MaterialsEuroRoads

Abridged

Workshop Report

Materials Innovations Empowering European Industries for Global Challenges

13th December 2017, 9.30 a.m. to 4.00 p.m.

Science14, Rue de la Science 14, 1040 Brussels

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Key Messages regarding the future of materials research in Europe

Research experiences from the past clearly verify that most innovations are based on the results of materials research and their uptake in new products and processes. We are sure that **collaborative materials research** in FP9 will have a tremendous **impact on the innovation capacity** of European players and will ensure the independence of European industry, acting as a key strategic enabler cross-cutting all industry sectors. In detail it was stated:

- Materials and nanotechnology often have longer innovation cycles than other fields. Therefore without a materials technology base, the hardware for new applications might be ready but cannot be used efficiently due to the fact that the innovative materials themselves are not ready to deploy;
- Modelling and characterisation aspects are very important for the acceleration of materials and nanotechnology research;
- There are clear trends towards unifying materials science and nanotechnologies at the electronic level. It is time for new technologies that combine both physical and digital technologies, taking risk assessment into account;
- Materials research, development and employment need to be seamlessly integrated in the digitised industrial value-add networks of the future;
- The whole value chain needs to be addressed, from raw materials to novel multi-materials by design;
- The translation of results from the Future and Emerging Technologies to the Key Enabling Technologies should be improved.

This type of research will enable industry and institutes to take care of global challenges and technological trends. Without this research, future missions and flagships will not be possible.

These key messages should be taken into account in FP9 and relevant activities in the fields of materials and nanoscience should be pursued.

Introduction

This workshop was an informal meeting of experts, strategists, decision makers and other major stakeholders in materials and nanotechnology research and business from more than ten European countries. The goal was to identify and discuss key research areas and advanced materials that are of strategic interest for a competitive European industry. The workshop was clustered into three parallel working groups according to the following relevant focus areas:

- **Materials for Clean Mobility**
- **Materials for Industry 4.0**
- **Materials for Extreme Environments**

And participants were invited to discuss the following questions in each of the groups:

- What are the **success stories** and **weaknesses** of European materials and nanotechnologies in innovation?
- Which **opportunities** for materials research have not been addressed sufficiently in Europe but might have a tremendous impact?
- What **happens** to the European economy if there is a **lack of further significant progress** in materials and nanotechnology innovation?
- Which **research areas** of materials and nanotechnology have to be **intensified** in order to be competitive in the future (with regard to disruptive technologies)?

Upon their request, participants had the opportunity to change between groups during the discussions.

Materials for Industry 4.0

Outcome of the discussion on "Materials for Industry 4.0"

This group initiated the discussion by focusing on the key weaknesses that still persist with regards to innovation activities in advanced materials. The participants expressed the view that risk mitigation at the "Valley of Death" continues to be a major challenge. They identified a lack of access to capital, inadequate knowledge of business processes and insufficient investment beyond the valley of death after TRL 6 as the major barriers for slow time-to-markets for most materials-related innovations. The majority view was that there is also a lack of understanding with regards to development timescales among industry and the investment community. Thus, most stakeholders fail to understand, for example, that the materials development timescale is generally much longer (10-15 years) in comparison to innovations in digital related products (3-5 years). A very good example on the discrepancy of timescale was cited in the area of 3D printing techniques for some advanced materials, where the hardware was already available ten years before suitable materials were available for testing and application.

Furthermore, the group expressed concern that there was a need to act quickly in order to fill in the gaps at the valley of death in order to both retain values that have been created in the EU over many years and to prevent losing innovation knowledge to other regions of the world. One example is the re-location of semiconductor manufacturing to South Asian countries in the late '90s and early 2000s. Another major potential threat that was discussed is data security. The group's view was that the EU should continue to develop systems and processes to ensure that sensitive information and data generated from current projects are protected.

A further important issue that was raised is the lack of mechanisms to create a link between FET-related developments and NMBP. Most members of the group felt that there were many ideas and technologies in FET that haven't been developed further for commercialisation because of this missing link and a lack of a clear development pipeline. The further development of FET within the scope of NMBP is a clear chance for Europe to increase industrial competitiveness. Concerning future opportunities the group highlighted a number of areas where the introduction of Industry 4.0 concepts to advanced materials innovation can play a significant role, e.g. in life cycle assessment or the development of modelling and simulation tools to optimise materials' production and to understand their degradation and ageing processes.

With regard to the EU's strengths, there was a high degree of consensus within the group that Europe is still very strong in possessing the key components required for the successful commercialisation of advanced materials. The group mentioned that EU has achieved a critical mass in terms of know-how, skills and expertise and the teams that can deliver the services required to build new capabilities and supply chains for future advanced materials-related products and services. In addition, the group agreed that the EU's strength lies in the collaborative research culture that has been built over the years and that it has a better understanding of the dynamics required to support such an innovation ecosystem compared to many regions of the world. However, it was mentioned that emphasis should also be placed on learning and implementing the best practices from current and past success stories such as from the renewable energy sector.

The group anticipated tremendous opportunities for biomaterials, bio-based sensors and bionic systems, self-organised and intelligent materials as well as quantum devices. Other key areas recommended for future programmes are applications for advanced materials in "Green Growth", customisation in advanced materials and the integration of safety and security concepts and techniques during the development of new materials. Creating new skills and technology-transfer expertise to meet the future requirements of the materials industry such as is pursued by test beds under the NMBP work programme is highly supported.

Overall, the group was optimistic about the future impact of the H2020 programme and expressed satisfaction that it focusses on the activities at higher TRLs.

Workshop results "Materials for Industry 4.0" at a glance

European materials and nanotechnologies **success stories**	European materials and nanotechnologies **weaknesses**
• Modelling / fast characterisation capability • Key components for successful commercialisation of advanced materials • H2020 not too low in TRL • Strong in delivery services • Renewables energy sector • On EU level: Best teams, collaborative research	• Long innovation cycles of materials research • Different innovation cycles digital (3-5 years) vs. material (10-15 years) • Materials are developed slower than hardware (10 years longer required), e.g. 3D printing • Valley of death: access to capital, time to market, introduction to economic processes,

culture, critical mass in terms of know-how, skills and expertise to cover EU value chains	after TRL 6 money dries up / state aid • Gap starts from TRL 3-4 • Many excellent results in FET are not further developed to reach higher TRL • Materials for digital services • Complexity • Missing regulatory targets
Crucial **opportunities** for materials research that have not been addressed sufficiently in Europe	Impact on Europe resulting from **the lack of further significant progress** in materials and nanotechnology innovation
• Integration of capabilities: integrate and link digital capabilities to physical infrastructure, e.g. connect modelling and characterisation expertise to pilot line facilities across the EU • Biological transformation (e.g. artificial photosynthesis, bio-based sensors, bionic systems) • Bioeconomy, integration of bio-principles • New business strategies • SME2SME interaction • Lifecycle assessment and tagging of materials for data collection while the product is in use • Example: Genomics, jobs creation, new profiles (“data/material scientist”) • Improved integration of capabilities • “Vision 2030”: data, production, product life-cycles • High-performance computing and training of personnel to analyse materials-related data generated at various stages of materials and product manufacturing	• Loss of materials for digital services • No incentive to integrate engineering / IT / science (multidisciplinary) • Lose potential to speed up material´s commercialisation (modelling, fast characterisation, scale up, …) • Loss of data security • “Brain drain”: Loss of technological innovation and know-how • Negative economic impact / competiveness • Multiplying effects in the economies for various sectors (batteries, photovoltaics, …) • Manufacturing and products’ costs increase • CO_2 and environmental targets not met • Increased societal challenges related to ageing populations and healthcare technologies • Companies failing to meet regulatory targets on time and thereby longer times-to-market

Research areas of materials and nanotechnology that have to be **intensified** to be competitive in the future (with regard to disruptive technologies)
• “Green Growth” • Customisation • Merging KETs / Biotech / integration of bio-principles • Adopting materials and digitise materials • Design / sustainable by design: biodegradable materials, fossil-free materials • Development of new modelling and simulation tools to understand materials performance once integrated in products and materials degradation during use, considering their overall life cycles • Extend materials modelling and simulation to processes • Create tools for “digital twins” • Materials databases and data format to be integrated in product lifecycle management software • Use data to create new materials • Materials especially for additive manufacturing • Smart materials (sensors, changing properties) / miniaturised and extremely sensitive sensors integrated into materials systems, embedded electronics (also for harsh environments)

- New material classes: self-organised and intelligent materials, swarm intelligence
- Quantum devices
- Meta-materials
- Integration of safety and security concepts
- Education / skills / collaboration structures
- Support for creating new skills and technology transfer (test beds)

Materials for Clean Mobility

Outcome of the discussion on "Materials for Clean Mobility"

Europe has amassed profound expertise in materials development for energy storage and in the field of alternative energy production. But also techniques such as additive manufacturing and the production of lightweight materials are strengths of European players in the field of materials for clean mobility. These strengths are based on a strong chemical industry with sustainable products and well established academic networks for research. The close connection between science and industry in many sectors is supporting active research for industrial applications.

Despite these successes improvements are needed in many aspects. In terms of materials there is still a strong dependence on non-sustainable and scarce raw materials. Regarding collaborative research and development there is an urgent need to match industrial roadmaps with academic research activities in order to overcome the valley of death. The uptake of research results by industry has to be fostered to achieve a more cost and time-efficient translation of research to competitive industrial innovation. It must also be ensured that technologies invented in Europe are not commercialised elsewhere such as what happened in case of energy storage.

One opportunity to increase the speed of materials development is the implementation of modelling including virtual design and virtual testing. Europe has great innovation potential in this sector that could be improved by a shared strategy based on a common roadmap for research and industrial development.

The group pointed out that the field of clean mobility is "too big to loose". It would have tremendous impact for the European economy in total to leave this field to competitors in Asia or the USA. If no steps are undertaken to strengthen its position, Europe will suffer from a loss of independence regarding the value chain and will have to rely on non-European suppliers. Furthermore, advantages in advanced materials fields such as the development of polymers or lightweight materials would quickly be obsolete. In all, this could very well prevent Europe from reaching sustainable development goals, especially that on climate action.

Although the group identified a variety of key areas to be addressed, there was great agreement that sustainability, recyclability and the achievement of a circular economy must be given the highest priority in the future. Therefore, the development of materials designed by considering reuse or recycling must be intensified. Processes to recycle hybrid and composite materials that offer great potential for clean mobility are of great interest. Since clean mobility is not only related to automotive there is a need to intensify the research and development of fuel cells (e.g. hydrogen), synthetic fuels and lightweight materials for other sectors such as aerospace.

Tools for modelling, multi-scale simulation, processing, life-cycle assessment and ageing might lead to greater efficiency and acceleration for product development. This can be based on standardised materials' databases and the exchange of data that offer a great potential. Prototyping is also critical to ensure cheaper and faster product development.

Workshop results "Materials for Clean Mobility" at a glance

European materials and nanotechnologies **success stories**	European materials and nanotechnologies **weaknesses**
• Materials for batteries (Li ion, Na ion, …) • Materials for fuel cells and electrolysers • Materials for power to fuels (catalysts, materials and assembly methods for reactors) • Lightweight composite materials • Additive manufacturing • Photovoltaic materials • Alternative energy production (wind and solar cells) • Long tradition in aerospace • Steel in body structures and electrical steels in E-mobility (motors, transformers) • Worldwide competitive car industry • Environmental friendly automotive • Lightweight solar powered electric scooter • Good understanding and development of materials (e.g. electrodes, electrocatalysts, characterisation) • Many institutes & universities and long tradition in chemical industry • Connection of science, industry, start-ups • Established academic networks for research • Chemical industry with sustainable products • High-level research and expertise • Research and innovation at different levels: academia, institutions, SME, large companies, OEMs • Industry pull: research for industrial applications • Most innovations are headed by EU citizens • Commitment of municipalities to urban mobility (smart cities)	• Dependence on raw materials • Energy storage invented in Europe but commercialised elsewhere • Weak network between science and industry in *some* fields (direct investment from industry to academia) • Innovation valley of death (exploitation of the academic developments by the industry, lacking interactions between industry and academia) • Insufficient environmentally friendly processes • Need for acceleration • Need to identify gaps for industrialisation • Pragmatism needed • Costs & Time: Materials science and implementation of new materials with industry is too expensive and too slow • Changing from established / traditional materials to innovative materials is difficult • Insufficient multidisciplinarity • Translation of research to industry & market • Industrial roadmaps and academic research do not match • EU roadmaps cover only 5 years which is too short with regard to the innovation cycle • Not risk taking • Legislation does not cover new things
Crucial **opportunities** for materials research that have not been addressed sufficiently in Europe	Impact on Europe resulting from **the lack of further significant progress** in materials and nanotechnology innovations
• Networking horizontal and not vertical • Modelling of materials (virtual design taking all scales into account, virtual testing)	• Too big to loose -> "If we lose we lose everything" • Loss of degree of freedom

• Shared strategies maximizing possible EU added value	• Loss of independence (value-chain integration, interruption of value chains) • No development of new fields • No lower CO_2 footprint -> no sustainable mobility • Dependence on non-sustainable materials • Losing advantages, e.g. in polymer / steel / lightweight materials

Research areas of materials and nanotechnology that have to be **intensified** to be competitive in the future (with regard to disruptive technologies)

- **Sustainability / Recyclability / Circular Economy** ("3 R's": Reduce, Re-use, Recycle)
    - Materials by design (virtual design)
    - Materials from "available resources" including recycled materials
    - Batteries based on sustainable elements (Zn, Na, Mg, Al, …) or organic cathodes
    - Replacement of critical raw materials
    - Low CO_2 footprint materials
    - Catalysts based on non-noble elements
    - Use of CO_2 for conversion into fuels / chemicals / materials / devices
    - Design for re-use / recycle and fully recyclable material streams
    - Hybrid and composite materials for lightweight construction / processes to manufacture and recycle these materials
- New materials solutions including processes, costs, high availability, recyclability
- Composability and functionality
- Battery not only for automotive -> fuel cells, light-weight, synthetic fuels, e.g. for aerospace
- Tools: modelling, multi-scale simulation, processing, life-cycle assessment, ageing
- Modelling degradation to accelerate adoption
- Materials databases and exchange of data, availability of standards
- Regulations: foster adoption
- Prototyping for products and product development
- Cheaper and improved processing technologies for batteries, turbines, fuel cells, …
- Scale up processes
- Next generation batteries and manufacturing processes (multivalent, metal-air, solid state, leap Li ion, high voltage Co lean cathodes)
- High performance lightweight materials
- New metal alloys (steel, Al, polymer) for lightweight, additive manufacturing, electrical manufacturing, fossil and renewable power, hydrogen economy
- Materials for automotive, aerospace
- Promote citizen acceptability for new materials
- Repair technologies of components
- Robust fuel cells (tolerant to dirty fuels)
- Smart materials to transfer data and information (e.g. traffic, pollution)
- Hydrogen technology (fuel cells and storage)
- 3D electronics for mobility / light and small power electronics
- Materials for 3D / 4D printing
- Flexible regulation / legislation

- High-strength steels
- Electroceramic materials
- Acceleration of products through process engineered materials for innovation
- Reliable low-cost materials
- Materials for long distance and heavy duty transport (hydrogen and power to fuels)

Materials for Extreme Environments

Outcome of the discussion on "Materials for Extreme Environments"

It was established that European researchers and citizens are very creative which leads to a good patent portfolio in the area of materials for extreme environments and a very good citation index for publications. Europe has very high competence in manufacturing technologies and is home to a strong production ecosystem. Europe's strong position in automotive, energy generation, chemical industries and aerospace is advantageous and the welfare of these sectors is strongly connected to innovations in materials for extreme environments. There is therefore a strong materials production in place for these materials. Europe has an excellent engineering infrastructure and a globally leading machinery industry, so that highly sophisticated materials can be produced. European materials researchers and industry are also organised in a close well-functioning network, which is an advantage for global competition.

However, there is a lack of long-term support from industry and business strategies are global rather than European. It is therefore not surprising that often follow-up projects from successful lower TRL projects are missing and the next steps are taken in other world regions. The speed for technology transfer has to be increased and the time from the first idea to the project realisation has to be shortened. It is difficult to pass successful innovation through the entire value chain. Also, there is a lack of raw materials in Europe and supply is critical. Several important materials for extreme environment-related sectors, e.g. the electronics sector and solar cell production are missing in Europe.

If European progress in materials innovation slumps, then Europe will have to import more materials for product development and the fabrication of high-tech products. This will be followed by a decrease of the production of European added-value products and ultimately lead to a de-industrialised Europe with increased unemployment. Highly skilled workers will leave Europe.

To face the societal challenges of the future and to reach the Sustainable Development Goals (SDG) of the United Nations as well as the CO_2 target of the Paris declaration on climate change, research in the area of materials for extreme light-weight applications, especially for the energy and transport sectors, is needed. To cut CO_2 emissions, materials for renewables are required which can tolerate extreme thermomechanical loads, for example materials for wind turbine rotors. To achieve a circular economy, which is another SDG goal, the usage of secondary materials has to be developed. Furthermore, research in materials such as membranes and filters for clean water and clean air has to be intensified. Materials solutions for air quality improvement and lower emissions have to face extreme conditions in combustion environments as well as in corrosive environments at high temperature. In the case of clean water, extreme bio-corrosion conditions must be managed. Therefore, solutions are needed in the fields of nanomaterials as well as multifunctional coatings and films to protect structural materials.

When considering materials in biological environments that have to face extreme conditions, a focus should also be on biomaterials for implants. These have to sustain extreme mechanical stress, resistance to wear and corrosion, be biocompatible and at the same time resist infections. Such materials must also have extreme high safety standards and be able to last for many decades without risk of failure. In the future, also flexible electronics will play an important role in the health sector.

Finally, for improving the safety and reduce costs of air traffic, self-healing and self-diagnostic materials are required to be developed. For the transport sector currently Li-ion batteries are being developed, which undergo high mechanical stress while being charged and discharged (so-called breathing of the cells) and improved materials are needed in order to reach vehicle autonomy targets. In the long-term, a hydrogen economy is expected and therefore many different materials developments have to be undertaken now if this technology is to be ready in about 20 years from today. Materials solutions are needed for the storage of hydrogen and for the fuel cells themselves. Virtual design and virtual testing offer great potential to deal with challenges among these different research fields.

Workshop results “Materials for Extreme Environments” at a glance

<table>
<tr><th>European materials and nanotechnologies
success stories</th><th>European materials and nanotechnologies
weaknesses</th></tr>
<tr><td colspan="2">Results were clustered: S=sectors, I=innovation/industry, F=framework, R=research, PA=public awareness</td></tr>
<tr><td>• Capability for testing and for building equipment (R)
• Engineering infrastructures of high quality (R)
• Efficient structures (R)
• Modelling and characterisation (R)
• Machine learning (R)
• European networks / projects (pre-competitive) (R)
• Characteristics (structure- property relation) (R)
• Machinery industry (I)
• Highly skilled work force (I)
• Materials manufacturing know-how on high temp. coatings (I)
• Strong production ecosystem (I)
• Strong materials production (I)
• Strong application industry (automotive, power generation, aerospace) (I)
• Reliable legal framework (F)
• Link between basic and applied materials (F)
• Publications (EU) (PA)
• Patents (EU) (PA)
• Creative community
• Free thinking (S)
• EU people have adventurous ideas (S)</td><td>• Silos / not open minded (I)
• Mining of excitement of technology (I)
• Transfer / translation of innovation through supply chain (I)
• Exploitation of innovations (I)
• Speed to-market too slow (I)
• Too long time from first idea to project (I)
• Lack of global benchmarks (I)
• Not adventurous for risk investments (I)
• Lack of long-term support from industry (I)
• Follow-up of projects is missing (I)
• Different expectations between industry and research (F)
• Different cultural backgrounds (F)
• Business strategy not sustainable (not focused on EU) (F)
• Conflicts of interest between EU member states (F)
• High cost of failure (F)
• Lack of entrepreneurship (F)
• Legal barriers (F)
• Not attractive for private financing (long-term research needed) (F)
• Funding and bank money do not mix (F)</td></tr>
</table>

	• Too much fragmentation • Lack of raw materials (F) • Lack of electronics industry (S) • No display builders (S) • Cheap production commodity (S) • Lack of solar cells builders due to lack of long-term commitment of incentives (S) • Insufficient use of modelling (R)
Crucial **opportunities** for materials research that have not been addressed sufficiently in Europe	Impact on Europe resulting from **the lack of further significant progress** in materials and nanotechnology innovations
• Materials for the hydrogen economy • Flexible electronics / 3D electronics • Usage of secondary materials • Multimaterials • Materials for energy harvesting • High value added coatings (+ multifunctional) • Composites (variable stiffness) • Nanomarkers and sensors • Smart materials: self-healing, self-sensing, conductive • Phase change materials • Materials for cost reduction • Materials for robotics, sensors, actuators • High strength, high performance, low weight materials for extreme environments	• Import all materials for societal solutions • Import products (from outside EU) • Lose manufacturing base • No security of supply • Unemployment • Loss of scientific excellence • Decreasing publications • Decreasing innovations • Lose sector activities: medical, automotive • No more high quality jobs • People leaving EU (special skills)

Research areas of materials and nanotechnology that have to be **intensified** to be competitive in the future (with regard to disruptive technologies)
Highly ranked research areas: • Extreme lightweight materials for transport (e.g. aerospace) • Materials for renewable energy • Secondary materials for transport (e.g. automotive, aeronautics) • Self-healing and self-diagnosing materials for aircraft and wind turbines with zero maintenance Further mentioned research areas: • Faster and cheaper development of materials for transport (e.g. air transport) • Multifunctional coatings for energy, transport and medical devices • Check TRL for picking up topics (not involve industry or consumers too early) • Materials for clean water (e.g. membranes, filters) • Materials for clean air (catalysis, filters) • Highly efficient thin film coatings for energy generation • Coatings for high-temperature applications (electrolysis) • Materials for the entire hydrogen chain (green creation, storage, transport, consumption) • Flexible electronics, papertronics and plastronics for mobility and health • 1-2 D (dimensional), and time dependent 4D materials for smart interfaces for health and ICT applications • Biomaterials and multimaterials for prostheses and implants • Artificial intelligence

• Materials modelling (processes and product performance)