational modelling of nucleation and growth in self-assembling organic materials
- setting up and optimisation of new methods for the preparation of nanostructured ceramic materials
- synthesis, functionalization and characterization of mesostructured templated silicates and zeolites
- synthesis and characterization of self bonded pellets containing carbon nanotubes

Development of self-repairing materials and surfaces

In recent years, the ever increasing growth of polymer-based composites as structural and functional materials has been the source of new problems that are beyond the chemistry of the synthetic process itself. Many applications not only require specific mechanical properties, but also demand suitable resistance to potential damages during their use (repeated mechanical stresses, attack by chemical or physical external agents, etc.). Usually, the damages are made evident by the appearance of microfractures (cracks) that occur in the matrix and follow chain degradation. An immediate consequence of the degradation process is a decrease in molecular mass as well as a variation in the chemical composition of parts of the polymer chain. So far, the exact localization of the events causing degradation to start is almost always rather difficult and a repairing service practically impossible. Above all, most microfractures are produced inside the polymeric material and become visible only when the mechanical resistance is irreversibly jeopardized.

The aim of this research sector is to make some of the efforts and results obtained by a few research groups in the world well-known, thereby striving to find and optimize self-repairing pathways of polymer materials, when the latter can face structural damages during their service. Hence, it is necessary to point out not only that the chemistry of the repairing process is not always fully developed at present , but also that the transfer of the research results to potential applications still requires relevant additional time to be accounted for. The interest for possible *in situ* self-healing approaches to apply to microfractures, wherever localized, has grown widely in the last few years and is centred on the development of self-repairing mechanisms, activated by the damage itself, as a key point common to most researchers.

Italian research lines of interest:

- Development of self-repairing and self-diagnosis materials and strategies for aeronautic and aerospace, biomedical (e.g. joint prosthesis, by-pass, cardiac valves and dental materials), sports and automotive fields.

Development of dendritic structures with tailored properties

Since the pioneering work of well-defined, three-dimensional structurally ordered macromolecules by Vögtle, Tomalia and Newkome, interest in dendrimers and hyperbranched polymers has increased at an amazing rate. The study of these polymers expands to all areas including theory, synthesis, structure characterization and properties and investigations of potential applications in different advanced industrial sectors. A broad range of dendrimers and hyperbranched polymers is now available; some dendrimers even commercially. Emphasis is shifting to an exploration of their potential use and application.

Italian research lines of interest:

- micelles and encapsulation
- self-assemblies and liquid crystals, layers,
- electroactive dendrimers and electroluminescent devices,
- conductive and ionic conductive polymers,
- catalysts, biochemicals and pharmachemicals
- dendrimers in analytical chemistry
- dendrimer-nanoparticles and polymer-nanoparticles for multiple biological functions

Development of new synthetic strategies: “Click” chemistry

Recently, researchers of the Scripps Research Institute, USA, developed a new synthetic strategy named “click chemistry”. This strategy is based on reactive molecular building blocks designed to "click" together selectively and covalently. Several research groups in the world are now extending the above idea by using protein binding sites, supramolecular complexes or functionalized surfaces as reaction vessels to direct the *in situ* formation of potentially functional click chemistry products. The products might be biological inhibitors, molecular-electronic components, sensor probes, nonlinear optical materials, light-harvesting compounds or compounds with any number of other useful functional properties. However, the polymer materials community has not yet fully developed the enormous potential of click chemistry in terms of new multifunctional macromolecule systems.

Italian research lines of interest:

- Development of new click chemistry strategies for innovative (macro)-molecules

Nano-scale materials and their interaction with biological systems

The objective should be to develop innovative nanostructured materials and surfaces with tailored properties and to explore the interaction mechanisms at a nano-scale between biological systems and nanostructures, in order to allow the design of nanostructured systems which interact in a predictable and controllable way with biological systems. These hybrid systems are of interest for industrial applications in view of potential benefits for health, food quality and environment. In this context, the properties of these hybrids depend in a complex manner on the interfacial interactions that determine their performance. Reactivity, diffusion phenomena and stability of the interfaces are main topics for applicative research. The design of novel nano-scaled materials with improved specific surface properties requires a detailed understanding of the underlying physical principles and the ability to control interfacial interaction parameters. The improvement of knowledge on stability, durability and performance of the nanohybrids, through the study of interactions, linkages and reactivity of new functionalities at the biomolecule/polymer interfaces are fundamental for industrial biotechnological applications in biosensing and drug delivery.

Italian research lines of interest:

- development of antimicrobial nanocomposites and nanostructured surfaces for films and fibres
- development of nanostructured antifouling materials and surfaces
- electronic interaction of photosensible proteins enclosed in polymer and glass matrices
- immobilization of proteins in membranes for biosensors.

- interaction lipids/proteins in electronic and protonic transfer processes in photosynthetic and biomimetic membrane systems.
- Development of iInnovative hybrid (inorganic-organic-biological) materials designed at nanoscale level (including nanoparticles, nanotubes, nanorods) and obtained by chemical routes or controlled self assembly for biocatalysis, biosensors and drug delivery
- macromolecular nanosized systems chelating paramagnetic ions for Magnetic Resonance Imaging (MRI) in medical diagnostics
- bio-inspired nanodevices for multiple biological functions such as drug delivery, gene therapy and medical diagnostics
- CNT as nano-substrates of DNA, RNA and proteins in drug and gene therapy
- design, synthesis and characterization of novel, nanostructured functional hydrogels and composites with tailored optical and electric properties for biotechnological applications
- use of ionizing redaition beams for structure and morphology control in nanobiocomposites

Nano-scale materials and their interaction with the environment

Engineered nanomaterials are showing high potentiality for applications in the environmental field and in particular in pollution prevention, sensing and remediation. On the other hand, the fate of nanoparticles in the environment is not fully understood and is the result of complex mechanisms arising from their small dimensions, the reactivity, the tendency to aggregate and to attach to surfaces.

Italian research lines of interest:

- development of new materials for the remediation of contaminated sites
- understanding the transport of nanomaterials in different environmental matrices

4.2.4.2: Priority b) - New materials with higher knowledge content

Research should focus on the development of new knowledge-based multifunctional materials and surfaces with tailored properties and predictable performance in order to obtain new products for a wide range of applications and taking into account potential impacts on health and the environment throughout their entire life-cycle. In particular the structure–property relationships at different scale should be analyzed using advanced characterization and modelling techniques in order to obtain design tool to improve materials performance, reliability and durability.

Main research themes for the Italian community should include:

Nanostructured composite materials

Nanostructured composite materials, mainly based on polymer matrices with inorganic nanofillers (clays, oxides and other ceramic nanofillers, metals, nanotubes and nanofibers) are emerging as materials with increasing industrial interest. These polymer nanocomposites, exhibiting radically enhanced properties, normally require a lower filler loading than composites with traditional fillers, resulting in markedly improved performance with higher homogeneity and lower density. Research efforts are still required in order to guarantee the dispersion of the nanofiller and the adhesion to the polymer. Fundamental studies on polymer-nanofiller chemical compatibilization, rheology, processing behaviour, thermal stability and life cycle analysis should allow a better understanding and control of the final structure of nanocomposites with enhanced performance in terms of mechanical properties, thermal and dimensional stability, bioresistance, fire retardancy and other barrier properties.

Among nanostructured composite materials an outstanding role is played by dispersions of metallic nanoparticles in ceramic matrices. Such materials may be obtained as follows: (i) subjecting to transition metal cation exchange various zeolites; (iii) reducing such cations to 0 oxidation number by thermally treating in hydrogen atmosphere the transition metal cation exchanged zeolites; (i) sintering such zeolitic powders

Italian research lines of interest:

- designed nanostructured hybrid materials from polymerization catalysis
- nanostructured and multifunctional polymer materials and nanocomposites by melt processing and in situ polymerization
- compounding, rheology and mechanical properties of thermoplastic matrix nanocomposites
- crystallization kinetics and morphology in thermoplastic polymers and their composites and nanocomposites
- environmentally friendly multifunctional fire retardant polymer hybrids and nanocomposites
- multifunctional barrier for flexible structures (textile, leather and paper)
- predicting the fire behaviour of nanocomposites from intrinsic properties
- design nanostructured hybrid polymers

- inorganic or organic metal/polymer nanocomposites obtained through radiation induced crosslinking reactions
- modification of nanofiller structure and surface to improve dispersion and polymer compatibility
- nanostructured, multilayered and functionally graded coatings for improved mechanical, wear, electrical and corrosion resistance properties
- nanostructured hybrids based on polymer matrix-carbon nanotubes interactions
- interactions nanotubes and nucleic acids (DNA or RNA for dispersion of CNTs)
- development of new processes for the transformation and functionalization of natural polyphenols, lignocellulosic materials, cellulose and hemicellulose derivatives for the polymers industry

Inorganic materials with tailored porosity

The interest in porous materials has grown rapidly in the recent years with the demands from new fields of applications and processing routes. The use of porous materials already assessed in thermal insulation, substrates for catalysts and filtration systems still holds great expanding potential into new technologies for energy conversion, health and environment care, transportation etc. Membranes find application in biotechnology, food processing, pharmaceutical, petrochemical, electronics; improvement of the thermo-mechanical properties while lowering production costs is necessary for further expansion of the applications. In the biomedical field porous ceramics find use in bone replacement and drug delivery systems. Innovative methods are required to modulate the functional properties (electric, acoustic, magnetic, drug delivery, etc.) of materials by tailoring the porosity. This research area is focused on the design and processing routes to develop micro to macro porous structures with controlled pore morphology, i. e. size, size distribution, shape, interconnection, volume distribution.

Italian research lines of interest:

- innovative porous structures for catalysis
- functionally graded porous materials (fuel cells)
- piezoelectric porous materials for ultrasonic applications
- porous supports as bioreactors
- biomimetic processing
- membrane and filter processing

Smart molecules and materials

This theme approaches complex molecules and advanced materials with a wide spectrum of enhanced functionalities and with the potential to replace whole devices at all scale levels (from nano to micro). Some industrial applications already exist but there are still immense possibilities of achieving improved functionality by further tailoring the material properties in many areas, from shape memory alloys and electroactive polymers to photochromic materials and tuneable dielectrics. The main objective is to design novel knowledge-based smart materials with tailored properties, releasing their potential for enhanced and innovative applications.

Italian research lines of interest:

- nanocomposites with high colouring efficiency for electrochromic smart plastic devices
- development of shape memory nanostructured polymer materials and blends
- synthesis of a new generation of molecular components for nanometric machines, suitable for photoconversion and/or photoemission, or able to control movements in response to a luminous and/or electric stimulus. In particular, multicomponent organic and organometallic structures, featuring both the active component - imparting the specific functionality - and the appropriate structural elements.
- development of visible light-sensitive photo catalytic materials and devices for solar energy conversion

Organic materials for electronics and photonics

Organic materials have the huge potential of increasing the competitiveness of the electronics and photonics industries. New developments in polymer based electronics and photonics (e.g. flexible display technology and lighting), and related photovoltaic innovations, rely to a large extent on new organic materials development. Research should focus on the materials performance, reliability, durability and processing (patterning, multilayering, self-assembly, molecular separation and recognition, vapour growth techniques, selective laser treatment, deposition at surfaces, etc.).

Italian research lines of interest:

- synthesis and characterization of functional materials at atomic, molecular and nano levels and their nanomanipulation through electronic, photonic and thermal mechanisms, for materials with designed optical and electrical properties
- development of nanostructured organic multifunctional molecules and polymers with tailored electronic, optical and sensing properties.
- design and fabrication of micro and nanostructured organic thin film transistors
- new conductive nanocomposite plastics (via CNT and CNF) for energy transmission, sensing and lighting devices
- nanocomposites of conjugated polymer and CNT and CNF for light transmission
- development of polymer based nanocomposites and nanostructured thin films for photovoltaics for energy applications.
- synthesis of nanocrystals for optoelectronics
- synthesis and surface engineering of semiconductor nanoparticles,
- modification of nanostructurable polymers using photolithography and non conventional patterning techniques: nanoimprinting lithography (NIL) and ink-jets, for optoelectronic applications
- self assembly of metal and semiconductor nanocrystals functionalized in 2/3 D structures by nanopatterning in optoelectronics and sensors.
- molecular, polymeric, supramolecular and hybrid nanostructured materials with specific electronic and optical properties for photonics.
- design and fabrication of optoelectronic devices based on innovative second-order nonlinear organic nanomaterials
- synthesis and characterization of polymers and oligomers for organic light emitting diodes

Nanostructured materials with tailored magnetic properties

Magneto-opto-electronics is an emerging field for the realisation of novel devices with huge potential for information technology. Understanding the coupling of magnetic, optical and electronic phenomena at a nanolevel still requires much research in areas such as spintronics, magnetic data storage/processing, photonics and sensors for medical applications.

Italian research lines of interest:

- fundamental analysis of the magnetic resonance of molecules
- quantum effects in molecular nanomagnets
- molecular approach to nanomagnets and multifunctional materials
- development of magnetic nanoparticles and core-shell structures with tailored magnetic properties.
- nanostructured magnetic materials for sensors for positioning systems

4.2.4.3: Priority c) - New manufacturing processes from resource intensive to sustainable knowledge-based industrial development.

Production routes are as important as material properties in increasing performance and the added value of products. Therefore, the development of knowledge based materials cannot be industrially exploited if no efforts are devoted to the development and understanding of innovative production routes. For example PECVD (plasma assisted chemical vapour deposition) is a technology with extremely low environmental impact due to the lack of wastes that allows to treat every kind of materials because of the low temperature and low pressure employed. Extensive modelling of transformation processes are required to analyze the transformation of materials during processing and during service life. Life cycle engineering is required to understand and optimize the environmental impact of products and transformation technologies. This priority should be developed in close interaction with the working group on chemical processes.

Main research themes for the Italian community include:

Materials from renewable feedstocks

The development and use of alternative feedstocks for raw materials that currently depend on oil availability are highly interesting to the Italian industry. This concept can be applied not only to energy and to the production of current polymeric materials but also affect the production of basic raw and intermediate materials in the chemical industries. In particular, the combination of bio-materials, or of natural and synthetic polymers, offers much potential for the substitution of current materials and the development of new ones with new functionalities and applications. This is clearly highly interesting for Italy, which has a critical dependency on energy and oil from geographical areas with high potential risks. On the other hand, Italy offers much potential for agricultural exploitation which can be applied to the concepts of bio-refinery and raw materials from biomasses.

Also in this topic, the use of other organic and inorganic renewable and/or natural renewable feedstocks are considered

Italian research lines of interest:

- new monomers from natural resources- processing of plastics from natural resources
- development of new polymers based on renewable resources (bioplastics) for bulk and coatings
- development of composite materials based on biopolymers
- development of pozzolanic cement manufacture based on natural zeolite additions
- utilization of industrial residues to produce bricks and other ceramics with properties of sound proofing and thermal proofing

Optimization of the processing of polymers, composites and nanocomposites

The efficient processing of new materials with tailored properties, in many cases, constitutes the main limitation of product development in many industrial sectors. These limitations are mainly related to the lack of knowledge on the fundamentals of processing behaviour and on possible environmental restrictions (i.e. solvent use, volatile side products, energy consumption, etc.). The main industrial products and application fields affected by these limitations include plastics, paints, textiles and electronic materials.

Italian research lines of interest:

- development and processing of polymer foams (PET, LDPE, PS, PU)
- injection molding of hybrid polymer-wood composites
- processing of innovative elastomeric thermoplastic materials and functional liquid-crystalline elastomers
- polymer injection advanced moulding (PIAM)
- development and processing of advanced polymeric systems for adhesives and coating
- melt rigradation of recycled PET through reactive extrusion (including use of nanofillers)
- analysis, optimization and control of the dimensional stability of injection moulded polymers, composites and nanocomposites

New catalysts with nanostructured tailor-made functional surfaces

A new generation of catalytic materials with tailored functionality at the surface are required for new sustainable chemical processes having higher energy efficiency and selectivity, Interdisciplinary efforts, including advanced multiscale modelling and characterisation techniques, are necessary to fully understand highly complex catalytic processes based on a controlled sequence of surface reactions and of active sites.

Italian research lines of interest:

- development of novel catalytic materials
- setting up and optimisation of new methods for the preparation of nanostructured catalysts with specifically tailored properties
- integrated design of catalytic nanomaterials for a sustainable production
- new polyolefin catalysts (homogeneous and heterogeneous)
- new polymer structures for PP, PE, PB-1, APO, polydienes and polycycloolelfins
- new production technologies for polyolefins
- development of novel methods for polyolefin production research
- high throughput screening platforms
- compounds and nanocomposites of new and available olefin based polymers

Computational modelling of the structural evolution during processing and full life-cycle

Major improvements in materials design and processing behaviour can be analyzed beforehand, by means of the mathematical simulation and experimental validation of the nano, micro and macrostructural evolution of material properties and phenomena that determine the macroscopic material response, during processing and under working conditions. Modelling approaches are expected to build on the relationship between processing conditions, microstructural evolution and specific macroscopic material properties and to take advantage of new multi-scale approaches.

Italian research lines of interest:

- modelling and design of advanced composite materials
- modelling and design of advanced ceramic and cermet coatings
- computational modelling of polymer processes with particular attention to the simulation of injection moulding of polymers, composites and nanocomposites including crystallization effects
- modeling and control of morphology of semicrystalline polymers under realistic processing conditions
- advanced processes for near to shape production
- multi-scale modelling of interfacial phenomena in nanocomposites, bridging molecular-level and continuum-level descriptions
- modelling of PECVD plasma processes, for process monitoring and control

4.2.4.4: Priority d) - Materials with higher knowledge content and innovative manufacturing approach for specific industrial sectors

The development of fundamental knowledge on the processing-structure-properties of new materials with the integration of the first three sectors described above, that is, nano-, materials-, and production-technologies, will support innovative applications in bulk and coating high-demanding sectors, such as health, construction, transport, energy, environment, information technology, textiles, chemical engineering and other important industrial sectors.

In particular the thin film technology concerning a large variety of non-equilibrium processes for leading-edge surface modifications of materials is gaining increasing popularity, because it allows the design of substrate by means of the deposition or modification of thin films in an extremely versatile and environmentally friendly way, i.e. by employing low pressure plasmas, also called cold plasmas or glow discharges. The environmental considerations are becoming more and more important after the Kyoto Earth Summit and its subsequent amendments, and the world-wide initiatives as EU IPPC Directive (Integrated Pollution Prevention and Control – 96/61/CE), that requires, as a target for the different industrial sectors, the development of the best available techniques.

Main research themes for the Italian community include:

Materials for energy conversion

The research in this sector should be aimed at the development of new materials with tailored and controllable complex architecture (quantum dots, nanocomposites, thin and thick-films, mesoporous 3-D architectures, carbon and inorganic nanotubes, aerogels and ionogels, etc.) and structure (specific surface area, porosity), which should provide improved efficiency and competitive cost/efficiency ratios as well as durability in energy conversion systems (supercapacitors, stacks, solar cells, high performance batteries, etc.). Moreover, research is required in highly efficient energy conversion technologies and related materials, such as catalytic combustion.

Italian research lines of interest:

- Polymers, composites, nanocomposites and ceramic materials for fuel-cells
- development, characterization and application of supramolecular systems for energy production systems
- materials for solar concentration plants
- development of polymer-based nanocomposites and nanostructured thin films for photovoltaics for energy applications
- catalysts for higher efficiency energy conversion, e.g. for catalytic combustion
- semiconducting materials for H2 production through photoelectrocatalytic water splitting

Biomaterials for tissue engineering

This theme addresses materials for biomedical applications designed with specific bioactive properties and controlled interaction with the surrounding biosystem. Bioinspiration should be the main driving concept from the nanoworld of proteins to macroscopic soft and hard tissues.

Italian research lines of interest:

- development of biomaterials for bone regeneration and cement
- innovative materials and technology for bio-engineered prostheses
- innovative materials and technologies for tissue engineering

- injectable macroporous biomaterials based on calcium phosphate cement for bone regeneration
- smart composites and nanocomposites for bone tissue and cartilage repair and regeneration including in situ gel forming systems and Gene Activated Matrix (GAM)
- natural and synthetic polymers for applications in the peripheral nerve regeneration
- innovative biocompatible biomaterials for wound healing and for prevention of post operative adhesion

New materials and technologies for extreme service conditions

This theme addresses polymeric, composite and ceramic bulk materials and surfaces, specifically designed for use in extreme conditions and environments: very high or very low temperatures, radiation, high pressures, high electromagnetic fields, damaging chemical reactions such as, corrosive or oxidizing environments, biodegradation, or possible combinations of these conditions at the same time.

Italian research lines of interest:

- structural ceramic nanocomposites for top-end functional applications
- development of nanostructured materials with specific photocatalytic properties for the protection of ceramic materials from aerial and aqueous contaminants
- development of advanced ceramic coatings for extreme environments with self-diagnosis properties
- composites for ballistic applications
- nanocomposites with tailored electrical properties for EMI-shielding
- innovative flame retardancy polymers for coatings, cables, etc
- development of advanced multilayer surface technology for extended resistance in extreme environments
- development of nanostructured materials with photocatalytic properties for the treatment of industrial aerial and aqueous contaminants
- development of refractory synthesis from zeolitic precursors
- development of PECVD plasma processes for corrosion resistance tribological coatings

Development and application of new materials and fibres in the textile industry

The development of materials with enhanced mechanical and functional properties, with the potential use of nanotechnology, is crucial to the competitiveness of the textile industry. Enhanced fibre properties include weight/ performance ratios, strength, durability, flexibility, bio-degradability, energy-efficiency, insulation, temperature and moisture management, permeability, self-cleaning and self-healing. Given the role of textile materials, the early involvement of consumers in the R&D processes may play a critical role in improving the selection of the research paths and reducing the risk of developing research trajectories which are far from the market.

Italian research lines of interest:

- development of bulk fibres with improved mechanical properties
- development of fibres with tailored functional properties (bulk and/or surface)
- development of bio-based fibres with tailored properties
- surface modification of fibres, yarns and fabrics to enhance the manufacturing of textile- and composite-based innovative products.
- development of multifunctional natural cellulose textile materials modified with advanced processing techniques
- development of smart textiles with embedded flexible electronics and sensing systems
- exploration and assessment of ways to involve the final consumers in the process of R&D regarding new fibres and materials

Development of multifunctional materials for transport applications

This sector includes the design, processing and application of new lighter, stronger and multifunctional bulk and coating materials for transport applications, in order to improve sustainability, reliability and safety during their complete life-cycle, with a direct impact on the competitiveness of the automotive industry. Natural fibre and wood composites for automotive applications can also be considered in this application sector. Innovative materials for aeronautical applications are also considered.

Italian research lines of interest:

- innovative nanostructured surfaces and coatings and thin films with improved tribological properties for automotive and aerospace applications
- innovative nanostructured surfaces and coatings with improved high temperature stability and resistance for aerospace applications
- polymer composite-metal laminates for aeronautical applications
- development of liquid moulding processes for composites for aeronautical applications
- smart materials for the monitoring of aeronautic and aerospace structures
- foams for aeronautical applications
- thermoplastic matrix composite materials for aeronautical applications
- acoustic properties of polymers and composites for aeronautic and other transport applications
- development of nanostructured materials for sensors of gas emissions
- development of self-healing and self-diagnostic materials for integrity sensors

Development of materials and devices for health care applications.

Nanotechnology is starting to provide nanostructured materials, surfaces and devices with specific, triggered and controllable functionalities that can be used for diagnosis and therapeutic applications. The main, highly interdisciplinary research activities, should include the *in vitro* and *in vivo* behaviour of developed systems, including absorption, distribution, metabolism, and excretion analysis, toxicity, allergic or inflammatory induced responses and biocompatibility.

Italian research lines of interest:

- polymers for drug release materials
- development of smart nano and micro-sized drug delivery systems
- nanostructured functional hydrogels and composites for biotechnological applications
- multifunctional microsystems for biochemical analysis
- composites for magnetic resonance diagnosis
- development, characterization and applications of supramolecular and selfassembling polymeric systems (polymeric micelles, biocompatible copolymers) for drug delivery
- polymerization of vinyl monomers in supercritical carbon dioxide for the preparation of controlled drug delivery systems
- development of stealth nanoparticles for i.v. drug administration of antitumoral drugs
- multifunctional systems for monitoring tumoral cells under chemotherapy
- calcium phosphates/biopolymers composite scaffolds for bone tissue engineering
- innovative biomimetic coatings for metallic and polymeric substrates
- multifunctional organic electronic systems for health monitoring
- hybrid multifunctional nanostructured silica-based mesoporous materials for drug targeting

- development of polymeric cationic systems for gene and oligonucleotide delivery
- microencapsulation of active molecules for pharmaceutical applications
- hybrid nanomaterials for imaging and sensing application

Advanced materials technologies for the construction industry

The construction industrial sector has a huge potential for improvements in building energy performance, reduction of raw materials and natural resources consumption of buildings during their entire life-cycle. Design tools, new materials and structures, new construction technologies, integrated socio-economic concepts and innovative life cycle engineering models are the main instruments that should be addressed to significantly increase the energy performance of modern buildings. Moreover, the consolidation and maintenance of modern and antique buildings is a key activity in the Italian construction sector. However, most of these activities are performed by SMEs with little experience in the use of advanced materials in this specific sector. The aim is to modernise these traditional SMEs, by developing new knowledge based construction techniques, thereby improving their competitiveness and ensuring that all relevant environmental and safety requirements are met.

Italian research lines of interest:

- smart composites for the non-destructive monitoring of structures
- innovative composites and structures for construction and retrofitting applications
- innovative materials and structures for indoor climate and energy consumption control
- innovative photocatalytic coating systems for a cleaner environment and/or with self cleaning properties
- preparation and characterization of concrete conglomerates containing industrial slag
- ultra-fine additions from natural zeolites in self-compacting concrete
- Innovative coatings and thin films coatings on metallic, glass and ceramic substrates for construction industry for improved surface properties and corrosion resistance.

Surface Modification of Materials

Cold-Plasma based technologies are emerging as systems allowing the modification of materials for many industrial applications. Virtually all materials can be modified with cold plasmas, without affecting their bulk mechanical properties, in order to obtain new performances and functions. The materials include polymers, metals, fibres, textiles, glasses, wood, etc. in the form of webs, plates, fibres, pellets, items with complex structures. Thin film coating the surfaces can modify the wetability, colour, printability, hardness, scratch properties, conductivity, adhesiveness, resistance to corrosion. This way *e.g.* anti-stain fabric and glasses can be produced, de-icing surfaces of metals, super-hard blades (films of diamond-like carbon, DLC), anti-bacterial and anti-thrombotic prostheses, colourable plastics components of cars, transparent barrier films for food packaging, corrosion-resistant metal alloys, self-cleaning materials, new membranes and filters can be produced.

Italian research lines of interest:

- cold plasma deposition of nano-films
- plasma treatments of materials
- functionalization of polymers by cold plasmas
- nanostructuring, nanolayering and nanoclustering by plasma technology
- plasma produced polymers with nano-fillers
- diamond and diamond-like carbon films via plasma and laser techniques
- transparent barrier, protective and scratch resistant coatings via plasma technology

Advanced materials technologies for functional packaging applications and films for agriculture

Packaging is one of the more important industrial sectors that directly affect the use of resources and the quality of life. In this sector, innovative renewable and recyclable materials and their ecoefficient processing are required to provide novel functional packaging solutions for a global market. Important drivers for innovation using life-cycle approaches are cost reduction, improved functionality, higher flexibility and prolonged shelf life of packaged consumer goods by improved barrier (e.g. active, antimicrobial, permselective, intelligent adaptive) performance. Smart features such as displays or sensors can be incorporated into packaging materials. Films for agriculture are also approached in this topic. The focus should be on the design and processing of innovative, renewable or recyclable packaging materials and agriculture films as well as on the interactions between different types of materials,

Italian research lines of interest:

- development of innovative light weight 3D packaging systems with improved performance (mechanical and barrier properties)
- development of high speed processes for packaging production
- use of nanocomposites for packaging with improved barrier properties
- modelling of barrier properties of innovative packaging materials and systems
- biodegradable films for food packaging
- deposition of thin transparent barrier films to improve performance of biodegradable films for food packaging
- development of new cultivation systems based on the use of biodegradable containers
- advanced recycling routes for new packaging polymers and nanocomposites

- plastomers and elastomers and nanocomposites based on recyclable polymers via synthesis and melt blending
- multifunctional nanocomposites films from renewable sources and their blends based on recyclable polymers via synthesis and melt blending
- nanostructured materials for flexible films sensible to external stimuli or chemicals for active packaging
- Films containing molecular sensors and electronic or optoelectronic systems for information recording and transfer (intelligent packaging)

Materials and technologies for cultural heritage protection

There is a noticeably interest in developing highly innovative, nondestructive and reversible techniques for the remediation and protection of cultural heritage artefacts exposed to indoor and outdoor environmental conditions. These techniques could be based on customizable nano-technologies mainly related with recent advances in plasma processing and applied on mosaics, glasses and glazed ceramics, and paintings in order to obtain long lasting duration, resistance to corrosion, abrasion, UV radiation as well as to moulds, bacteria and spores (non-fouling properties). These treatments should aim to be reversible and to produce surfaces that are free of colouring, haze, opalescence and glitter. Cold plasmas exhibit some major advantages that suit perfectly to the specific application.

Italian research lines of interest:

- customized dry process (plasma, nanocoatings) for protecting paintings, glasses and other materials for cultural heritage from humidity, environment, light radiation with transparent nano-coating free of colouring, haze, opalescence and glitter

4.2.4.5: Priority e) - The LCA approach: a selection criterion of defining eco-materials based on their environmental performance

In the last years, much concern has been expressed for the rate of depletion of the Earth's limited natural resources and shortages in the foreseeable future. These considerations lead to the conclusion that there is a need for the reduced use of raw materials and fuels by all production systems and ultimately by the consumers. In order to propose sensible changes of practices that might achieve such an objective, current consumption levels as well as emissions to the environment need to be known with some precision and this led to development of the technique now known as Life Cycle Analysis. .

Recent years have therefore seen an increasing interest in describing the performance of materials in terms of the consumption of energy and raw materials and of the emission of solid, liquid and gaseous wastes. In this context, material production systems start with raw materials in the earth and trace all industrial, transport and consumer operations until final disposal of the product at the end of its useful life and is often referred to as "cradle-to-grave".

As a consequence of the methodology, a material "eco-compatibility" value judgement should not regard only its "natural content" but all the performances - technical and energetic/environmental - during the whole Life Cycle.

This is the reason why LCA is standardized at international level by ISO 1404X series, while an accepted procedure to evaluate an eco-material has yet to be developed.

Italian research line of interest:

- Life Cycle Engineering applied to the impact of adopting and implementing proposed material nanotechnologies.
- application of Life Cycle Analysis (LCA) to the environmental impact of innovative materials compared with traditional ones.
- definition and analysis of methods for the recycling of materials at the end of life and their environmental impact
- analysis and definition of eco-indicators for the application of LCA and LCE methodologies.