Materials research topics for the 2nd Work Programme of Horizon 2020 (2016-2017)

A joint proposal by EuMaT ETP, E-MRS and FEMS

Feb. 2015

In what follows a number of research topics are proposed for a possible inclusion in the work programme NMP-B 2016-17 of Horizon 2020.

These topics have been worked out in a cooperative manner by the three Organizations and represent some selected research priorities as suggested by the stakeholders from the academia and industry.

The topics are arranged in several thematic groups such as Modelling and Multiscale, Energy Materials, Nanomaterials and Nanoassembled Materials, Knowledge-based Structural and Multifunctional Materials, Life-cycle, Impacts and Risks, Materials for ICT and Biomaterials.

Further improvement could be easily implemented on those topics considered of immediate interest by the Commission. The proposers are open to any further work on the call text(s) preparation, if requested by the Commission, and offer the support of the corresponding working groups for a final tuning and/or discussion on the proposed topics.

List of proposed topics (1st priority topics in blue font)

MODELLING AND MULTISCALE

TOPIC 1 - *Development of integrated software simulation environments including mathematical models and experimental hardware for the implementation of future combined advanced materials and manufacturing processes design concept.*

TOPIC 2 - *Development of standard interfaces between product designers and material manufacturers.*

TOPIC 3 - *Paired materials design with focus on useful life, interaction of surfaces, friction, wear, corrosion and degradation.*

TOPIC 4 - *High-throughput multiscale simulation for mapping new material compositions and processes.*

ENERGY MATERIALS

TOPIC 5 - *Performance driven integrated computational materials for energy design including requirements and effects of function, manufacturing and operating environment.*

TOPIC 6 - *New high-performance metal materials based on precipitation hardening.*

TOPIC 7 - *Advanced Materials for Stationary Energy Storage with Li-ion batteries.*

TOPIC 8 - *Development of novel low cost inorganic and hybrid nanomaterials for high efficient solar cells.*

NANOMATERIALS AND NANO-ASSEMBLED MATERIALS

TOPIC 9 - *Advanced industrial research to enhance performances of functional nanocoatings for several sectors including hybrid multifunctional materials and systems.*

TOPIC 10 - *Reactive/in situ /in process generation of the nano-features as large scale, low cost source of nanomaterials including plasma treatments for process industries.*

TOPIC 11 - *Open access pilot lines for advanced nanosurfaces and surface functionalization technologies enabling breakthrough applications and modelling tools for microfluidic behavior of nanoparticles and/or advanced fluids.*

TOPIC 12 - *Development of Additive Layered Manufacturing systems.*

TOPIC 13 - *Networking, sharing best practices on managing nanomaterials and effective communication on nano.*

KNOWLEDGE-BASED STRUCTURAL AND MULTIFUNCTIONAL MATERIALS

TOPIC 14 - *Development of innovative lightweight, high performance metal-based structural materials with tailored microstructure based on modelling and failure mechanism simulation.*

TOPIC 15 - *Development of advanced multifunctional surfaces by means of industrialized technologies.*

TOPIC 16 - *New thermoset and thermoplastic polymer systems for light-weight carbon fiber structures.*

TOPIC 17 - *Surface functionalization of polymers for advanced taylor-made properties.*

LIFE CYCLE, IMPACTS, RISKS

TOPIC 18 - *The European Competence Centre– Joining and integration issues of innovative-to-traditional materials, including the new technologies (innovation) risk management, sustainability, safety and life-cycle analysis (LCA).*

MATERIALS for ICT

TOPIC 19 - *Key materials to enable « electronics for everyone everywhere »: low cost, low loss, green, recyclable, safe, flexible.*

TOPIC 20 - *Paper as a low cost new material, smart and safe platform for advanced materials integration on devices and systems*

TOPIC 21 - *Multifunctional materials for piezotronics.*

TOPIC 22- *Functional, reconfigurable and nonlinear metamaterials, photonic and phononic crystals.*

BIOMATERIALS

TOPIC 23 - *Hierarchical Biomaterials for diagnostic and theranostics.*

TOPIC 24 - *Multifunctionalised biomaterials for bone tissue repair.*

TOPIC 25 - *"Living implant" for cardiovascular application: development of scaffolds obtained using new technologies and considering cell-substrate interactions at the micro/nano scale.*

OTHER TOPICS

TOPIC 26 - *Innovative materials recycling approaches in a circular economy*

TOPIC 27 - *Material Technologies for Waste to Product*

MODELLING AND MULTISCALE

INTRODUCTION

Multi-scale modeling and mathematical methods necessitate **a CSA** to coordinate EU activities in Integrated Multiscale Science – Engineering Technology, Product and Process Development. A new Environment and Strategy to promote modeling in Research, Technology Innovation and Industrial Competitiveness. **Topic 1**.

Generally speaking, new methods and tools are needed for the design and management of integrated product-process-production systems that are well embedded into their social, environmental and economic context. New Methods are based on advanced tools and interfaces to simulate manufacturing processes or forecasting the behavior of manufacturing systems and processes, be it during the design phase or during their operational phase. It is a well-focused small project described under **Topic 2.**

Topic 3 is related to simulate and modeling the failure mechanism and materials lifetime of mechanical components and systems that suffer from friction, wear or corrosion resistance in order to increase their durability and reliability during use.

The Structure-Property-Performance and Process-Structure approaches is proposed in **Topic 4**, trying to tailor the performance of the materials in function of the processing. The added value is the capacity of engineering solutions to improve the operating performance of component surfaces, for example in energy and medical applications or automotive.

TOPIC 1

Title: *Development of integrated software simulation environments including mathematical models and experimental hardware for the implementation of future combined advanced materials and manufacturing processes design concept.*

Motivation / Specific challenge

The insertion of components design and manufacturing issues is in line with recent trends as the US Integrated Computational Materials Engineering (ICME) and Integrated Computational Materials Science Engineering (ICMSE) Programs.

Scope

Multiscale Modeling and Simulation is a key component of the new "materials by design" approach. The objective of this new project is to develop a new Framework which implements what can be regarded as "Materials by Design Next Generation Strategy": Integrated Multiscale Science Engineering Design of Materials, Components and Manufacturing Processes. The concurrent development of Materials, Components and Manufacturing Processes is a key element to achieve at the same time, inside a coherent and unified strategy three fundamental goals: Innovation, Competitiveness and Sustainability.
The focus could be directed to different Manufacturing Process, *for example* could deal with qualitative and quantitative prediction of typical failures creating a micro-model to simulate the phase formation and microstructure. It would be possible to combine the process simulation method for a high range of different materials with other process simulations. The described effects will expand the simulation areas and increase their accuracy. This approach will reduce the time to develop robust product avoiding overdesign.

Furthermore, surface functionalisation and interface engineering in complex products/systems represent transversal themes of relevance for a wide spectrum of manufacturing sectors. Moreover, being surfaces one of the major channels of interaction with the final user, both enhanced functionalities and improved aesthetics enabled by innovative surface treatments can deliver important results in terms of perceived quality and level of innovation of industrial products.
The focus is the development of a new open, interoperable framework that can be used to design, certify, and manufacture a spectrum of new materials and components characterized also by innovative hierarchical architectures. The Framework would enable the design of new cutting-edge manufacturing techniques. Concurrent design of materials components and manufacturing is a key feature of the new Framework. All the scales and related codes typology should be accounted for: quantum, atomistic, micro, meso and macro as needed for specific tasks.
Multiscale Modeling will allow the integration of materials information with product performance analyses and manufacturing - process simulation and the application of a holistic integration of scientific and engineering knowledge and methodologies.
Distinguishing features of the Framework:

- Multiscale Science – Engineering Data, Information and Knowledge Analysis, Integration and Management Environments
- Multiscale Computer Aided Design SW Tools (as evolution of the existing ones) to describe multiscale structures of materials and components

- Multiscale Science – Based Computer Aided Engineering and Manufacturing (CAE/CAM). A full integration of Computational Multiscale with Multiscale Experimental and Testing Techniques is an important element of the new approach to reduce costs, risks and time, but it will also allow for an in depth understanding of the dynamics of materials and components over and extended range of operational conditions.
- Verification and Validation (V&V) techniques and related Environments. A key objective of V&V strategies is the characterization in a formal way of the "Information Potential" both for Computational Models and Experimentation and Testing. The definition of an "Information Potential" for computational models, experimental and testing techniques for specific tasks will allow to integrate in an optimal way a cluster of models and techniques to address specific issues (Integrated Multiscale Science – Engineering Strategies)
- Implementation of mathematical and statistical methods for uncertainty quantification and cost effective approach for managing uncertainties.

A Scenario Analysis to assess the degree of use of the "materials by design" approach inside industry and how and to what extent this trend is regarded as "strategic" should constitute a part of the proposal. The Analysis should also evaluate what development trends over existing methodologies are seen by industry of particular relevance as well as the need of Open Software availability and the role of Software Vendors. The creation of a Forum dedicated to promote new techniques and strategies inside industry and medium – long term coordinated (university – research – industry) activities can be inserted into the proposal.

Expected Impacts

(i) foster the definition of new advanced strategies in the materials field: concurrent development of innovative materials – component – manufacturing solutions and architectures; (ii) strengthen University – Research – Industry Cooperation establishing more structured and long term cooperation schemes (iii) reduced costs, times and risks to develop certificate and manufacture new materials/components with an extended range of performance and functionalities; (iv) foster the design of new materials and components characterized by innovative architectures and promote the development of new manufacturing techniques (additive manufacturing) which are an important asset to improve European competitiveness levels; (v) establish new standards for design, certification and manufacturing; (vi) definition and promotion of a wide and timely industrial take-up: (vii) put the bases for the design new Multiscale CAD, CAE and CAM software tools; increase lifetime prediction precision

Type of action: CSA. Coordinating Action.

TOPIC 2

Title: *Development of standard interfaces between product designers and material manufacturers*.

Specific challenge

The needs of standard interfaces have been highlighted under the EUMAT materials platform and will reduce development time and effort for development of new products and process incorporating higher performance alternative materials. This is especially relevant for transport and home appliance sector where reduction of weight is directly linked with reduction of CO_2 emissions.

Scope

The market is more and more demanding for increasing productivity, while guaranteeing flexibility and agility, with potential drop of components quality and increment of maintenance costs. The effort in enhancing the performances of the devices has led to a deep study of the different physics at different scales, thanks also to the advances in technologies, able to boost the growth of more complicated and complete models. Computations based on multi-scale workbenches and clouds networks, multi-core and parallel computation, in fact, has permitted the material designer to have powerful tools in their hands. On the other hand, the transference of information from the material manufacturer to the product designer operating in continuum scale and defining the actual exploitable property relevant information to transfer, are still bottle necks.

A step forward is therefore required in order to enhance consistently the components design benefitting of the new tools used for designing the material characteristics. In this way, the uncertainty on material characteristics, which has led to the use of wide coefficient of security contributing to the increment of weight, cost and waste of material, is expected to be significantly reduced.

One of the objectives of this topic is therefore the creation of an interface system between the product designer and the material manufacturer taking into account the whole characteristics and performance known at different scales for a higher accuracy in designing and enhancing the usage of materials. To this purpose, standardization of inter-communicative links has to be addressed. The requirement for such interfaces exists and well matured solutions are unavailable. The effort should focus on computational means and aspects since in that regard defining interfaces appears a feasible and obtainable solution. An important role will be taken by the experiments for validating the final system.

Expected Impacts

More effective and resource efficient design of enhanced products according to the normative in force thanks to the availability to use the material information at different scales; unless 10-20% weight and energy consumption reduction in transport and energy applications; standardization of the communication interfaces between material manufacturer and design software users; life-time prediction; improving predictive maintenance practices; streamlining of material design – product design – engineering cycle and reduction of time to market.

TRL: from 3-5 to 4-6
Type of project: Research and Innovation Action

TOPIC 3

Title: *Paired materials design with focus on useful life, interaction of surfaces, friction, wear, corrosion and degradation.*

Specific Challenge:
Currently, functional materials, tool materials and highly loaded structures are frequently subject to wear and degradation due to relative movements or vibration on a micro or macro scale. Friction and wear of these couples are largely or power generation requires enormous amounts of cooling media, being necessary to optimize resources.

Scope
Proposals should develop robust paired materials solutions, near-surface structures, and surface structures for targeted friction (high- or low) and controlled wear and corrosion properties over their useful life. Implementation of interaction models including different friction regimes, wear processes, and lubricant or third-body effects is necessary, opening up new and promising avenues for optimisation components and devices. This will allow for long-life components, reduced wear and debris, and energy savings due to low friction (where appropriate). Sometimes corrosion and tribocorrosion also affect the durability of the components especially in contact with water or aggressive environments.

Expected impact

- Significant increase of useful lifespan of components and devices in contact
- Savings on components (mass, energy, water cooling, etc.) due to long-life performance
- Less energy waste (friction) , debris (wear) and chemical deterioration (oxidation, corrosion) in operation

TRL: from 4-6
Type of action: Research and Innovation Action

TOPIC 4

Title: *High-throughput multiscale simulation for mapping new material compositions and processes.*

Specific challenge

There is a need for extending the number of known materials with their properties and using this data to shorten the development of new products and processes via multiscale materials design frameworks. Following the model of the US Materials Project, an efficient work method is to form industry-academic consortia which search via high-throughput computational methods for specific desired material solutions. After search and selection of promising candidates by commercial partners, the by-products (such as comprehensive data sets of material properties, data mining tools and multiscale linking frameworks) are entered into open access databases. Within reason given the target materials, products and processes, projects should be designed to utilise as wide a range of methods (from quantum mechanical first-principles, atomistic modeling, mesoscale, up to continuum finite-element), spatial (nano-micro-mm) and temporal time scales (fs-s) as possible. It is important to back up theoretical predictions with experimental validation for the promising candidate materials and processes and to have a concurrent data framework for validation of predicted multiscale modeled data.

Scope

High-throughput computational search for new material compositions and processes utilizing any combination of methods in first-principles (ab initio), atomistic, mesoscale (e.g. phase field) and finite element modeling. Projects can focus on modeling one or more of: structural, electronic, optical, thermal or phase transition properties. Provision of routines and/or frameworks for verification of theoretical models and interlinking multiscale hierarchical data-passing as well as concurrent experimental validation is a priority.

- Materials to be used in structural (energy, construction, transport, automotive, aerospace, additive manufacturing), optoelectronic (energy harvesting & storage, ICT, power infrastructure, sensors) or chemical processing (catalysis, interface chemistry, storage) applications.
- Projects can focus on finding new materials or improving a known class of materials through multiscale modelling techniques.
- Materials and processes with low environmental impact, recycled materials in substitution of virgin, critical or toxic (raw) materials, recycling or enabling more efficient processes with less environmental impact;
- Creation of open access data bases providing materials properties (structural, thermal, phase, optoelectronic, etc.) as well as online tools for data mining and multiscale parameter passing.
- Priority on utilising and improving existing open source and Lesser Gnu Public License or equivalent frameworks (e.g. pymatgen, Atomic Simulations Environment, etc.) and multiscale simulation codes and methods.

Expected Impacts

- Demonstration of high-throughput multiscale methods used for finding new material and processing solutions.

- Sustainable open access materials data bases with verified theoretical predictions, validating experimental data and data mining tools which can be used to get input parameters to multiscale modeling techniques.
- Significant progress beyond the state of the art in the range of phenomena described, spatial and temporal scales covered and types of methods linked and with the tools to do so.

TRL: from 3-4 to 5-6.
Type of project: Research and Innovation Action

ENERGY MATERIALS

INTRODUCTION

Energy Materials addresses the materials challenges across the range of low carbon energy generation and end-use-efficiency technologies being developed across the EU to provide affordable, secure and clean electricity and heat for EU industry and citizens. Inevitably, meeting this societal challenge requires a wide range of technologies and a corresponding diverse range of enabling materials and related technologies.

As a result, many of the call topics provided in this document can apply to energy technologies, e.g. the development of advanced composites for wind turbine blading.

In addition, the Energy Materials Industrial Research Initiative (EMIRI) is specifically addressing these materials challenges for all emerging technologies, i.e. photovoltaics, solar thermal, wind, wave/tidal, biomass/waste, conventional fossil fuels/carbon capture, utilisation & storage (CCUS), thermal & electrical energy storage and end-use efficiency. The following proposed topics identified through the EuMat Energy Materials group, and those relevant in other parts of this submission, complement and reinforce the priorities highlighted in the EMIRI contribution which is currently in preparation.

A priority area for the EuMat group (in collaboration with the Zero Emission Technology Platform), and which overlaps strongly with EMIRI interests, is in addressing the advanced materials requirements to enable advanced, low carbon power generation using fossil fuels combined with CCUS, and the parallel need to implement CCUS to decarbonise the energy-intensive industries, such as steelmaking, cement manufacture, etc. The successful implementation of CCUS requires the CO_2 capture process to be integrated with the highest available efficiency power generation or industrial process, to ensure acceptable performance and minimum costs. Both structural and functional materials play a key role in increasing efficiency by allowing operation at advanced conditions (higher temperatures and pressures) in aggressive process environments. Cost-effective and reliable structural materials (alloys and refractories), process materials (sorbents, membranes, etc.) and coatings are required if these advanced systems with CCUS are to be commercially viable. Combined with materials development, the cost-effective engineering of components, their durability in service and repairability are also priority issues.

The challenges for the EU's materials supply chain, and those manufacturing components, is to deliver the promising properties of the best available materials in the fully engineered components and systems required, and to evaluate the performance of the components and sub-systems under realistic conditions. European industry has a long history in producing innovative solutions for these components which are used in power and industrial plants around the world.

The topics highlighted below focus on the development of advanced materials for selected energy and related technologies, the scale-up of materials processes, component manufacture and experimental testing under simulated service conditions to keep European industry at the forefront of developments for cost-effective low carbon technologies, and to reduce the risks associated with their deployment.

TOPIC 5

Title: *Performance driven integrated computational materials for energy design including requirements and effects of function, manufacturing and operating environment.*

Specific challenge

Traditional routes for designing, manufacturing and testing the structural materials and protective coatings adopts a process of trial and error. The recent development and advancement of modelling technologies make it possible for researchers and industrialists to design, manufacture and test the new materials based on modelling capability to save significant costs.

The integrated computational materials engineering (ICME) paradigm with the utmost coverage for material design and operation specific tailoring is the Process-Structure-Properties-Performance (PSPP) principle. The PSPP principle is intertwined with the fundamentals of exploiting advanced multiscale computational and simulation technologies, and is cross cutting across several EUMAT platform working groups. The ability to exploit multiscale modelling across the PSPP range enables the solution of two key problems of computational material design: the structure to properties to performance problem and process to structure problem, the material solution cost being an ever present feature. The former enables e.g. tailoring of nano-microstructures to meet component functional requirements, while the latter introduces a far less exploited area of ICME – the effects arising from manufacturing processes and complex component operational environments and their interactions. Simulation methodologies and tools which enable one to tap to both of these areas simultaneously enable a holistic digitalized approach for material and process design and inclusion of e.g. complex environmental effects using the same modelling toolset. Only multiscale modelling tools can capture the required complexity, and the potential for exploitation and industry benefit is immense.

Scope

Modelling of effects of material nano-microstructures to address structure to properties and performance critical mechanisms. Linking to process to structure approach to tackle both manufacturing (e.g., forging, welding, casting, solidification, sintering, coating deposition etc. utilizing computational thermodynamics, kinetics of microstructure changes, secondary phase precipitation, phase fields etc.) and operating environmental effects and properties (corrosion, diffusion, material aging, texture and manufacturing history effects etc.) as case specific design needs dictate. The microstructural evolution of metallic materials under such conditions is generally the result of complex and highly coupled thermo-electro-chemomechanical processes. Diffusion (mass, solute, heat, electric current) is a key common mechanism in such context and it is strongly dependent on the state of stress and the dominant microstructural features. Exploitation of both the Structure-Property-Performance and Process-Structure approaches to harvest impacts arising from computational material design for extreme performances (and/or case tailored material solutions) within the same simulation framework and scheme. Simultaneous computational material design for multiple extreme performances (e.g. corrosion-wear, fatigue-creep, fatigue-corrosion, thermal mechanical fatigue, manufacturing prior history and phase transitions-strength and fracture etc.). Utilize principles of physics based computational material design throughout the ICME approach by establishing such “digital design factories”. Verification and validation of complex multiscale schemes with numerous scale bridging approaches. Address material systems seen to benefit from such an approach such as:

- Advanced powder metallurgical materials, nanostructured and nanoadditive materials, hybrid and metal-ceramic composites and coatings and refractory materials; designed for specific application integrating demands and requirements for function, environment, cost and sustainability. Integrate manufacturing affiliated aspects and technologies, such as additive manufacturing or injection processes.
- Thin films, hybrid materials, composite, multilayer and gradient structures, surface treatments and bioinspired solutions for e.g. tailored tribological performance and wear resistance.
- High strength, toughness and fatigue resistant metallic materials and composite solutions for extreme performance. Include processing history effects (texture, solidification structures and residual states) as well as operating environments and their effects (corrosive, elevated temperatures, material aging, wear).

Expected Impact

Multiscale modelling abilities to deliver key enabling technologies for extreme multi-performance conditions including effects of operational environment and prior manufacturing history and their systematic design via computational material design, with the following impacts:

- Building a real “Science – Engineering Industrial World” and a related new University, Research and Industry Cooperative Environment
- Modelling facilitated design, manufacture and test of advanced materials and coatings will significantly shorten the cycle of new materials development, maximise the natural resources and personnel power, reduce the emission of green-house gases and improve the environment.
- ICME (Integrated Computational Materials Engineering) approach applicable for exploitation of specific material and product performance dominating mechanisms, merging features from digitalization of manufacturing to performance driven design.
- Ability to systematically identify disruptive and innovative material solutions for extreme operating conditions by incorporating computational design features from elements of performance, manufacturing and operational environment.
- Ability to design sustainable and case optimal material solutions, decrease environmental impact and address material substitution concerns for demanding applications.
- Changing R&D Engineering and Manufacturing/Processing organization, practices and strategies to reduce cost, time to market and risks to develop innovative materials, products and processes based upon a scientific understanding as a fundamental means to improve Industrial competitiveness levels
- The engineered technologies are exploitable across a range of industry sectors, bridging the gaps between fundamental and applied sciences and industry.
- Promoting the Design and Manufacturing Of a New Generation of Science – Based Hierarchical (Nano To Macro) Materials, Devices, Components, Systems and Manufacturing Processes

TRL: from 3-4 to 5-6

Type of project: Research and Innovation Action.

TOPIC 6

Title: *New high-performance metal materials based on precipitation hardening*

Motivation / Specific challenge

A key to the development of many advanced alloys (Al, Mg, steel, copper, Ti, Ni) is a common denominator – that of precipitation hardening phenomena. Each industry has made huge steps forward over the years in their specific fields. However there are areas where progress is required to maintain Europe's competitiveness in this sector so that new metallic solutions be developed for ever more demanding market driven applications for energy, transport, consumer electronics, packaging, buildings & societal infrastructures. These include rapid optimization of precipitation and ageing kinetics for new alloys targeting reduced processing times, right first time alloy mechanical performance, consistent quality (e.g. elimination of void formation and residual stresses), identification of element substitution routes for rare or toxic alloying element replacement and further improve the ease of recyclability of less pure systems.

Scope

The proposed research should prioritise the major metal alloy systems and metallurgic phenomena to be studied based on recommendations provided by the major European industrial players with a dedicated workshop with recognized international experts in the field. Among other things, research should address germination in concentrated systems (thermodynamics of nano-objects; mismatch factors; diffusion void formation; stress fields…); sequence of precipitation; etc.

Experimental and modelling approaches should be used: alloy elaboration and TMP routes; ab initio, phase field & Monte Carlo calculations; statistical physics; ultra-high resolution 3D characterization (TAP, TEM-HAADF, x-ray & e- tomography…).

Expected Impacts

A key deliverable will be the publication of a white paper targeting the European aluminium, titanium, copper, magnesium and steel industries providing recommendations for step change gains in metal processing routes paving the way for energy savings, reduced recurring production costs, high mechanical in-service performance, consistent, defect free, metal quality and efficient recyclability.

A session dedicated to the dissemination of the results from this topic is planned for the International FEMS Conference EUROMAT 2015.

TRL: 4-6

Type of project: Research and Innovation Action

TOPIC 7

This topic is part of a broad selection of strategic topics proposed by EMIRI for the implementation of the SET-plan Materials Roadmap

Title: *Advanced Materials for Stationary Energy Storage with Li-ion batteries*

Motivation/Specific challenge

Significant advances in materials are needed to realize the potential of energy storage technologies (electrical grid providing reliable & affordable electricity, improvement of transmission efficiency from renewable energy sources, improvement of overall power quality, off-grid power solutions, ...). Industry experts and research & technology organisations have identified in the SET-plan Materials Roadmap areas where substantial progress is needed. The purpose of this proposal is to focus the research activities on Li-ion batteries systems to develop new, more cost-effective, efficient and reliable materials paving the way to bringing the cost of the technology typically below 0.10 euro/kWh/cycle.

Scope

Research activities on advanced materials for lower cost, higher life span and safer Li-ion batteries should encompass:

Activity 1. *Competitive low cost high capacity cathode materials for Li-ion batteries including adjacent battery materials such as electrolytes, binders, separators*
Highest priority - Starting TRL: 4-5

Advanced materials developed in Activity 1 should demonstrate a higher capacity and a higher voltage versus the reference being lithium iron phosphate ($LiFePO_4$) cathode materials. Materials systems such as doped olivines for instance still face numerous technical challenges today. It will also be needed to re-engineer the Li-ion battery system for high voltage applications and therefore devote attention to ensuring the compatibility with electrolytes through coatings and additives to the electrolyte or to the advanced materials (core shell materials, organic additives, surface treatments).

Activity 2. *Novel high energy density anode materials with long lifetime for Li-ion batteries*
Medium priority - Starting TRL: 3

Optimisation of cathode materials goes hand in hand with attention being also paid to the development of novel high energy density anode materials with long lifetime. New anode materials to be developed in Activity 2 will need to demonstrate cycle life similar to anode materials based on graphite with performance benchmark beyond 1.000 mAh/g.

Activity 3. *Solid state Li-ion batteries*
Lowest priority - Starting TRL: 1-2

Purpose of Activity 3 is the development of advanced materials for solid state Li-ion batteries. The main innovation focus is the improvement of safety while minimizing the impact on capacity. Typical challenges are the development of solid electrolytes with adequate conductivity (new chemistries), composite electrodes, ...

Expected Impacts
The overall expected impact is a cost reduction of the Li-ion battery technology down to below 0.10 euro/kWh/cycle (150 – 350 Wh/kg, 300 – 800 Wh/l, up to 10.000 cycles) while preserving safety of the technology. Such a cost reduction will undoubtedly facilitate penetration of Li-ion battery technology (market increase of 10% by 2020 reaching 10 GWh of storage could be expected).

TRL: 4-6
Type of project: Research and Innovation Action

TOPIC 8

Title: *Development of novel low cost inorganic and hybrid nanomaterials for high efficient solar cells and hybrid thermal-solar devices*

Specific challenge

Today the main challenge that solar cells face concerns how to reduce production costs and simultaneously enhance their efficiency in order to make them economically valuable at a medium to long term strategy, when compared to other energy sources. To answer this challenge, novel materials at a nano scale level are required to take advantages of quantum effects that may lead to exceptional material performances concerning wide band light capture and absorption by creating multi band-gap structures, improving so substantially the energy conversion efficiency. A promising new direction are hybrid solar and thermoelectric devices, including those based on hot carriers generated by photons.

Scope

The proposed research should focus on the development of quantum dots to be embedded in organic or inorganic matrixes as active layers in single-/multi-junction or hybrid solar cells. Low-temperature processes are pursued for applications with flexible and low-cost substrates. Enhanced light scattering by nanoparticle based plasmonic structures should be also foreseen.

Expected Impact

The main expected impact of the research performed will be turning the PV energy market competitive at medium to long term strategy, by promoting disruptive technologies such as solar paints and printed solar cells, and to give a strong impulse to the BIPV products. Besides, it should be able to answer short to medium term market demands concerning energy harvesting for commodities such as vehicles, mobile electronic devices, smart tags, electronic paper, labels….

TRL: 4-6
Type of project: Research & Innovation Actions

NANOMATERIALS AND NANO-ASSEMBLED MATERIALS

TOPIC 9

Title: *Advanced industrial research to enhance performances of functional nanocoatings for several sectors including hybrid multifunctional materials and systems*

Specific challenge

Functional nano-enabled surfaces have huge potential in different sectors: antimicrobial and antiviral surfaces for medical devices or HVAC systems; self-cleaning surfaces for buildings, automotive sector and roads; highly mechanical resistant coatings for technical textiles to be used in arch conditions and structural elements for construction and transportation etc.

Advanced lightweight composites are expected to improve technologies already existing on market and assure sustainable and affordable low-carbon based manufacturing processes needed for production. The future of engineering materials is to manufacture multifunction for Performance-Tailored products. Multifunctional materials are typically a composite or hybrid of several distinct material phases in which each phase performs a different but necessary function such a structure, packaging, transport, logic, and energy storage.

Scope

The combination of three or more functions including logic, sensing, energy storage, structure, and actuation will be required to achieve truly smart material systems, ultimately analogous to biological systems. The scope of the work is to define a mixed and integrated approach able to connect the modelling optimization as a direct consequence of LCA & LCC results as well, apart from the technical requirements to be taken into account for realization.

Expected Impact

- Strengthening of European plastic converters industry and in-sourcing of production to Europe. Enabling state-of-the-art nanotechnology in traditional production of plastic products will create an efficient technology and market advantage. Production capabilities and know how to enable new intelligent production and products will allow for a first mover effect with an unique opportunity to allocate production lines back to Europe and maintain production workplaces in future.
- Promoting energy efficiency and safety in production. Through integration of micro- and nanotextures directly on the surface of plastic products during production; novel functionalities such as colour, anti-reflection, super-hydrophobic, anti-drag and similar can be created. This will eliminate post-production steps such as energy intensive vacuum processes that will provide great energy savings. Moreover this approach will create more work environmentally friendly work places – ultimately having production lines of plastic products with no health precautions, even allowing pregnant women to take part in production lines.
- Enabling of investment decisions for market introduction of novel, cost-effective, safe and sustainable nano-enabled products that demonstrate superior performance in terms of multifunctionality and sustainability

- Demonstrated scaling-up and increased degree of automation of multifunctional material production lines/processes, leading to higher production volumes, improved reliability and repeatability of produced multifunctional materials and lower production cost;
- Contribution to improved resource efficiency, safety and environmental friendliness of adoption of the multifunctional materials and related products (e.g. aiming at fully recyclable products);
- Improvement in competitiveness by evaluating all processes among the proof-of-concept and the launch on market phases and leading to a reduction of the capital (CAPEX) and/or operating (OPEX) expenditures;
- Rapid deployment of lower-cost advanced materials solutions through predictive design of novel materials and production routes optimized by means of mixed methods for environmental and life-time costs assessment;

TRL: from 3/4 to 5/6
Type of action: Research and Innovation Action

TOPIC 10

Title: *Reactive/in situ /in process generation of the nano-features as large scale, low cost source of nanomaterials including plasma treatments for process industries*

Specific challenge

Successful adaptation of nanotechnology in the end-products requires in many cases to utilize material that are able to develop their nano-functionalities during the standard process of product and semi-finished product manufacturing. As an examples plastics additives that crystallize in nanoparticle during injection moulding, metal phases that are formed during forging, or hieratic structures that spontaneously forms during application of a coating. Plasma treatment could allow modifying the chemical composition of the surface enabling to produce multifunctional surfaces that cannot be easily produced by conventional finishing methods due to economic or safety reasons. A new design and optimisation of atmospheric plasma in terms of process versatility (gas to be processed, effectiveness of aerosol dispersion of the reactive compounds) must be addressed in order to allow a significant spread of the technology at industrial level.

Scope

The manufacturing principle require a strong connection between all the actors in the production line and in particular between material producer and end-product manufacturer. The main objective of this action is offering custom fabricated semi finished components from advanced materials, including nanofoams and nanocomposites obtained from the Reactive/In Situ /In process generation of the nano-features. Plasma treatment of plastics, metals and textiles are used in the energy, automotive, medical, packaging, assembly and many other industries to add functionalities that improve the performance of the existing materials.

Expected Impact

- Demonstrated increased degree of compatibility of advanced reactive materials with existing production lines, leading to higher production volumes, improved reliability and repeatability of produced nano enabled product and lower production cost;
- Accelerated market uptake of nanomaterials and nano-enabled products
- Improvement in technical knowledge on the integrated manufacturing processes for nanomaterials in terms of productivity and cost-effectiveness.
- Improved performance, energy efficiency and usability at high-performance of plasma surface treatments;
- A higher level of automation and lower production times compared to current technologies ;
- New market opportunities through introduction of novel process in existing production lines;
- Improvement in technical knowledge concerning manufacturing processes of surfaces;
- Significant improvements in industrial productivity and cost competitiveness in comparison with traditional processes.

TRL: from 4 to 6/7

Type of action: Research and Innovation Action

TOPIC 11

Title: *Open access pilot lines for advanced nanosurfaces and surface functionalization technologies enabling breakthrough applications and modelling tools for microfluidic behavior of nanoparticles and/or advanced fluids*

Specific challenge

Nanotechnology applied to nanostructured surfaces open up possibilities for breakthrough applications which may strongly contribute to solve the grand challenges of our time, like for example the availability of clean water for all and everywhere. However, for such technologies, one of the current problems is to support small production of high added value products, possibly upgrading research labs.

The behaviour of fluids at the microscale can differ from macrofluidic behaviour in that factors such as surface tension, energy dissipation, and fluidic resistance start to dominate the system. Microfluidics studies how these behaviours change, and how they can be worked around, or exploited for new uses. At nano scales some interesting and sometimes unintuitive properties appear. In particular, the Reynolds number can become very low. A key consequence of this is that fluids, when side-by-side, do not necessarily mix in the traditional sense; molecular transport between them must often be through diffusion. Microfluidic structures include micro-pneumatic systems, i.e. microsystems for the handling of off-chip fluids (liquid pumps, gas valves, etc.), and microfluidic structures for the on-chip handling of nano- and picolitre volumes.

Scope

- Targeting specific target surface technologies and related products which may impact on the availability of clean water.
- Creating a network of specialized labs which may offer a wide variety of technologies at affordable costs.
- Collaborative projects in fluidics will be focused on modelling emerging application areas for biochips like clinical pathology, especially the immediate point-of-care diagnosis of diseases or microfluidics-based devices, capable of continuous sampling and real-time testing of air/water samples for biochemical toxins and other dangerous pathogens.
- Rapid deployment of advanced devices and solutions through predictive design of microfluidics behavior for specified applications ;
- Definition of guidelines and reference cases that contribute to the diffusion and adoption of the microfluidic technology.
- Accelerated introduction of new microfluidic devices in EU and international market.

Expected Impact

- To contribute to social grand challenges of our time (e.g. i.e. sustainable solutions for availability of clean water).
- To increase the competitiveness of European industries and expand their market potential, also beyond non-EU countries.

TRL: from 4 to 6

Type of action: Research and Innovation Action

TOPIC 12

Title: *Development of Additive Layered Manufacturing systems*

Specific challenge

Additive layered manufacturing (including 3-D printing technologies) has a huge potential in many sectors (e.g. transportation, medicine and health, mobile industry etc.). ALM has become a breakthrough technology because of the great advantage of allowing an incomparable freedom of design respect to traditional non additive technologies. This is a useful characteristic that enables the manufacturing of complex and lighter shapes, sometimes decreasing the cost of the component. This added value in terms of design must deal with the material availability for this kind of techniques. On this topic in fact there is still a big gap between conventional machining and additive manufacturing, since actually only a few number of materials can be processed with this technique and a smaller sub group of them is made available with ALM process parameters directly from the machine manufacturer. The designer is then constrained from the material properties point of view and sometimes the application of ALM technique is a compromise between a simplified, lighter and cheaper geometry built with a material with not optimized properties. Some applications require for example an improved functionality respect to the environment where they are going to operate. Component operating in certain conditions, exposed to fluids, gases, pressures and temperatures can require further properties that now can't be obtained from the ALM process.

Scope

The convergence between nanotechnologies and 3D printing would offer large opportunities for innovative 3D smart components. Development of new materials and/or introducing a post processing e.g. a functional coating can increase corrosion or wear resistance. Another improvement can be obtained with development of new materials for ALM enhancing specific mechanical properties, for example improving impact strength or fatigue resistance.

Expected Impact

- Enabling manufacturing activities by SMEs to enter markets with innovations that were not possible before.
- Such new innovative products could offer a large spectrum of applications
- To promote development of a new class of materials or a combination of material and post process which enables to cope very specific problems but with a high improvement in terms of results when compared both with traditional machining and with commercially available ALM materials
- To help ALM technique to be introduced also in processing and post processing workshop
- To increase the production of components with improved performances
- To stimulate the research of new materials for ALM with improved properties relevant for specific applications (e.g. Corrosion protection, wear protection, fatigue resistance, etc.)

TRL: from 3 to 5/6
Type of action: Research and Innovation Action

TOPIC 13

Title: *Networking, sharing best practices on managing nanomaterials and effective communication on nano*

Specific challenge

Nano-related materials either in research or already in late development are further on expected to play key roles for the promotion of innovations in the various industrial products. In order to make such nanomaterials to be socially and industrially acceptable and widely used, it is very important and necessary to establish and promote reliable standardized approaches for their characterisation, monitoring and safe and sustainable management.

A nomenclature for nanotechnology and nanomaterials is under development however not yet introduced and accepted. This nomenclature has to be finalised so that regulators, stakeholders, and consumers can work with a common vocabulary and a common understanding of terms and their implications.

Moreover, the communication of "nano inside" on as many value-adding products as possible should be improved in view of relativizing consumer's fear on toxicity of nanomaterials. The "nano inside" should signal safety by design. Consumers and decision makers need to learn that many products contain "nano" but that nano does not mean toxic by itself.

Scope

- Strengthen the exchange between academia and industries for management of nano-related products in a coordinated and standardized way.
- To promote discussion for consensus among key nomenclature issues regarding nanotechnology through surveys and dedicated mutual learning workshops.
- To promote communication between researchers, industry and consumer organisations (lay people) of "nano-inside" and safety by design and promoting best practices on actual products with detailed "lay term summary".
- To promote training and extended guidance for companies on how to best communicate the safety by design concept.
- To collaborate with Nanosafety cluster in order to o develop clear, easy to understand guidance regarding nano-materials for non-specialists.

Expected Impact

- to promote effective nanolabeling among EU industries;
- to contribute effectively in raising the awareness of European consumers, end-users and citizens, on nanotechnology;
- to enhance support to good governance in nanotechnology by providing information about instruments being validated in other projects dealing with awareness in general,
- to contribute to the implementation of the European Commission's Action Plan for Nanotechnology.

TRL: from 2/3 to 6/7
Type of action: CSA

KNOWLEDGE-BASED STRUCTURAL AND MULTIFUNCTIONAL MATERIALS

TOPIC 14

Title: *Development of innovative lightweight, high performance metal-based structural materials with tailored microstructure based on modelling and failure mechanism simulation.*

Specific challenge

Despite the remarkable progress in development of advanced metallic materials for structural applications in various industry sectors and the high level of maturity of metallurgy in Europe, much remains to be done regarding the string of processes from material development to market deployment of the product. This has been reflected i.a. in the roadmap "Metallurgy made in and for Europe" published recently by the European Commission. While enhanced physical, mechanical and service properties of the materials are the main drivers in materials research, the persisting challenge is to process them with lower energy expenditure, environmental footprint and at lower cost, thus meeting volume, cost-competitiveness and sustainability criteria. When moving towards more and more specialised products the structural materials often reach the limits of their performance capacity. Basic mechanisms leading to materials failure need to be understood and simulated to better exploit the load bearing capacity and durability of the innovative material systems developed by the methods of metallurgy.

Scope

Research should focus on novel metal based lightweight material systems which by the tailoring of their micro and nanostructure will result in major enhancements of the mechanical properties and durability, while providing structural applications. Innovative concepts for designing tailored materials by metallurgical methods are expected to be guided by advanced modelling and simulation tools predicting the material compositions and properties to minimize the costly trial and error experimental procedures. Particular attention needs to be paid to fundamental understanding and control of processes limiting materials' structural performance such as residual stresses, physico-chemical degradation and damage and failure mechanisms. High precision processing must be addressed, in this respect, as a key factor when it comes to delivering value in new markets. Processing and recycling of the developed materials should have low environmental impact. Combining the enhanced structural properties with functional ones as well as using nano-additives in substitution of traditional ones, based on critical or toxic elements, will be an asset. Upscaling solutions from laboratory scale to industrial use, building up complete industrial value chains, are expected, taking into account the complexity of proposed technology and final component costs. Cross sectorial applicability of the developed novel metal-based materials needs to be addressed in the project proposals.

Expected Impacts

Outcomes of the proposed R&D effort should contribute to the deployment of key enabling technologies, comprising new materials and processes, in order to achieve (i) enhanced product performances and faster time-to-market while guaranteeing higher resource efficiency, (ii) innovative and complex knowledge-intensive products characterised by new performances and functionalities, (iii) reduced environmental impact (iv) high-added value products for a wide range of application fields, such as transport, bio-medical and health, and energy (contributing to the implementation of the European energy policy).

TRL: 4-5
Type of action: Research and Innovation Actions

<u>TOPIC 15</u>

Title: *Development of advanced multifunctional surfaces by means of industrialized technologies*

Specific challenge

Today, industry requires multifunctional surfaces able to improve the performance of their products without increasing its cost. In sectors such as transport, moulds and dies and machine tools and cutting tools, losses due to inadequate surface-medium interaction may involve high costs like high fuel consumption, energy losses, etc. Markets are demanding innovative solutions to overcome these drawbacks. New surfaces functionalities such as superhydrophobicity, self-cleaning and anti-icing and its combination could produce a significant, positive impact in several industrial applications. However, the conventional industrial technologies and manufacturing processes are limited in providing multifunctional surfaces. In this frame the use of new technologies and processes meeting volume, cost-competitiveness and sustainability criteria for producing this sort of functionalities is starting to become a promising research field. The functionality of surfaces offers a wide range of possibilities. A surface may offer mechanical performance such as high hardness or tailored tribological properties as low friction or high wear resistance. Furthermore, a surface may provide certain chemical and thermal performance depending upon its environment of operation. The effort in enhancing the performance of functionalized surfaces in last decades has led a great improvement in load-carrying capacity, wear resistance and friction coefficient. However, some emerging surface functionalities, as superhydrophobicity, self-cleaning and anti-icing and also improved tribological properties have to be investigated to fulfill more exigent environment requirements.

Scope

The objective of this topic is the development of new advanced functional surfaces by promising technologies and innovative processing, such as laser technology or chemical functionalization of surfaces, providing solutions from laboratory scale to industrial use, hence building up complete industrial value chains. The proposed technologies must improve, for instance, ice protection and hydrophobic properties in different surfaces while maintaining or improving other tribological properties such as erosion or wear resistance. Durability of coatings and materials will necessarily be part of these studies. Innovative concepts for designing tailored coatings are expected to be guided by advanced modelling and simulation tools predicting surface properties to minimize the costly trial and error experimental procedures.

Expected Impact

Development of new advanced multifunctional surfaces through innovative technologies and processes shall fulfill the new requirements and demands of the market, such as superhydrophobicity, self-cleaning and anti-icing, but maintaining or even improving the tribological properties of the surfaces. High-added value products for application fields such as transport are expected to be achieved. Decreasing environmental impact and therefore making easier the industrialization process is expected too.

TRL: from 3 to 5/6
Type of action: Research and Innovation Actions

TOPIC 16

Title: *New thermoset and thermoplastic polymer systems for light-weight carbon fiber structures*

Specific challenge

Air traffic and all types of terrestrial vehicles need to reduce emission. The climate debate and the higher costs for energy initiate activities to increase energy efficiency in transportation. The progressive globalization and the increasing need for mobility. There is a need to rethink the selection of materials for aircraft and other vehicles. There is a high probability that this topic will have significant influence on the constructions of buildings and engineering by the same reasons in the near future.

Carbon fibers are actually the most important substitute material because of their low mass, high stiffness and strength. In combination with polymer matrix systems they are 80 % lighter than steel and 50% lighter than aluminum by double strength and stiffness. Further potential is expected by using the specific anisotropy of such composite materials which can be custom-tailored to the load application. This offers the chance for completely new technical construction solutions with material adapted loading cases. The transfer of the carbon fiber textile properties into the composite material requires in-deep understanding of the interfacial interactions between the fiber surface and the matrix polymer. The chemical and physical control of the interface and the reproducible adjustment of the composite properties is still one of today's challenges of analytical science and resulting conclusions.

Unfortunately thermoplastics are already partially or fully polymerized when used to impregnate the textile carbon fibers. Classical polymers developed since the 1920's are not able to fix textile fibers forming a composite material. In case of thermoplastics their viscosity at processing temperature is relatively high. Impregnation of flat carbon fiber structures or fiber bundles with a thermoplastic must either be carried out from solution or by melt flow at a suitably high temperature. There is a variety of methods to adapt the production process to the existing polymers by powder impregnation, film-stacking or using pre-impregnated reinforcing textile layers. Besides several advantages of thermoplastics, their disadvantage is the time- and temperature-dependent flow of the material under load which has to be considered in dimensioning.

Innovative solutions to overcome these drawbacks are demanded by the markets. An inventive combination of materials and processing might lead to meeting the challenges set out above. The amorphous thermoplastics with their excellent chemical resistance, reduced water adsorption and higher toughness under impact, offer a high potential for industrial breakthrough. However, the cost of the material and considerable processing costs needs further optimization i.e. by innovative and cost effective processing meeting volume, cost-competitiveness and sustainability criteria.

Scope

The proposed research aims to provide innovative solutions encompassing the whole value chain, all the way from the development of novel materials, matrix polymers optimized for the special process technologies of carbon fiber reinforced composites, to the final products, including intelligent process technologies. The project proposals should address *inter alia* such issues as the reduced material costs compared to metal, reduced number of parts, reduced post treatment (near net shape), advanced understanding of failure mechanisms and long-term behavior, improved design guidelines for plastic components, optimized hybrid material architectures in terms of weight saving, alternative matrix systems, designed molecular structures with high compatibility to reinforcing fibers, combination of organic and inorganic polymer structures, new hybrid polymers (inorganic and organic parts blended on molecular level), increased application of cellular polymer materials (open or closed foams), gradient materials and sandwich materials based on folded structures matrix systems adapted to CFRP related automation processes, low viscosity for good impregnation of the fiber structure, smart tooling, high modulus, high glass transition and melting temperatures, high chemical resistance and controlled electrical and magnetic properties.

Low energy processing, low cost processing of high performance polymers, hybrid thermoplastic material design (blends with thermosets), hybrid yarn capability for all relevant textile processes, controlled post network reactions, controlled design of crystalline and amorphous polymer structures, self-reinforcement by crystalline and nano-scale substructures might foster breakthrough and innovation.

Advanced understanding of failure mechanisms between reinforcing fibers and matrix polymer should help to create design guidelines for composites and hybrid materials. The combination with other materials like metals, wood, ceramics and using cellular polymer materials, gradient materials and sandwich materials could create new solutions for light-weight composites with acceptable costs.

Innovative concepts for designing novel materials and reinforced products are expected to be guided by advanced modelling and simulation tools predicting the material and product properties to minimize the costly trial and error experimental procedures.

Expected Impact

Outcomes of the R&D proposal should contribute to the deployment of key enabling technologies leading to enhanced product performances guaranteeing higher resource and energy efficiencies throughout their processing. High-added value products for application fields such as transport are expected to be achieved. The reduction of the overall weight of an aircraft can be made profitable use of to achieve a higher payload or considerable reduction in kerosene consumption. In the automotive industry, the trend towards CFRP parts is still very weak. But initial experience with using CFRP in the sports car sector shows that there is enormous potential here as well, all the way to new designs. The evolutionary development in aircraft construction could be followed by a revolution in automotive engineering – with far-reaching consequences for processes and systems. The replacement of steel mats by carbon fiber mats with suitable layers of polymers can significantly help improve stiffness and reduce net weight at the same time. As a result, carbon-fiber-reinforced concrete elements could be designed with much thinner cross-sections, while retaining at least the same load-bearing capacity.

With regard to the research on new thermoplastic matrix systems the impact is expected on the materials cost reduction, component weight reduction, processing cost reduction and automation, improved energy efficiency across the whole production process, in optimized design and improved understanding of failure mechanisms and long term behavior.

TRL: from 3 to 5/6

Type of action: Research and Innovation Actions

TOPIC 17

Title: *Surface functionalization of polymers for advanced tailor-made properties*

Specific challenge

Polymers are materials widely used in our daily lives and industry. Nowadays new advanced properties on these materials are being demanded by the markets in order to achieve an appropriate balance of mechanical, chemical and aesthetical properties, manufacturability and cost. Material wettability is an important property as its modification can, depending on the material's use, contribute to less energy consumption, enhance the functioning of the device or improve cleaning. Selecting the right features for the user will lead to structural durability, saving effort in maintenance, optimizing the use of chemical resources and environmental benefit. These changes in surface roughness geometry in the micrometer and/or nanometer scale could generate tailored properties such as easy to clean, condensation control, self-cleaning, anti-finger, anti-frost or anti-fouling properties. However, the conventional industrial technologies and manufacturing processes are limited in providing multifunctional surfaces. In this frame the use of new technologies and processes meeting volume, cost-competitiveness and sustainability criteria for producing this sort of functionalities, is key.

Scope

Cross-sectoral cooperation in methodologies for knowledge-based, specialised production is envisaged. Project proposals should address industrial needs by developing and demonstrating in relevant industrial environments intelligent process technologies including new methods of lithographic techniques, injection moulding, thermoforming, embossing, and roll-to-roll. Projects should develop functional surfaces that can function within a day to day operational environment without loss of functionality and sufficient thermal, mechanical, chemical and aesthetical properties. Pilot line setting should demonstrate the effectiveness of the developed approaches and technologies, through a pilot line aimed at the production of semi-finished products, with sufficient yield, quality and functionality for the intended application. Study of combination of materials and structures to give different wetting behaviour must also be looked at Safety considerations and contribution to standardization should be an integral part of the projects.. The implementation of this proposal is intended to start at TRL 4-5, target 6. Implemented as cross-KET activities.

Expected impact

- Promoting safe-by-design approaches and contributing towards the framework of EU nanosafety and regulatory strategies.
- Contribution to on-going and future standardization work in the field.
- Paving the way for the future commercialization of such products, based on an analysis of the efficacy, safety and cost-benefit of functional surfaces for the end-users.
- Supporting European competitiveness through accelerated market uptake of functional materials in one or more of the following application fields: automotive; aeronautic; home appliances; shipping or construction and building. This non-exhaustive list does not preclude submission and selection of proposals addressing other application fields.

TRL: 4-5, target 6

Type of action: Innovation Action

TOPIC 18

Title: *The European Competence Centre– Joining and integration issues of innovative-to-traditional materials, including the new technologies (innovation) risk management, sustainability, safety and life-cycle analysis (LCA)*

Specific challenge

Gathering, integrating and implementing expertize now available but scattered in EU companies, universities and research centres is a generic challenge for innovation in Europe. In particular, the challenge is related to joining and integration issues of Innovative-to-Traditional Materials, as, currently, there is a wide gap between the information available within the formalized system established by the REACH directive and the information available about the "under-the-development" advanced engineering materials, e.g. in the EU, other public and private research. In order to achieve "safe and sustainable materials development", declared in the strategic goals of Horizon 2020 and the strategic research agendas of groups like SPIRE, EMIRI, EuMaT, this gap should be bridged by a European PPP platform acquiring and offering knowledge and information about risks, safety (MSDS) and life-cycle on a collaborative, "wiki-like", system-of-systems (platform) basis. The platform should support the work of the European Common House Material developed under the call NMP – 33 2014, possibly being organized as (e.g.) a self-funded Virtual Institute able to provide a reliable source of expertise and assistance to the European industry, possibly profiting from the successful examples of Vis like KMM-VIN, EU-VRi and similar.

Scope

Different aspects of safety and risks of advanced engineering materials must be addressed in a more and more integrated way, including their characterization, exposure and life cycle assessment, as well as human and ecological hazard assessment. As the developing one single system ("from scratch") would be technically and organizationally out of date, the project(s) should target development of a an intelligent, interactive, collaborative European knowledge-based system system-of-systems which would include existing systems and initiatives, enable their synergies and enhance and facilitate development of the new systems.
The development should take into account the results from existing projects, knowledge-based and database systems, regulatory databases and standardization initiatives (national, EU, international, e.g. OECD) and strengthen the capacity to interact, cross-link and align further development of the above systems. The system-of-systems should be developed in such a way that current and new methods needed for future development of 'safe-by-design' advanced engineering materials is ensured. A particular feature should be seamless self-inclusion of the results from the preceding, current and future research projects, not limited to the EU projects only. The pilot implementation of the system should address the issues of data protection (e.g. pre-publication or pre-commercialisation), data quality assurance, data-sharing capability, and communication with other databases and search tools (TRL4-6). Due to the increase use of new thermoset and thermoplastics polymer systems for light-weight carbon fibre constructions, preliminary cases on risks, safety and life cycle assessment should focus on the innovative novel matrix polymers for process technologies of

carbon fibre reinforced composites. The application should be used as the "template" for former NMBP –relevant systems.

Expected Impacts

The European competence centre on Joining and Integration Issues of Innovative-to-Traditional Materials is expected to be of high impact for a wide range of applications ranging from automotive to aerospace, but not confined to them; it is also aimed to fill the lack of an EU competence centre on joining, which already exist in USA and Japan. It will provide a reliable source of expertise and assistance to the European industry, positively impacting on their innovation and revenues. Once established and possibly interlinked and supported by existing national and industrial systems, the system would boost the trust in and social acceptance of research in the area of advanced engineering materials in Europe. Although non-mandatory, its use would be a guarantee of Corporate Social Responsibility (CSR) of the companies involved in the process and proof of their readiness to contribute to the idea of the EU as the cradle of "responsible material innovation". This will be also related to the new EU directive on Disclosure of non-financial and diversity information by large companies and groups - http://europa.eu/rapid/press-release_MEMO-14-301_en.htm). It is envisageable the competence centre will be sustained by industrial partners, demonstrating the legacy of this call.

TRL: 4-6

Type of action: One CSA, in order to establish the structure and one Research and Innovation Action for the development of the IT system.

MATERIALS for ICT

INTRODUCTION. Perspective of Materials for ICT, Mobile and Autonomous Devices to hit the Societal Challenges of H2020.

ICT devices, in particular mobile, wearable and implantable ones will play an increasing role in our societies and consequently in our industries. EU has to be at the forefront of these innovations and for this it has many assets that it can build on, among which novel materials and advanced technologies, particularly at micro/nano scales. EU citizens will be the first to benefit from the functionalities brought by such innovative devices.

Health, Demographic Change and Wellbeing

Wearable or implantable autonomous devices such as hearing aids, pacemakers and novel implantable devices that are currently being developed, for instance to treat several brain pathologies, require new materials whose functionalities allow to ensure functions such as sensing, actuation, energy conversion, energy harvesting, energy storage and/or data transmission. Such novel materials need to be easily miniaturised and integrated with other more classical materials and the structures they are integrated in need to be biocompatible. Materials that combine several functionalities such as piezoelectric, electrocaloric, thermoelectric, ferromagnetic or semiconductors (particularly high bandgap) are key elements in such devices. New materials with higher energy density and lower dissipation than currently available ones are required to answer these needs.

Food Security, Sustainable Agriculture and Forestry, Marine

Novel sensor systems that can be used to ensure safety of food and to monitor transformation process of food and other agriculture products are a major issue for safe and durable supply both for human and animal needs. These systems need to be able to transmit data without wiring and in some case to be autonomous. Functional materials that can combine sensing with other functions such as energy harvesting and energy conversion need to be developed for these applications.

Secure, Clean and Efficient Energy

Whenever energy is concerned, which is the case in practically all human and industrial activity, conversion to or from electricity is required. Materials that can convert energy (from electrical to electrical, from mechanical/thermal/electromagnetic to electrical or vice-versa) with high energy density and minimum energy losses are at the centre of devices. In particular, with the increasing number of mobile devices, efficient management of small quantities of energy is becoming a limiting factor. For instance, some high performance smart phones have autonomies of a single day. Novel and improved materials that can harvest and/or store and/or convert energy with higher efficiency will allow increased autonomy and to support even more diverse applications within these mobile devices.

Smart, Green and Integrated Transport

Smart transport is only possible if reliable measurements from a large number of sensor systems are available to inform IT of the current status of the vehicle and its sub-systems. Integrated transport requires that data should also be exchanged between different vehicles and between each vehicle and the external environment. Finally, green transport requires particularly precise sensing to optimise energy consumption and reduce pollution. Actuators with quick and precise response are also needed here. Functional materials, among which piezoelectric, allow addressing many of these challenges, at the condition that their performance is improved and their resistance to harsh environments as well as lifetime are improved. These materials are also the basis for non-destructive testing systems, thus improving the safety of transportation.

Climate Action, Environment, Resource Efficiency and Raw Materials

The functional materials that are at the centre of this WG can be critical in order to improve energy efficiency, and thus reduce effects on the environment of the use of natural resources. This concerns energy management and conversion systems (low dissipation, high energy density) as well as sensors and actuators. Developing devices without using hazardous chemicals and that can easily be recycled requires the design of novel functional materials based on low-cost environmentally-friendly materials having performance at least comparable to currently available compositions.

Secure societies – Protecting freedom and security of Europe and its citizens

Many types of sensors that are required to detect very small concentrations of chemicals such as narcotics, hazardous molecules or explosives need to be developed, and existing sensor systems need to have higher sensitivities (to lower their detection threshold), to be less sensitive to external perturbations and to be able to regenerate quickly after a detection in order to be able to stay functional at all times. The functional materials targeted in this WG are not only a key element of such sensing systems, but can also be used to power them through harvesting of energy in the environment (vibrations, heat, light).

TOPIC 19

Title: *Key materials to enable « electronics for everyone everywhere »: low cost, low loss, green, recyclable, safe, flexible*.

Specific challenge

Enabling electronics for everyone everywhere means providing all categories of citizens with functionalities such as monitoring of their wellbeing, communication, security, ... without the need for them to worry about any of the technological issues. This includes devices for sensing, actuation, communication, as well as energy harvesting and storage to power them so they can be autonomous for relatively long periods of time.
The electronics for such a goal and **all the materials they are made of** need to fulfil several, if possible all, of the following requirements:

- Flexible or stretchable
- Lightweight
- Wearable and possibly compatible with Fashion (Street, Sportswear, Design...)
- User Friendly / Non toxic
- Washable
- Recyclable
- Low cost
- Autonomously powered
- Reliable
-

The Devices and/or systems to be developed must exhibit high electronic performance and have ultra low power consumption.
Today, technologies are appearing to ensure these functions, but the devices are generally very expensive and not compatible with the uses targeted here. Therefore an entirely new family of low cost flexible and stretchable green electronics is required, which can only be made possible by developing a **novel generation of green flexible and/or stretchable functionalized materials** as basis of new components, interconnections and substrates. These materials need not only outstanding performance but also to be compatible with their full recyclability, especially for a broad range of nomadic, wearable or implantable electronic commodities.

Scope

The activity should be focused away from solutions such as sputtering routes, targeting mainly low cost processes, compatible with the use of inexpensive flexible or stretchable substrates. The materials to be developed should be free from hazardous chemicals such as lead or indium (to avoid any toxicity issues materials scarcity cost issues during fabrication and all along their lifetime including recycling), use very little or ideally no costly chemicals at all such as rare earths (to guarantee the devices will be affordable and reduce dependence towards suppliers that have monopoly on specific substances), they should be highly stable electronically, physically and chemically, and be obtainable by simple/low cost/low temperature mass production fabrication routes.

Some strategic targets to be considered are:

- Solution-processed n and p-type AOS and hybrid for their integration as proof of concepts in full non-silicon or grapheme based TFTs; CMOS circuits; solar cells or thermoelectric energy harvesters. Solution-processing or other high-throughput methods such as aerotaxy should be used;

- Innovative solutions of power management at micro-level
- Nano-devices for portable / wearable applications
- Tuneable nanostructures including nanowires for novel electronics applications, including the sensing area;
- Electrochromic devices with solid-state and polymeric electrolytes for integrated pixel electronics and detection of electrochemical-active bacterias by exploring the electrochromism properties of such materials/devices;
- Nano-devices based on nano-assembled structures;
- Laboratory lifetime prediction tests and standards to rank materials and surface protection development from early development state
- Printed electronics design tool kit. The aim is to define technical specifications for printing and converting operations of discrete components: transistors, resistors, displays.

Expected Impact

The applications of the materials with the performance described above will have a high impact on key enabling technologies for ICT, targeting a potential low cost electronic market over more than 130 b€, which includes novel electronic components, hybrid thin film transistors, logic gates, ring oscillators, bio-sensors/bio-detectors with exceptional properties that can be integrated in small and large area low cost flexible substrates for a plethora of systems integration, in particular wearable or implantable ones, serving multisectorial industries such as food, textile, security, communication and health.

TRL: 4-6

Type of project: Research and Innovation Actions

TOPIC 20

Title: *Paper as a low cost new material, smart and safe platform for advanced materials integration on devices and systems*

Specific challenge

Advanced device platforms can be radically transformed by introducing new materials at a basic level. For example similarly to what happened with microelectronics in the last decades where a materials evolution from highly expensive to low cost substrates has been observed, we can envisage the same for paper since it is the latest material to transform the device landscape. Despite the fact that paper has more than 2000 years, new and important applications by using this unrevealed material are still emerging.
The main new developments should target also the paper functionalization aiming to turn it an active component

Scope

The aim is to develop a completely new, disruptive and sustainable paper-based platform not only by the simple integration of discrete devices but also by using the cellulose as a real electronic material like insulators, electrolytes, conductors and semiconductors. In order to fulfil these objectives novel printing and patterning methods combined with hybrid materials need to be exploiting, aiming to keep Europe the major key player in the area of the emergent field of Paper Electronics.
As target applications we would like to stress the Paper-based Platform to the Intelligent Packaging and Diagnostics in Medical and Pharmaceutical applications due to their large markets as well as their gigantic revenue streams, due to its easy recyclability. For example the world pharmaceutical packaging market is expected to grow approximately 6.3% annually, giving a total market value of 46 000 €M. By doing so we are generating a free real stat electronics that is able to add new functionalities to a very old and conventional support, which currently are not used in this manner and where silicon cannot any more contribute.

The following actions/activities should be considered:

- To turn paper into an electronic substrate and active material; heterogeneous integration and emerging of a full disruptive paper industry.
- Electronic functionalization of paper fibres; fully energy autonomous test vehicles; intelligent packaging and diagnostics in medical and pharmaceutical applications/ fully high tech disposable and low cost integration for a broad range of industry and laboratory commodities.
- Development of smart fibres – i.e. fibres with embedded sensors, signal processing elements, and energy elements
- Development of materials: a) conducting polymers, semi-conductors, organic and inorganic, b) functional inks reactive to their environment c) printing techniques, coating and surface treatments techniques, drying-reticulation techniques for materials.
- printed electronics design tool kit. The aim is to define technical specifications for printing and converting operations of discrete components: transistors, resistors, displays.

Expected Impact
Development of low cost, recyclable and sustainable paper-based platforms, ranging from intelligent packaging to pharmaceutical industry leading to the implementation of breakthrough technologies relevant for all regions of European pulp and paper industries. The envisaged applications should offer huge potential for new multifunctional paper-based products as well as the opening of new markets for the SME dominated sector of the printing industry.

TRL: from 1-3 to 4-6
Type of project: ERC/FET and Research and Innovation Actions

TOPIC 21

Title: *Multifunctional materials for piezotronics.*

Specific challenge

Piezoelectric materials, even though not well known by the general public, are key components of many devices of our every-day life as well as in fields such as health and industries. Mobile electronic devices including phones and portable computers, radios and televisions, ultrasonic medical imaging and therapy systems, physical and chemical sensors, actuators including fuel injectors and micromotors are just a few examples among the vast list of their applications. Market studies predict a growth rate of over 12%, the main domain being ICT (including telecommunications, information technology and systems, robotics etc.).

Piezotronics can be defined as the combined use of piezoelectric effect and other functionalities (semiconductor, multiferroic, photovoltaic, pyroelectric, electrocaloric etc.) in an integrated component or device. In particular, piezotronic devices are regarded as a new semiconductor-device category and are likely to have important applications in micro/nanoelectronics, MEMS/NEMS, sensors, nanorobotics, active flexible electronics and energy harvesting.

The survival and development of EU industry in these fields can only be obtained through radical innovation since classical materials and devices are being produced at low cost outside EU.

Scope

The research and developments on materials for piezotronics aim at producing new materials that combine several unique functionalities, one of which is piezoelectricity, thus opening the way to new components and devices, in particular tunable devices.

In this field, materials and technologies are closely linked and need to be considered as a whole. Indeed, very specific technologies, in particular micro/nano technologies, need to be co-developed with the new materials since most of the novel structures targeted here are designed at nanometer scale, if not even smaller. The required forms can vary from bulk materials (generally for first stage studies to identify most promising compositions), to films and 3D micro/nano structures including composites.

Topics should include:

- multifunctional piezoelectric materials with optimised properties thanks to design and control of nanostructure
- novel piezo-semiconductors, in particular high bandgap SCs, as well as compatible materials for electrical contacts, isolation and for substrates,
- low cost technologies for mutifunctional materials,
- technologies for multifunctional material design at nanometer scale,
- multifunctional films and 3D micro/nanostructures.

Expected Impacts

The applications of these materials will include novel electronic components (*i.e.* piezoelectric/piezoresistive transistors, piezopotential gated field-effect transistors, piezopotential gated diodes, hybrid field-effect transistors, piezotronic logic gates, electromechanical memories) with unique properties, namely reduced size and switching time, as well as integrated sensors and transducers (strain/force/acceleration/flow sensors, chemical sensors, ultrasonic transducers for medical and industrial diagnostics), miniature actuators and motors etc.

Through such devices, these materials will contribute to the following societal challenges:

- innovative societies: intelligent, autonomous or very low consumption and user-friendly mobile devices thanks to increased functionalities and energy harvesting
- transportation: improved safety, reduction of energy consumption, of pollution, of emissions & waste thanks to more efficient monitoring, control and test systems
- energy: increased efficiency and improved safety of energy production/distribution/use thanks to intelligent sensing and monitoring as well as protection systems, harvesting of currently wasted energy
- health: novel medical diagnostic, monitoring and therapeutic systems allowing for earlier detection, more efficient monitoring of patients with chronic diseases (from home) and less traumatic treatments - food: improved quality and security in food industry thanks to processing monitoring and quality control systems

TRL: from 3-4 to 6
Type of project: Research and Innovation Action; ERC and FET.

TOPIC 22

Title: *Functional, reconfigurable and nonlinear metamaterials, photonic and phononic crystals.*

Specific challenge

The Horizon 2020 objectives aim at raising the level of excellence in Europe's science base and technological advancements. A steady stream of world-class research combined with the development of enabling technologies will lay the foundation and pave the way for industrial innovations.

One of the key goals of Horizon 2020 is to build leadership in enabling and industrial technologies, with dedicated support for ICT, nanotechnologies, advanced materials, and space, while also providing support for cross-cutting actions to capture the accumulated benefits from combining several Key Enabling Technologies.

Leadership in enabling technologies such as functional and adaptive electromagnetic or acoustic metamaterials will provide the critical capability for the development of technologies underpinning innovation across a range of sectors, including ICT and space. The Horizon 2020 will have a strong focus on developing European capabilities in Key Enabling Technologies (KETs) which include the relevant areas:

- Advanced materials
- Micro- and nano-electronics; photonics
- Nanotechnologies

Functional, reconfigurable and nonlinear metamaterials and photonic crystals have been identified as one of the priority topics in the "Electromagnetic Metamaterials: Research Roadmap Directions" by the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials – METAMORPHOSE VI. The research in this area and the development of the respective technologies requires a multi-disciplinary, knowledge and capital-intensive approach. To ensure a steady progress of world-class research and the development of cutting edge-technologies securing Europe's long-term competitiveness, it is essential to support the best ideas, develop talent within Europe, provide researchers with access to priority research infrastructure, and make Europe an attractive location for the world's best researchers and industries. The latter priorities have been defined in the programme documents of Horizon 2020 which will:

- support the most talented and creative individuals and their teams to carry out frontier research of the highest quality by building on the success of the European Research Council;
- fund collaborative research to open up new and promising fields of research and innovation through support for Future and Emerging Technologies;
- provide researchers with excellent training and career development opportunities through the Marie Curie Actions;
- ensure Europe has world-class research infrastructures (including e-infrastructures) accessible to all researchers in Europe and beyond.

Scope

The strategic targets and scope of activities comprise the three main interrelated strands:

A. Discovery and exploration of **new artificial electromagnetic or acoustic materials** with unusual and extreme properties, novel phenomenology and functional capabilities

B. Development of the novel application specific artificial materials and metamaterials for future and emerging technologies and industrial applications and **close the gap between the scientific ideas, conceptual experiments and practical applications** of metamaterials
C. Nurturing and **training next generation of researchers and engineers** equipped with the adequate skills.

The content of individual strands will include the following targeted directions.

A. Discovery and exploration of new artificial electromagnetic or acoustic materials with unusual and extreme properties, novel phenomenology and functional capabilities
   - New material architectures providing control of the material parameters, e.g. frequency and spatial dispersion, losses, gain, nonlinearity, power handling capability
   - Electrical, magnetic, optical, thermal control of the properties of engineered materials
   - Phenomenological theory and material synthesis methodologies
   - Fabrication techniques and experimental characterisation and metrology
B. Development of the novel application specific artificial materials and metamaterials as enablers for future and emerging technologies and industrial applications
   - Predictive theoretical modelling and design of tunable artificial materials
   - Targeted synthesis of metamaterials with specified electromagnetic or acoustic parameters
   - Development and realisation of extraordinary-property and non-classical artificial media
   - Reconfigurable microwave, optical and ultrasonic materials
   - Artificial materials with loss compensation and engineered non-linearity
   - Artificial materials for control and optimization of radiative heat transfer
   - Fundamental aspects of novel fabrication technologies
   - In-situ and non-destructive characterisation of artificial electromagnetic or acoustic materials
C. Nurturing and training next generation of researchers and engineers equipped with the adequate skills
   - Future career perspectives and employability of researchers and engineers will be developed on a solid foundation laid by the reputable academic and industrial partners involved in the project activities.
   - The provisions for the training activities will go beyond traditional specific areas to effectively cover the diverse aspects of multidisciplinary research in artificial electromagnetic or acoustic materials and metamaterials.
   - The training activities will be supported by the well-established "European Doctoral Programmes on Metamaterials" which offer courses within the geographically "**Distributed European School on Metamaterials**".

Further details of the envisaged scientific and technological developments and activities are outlined in the "Electromagnetic Metamaterials: Research Roadmap Directions" and "European Doctoral Programmes on Metamaterials" by METAMORPHOSE VI.

Expected Impacts

Functional electromagnetic or acoustic materials and metamaterials are the enablers of advances in ICT and optical technologies. Innovations in this knowledge intensive multidisciplinary field are the key factors in commercial success of many actors in the rapidly evolving and expanding ICT market serving vital infrastructure of modern society. Thus, the proposed area of research will also be highly beneficial for the community in the long term because future technological and industrial advances critically depend on the development of new knowledge and in-depth understanding of diverse scientific and application aspects of electromagnetic or acoustic materials and their use for the cost-effective product design.

From their first conception in the late 1990s to finding widespread applications in the near future, metamaterials have advanced at an unprecedented rate. In just over 10 years, they have found applications in very small antennas, cloaking from earthquakes, imaging of objects below diffraction limit and magnetic resonance imaging. The applications range from the radio frequency to the optical range, from sea waves or seismic waves to ultrasonics. Some of these applications, such as antennas in mobile phones, are already finding routes to commercialisation. Now it is time to concentrate efforts at the European scale with the main goal of bringing the ideas and first demonstrators to a wide scale commercialization. The multi-disciplinary nature of metamaterial research and development (material science, electrical engineering, electronics, nanoscience, photonics, acoustics, seismology, ...) needs concerted efforts, and the Horizon 2020 is evidently the proper framework for such undertakings. While the proposed topical area is primarily aimed at ICT applications, it is clear that it will engage expertise from other disciplines and the results will have a much broader impact on other technologies.

The adaptive and reconfigurable electromagnetic or acoustic materials become of paramount importance for modern communications technologies due to increasingly limited spectrum availability and the requirements of reducing power consumption. Also, reliability and sustainability of the ubiquitous communications networks and devices critically depend on the functional capabilities of the materials used in the electronic, photonic or phononic devices and systems. Therefore the research and development of the artificial materials and metamaterials with novel and unconventional electromagnetic or acoustic properties will pave the way to new approaches to the design of the communications systems with increased functionalities and higher efficiency. This will influence not only the terrestrial communications infrastructure but also the space communications and overall European capability of space exploration and exploitation. For this reason, from their outset research activities in metamaterials have been encouraged and supported by the European Space Agency.

It is also important to recognise that neither industry nor academia alone have nowadays sufficient resources and complete skill set required for the development and exploitation of rapidly evolving technologies. Therefore multidisciplinary training of researchers and engineers at the frontier research becomes another critical mission of the proposed activities. Through the collaboration between industry and academia and support of the European Doctoral Programmes on Metamaterials, the tailored research training programmes will create unique opportunities for the development and advancement of the research capabilities, complementary skills and experience of converting the research outcomes into product design. The knowledge and experience acquired in the course of such training programmes will also be highly *beneficial in the long term*:

- The future research career opportunities in industry and academia will be developed on a solid foundation of the advanced research activities that will also create better perspectives for employability.

- The provisions for the training activities go beyond traditional specific areas to effectively cover the diverse aspects of multidisciplinary research and development of advanced skills.

Entrepreneurship will be promoted here through various routes. On the successful completion of the research projects, commercialisation of the research outcomes will be pursued within the limits of the IPR provisions. The envisaged training activities will therefore target research excellence combined with professional awareness and will provide significant career opportunities for the next generation of researchers.

TRL: from 3-4 to 5-6
Type of project: Research and Innovation Action; ERC and FET.

BIOMATERIALS

The Work Programme 2014-2015 states: “the integration of different KETs represents a vital activity in Horizon 2020”, therefore one of the objectives of LEIT is to support "cross-cutting KETs projects" that could deliver new solutions in the Health field (for ex. Medical Devices) able to open new markets and increase the competitiveness of European Industries bringing to "A New Start for Europe".
One example of integration of different KETs is the 3D Bioprinting. Additive Manufacturing (AM), could make parts and products that were thought impossible to produce and, if applied to the medical field, could “change the face” of surgery. AM could transform the manufacturing value chain (allowing also to minimize waste and the use of resources) bringing production closer to the location of demand and strengthen Regional economies.

Moreover, cross-cutting Key Enabling Technologies applied to the Healthcare area, where technologies are intended to support critical societal challenges, will bring a variety of societal benefits, such as the development of new products for the early, safe, low cost and efficient diagnosis, treatment and monitoring of pathologies. In this contest, Nanomedicine activities (Advanced materials and nanotechnologies for healthcare) meet the objective of improving the speed of innovation for healthcare by increasing the design of personalized therapies for pathologies related to aging population, chronic and rare diseases.

The following topics could be the “solution” for some unmet needs, especially Topic 25, focused on the development of an innovative biocompatible & biodegradable “Living implant” for cardiovascular application obtained using new technologies (3D-4D printing), and Topic 24, focused on innovative and nanotechnology-based smart biomaterials able to integrate with host tissue and promote multifactorial biological responses.
Topic 23 (regarding multifunctional nano-materials (MNM) for theranostics) represents, as well, a platform for the innovative upgrading and innovation of nanotechnologies, advanced materials and advanced production technologies.

TOPIC 23

Title: *Hierarchical Biomaterials for diagnostic and theranostics*

Specific challenge

Despite the wide interest in scientific community, theranostics remains still at the embryonic stage, mainly because of the difficulty of developing suitable materials for applications in humans. On this respect, in the last ten years significant efforts have been dedicated to the synthesis and functionalization of nano-materials and nano-particles (NPs) enabling the widest possible multi-diagnostic capability and the highest selectivity towards specific disease receptors. Such a multi-parameters detection and therapy is believed to considerably increase the success rate for both diagnostic and therapeutic outputs. However, specific difficulties already at preclinical level have been experienced, like toxicity, inability in reaching specific target after IV injection (fate control), inhomogeneity of distribution inside local organs (thus inhibiting the therapeutic and, partly, diagnostic power) as well as difficulties in the control of size, charge, surface chemistry and tendency to aggregate, which play a significant role in the biokinetics, biodistribution and bioavailability in vivo. Further on it is very important and indispensible to achieve the higher TRL Level in the industrial development and clinical exploitation (clinical studies) to enable GMP like production of small quantities of such nano-particles or nano-materials. Besides, there is a highly demanded alternative to the currently used supports for clinically approved analytical and diagnostic devices, which should intrinsically provide 3D enhanced structures with a higher entrapment capacity and multiple automated functions

Scope

Proposals should contain the development and innovative upgrading of multifunctional nano-materials (MNM) able to promote simultaneously diagnosis and therapy, thus realizing agents for theranostics at preclinical level, but with a solid translational perspective to clinical activity. As only GMP-like material can be used for first clinical trials important to convince industry, the GMP production on laboratory level should be integrated in projects. The MNM actions will include optical, magnetic, chemical, and other specific functions. Injectable solutions, suspensions of nanostructures, or nanoparticles supported in smart systems and materials, in the form of individual or controlled-size clusters of nanoparticles are expected to act as nano-laboratory vectors able to recognize selectively various receptors expressed by different diseases in vivo, and to activate "on-site" the pathology treatment. External means (*e.g.* magnetic field, chemical gradients) able to promote remote guidance of MNM thus reducing their concentration to minimal invasive levels, are also encouraged. Significant efforts should be dedicated to MNM functionalization enabling the widest possible multi-diagnostic capability and the highest selectivity towards specific disease receptors as well as, where requested, the local drug release. The development of advanced theranostics hopefully has to contribute also to the studies on materials/biomolecules interaction, both experimentally and computationally, here including the explanation of *in vitro* predictions. The MNM should be able to activate more than one treatment, like hyperthermia, targeted drug release, MNM-assisted cancer immune therapy, MNM-assisted gene delivery and others, guaranteeing a full eradication of ill cells. On the other hand, diagnosis capabilities should be focused on clinically approved methods like Magnetic Resonance Imaging, Magnetoencephalography, X-rays, SPECT, PET, Optical Imaging, immunoblotting, antibody arrays, etc.

Expected impact

- Innovative biocompatible nano-materials for the simultaneous diagnosis and treatment of chronic and tumour- or inflammation-related diseases, whose care currently is mainly surgical or pharmaceutical
- Improved quality of life and prolongation of life expectancy, due to effective local action of therapeutic agents
- Reduced costs of long-term treatment and cures by early-detection of diseases
- Market uptake and distribution of innovations of nanotechnologies, advanced materials and advanced production technologies by allowing clinical tests using GMP-like materials on small-quantity level.
- Enhance competitiveness of the biomaterials and biomedical industries in the EU

TRL: 3-5
Type of action: Research & Innovation Actions

TOPIC 24

Title: *Multifunctionalised biomaterials for bone tissue repair*

Specific challenge

It is well know that musculoskeletal disorders, such as osteoporosis, osteoarthritis, bone tumours, cause decreased life quality and enormous economic loads on National Health Services worldwide. In Europe osteoarticular diseases are the first cause of absence and permanent invalidation from work with a huge economic impact every year. Moreover, increased bacteria resistance to the available antibiotics is a tragic issue to be faced.

The problem requires innovative and micro-nanotechnology-based smart biomaterials able not only to integrate with host tissue and/or promote new bone formation, but also to stimulate angiogenesis, to minimize or control the inflammatory response, to prevent spread of infections and pandemics and, eventually, to provide anti-oxidant and anti-cancer abilities, depending on the specific pathology of the implant site. In this context the integration of bioactive molecules, nanoparticles and ions with implantable materials is an emerging facet of the medical industry. Indeed, the incorporation of such functionalities into implantable devices will significantly expand the therapeutic scope of device technology in the foreseeable future. The biggest specific challenges in this field can include (i) the design of innovating smart technologies able to ensure the safe and controlled delivery of the bioactive organic or inorganic chemical (targeted location, release profile...); (ii) the use of antibacterial functionality based on metal nanoparticles or nanoclusters in alternative to antibiotics; (iii) the definition of the particularly complex regulatory status of this new class of products by health authorities (drug classification or class (III) medical device), which requires well documented evidence on which of the two components has the primary mode of action.

Scope

Proposals should develop one or more multifunctional biomaterials, especially advanced biocompatible and biodegradable materials (e.g. bioactive glasses, calcium phosphates, polymers, ceramics, metals...) intended for combination with bioactive agents, for bone tissue repair/substitution capable to promote bone growth and to inhibit bone abnormal resorption, as well as to release molecules and/or ions that increase the production of angiogenetic factors, prevent infections and/or adverse immune reactions and <u>control oxidative stress and tissue inflammation.</u> To this aim, proposals should embrace the study of these materials at the nano and meso-and micro scale levels to achieve a full chemical, physical, cell- and molecular-biological and pre-clinical characterization; projects could also develop pathological models for *in vitro* and in *vivo tests* to assess biocompatibility, osteointegration, angiogenetic properties, antibacterial activity and immunogenicity in comparison with healthy models. In addition, with regard to the directive 2010/63/EU, projects implementing the development of innovative tools offering alternatives to animal studies for the biological evaluation of these medical devices will be favorably considered.

Proposals should generate comprehensive pre-clinical data and after completion of the project, the material should be in an optimal position for entering clinical. GMP like production is one of the pre-requisites to achieve industrial translation.

In order to maximise the effect of such an action, the adoption of a wide-ranging multidisciplinary approach is critical. The participation of SMEs is strongly encouraged and that of clinicians even necessary to allow the right clinical follow-up.. The involvement of end-users (surgeons, interventional radiologists) early within the process will facilitate the design of novel combined devices by taking account of their needs, expectations and concerns, leading to an efficient synergy. Similarly, participation of SMEs operating in the medical device field will enable the ability to address important issues pertaining to regulatory matter, up-scaling and good manufacturing practices (GMP).

Expected impact

- Improvement of the quality of life of patients with muscoloskeletal disorders
- Reduced direct and indirect costs linked to the treatment of different diseases of the musculoskeletal system, and wide availability of personalized treatments
- Development of biocompatible and bioactive multifunctional materials with high technology value
- Optimisation of the targeted delivery of biologically active substances or pro-drugs
- Measurement of the impact of local release and the effectiveness of synergy between the drug and the device on healing, with possible reduction or suppression of adverse effects compared with a systemic administration
- Involvement of end-users so as to take account of their needs, expectations, and concerns
- Increased competitiveness of the European biomaterial and biotech industry.

TRL: 5
Type of action: Research & Innovation Actions

TOPIC 25

Title: *"Living implant" for cardiovascular application: development of scaffolds obtained using new technologies and considering cell-substrate interactions at the micro/nano scale.*

Specific challenge

Cardiovascular diseases represent the leading cause of mortality worldwide. Very often the etiology of the disease relies on a damaged or failing tissue (e.g. vessels, heart tissues and valves) and a definitive solution is still missing. Medical treatments usually aim at limiting the disease progression, whereas surgical or interventional approaches entail the use of prostheses which highly affect the patient quality of life.

Inert materials used in cardiovascular implants do not growth with the patient and lead to life-long biocompatibility issues; grafts lead to rejection due to immunologic barrier and progressive degeneration, especially in younger patients. Tissue engineering and regenerative medicine are emerging multidisciplinary fields in rapid growth over the last 10 years, focused on innovative biomaterials, molecular and cellular biology, and design engineering. Their main objective is the creation of functional, living tissue constructs that can reestablish the structure and function of the injured tissues, thus overcoming the limitations of the current clinical approaches. The emergence of innovative biomaterials, able to interact with the body cells, has revolutionized the field of biomedical research. As such, biomaterials are central to many strategies focused on localized delivery of bioactive moieties, and on scaffold engineering. An ideal scaffold for tissue engineering should be bioresorbable, biocompatible and with highly porous macrostructure necessary for cell repopulation, growth, nutrient supply, and waste removal. In particular, in order to interact with living cells some features of the native 3D tissue environment associated with their renewal, differentiation and organization have to be mimicked in the target scaffold materials. The ability to manipulate cell-substrate interactions at the micro/nano scale may represent the key to achieve a viable cellular environment which can be effectively integrated with the host tissue.

The specific challenge is the development of ***"living implants"*** with the potential to grow and last during lifetime, like most native tissues do, by exploiting the unique properties and phenomena exerted by matter at the nano-scale.

Numerous scaffold fabrication technique are already available, however the accurate control of the spatial distribution of pores, 3D pores architecture and structures within the scaffold is still an open challenge. Promising technique are represented by Additive Manufacturing (AM) processes (e.g. fused deposition modeling, 3D/4D printing, selected laser sintering, stereolithography and inkjet printing) in which structures are constructed layer by layer according to computer aided design. The recent application of AM principles to electrospinning techniques has allowed to obtain smaller fiber resolution in comparison to what achieved with conventional AM techniques as well as to enhance the control over electrospun fibrous assembly in terms of interfiber pore size and geometry, sample thickness and external shape.

Scope

Aim of this call is the development of an innovative biocompatible "*living implant*" for cardiovascular application, obtained by exploiting the latest advances in nanomaterials and nanotechnology. Porosity, pore size and inter-pore connectivity represent essential design features for a modern scaffold. The attempt must focuses on the realization of a scaffold with controlled porosity, surface chemistry and structure so that it can successfully induce new tissue development and growth. Biodegradability issue should be considered in order to control the degradation rate of the scaffold and the mechanism involved. The degradation of the scaffold should take place at rate equal or lower than that of new tissue formation process, since the scaffold should retain the necessary mechanical properties and provide the temporary support structure needed for tissue/organ functioning prior the complete tissue formation.

Moreover the in vivo degradation of a polymeric scaffold leads to the creation of low-molecular-weight degradation products within the body tissues, the effects of which must be considered. Neither the scaffold material itself nor its degradation products should have local or systemic toxic effects on the host cells.

Proper functionality and durability shall be pursued in order to avoid the fate and the failure mechanisms commonly reported for current bioresorbable approaches applied to heart valves – mainly known are fibrosis, retraction and incompetence. *[Ref. Heart Valve Tissue Engineering, Ivan Vesely, Circ Res. 2005; 97:743-755)*

Advanced techniques of rapid prototyping allow the realization of scaffold without the need of templates and provide precise control over scaffold architecture. The integration of this techniques based on additive manufacturing processes shall enable the design of morphology-controlled scaffold, potentially even in a custom made fashion.

Furthermore the recent application of additive manufacturing (AM) principles to electrospinning techniques has allowed to obtain smaller fiber resolution in comparison to what achieved with conventional AM techniques as well as to enhance the control over electrospun fibrous assembly in terms of interfiber pore size and geometry, sample thickness and external shape. While significant progress towards the development of predesigned constructs composed by ultrafine fibers made of synthetic polymers has been achieved, mainly by means of melt processing, innovative solutions for electrospinning as an AM approach to produce biobased polymeric constructs appear to be at present of utmost interest in the area of smart biomedical devices.

Biobased polymers (with structural relationship to biopolymers that constitute the building blocks of living organisms) or synthetic solutions could be developed and both *in vitro* cell seeding (i.e. before implantation) and *in vivo* cell repopulation (after implantation) could be pursued.

Moreover the use of cold plasmas technologies could allow to modify and functionalize the surface of the scaffolds (e.g. by tuning hydrophobic or hydrophilic properties or through the immobilization and/or embedding of biomolecules). Penetration of active species in the scaffold can be optimized by properly tuning plasma parameters such as plasma regime, pressure, applied power, feed gas composition, and others.

Proposals activities should lead to high degree of automation and quality control on lab scale of cost-effective manufacturing processes that can be easily translated to industrial scale.

The above mentioned materials and technologies should specifically target to the cardiovascular field, but could be further exploited in other areas.

In order to ensure industrial relevance and impact of the research efforts, active participation of industrial partners represents an added value to the proposals and this will be reflected in the evaluation.

Expected impact

- Definition of new advanced biomaterials/implants with specific and innovative nano/micro-scale properties.

- Development of a “predictable/controlled biodegradation scaffold” for application in cardiovascular field.
- Development of a “*living implant”* with the potential to grow and last during the whole lifetime and without the current drawbacks of grafts and prostheses.
- Exploitation of highly innovative technologies for new applications in biomedical field.
- Enabling Europe to compete at the forefront of the AM revolution.
- Increase in competitiveness of the biomaterials and biomedical industries in the EU.
- Promoting safe-by-design approaches in collaboration with the EU nano-safety cluster.
- Collaboration with the Authorities operating in Healthcare in the definition of the regulatory perspective for this new class of products.

TRL: 3-5
Type of action: Research and Innovation Actions

OTHER TOPICS: RAW MATERIALS

TOPIC 26

Title: *Innovative materials recycling approaches in a circular economy*

Specific challenge

Over the last decades, the number of chemical elements that is functionally used in components and packaging for electric & electronic equipment (EEE) and mobile phones & computer (IT) devices has increased dramatically. At the same time, these components are integrated in an ever growing amount of applications and consumer products, ranging from domotic systems and smartphones to cars. Globally, the marketed volumes of these products still are on the rise, especially in developing countries. At the same time, concerns about material efficiency and consumer satisfaction have been key drivers for the development of nanotechnologies and of more complex materials, like multi-layered composite materials.

In the circular economy, maintenance, repair, re-use and remanufacturing prevail over recycling. Nonetheless, recycling is and will continue to be an indispensable element of any sustainable materials management system. Unfortunately, for a very large number of often critical elements, recycling rates are below 1%, either because their recycling is not economical, or because no suitable technology exists. Recycling systems capable to process IT containing waste streams also have gained complexity. The waste is categorized, collected and registered through a wide variety of regional and national schemes. Then this waste is recycled and refined by making use of combinations of mechanical, thermal, hydrometallurgical and pyrometallurgical treatments, including electrowinning, bioleaching, etcetera. The subsequent processes require the participation of dedicated or complementary industries, geographically distributed over different countries and continents, that are at the basis of new, secondary material value chains with numerous stakeholders.

Main challenge will be to create the conditions needed for increasing the functional recovery from EEE and IT components and devices of those critical elements with recycling rates below 1%.

Scope

At present, a number of end-of-waste criteria apply, some of which were determined at EU level, others were developed by regional or national authorities. Harmonized standards lack on the characteristics and quality of subsequent output streams of the many recycling steps, often performed by different industries. The lack of standards hinders the generation and growth of confidence and trade between the different collection and recycling process stakeholders, as well as the use of recycled materials in products. Co-ordination and support action is needed to facilitate the development of such standards.

Innovative collection schemes and an appropriate categorization of EEE and IT waste should be proposed and developed in order to boost collection rates of particular applications with a high (critical) material value. Collection schemes and categorization should explicitly consider and facilitate the maximization of the economic, technical and environmental potential of existing and innovative recycling process chains, particularly when complex materials are targeted. New recycling targets should be discussed by public and private material value chain stakeholders, in accordance with specific policy priorities on critical materials, instead of targets being determined on a mass basis and referring to recycling system inputs only. Ambitious but realistic recycling targets have proven to be a potential driver for research & innovation, on the condition that material platforms are open for policy dialogues and mutual learning exercises.

In a circular economy, recycling (i) warrants the removal of unsafe substances from waste streams, without creating new ones, and (ii) maximizes the recovery of targeted materials while minimizing loss of their functionality. Thereto, environmental and economic costs of existing and newly proposed recycling routes for complex materials should be assessed, before setting goals and targets, taking into account the complete chain of subsequent processes (collection, sorting, disassembly, mechanical, thermal, bio-, hydro- and pyrometallurgical treatments), that are required to convert waste inputs to functionally recovered output materials. Even more than in linear model, transparency is essential to put into practice a circular economy. Therefore, a fruitful and effective collection and interpretation of data available from industrial activities and results of research, spread across different countries and continents, requires continued efforts to improve transparency on both the results and expectations, of companies, research organisations and policy makers.

Expected Impacts

- Harmonized standards on recycling output characteristics and qualities.
- Prioritization and categorization of EEE and IT (containing) waste streams.
- Collection schemes and recycling targets according to the economic, technical environmental possibilities of existing and proposed recycling process routes.
- Environmental and economic assessments over the complete chain of subsequent or combined processes (collection, sorting, disassembly, mechanical, thermal, bio-, hydro- and pyrometallurgical treatments) of recycling systems for complex and/or critical materials.

Type of project: Coordination and Support Action

TOPIC 27

Title: *Material Technologies for Waste to Product*

Specific Challenge

Within a materials constrained world where Europe is particularly raw materials dependent, closing material loops in a circular economy will be essential in the future manufacturing and processing industry value chains and our society as a whole.

In the circular economy, maintenance, repair, re-use and remanufacturing prevail over recycling. Nonetheless, recycling is and will continue to be an indispensable element of any sustainable materials management system.

Advanced material technologies play a vast yet largely unexplored role in closing material loops by recycling.

Scope

At present near-to-market research is on-going to develop innovative recycling flow sheets for high-tech End-of-Life (EoL) products like WEEE, rich in base and (critical) metals. As the price of such materials is steadily increasing, the business cases for these recycling flow sheets are gradually improving.

Another source of critical metals can be delivered by secondary resources that are not as rich in valuable materials but which are present in vast amounts, e.g. in metallurgical slags, bottom ashes, fly ashes, and industrial by-products such as bauxite residue, goethite, etc.. These freshly produced flows and stocks as well as landfilled industrial residues containing valuable materials in lower concentrations can provide vast amounts of material resources. Moreover, such waste streams may concurrently deliver a major stream of minerals from the residues after metal recovery that can be used for added-value construction and other technical materials.

In maximizing the use of recycled materials (cycle closure), advanced material technologies remain relatively unexplored in this field, while they provide vast potential to convert waste streams into material resources and industrial products, as demonstrated by the following examples:

- Powder processing currently used in powder metallurgy and ceramics can be used to convert fine waste streams in manageable and functionalized secondary raw materials;
- Surface technologies can specifically alter the properties of waste fine particles to increase the efficiency of the required pre-processing steps necessary to separate valuable materials from residues;
- Fluorescent lamp can be recycled in novel thermal processing cycling for recovering both mercury and rare earth elements. Complex multilayered materials can be recovered layer by layer;
- New electrochemical processing technology can boost the recovery of CRMs from low grade, complex industrial waste streams;
- Waste particles can be upcycled by surface functionalization tailored to the envisaged application; for example plasma surface treatment may activate the surface of waste polymer particles to produce performant composites with high recycled content;

- Advanced chemical activation of recycling residues: e.g. several mineral waste matrix materials can have pozzolanic activity upon activation, thereby constituting effective cement substitutes;
- Modern plasma fuming is capable to process a diversity of new and landfilled solid industrial residues, to recover valuable metals and valorise the residual slag matrix as building material;
- Accurate and high-throughput characterization techniques are able to precisely determine the critical element content of waste materials to gauge their economic exploitation feasibility;

Proposals should aim at valorising industrial residues (both solid and liquid/aqueous) by extracting valuable (critical and economically scarce) metals and valorising the residual matrix in the case of solid residues, exploiting the so called zero waste concept.

Expected impact

Maximize the use of recycled materials, and cycle closure: the use of materials to satisfy our needs can be minimized but never avoided. However, natural resources can be saved by minimizing the share of primary materials in the total requirement of materials that provide the functionalities required to fulfil our needs. The consequent strategies are:

- Increasing the supply of recycled materials with similar or superior functionalities as those that are obtained from primary resources, by recycling for loop closure and upcycling, urban mining, and design for recycling;
- Increasing the recycled content of materials and products.

Projects succeeding under this call shall, besides their strong environmental impact, be economically driven by mitigating costs related to industrial waste and targeting overall optimum value creation by valuable material recovery and residue valorisation (zero waste concept), representing key enablers for:

- Exploiting industrial waste streams by the recovery of technology metals and the conversion of residues into products and resources;
- Ensure the supply of recycled resources to the EU processing and manufacturing sectors;
- Attract and exploit international selected waste streams for added-value conversion;
- Export of technology for industrial waste recycling as well as the similar mining of primary low grade, complex ores (precluding technology drain by adequate IPR protection);
- Consequent increased and sustainable job creation in the European recycling sector.

TRL: 4-6

Type of action: Research and Innovation Action