

Federal Ministry of Education and Research

# Principles paper on support for materials research

It's time to act!



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# Materials research – a basis of industrial value creation

Progress in Germany as a country of innovation depends not least on excellent and high-performing materials. They are a prerequisite for many key technologies. New and enhanced materials provide the basis for Germany to address urgent challenges such as the delay in digital transformation, the climate crisis and the lack of sustainability in many business activities. The broad range of potential applications of materials research includes carbon fibres for lightweight construction, polymers for biocompatible medical products, catalysts for synthetic fuel production, battery materials for efficient mobile energy storage, semiconductor materials for electricity generation from solar power or for more powerful computers, ultra-high strength steel for high-performance applications or durable concrete.

Materials research involves not only diverse materials classes and applications but also various players: universities and non-university research institutions as well as federal and *Länder* institutes. Many of the approximately 1,000 publicly financed institutions conducting research in Germany are directly or indirectly involved in materials science. Furthermore, numerous manufacturing companies are also engaged in materials research including both large businesses and small and medium-sized enterprises (SMEs) across all fields of application.

New products, processes and services in many fields depend on progress in materials research which enables subsequent innovation. Due to its basic and generic nature, materials research is not only the driver of development in economically relevant fields of technology (such as artificial intelligence, quantum technologies or production technology) but also the key to technological sovereignty of the German research and industrial sectors. This sovereignty also depends on possibilities for replacing fossil fuels and critical resources, on improved materials and process efficiency in industrial materials cycles and on new approaches in recycling and the circular economy.

Consequently, materials are of great economic importance as they determine industrial success and the prosperity of all of us and form an indispensable part of the innovation process in Germany. This is also reflected by the fact that material costs account for roughly 46% of production costs in the manufacturing sector<sup>1</sup>. Overall, materials-based industries in Germany have an annual turnover of approximately one trillion euros and thereby secure about five million jobs.<sup>2,3</sup> In view of this societal and economic importance, the Federal Ministry of Education and Research (BMBF) has for decades provided continuous support for materials technologies in the most varied fields of application.

# Supporting societal change with materials research

Societies all over the world are currently undergoing fundamental change which massively impacts the way in which people live and do business today and in future. Climate change, geopolitical hazards and economic uncertainties, the ageing of the population and the rapidly progressing digital transformation are all having an increasing impact on our lives and habits as many people experience changes at the workplace and/or at home and in their private lives. The traditional structure of production and the economy as a whole is changing due to ever shorter innovation cycles. The digital transformation is an expression of such technological progress. In the face of global economic competition with Asia and the US, the forthcoming transformation of key industries and the required decarbonization of the economy, there is further extensive need for structural change to secure economic prosperity.

We are therefore about to take major strategic steps in order to ensure the viability and resilience of German industry. Progress in these important areas depends on societal aspects and on technological innovations in particular. Such innovations are not only the basis of today's prosperity but they are also required to maintain Germany's technological sovereignty. The major goal of a sustainable research and innovation funding policy is therefore to lastingly strengthen the

<sup>1</sup> rkw-kompetenzzentrum.de/innovations-blog/kostenstrukturim-verarbeitenden-gewerbe

<sup>2</sup> Deutsche Gesellschaft für Materialkunde e. V.: Werkstoffe mit Zukunft – Zukunft mit Werkstoffen (2015), available at: old.dgm. de/fileadmin/DGM/Upload-Datein/ Expertenbroschuere.pdf

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global competitiveness of German research and industry which secures or even increases such prosperity and people's quality of life.

While the thematic, structural and organizational diversity that is typical of Germany enables international success and top-quality research, the great number of players and their research activities leads to a certain degree of fragmentation in the national research landscape. Only few structural elements linking individual players already exist that can help increase the efficiency of allocated research budgets and accelerate innovations. Yet it is the speed of innovation which determines the international competitiveness of German research and industry. International surveys clearly reveal that Germany risks losing its previously established status as a leader in materials research to other, aspiring nations.<sup>4</sup>

This principles paper outlines the BMBF's position in the current "From Materials to Innovation" programme and marks the start of a **strategic reorientation of materials research. We want to use new instruments and give early consideration to current technology trends in our project funding to promote materials innovations** which act as drivers in various fields of application ranging from medicine to microelectronics to battery research. The BMBF's funding policy thus provides a clear signal to all the stakeholders involved in materials research with the firm aim of preventing a loss of know-how, international competitiveness and jobs in Germany.

In order to successfully pursue these aims in cooperation with industry and public research, the BMBF launched a stakeholder dialogue which started with expert talks in early 2021. These involved representatives from non-university research institutions, industrial associations and scientific and technical organizations in an effort to refocus and optimize project funding. The results of the expert talks have been incorporated in this principles paper.

### 1. Increasing agility to enable success in competition

It often takes up to 20 years for major materials developments and applications to supply solutions that are of relevance to society. In the face of dynamic markets and shorter product development and product life cycles, we will only be able to compete internationally with our knowledge and production if we respond to changes more quickly and flexibly. Current and emerging trends must therefore be quickly addressed in research, development and production, and innovative approaches such as digital materials research methods (see below) must be used to markedly shorten development cycles for new materials.

We want to build on broad basic research to ensure a high degree of flexibility and agility when designing subsequent steps in the value chain. Moving towards commercial application, we will focus materials research on specific industrial issues, taking account of the different time scales and technology readiness levels (TRLs) of scientific findings and industrial application.

We will enhance interdisciplinary and cross-sectoral cooperation of major stakeholders to achieve these aims. Furthermore, we will create general funding conditions that enable the emergence of new holistic formats of cooperation. These will include networking among different stakeholders and the establishment of links between different funding calls.

### 2. New instruments for knowledge and technology transfer between academia and industry: Working jointly to enhance value creation

Academia and industry must cooperate more closely in the context of technology transfer so that cooperation potential and synergy can be used for value creation. Germany has an excellent basic research sector but industry only makes limited use of the findings it generates. In coordination with other government departments, we intend to focus the funded research and development activities more strongly on specific topics with relevance for both society and industry; we will establish materials hubs to address these issues. By involving an industry

<sup>4</sup> Monitoring of the Asian-Pacific Research Area (APRA), second report (fraunhofer.de)

committee, we will guarantee the know-how transfer within a hub. Major input will be provided for new funding activities. Relevant materials research expertise also exists in participating organizations, which we also want to involve in specific ways. Industry and academia will be closely linked in our research funding so that inventions can be translated into innovations. In this way, we contribute to creating new incentives and models for industrial involvement and support spin-offs. By introducing the new materials platforms and materials hubs, we now have suitable instruments and schemes for funding.

### **Materials platforms**

Responding to market and sector-specific requirements, this instrument aims to help individual materials classes and related technologies reach higher technology readiness levels. Technologydriven materials developments are thus initiated prior to potential application and transferred to industrial practice. The materials platforms consider and address any scientific-technological, ecological or regulatory obstacles in this context which hamper potential commercialization. So far, two materials platforms have been set up for the two classes "Hybrid materials" (HyMat platform) and "Biomaterials". Further materials platforms will be established as soon as specific needs of materials research have been identified. We are engaged in a regular dialogue with the research community for this purpose.

#### Materials hubs

The materials hubs thematically integrate existing funding instruments in a multi-stakeholder approach to enable joint work on a major vision that addresses vital societal needs while pursuing ambitious technological goals. This approach creates synergy by combining available knowledge with further expertise from science, industry, politics and society. One such hub (BatterieMaterial) has already been successfully established which forms part of the Battery Production Research Factory umbrella project and covers the entire value chain from materials, including cell chemistry, to battery cells and their large-scale production (Battery Cell Production FFB) as well as recycling approaches and secures Germany's technological sovereignty in this field.<sup>5</sup> Materials hubs will be a focus of future materials research funding, particularly as regards resource efficiency/sustainability (MaterialNeutral, see below) or new technological trends like bio-inspired technology (MaterialVital: 3D tissue and organ bioprinting).

All the necessary strategic steps are pursued to ensure the success of a specific materials hub, including a conceptual phase followed by an R&D phase with prototype or methods development and subsequent technology transfer and commercialization. Depending on their thematic focus, materials hubs can be designed in a cross-cutting approach involving different divisions within the BMBF or even other government departments. Early consideration is not only given to technology but also to ethical, legal and social aspects (ELSA) as well as to materials safety.

# Support for outstanding talent in science and industry not limited to specific topics

Disruptive ideas emerge where researchers decide to leave well-trodden paths and try new out-of-the-box thinking. This requires funding instruments that provide optimum freedom for researchers and give even unusual ideas a chance. We use two instruments to fund such open-topic projects in materials research. These target two particularly innovative groups engaged in research, that is, SMEs and junior researchers. Germany is much envied for its SME sector throughout the world. A good 99% of all companies in Germany are small and medium-sized enterprises<sup>6</sup>; many of them are privately owned or family-run businesses that are global leaders and belong to the "hidden champions" in their field. We will continue to support them in future with the tried-and-tested instrument of "KMUinnovativ: Materials Research". The submitted projects may address the full range of materials research and relevant fields of application. Start-ups are highly welcome under this funding scheme. The same applies to our "NanoMatFutur" funding competition, which enables junior researchers to start a career in materials research with their own research group (see below).

<sup>5</sup> batterieforschung.de

<sup>6</sup> BVMW – Bundesverband mittelständische Wirtschaft: bvmw.de/ themen/mittelstand/zahlen-fakten

# 3. Digital technologies for more speed, resources conservation and sustainability in materials research

Materials research is increasingly benefitting from progress in digital transformation. Computer-based processes enable the virtual generation of optimized or new materials for diverse applications. In future, extensive multi-scale simulation of materials properties can be used instead of costly experimental development in the lab over many years. The mechanisms of materials failure will be analysed in detail, component safety will be increased and materials development markedly accelerated. A digital twin is created for each material to accompany it during its entire life cycle from production to its use in a component to recycling. Artificial intelligence technologies are involved in this process. This paradigm shift shortens development periods, optimizes energy and resources consumption and saves costs, thus helping to pave the way towards a circular economy. Furthermore, this provides for advantages over global competitors.

In order to secure the methodical expertise needed for digital transformation, the BMBF has established the "MaterialDigital" innovation platform which will be developed into an operational infrastructure.7 The platform helps address key issues regarding standardization, databases, workflows, materials ontologies and other sub-topics and coordinates the exchange of information and findings and networking between the stakeholders involved. The initiative links players from research and industry in Germany and cooperates with the European Materials Modelling Council (EMMC) in setting standards with an international effect. An internationally visible beacon of digital materials research is being established in Germany in close coordination with European bodies. Industrial needs are explicitly considered in this context.

The BMBF will further develop the activities of the "MaterialDigital" platform and announce focussed funding calls to speed up the transition from a traditional to an overall digital materials research approach. In this way, we will promote industrial application and encourage links between digital materials research and the "Industrie 4.0" concept. "MaterialDigital" provides research and industry with a decentralized infrastructure for the licensed exchange of materials data, for example to develop new business models. Over the next few years, we will thus achieve open digital standards for the use of materials data in research and industry to support Industrie 4.0. The "MaterialDigital" initiative takes us a major step forward on our way towards digital materials research and digital twins. This makes materials development quicker, more sustainable and resource-conserving.

### 4. Bio-inspired technology: Learning from nature

Technology benefits from nature already today. Major examples include the use of biogenic starting materials (biopolymers), the industrial application of biotechnological methods in the bioeconomy or technology which is directly modelled on biological materials structures (biomimetics) and has already been used to generate materials-based innovations.

We are breaking new ground with our "Bio-inspired technology" funding line: We want to use the knowledge about biological systems and processes generated in the life sciences and translate the underlying principles into technical applications. This will help us design new functional properties for technical materials and the systems based on them.

Nature can serve as a blueprint for potential technical applications in fields such as autonomous energy supply, programmability, adaptation, information processing and storage, and self-healing.

For example, self-organization processes offer great innovation potential for new, longer-lasting self-healing materials (e.g. self-healing concrete). Programmable materials enable completely new ways of using materials so that multi-material technical systems composed, for example, of sensors, control units, actuators and energy supply can be replaced by a single, locally configured system. The key to this is programmability of the materials' internal structure, something in which nature excels in a unique way. We want to encourage and support the use of biological knowledge and the translation of biological principles and processes into technical applications for materials research (bio-inspired materials) and industrial value creation in order to generate new material properties and more sustainable materials systems. We will therefore build on the success of the ideas competition for bio-inspired technology and launch further funding activities.

# 5. Making sustainability and resource sovereignty a long-term focus in the materials sector

There is a growing demand for sustainable, locally available, secure and environmentally friendly resources. Materials research can make a substantial contribution to meeting this demand. We therefore need progress in research for sustainable materials and for an efficient use of resources. This will also increase our independence from major global players. Where imports of metallic resources in particular are indispensable, we need to ensure their efficient use and recovery. Efficient reuse of the recovered components requires us to maintain resource quality. Our targeted materials design approach gives consideration to the use of recyclable materials and to possible recycling strategies. The sustainable use and the conservation of resources are major priorities of research. As technological processes often cause high energy demand and carbon emission levels, we need to establish alternative materials and processes. Aspects of materials safety, digitalization and standardization are essential in this context and must be taken into account.

Pursuing this approach towards climate protection through resources conservation, the BMBF is establishing a materials hub entitled "MaterialNeutral– Resource sovereignty through materials innovations". Our aim is to strengthen resource and materials efficiency in order to achieve greater benefit with fewer resources and reduce greenhouse gas emissions. In this way, we want to design innovative materials that are safe, available, environmentally friendly and sustainable. With the mission-oriented "MaterialNeutral" hub, we will contribute substantially to the Federal Government's climate action goals as well as to several of the United Nations' Sustainable Development Goals. The hub will focus on long-term visions and support for collaborative R&D projects along the value chain to ensure a high level of technological sovereignty. We want to help build greater methodical expertise in Germany and to make progress with the exploitation and scaling-up of results through to the transfer of technology into industrial application.

By funding materials-based innovations, we want to create vital prerequisites for the development of competitive products in major industries and key areas of society so that Germany can become a global pioneer in climate-friendly and sustainable materials innovations. The comprehensive networking activities are intended to promote cooperation and exchange between relevant stakeholders and to accelerate transfer into application.

# 6. Showing the way towards more efficient use of research infrastructures

We want to use targeted measures to strengthen the cooperation of non-university research institutions with universities and industry through the shared use of existing infrastructure (from lab to high-end equipment). Our aim is to create suitable conditions and greater transparency for the existing infrastructures such as large facilities funded by the DFG or infrastructures available at industrial institutions under the umbrella of the Helmholtz Association (Hereon).

In this way, we particularly want to facilitate shared use by SMEs, research institutions and makers.

## 7. Support for young research talent: Investing in bright minds

We provide support for qualified junior researchers from Germany and abroad under the NanoMatFutur and BattFutur funding programmes, enabling them to set up their own research teams at research institutions. Experience from previous funding has shown that junior research groups serve as catalysts for new interdisciplinary research at universities and non-university research institutions, thus contributing to excellence-building at these institutions. We have designed NanoMatFutur as a funding measure to build sustainable research structures. It provides excellent junior researchers with a unique opportunity to drive research projects with their ideas, stimulate new applications in industry and transcend the boundaries between traditional fields like chemistry, physics, biology, nanotechnology and process engineering with their interdisciplinary work. Their novel approaches towards innovative products, processes and services also contribute to securing and enhancing Germany's position in research and technology development. We will continue this successful career advancement measure which enables young researchers to work independently in science.

# 8. Building confidence by enhancing the safety of new materials

It will only be possible to exploit the innovation potential of materials research in a sustainable way if a safe and environmentally friendly use can be guaranteed. We are aware of the necessity of studying the impact of materials on humans and the environment. It is our aim to take advantage of the opportunities of materials research without ignoring the potential risks for humans and the environment.

All materials innovations and funding activities will therefore address safety aspects at an early stage. We know that safe materials development means taking the entire life cycle of materials and the products containing them into account. This covers the manufacturing, processing, application, disposal and recycling of products. The aim is to fully exploit the application potential of new materials for the benefit of industry and society without causing damage to humans and the environment.

### 9. Continuing the dialogue with society

We consider the involvement of the public as important as the provision of information by researchers about their work and findings (science communication). Our support for materials research already offers different forms of participation that are constantly being developed further. We provide information about current funding activities and interesting research results on our website werkstofftechnologien.de. Our "Zukunftstalk Materialforschung" enables the general public to engage in a moderated debate with selected experts about the opportunities and challenges of new materials developments. Our online platform "DaNa" (nanopartikel.info) provides citizens and experts with more or less detailed information about nanomaterials and other innovative materials. We will continue to use established and new discussion formats to enable, for example, school students on lab placements or interested citizens to contribute their creative ideas in the context of new materials. At the same time, we will continue to promote future events that provide both the scientific community and the general public with insights into current research funding.

### 10. Strengthening methodical expertise – Overcoming fragmentation

We will continue the stakeholder dialogue launched during the preparation of this principles paper and keep a firm eye on the views and needs of industry and research when designing our future funding policy. We are working to create stronger links between project funding and institutional funding in materials research by improving strategy coordination with the major research organizations. This will enable the synergistic use of institutional funding and project funds. Furthermore, we are intensifying exchange of experience and the search for connections with materials research activities of other government departments in order to achieve synergy and join up public funding for research and innovation in a seamless way. As a next step, a national roadmap process involving all stakeholders and led by the BMBF is needed in order to ensure the international competitiveness and technological sovereignty of German materials research. As a high-tech country, Germany needs to be integrated into global knowledge flows and value chains. Successful international networking is a direct competitive advantage. This is why we want to promote the further integration of national materials research activities into the European Research Area and to work with our European partners on research topics with European added value.

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