www.dkv.global
info@dkv.global

Advanced Materials Overview

Report

The 5th Industrial Revolution

DEEP
KNOWLEDGE
GROUP

Table of Contents

Deep Knowledge Group and its analytical associates, have constructed intricate analytical frameworks competent enough to analyze, define and foretell DeepTech industries of exceptional breadth, depth, and sophistication which have in 2021 been transformed into an incorporated whole: a manner of Mega-Analytical Framework worthy of characterizing the 5th Industrial Revolution for the first time, and of predicting the most practical means of advancing, optimizing, and coordinating the trajectory of its constant advancement and the careful, de-risked and socially responsible delivery of its advantages for global humanity. The Fifth Industrial Revolution is poised at the cusp of a future in which things considered unimaginable today become the norm helping ease the sting of automation.

The driving forces of the 5th Industrial revolution will bring substantial changes across various industries with advanced materials being among them. This report delivers the comprehensive overview of the development of the advanced materials, covers the innovative material architecture and frameworks, investment landscape, and gives the in-depth view on the future holding for this ever-evolving industry.

The 5th Industrial Revolution Outlook

	1st Industrial Revolution	2nd Industrial Revolution	3rd Industrial Revolution	4th Industrial Revolution	5th Industrial Revolution
Major Driver	Mechanisation	Electrification	Automation	Digitalisation	Humanism, Creativity and Personalisation
Timeframe	Between 18th and 19th century	Late 19th century	Around 1980s	Start of 21st century	2nd decade of 21st century
Tools	Beginning of mechanical production facilities powered by steam and water	Labour and production enabled by electricity	Production automation using IT systems	IoT, VR, AI, Big Data Science	Cyber physical system networks, multi-level cooperation between humans and machines

The Industrial Revolution has passed a long way from the 18th century when the production started to be mechanised up to the 2020s with machine learning algorithms that tends to replace human intelligence. As technology developments gather pace the workflows become ready for next generation progress boost - **the Fifth Industrial Revolution (5IR)**.

The 4th Industrial Revolution is the state of humankind's development we live in these days. Singularity is the state which is about to happen in 2045. It is quite apparent that between the state of the 4th industrial revolution and 2045, naturally there will be some kind of stage in between, which may be defined as the 5th Industrial Revolution if the proper actions are performed.

The 5th Industrial Revolution (5IR) can be summarized as the combination of humans and machines in the workplace. Nevertheless, this is vastly oversimplified and does not even begin to explain the magnitude and complexity of the change. The Fifth Industrial Revolution will actually place more weight on the importance of human intelligence than ever before and how these unique human traits, when harnessed in tandem with the accuracy of AI lead to greater outcomes.

Introduction to the Advanced Materials

Advanced Materials refer to materials, including processes of their manufacturing, that yield significant advances in operational capability and/or cost-efficiency of equipment.

These advances include enhanced physical characteristics e. g. weight, strength and resilience, observability, and other attributes. The term ‘advanced materials’ covers materials with properties and functionalities that differ from ‘conventional’ materials.

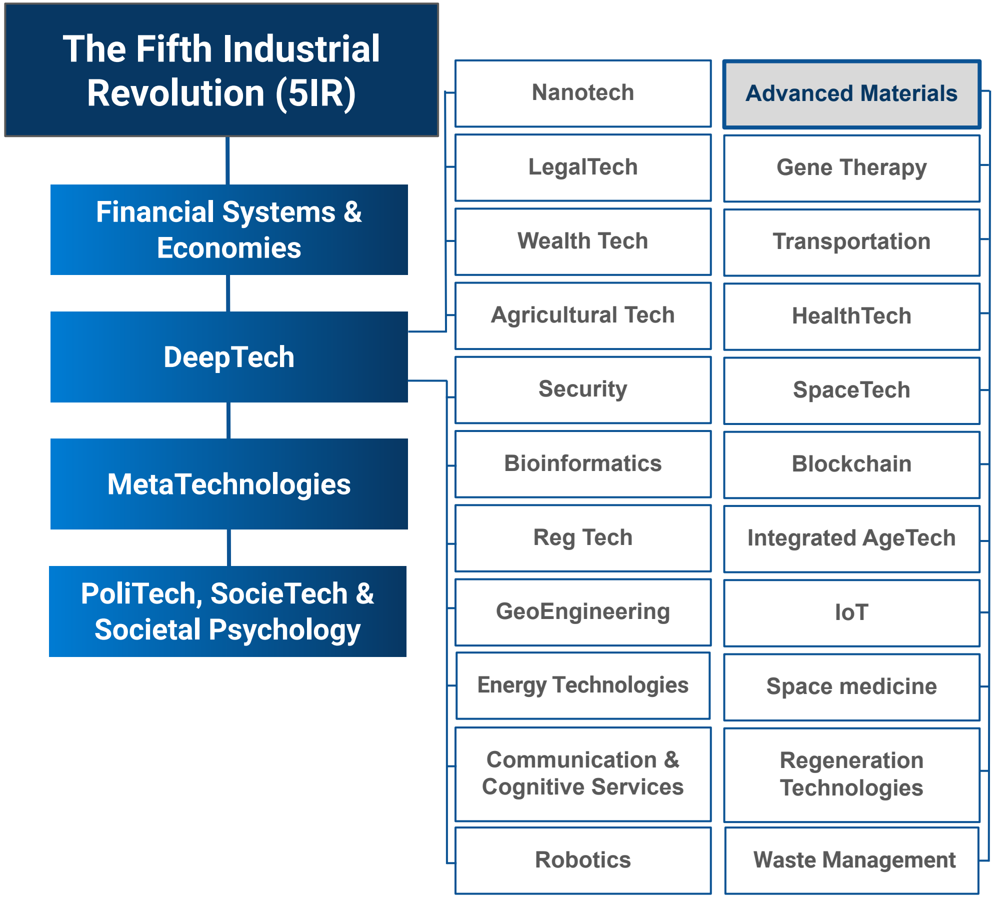
Advanced materials are used in a large number of applications and products and frequently fulfil high performance requirements. Some unite totally new functions or different functionalities within one material. Others may enable the production of qualitatively new products or processes. The development of advanced materials aims at, among others, saving critical resources, increasing the performance of components and devices, reducing adverse environmental impacts of products and processes etc.

Advanced Manufacturing includes both new ways to make existing products and new products emerging from advanced technologies. Advanced manufacturing employs the use of cutting-edge materials and emerging capabilities enabled by the variety of sciences. It includes improvement in processes such as mass production efficiency, customization, and quality controls.

Key goals set for advanced materials

Meeting unmet customer needs	Improving product performance and capability	Unlocking revenue potential and market share
Satisfying sustainability and regulatory requirements	Utilizing the research understanding of materials’ compounds	Achieving greater profitability goals
Increasing the efficiency of production processes	Enhancing products designs	Achieving greater customization

Advanced Materials within the 5th Industrial Revolution Framework



The 5th Industrial Revolution (5IR) can be divided into four major components: **MetaTechnologies, DeepTech, PoliTech and SocieTech, and Financial Systems and Economies**, each having its subsets of parts.

Advanced Materials are set within the DeepTech sector since it comprises industries with an objective of providing technology solutions based on substantial scientific or engineering challenges. The industries utilizing DeepTech have profound enabling power, they are able to create great differentiation and catalyze changes.

Advanced Materials Industry challenges the existing state of affairs because there is a greater demand for achieving high performance properties. Advanced Materials Science along with other DeepTech fields like AI, blockchain, biotechnology, robotics, photonics and quantum computing are moving more and more quickly from early research to market applications. In a sense they accelerate the 5th Industrial Revolution, where new platform technologies and infrastructures make an enormous change to the ways we live and work.

Introduction to Advanced Materials: Categories and Key Applications

By Product Type

Lightweight Materials	Polymers
Bio-Based Materials	Woven Materials
Ceramics	Conductive Materials
Colloids	Organic Materials
Nanomaterials	Insulation Materials
Smart Materials	Packaging Materials
Catalysts	Biomedical Materials
Fibers	Graphene
Plastics	Polymer composites
Resins	Optical Materials
Composites	Multifunctional Materials

The area of advanced materials research is extremely broad in its scope and has numerous potential applications. While some advanced materials are already well documented and have commercial application, it will take a more years for others to appear in products on the market.

The scope of product types and range of applications is not limited to those represented in the framework. Materials technology is a constantly evolving discipline, and new materials with interesting properties lead to new applications. For example, the combination of different materials into composites gives rise to entirely new material properties.

Advanced materials enhance the performance of entire industries and, subsequently, allow to develop a more compact designs, with improved efficiency, and greater overall durability.

By End-User

Energy Storage & Generation	Building & Construction
Telecom	Aerospace
Metallurgy	Marine Industry
Furniture	Automotive Industry
Papermaking	Defense
Textile Industry	Electronics
Bioengineering	Oil & Gas Industry
Waste Management	Healthcare
Logistics	Paints & Coatings
Security Systems	Transportation
Medical devices	Robotics

Introduction to Advanced Materials: Framework

Global Challenges
What major mega trends are shaping the world?

End-market Trends
What are specific trends impacting end markets?

End-market need
What are key end markets doing to address the need?

Functional solution is designed to address specific end-market needs

Materials
Develop inventive combinations of materials leveraging existing product portfolios to obtain desired physical properties

Process technologies
Apply physical advanced manufacturing techniques as well as digital technologies to accelerate development speed and impact potential

Business models
Maximize value capture by employing collaborative business models (e. g. Intellectual property protection frameworks, private-public partnerships)

Stakeholders
Involve the right mix of players via a diverse collection of stakeholders from industry, civil society, government and academia

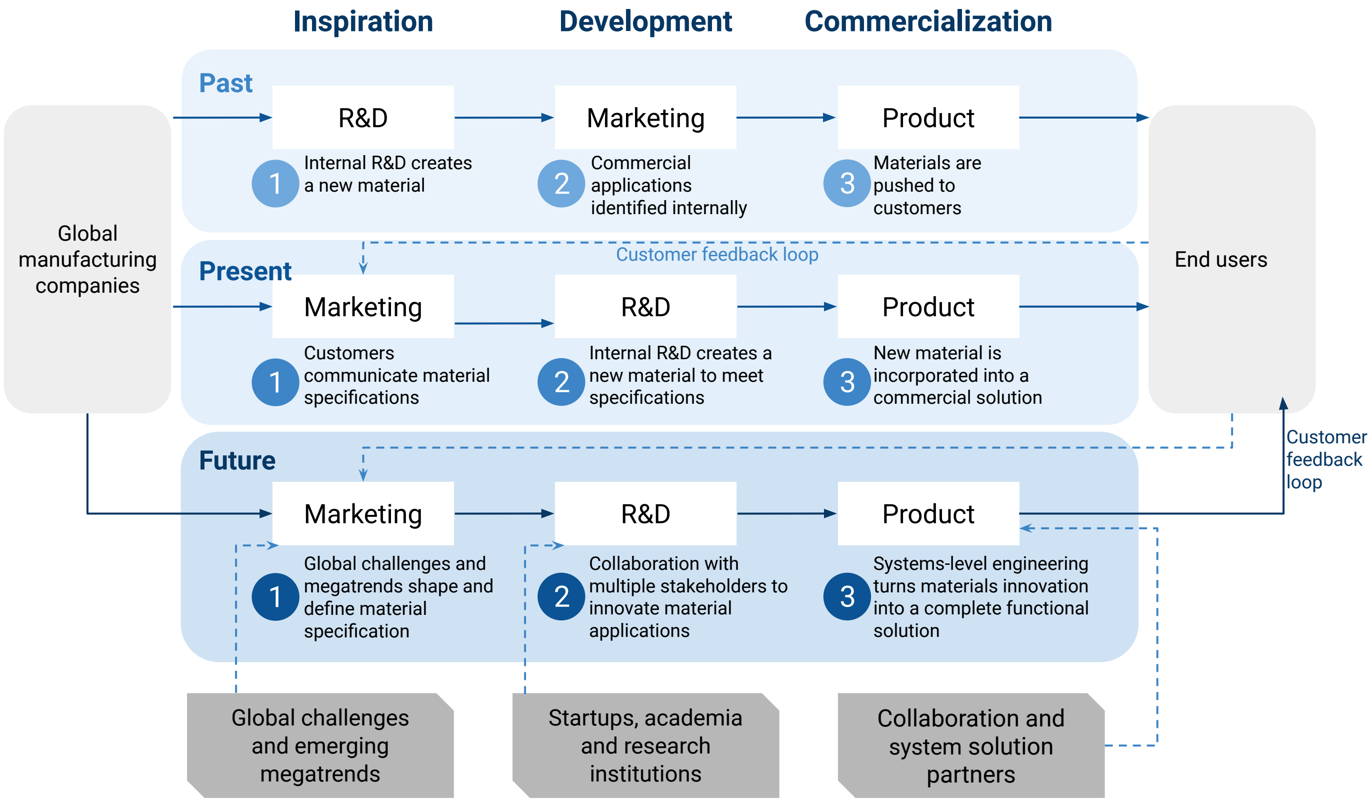
Functional Solution
Decisions related to materials, process technologies, business models and stakeholder engagement are made in parallel to develop a market-growth functional solution.

Business Outcomes
- Decreased development costs
- Improved performance
- Less raw materials use
- Shorter research and development cycles
- Mitigated commercialization risk

Introduction to Advanced Materials: Conventional vs. Advanced Materials

	Conventional Materials	Advanced Materials
R&D Approach	Iterative cycle of experimentally producing and testing variations of a material until the desired properties for the specific use are achieved.	• Data-driven approach to materials, enhanced by principles of informatics; • High-throughput experimental testing of material properties, periodic verification of properties against the commercial needs; • Deriving scientific insights from complex materials data.
Properties	Hold the properties meeting the common industrial needs.	Superior properties, outperforming conventional materials, including greater toughness, hardness, durability and elasticity. There could be novel properties, including the ability to memorise shape or sense changes in their environment and respond to these changes.
Timelines	10-20 years or more for a new material to advance from initial discovery of the material, through its development, to initial commercialization.	Use of materials informatics allows to accelerate the timelines for R&D, saving resources on previously time-consuming and labor-intensive practices.
R&D Tools	Utilizing the existing theory and knowledge experience to find the materials that meet the needs through characterization test by adjusting material ratio.	Big Data analytical tools, computational techniques, ML and AI.
Customization	Low level of customization.	Customers benefit from improved performance, as the functional solution will by definition meet their requirements.
Multidisciplinary Engagement	The scope of application predominantly doesn’t involve interindustrial experts and organizations.	Advanced materials require close cooperation between research scientists, designers and production engineers.

The Evolution of Materials Research, Development and Innovation



Declining viability from traditional materials R&D has led to increased interest to advanced materials application. Moreover, the industry's present innovation model has evolved to include greater customer feedback.

Customers often dictate specifications for materials, which are then developed and produced. Currently, end users choose materials based on their ability to perform in sustainable systems. As a result, the more promising and disruptive opportunities are enabled by materials optimized for a total solution.

Factors Driving the Demand for Advanced Materials: Technological Drivers

As a rule, the timeline for getting a new material into an industrial setting or product does have a long time horizon for many different reasons. The advanced materials manufacturing stands for trail-and-error method, therefore, new technologies serve as a primary vehicles for making and scaling up a new material and its integration into commercial use.

The table below summarizes several case studies of advanced materials research areas along with quantitative estimates of benefits. While the potential economic benefits of materials innovation can vary widely and are highly case specific, there is **a trend of compressing the timelines for advanced materials manufacturing.**

Category	Description of Example Technology	Benefits
Coatings and Surface Treatments	A novel catalytic coating is being developed for ethylene crackers, which greatly reduces coke formation in furnace coils. Less coke formation contributes to longer run times and lower decoking frequency, leading to savings in energy use and corresponding air pollutant emissions.	15-25% energy reduction (fuel savings) might be achieved in the ethylene cracking process. Energy savings for the petrochemicals sector as a whole would range from 4%-6%.
Separation Membranes	A novel ceramic membrane technology has been developed to replace rubber-based polymer membranes for separating volatile organic compounds from air at fueling stations.	Prevents fuel vapor escape from a gasoline storage tank, thereby potentially saving 180 million gallons of gasoline per year domestically
Net-shape processing	An improved lost foam casting process has been engineered by General Motors which more accurately measures the size and shape of sand used in casting and better characterizes rheological properties to reduce casting defects	Significantly reduces aluminum and sand scrap rates during production of the complex General Motors L61 engine. Increases labor productivity and reduces materials costs compared to conventional sand casting.
Energy/ feedstock conversion technologies for industry	New process technologies have been developed to yield semicrystalline polylactide particles derived from biomass feedstocks that have improved physical properties, thereby offering a viable replacement to fossil-fuel-derived polymers.	Consumes up to 68% less energy in the form of fossil resources compared with producing products from petroleum. Competes in a market based on price and performance, with a better environmental profile than today's plastics.

Factors Driving the Demand for Advanced Materials: Economic Drivers

Advanced Materials is a promising technology transforming the global manufacturing industry, especially in its replacement of plastics and metals with ceramics and composites in high-performance applications. Growing public interest towards products replacements will further enhance the overall market demand for advanced materials during the forecast period.

We highlight **four economic market drivers** that move industry of Advanced Materials forward:

Growing demand for battery electric vehicles

The shift towards electric vehicles in the developed and developing nations would increase the growth of existing IC engine vehicles and also increase the advanced materials market over the forecast timeframe. According to IEA, Norway, the Netherlands and Japan are frontrunners in the electronic vehicles segment.

Evolving aviation & aerospace sectors

These industries are to see the subsequent introduction of new materials to replace the existing ones. Composite parts of aircrafts are defined by their material, processing, manufacturing specifications, and material allowed by engineering. The amount of carbon fiber reinforced polymer (CFRP) used in their structure is only slightly less than the number of metals.

Rising demand for infrastructure development

The rising need for infrastructure development adds a positive outlook on the future market growth. However, the advanced materials market will deal with decreasing production costs and the manufacturing complexities.

Need for enhanced value chains

Advanced materials are promising for improved production processes. It’s likely that the market will witness the emergence of collaborative platforms for generating intangible value, including the creation and dissemination of knowledge. They are aimed to eliminate a lack of honest communication between materials providers and customers thereby addressing a clear need and meet a market demand.

Introduction to Advanced Materials: Advantages

Advanced Materials are revolutionizing the way companies do business and demanding that R&D and engineering teams keep up. At any given time, a company or its competitors may launch a new material or application that unlocks revenue potential and market share, meets unmet customer needs, achieves profitability goals or satisfies sustainability and regulatory requirements.

Differentiation can be achieved from the molecular level and up— as new materials utilize the research community's understanding of chemical compound structures and other properties, and can be used to improve product performance, capability and efficiency of production processes.

We define 3 key advantages that advanced material leverage for business and end-users:

Advantages of Advanced Materials

1 Reduced costs and increased profitability

Advanced materials are stronger, lighter and more durable will last longer and save money on replacing parts or can compensate for operational and manufacturing challenges unsolved by relatively less functional materials.

2 Increased customer satisfaction and loyalty

Because of their inherently improved properties, advanced materials can lead to final products that better fulfill customer requirements and contain fewer defects, which will translate into increased competitiveness.

3 Regulatory compliance and sustainability

Newer and more stringent regulations are making manufacturing and production more and more arduous. Using advanced materials should help companies comply with regulations without sacrificing performance objectives.

Factors Driving the Demand for Advanced Materials: Environmental Drivers

Preference for sustainable products

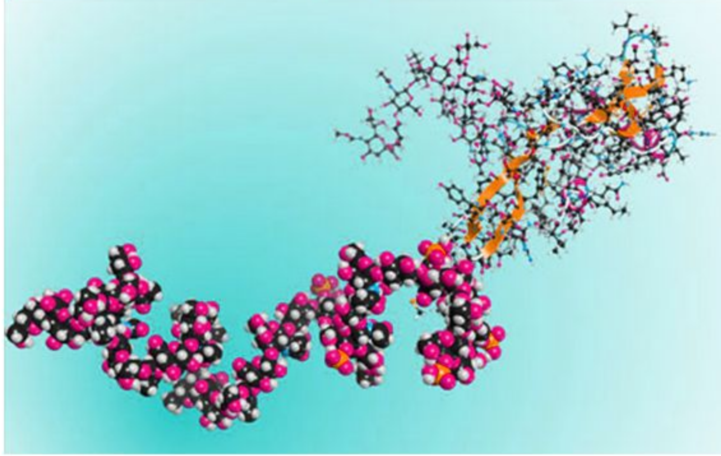
Products that had a sustainability claim on-pack accounted for 18.6% of the market in 2020, and delivered nearly $114 billion in sales. Most important, products marketed as sustainable grew 5.6 times faster than those that were not. In more than 90% of the CPG categories, sustainability-marketed products grew faster than their conventional counterparts. All these factors reconfirm increased demand for sustainable products from consumers' side.

Emergence of enhanced "green advanced" with the same performance

Besides being better in terms of environmental impact greener materials often perform just as well as their cheaper, but more problematic alternatives. If quality is equal, ever increasing number of companies set sights towards advanced materials.

Accelerating the Circular Economy

The development of the advanced materials must manage the scarcity of resources and be part of a circular economy value chain which will contribute markets' competitiveness in a context of increased sustainability standards.



Source: [Byju's.Biopolymers - Definition, Types, Examples & Applications of Biopolymers]

Biopolymers for sustainable development

Recently, polymer science and engineering research has shifted toward the development of environmentally benign polymers to reduce the impact of plastic leakage on the ecosystems. Being sustainable, carbon neutral, and always renewable, biopolymers from plant materials and microbes would create a sustainable industry.

Factors Driving the Demand for Advanced Materials: Political & Societal Drivers

Increasing participatory processes

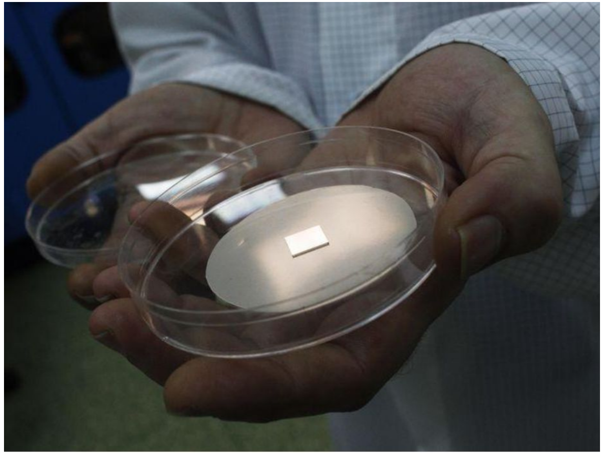
Overall, societal needs and concerns known from the discussions on chemical safety and nanomaterials should guide companies and academia in product development. It would therefore be important that societal perspectives and aims of innovations are stated specifically and transparently and are discussed, e.g. in participatory processes (open innovation).

Governmental de-risking and accelerating the innovation

History shows that it takes about 10 – 15 years of R&I activities before the required advanced materials are developed and are ready for market uptake. Long capital-intensive development times in combination with substantial technology and commercialization risks are key factors that make it difficult for new materials to make the journey from the lab to industrial-scale production and the markets. Thus, it is vital that governments focus public funding on advanced materials, that will facilitate and accelerate the transition to a low carbon future.

New regulatory requirements

The governments imply requirements for defined materials in terms of safety assessment and the identification of potential risk management measures.



Senior technologist Dariusz Czolak holds a piece of silicon carbide disk covered with a layer of graphene, Warsaw, 2012.

Source: World Economic Forum: How will graphene change the world?

Discovery of graphene was billed as potentially the most important discovery of this century. In similar way the humanity may witness the emergence of new revolutionary materials in future making them more suitable to commercial needs.

Methodology of Multiparametric Assessment

This report incorporates the multiparametric assessment of selected advanced materials for each category. It's aimed to identify promising materials along with materials which R&D and commercialization may face certain obstacles in future. The aggregated score consists out of ten parameters mentioned in table below.

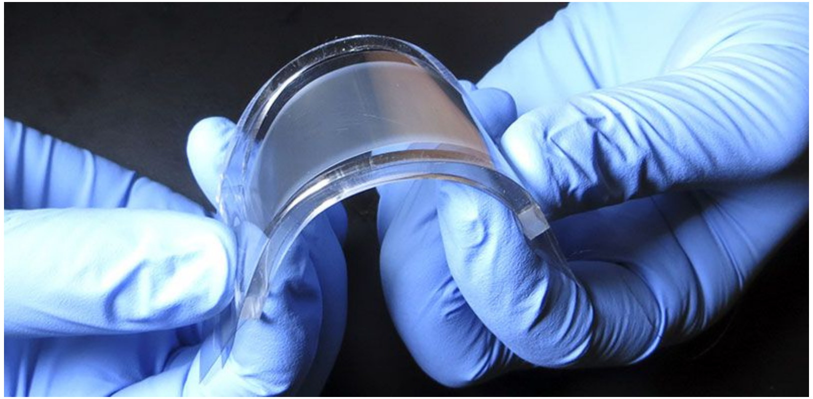
Parameter	Description
Technology Readiness Level (TRL)	Parameter for understanding the technological maturity of a given material. It helps to have a consistent datum of reference for understanding material's evolution.
Investment Readiness Level (IRL)	Aims at taking proper investment decisions.
Market Volume Aggregated Mark	Helps to evaluate the size of a particular sector in which technologies will evolve.
Compound annual growth rate (CAGR)	Provides a constant rate of return over the time period. CAGR values are taken for specific sub industry in which each material is developed.
Market Entry Complexity	Parameter that evaluates the barriers for further development of any given material.
Commercialization Ease	Helps to evaluate obstacles that can occur while bringing a technology for commercial use and its possible implementation to other products available on the market.
Ecological Safety	Valuates the environmental impact of either material's manufacturing or its further application.
Dependency on Industry's Development	Helps to understand to which extent R&D of any given material depends on the development of the overall industry. This parameter also involves side-by-side technologies that are required for manufacturing of a particular material.
Industry's Readiness	Describes the stage of developments in an industry and helps to understand if there is the necessity for the evolution of the material at the current stage of industry.
Level of Governmental and Legislative Interference	Represents the barriers arising from state governance of material's commersalization.

Investment Landscape of Advanced Materials

The 5th Industrial Revolution

DEEP KNOWLEDGE GROUP

Investment Landscape: Market Feasibility for New Investments



Source: UCLA Samueli.Engineer Change. Advanced Materials

Phoenix Venture Partners, a leading venture capital group focused on advanced materials, describes this sector:

“Advanced materials is unlike other traditional venture capital sectors, which are dedicated to fully integrated end product manufacturing, distribution, and marketing in addition to technology development.

Advanced materials are enabling and tend to have diverse applications across multiple industries: enabling new products, enhanced performance of existing products, and superior manufacturing process improvements.”

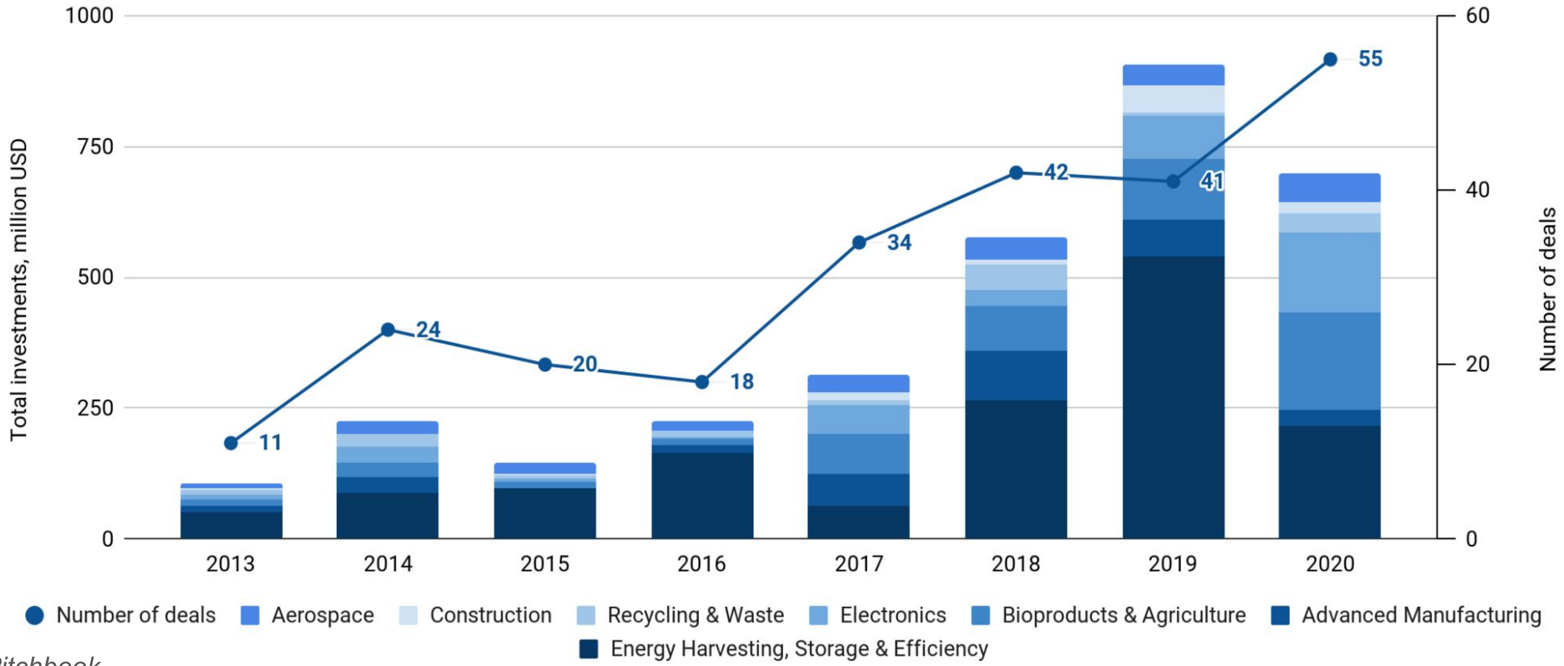
On a global scale, substantial evidence in recent years shows that both public and private organizations are willing to invest in advanced materials industry and are dedicating resources to research and develop new materials that produce and commercialize better finished products.

Companies in this sector are not only creating more durable and efficient derivatives of existing materials and designing novel materials from the ground up, but are also developing new materials discovery platforms and manufacturing processes. These materials and processes enable some of the most promising growth sectors – including water, agriculture, oil & gas, solar, aerospace, and others – while avoiding controversial connotations with cleantech and some of the risky projects undertaken by these industries.

If Advanced Materials can continue to meet converging technological and financial demands, this sector can become a major financial opportunity for entrepreneurs and investors alike. Jordi Lopez Launes, Investment Manager for Solvay and Aster, thinks that “Advanced Materials is the driver of most of the cleantech sectors, pervading the majority of challenges that cleantech wants to address.”

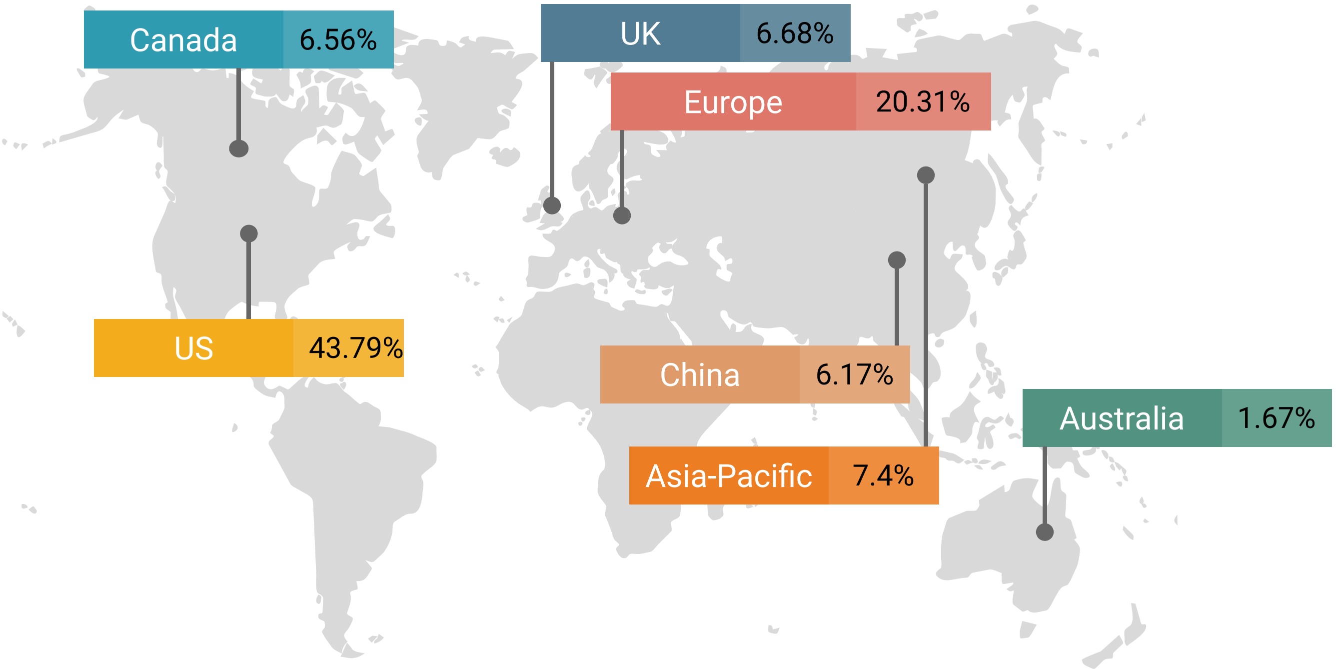
Activity in the sector has been growing fast, more than doubling from 2017 to 2018 in terms of invested sums. The amount of funds invested declined from 2019 to 2020, but even so, over **$700M** went into companies focused on materials innovation last year. Investors spread their bets across multiple companies: the number of deals increased by 34%.

Investment Activity in Advanced Materials over years



Source: Pitchbook

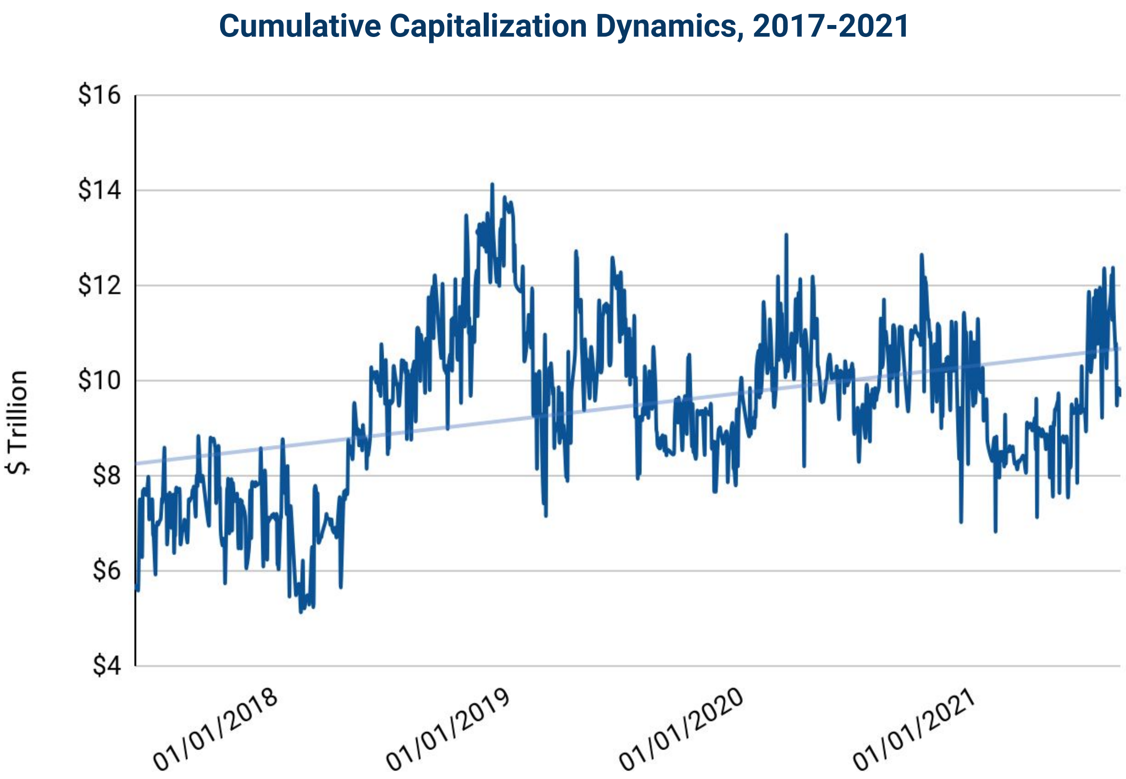
Regional Proportion



Source: DKG calculations

The US is still firmly in the lead in terms of the number of advanced materials manufacturing companies, and the EU is the second biggest market in the world. However, China and Asia-Pacific region overall increased the market share to 13.57% (represented by 183 companies of different sizes and funding structures) and keeps growing today. We expect steady growth of the Asia companies with increasing the number of public offerings among them.

Advanced Materials Publicly Traded Companies



Source: DKG Analytics

The 73 publicly traded Advanced Materials companies experienced growth **from $6T to $10T** of cumulative capitalisation, representing **19.89% of 3-year CAGR**

In 2021, **5 companies** announced the closing of their IPOs: **Origin Materials Inc, Codex DNA Inc, Hyunjin Materials company, Ltd, Atomera Inc and Meta Materials Inc** by resulting in capitalization.

The largest Advanced Materials companies are **Yongxing Special Materials Tech Co Ltd, DuPont, China Northern Rare Earth Gp H-T Co Ltd, Applied Materials, Inc and JA Solar Technology Co Ltd**

Technologically, publicly-traded Advanced Materials-focused companies are similar to other companies in the sector (i.e., those that reached B or C funding rounds), which means that their market capitalization growth can approximate the dynamics of the whole industry.

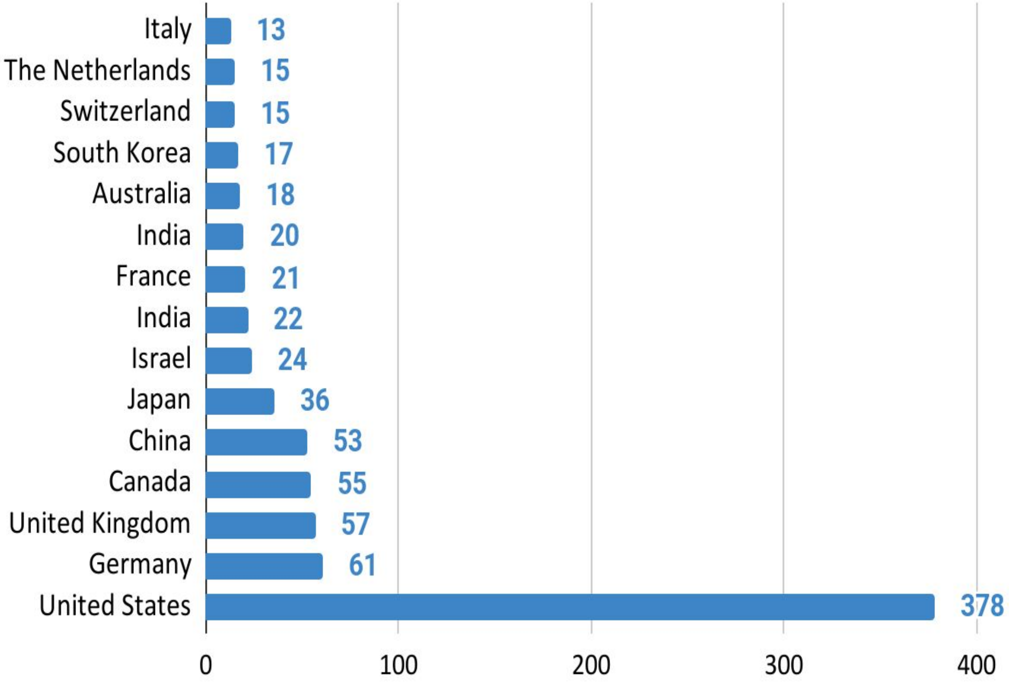
Top 15 Countries in the Advanced Materials Sector

The chart on the right represents the top 15 countries with the largest investment in the Advanced Materials Sector (as of 2021). The undisputed leader here is the United States accounting for 378 companies. It is followed by Germany, the second largest country for the advanced materials industry, which has a total of **$17.4B** invested in 113 companies. China's closest competitor is the United Kingdom where funds are mostly raised from public sources and IPOs, and not from private investors.

The US spends about 3 percent of its $21T economy on innovation and research, while China spends 2 percent (of $15T), Japan spends 3.6 percent (of $5T), and Germany spends 3 percent (of $3.9T). All four economies operate on advanced infrastructure, technology and manufacturing, which incorporate significant materials innovation.

The Europe region is expected to observe adequate growth. Economies such as Spain and UK are destined to be the chief contributors to the germination of the advanced material market. Moreover, increasing demand for power in Africa and the Middle East region is assumed to fuel the extension of the advanced material market in this region.

Countries by Number of Companies



Source: DKG calculations

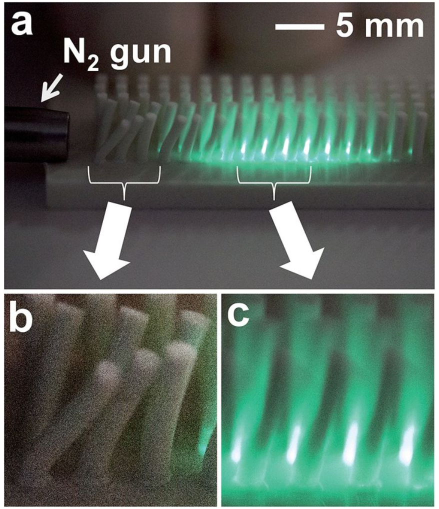
Construction Chemicals and Advanced Materials (CAMs)

Construction Chemicals and Advanced Materials: General Overview

New advanced materials offer opportunities to change the way in which people construct and retrofit buildings. They give added value in terms of **increased performance and functionality**. The **reduction of carbon footprint** for construction materials can start at the production phase, where energy efficient processes can be developed and waste or recycled materials can be employed. New materials can also **help address the new challenges of durability in a changing climate**.

It's notable that the **construction sector was among the first to be identified as a promising application area for nanotechnology** back in the beginning of the 1990s. Currently the application of nanotechnologies and other innovative approaches are the subject of investigation of many R&D centers working on construction materials.

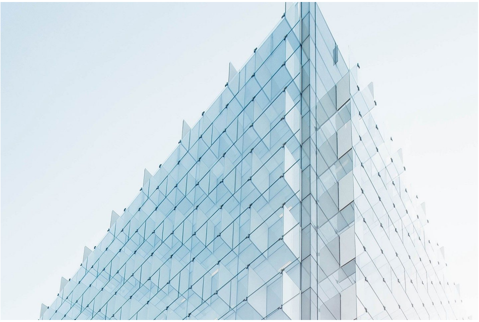
To facilitate the digital transformation and relevant technology adoption, the key enablers of Industry 5.0 in the construction field must be explored. **Such adoption of Industry 5.0 technologies will help uplift the state of practice of the construction industry** that is otherwise lagging the technology curve. Additionally, these technologies will achieve a smart and sustainable construction sector for enabling a resilient built environment.



Plastic That Lights Up in the Wind

The researchers moulded the plastic into tubes — when the wind blows, the tubes deflect and the light appears. The material can be potentially used in engineering next-generation buildings.

Source: [Energy & Environmental Science Journal]



Source: [Chris Hristov on Kinetic Glass]

Kinetic Glass

This is a material which can be used to monitor CO2 levels in the air and automatically open and close gills in response to these emissions. This helps regulate air quality without the use of a thermostat or other such tools.

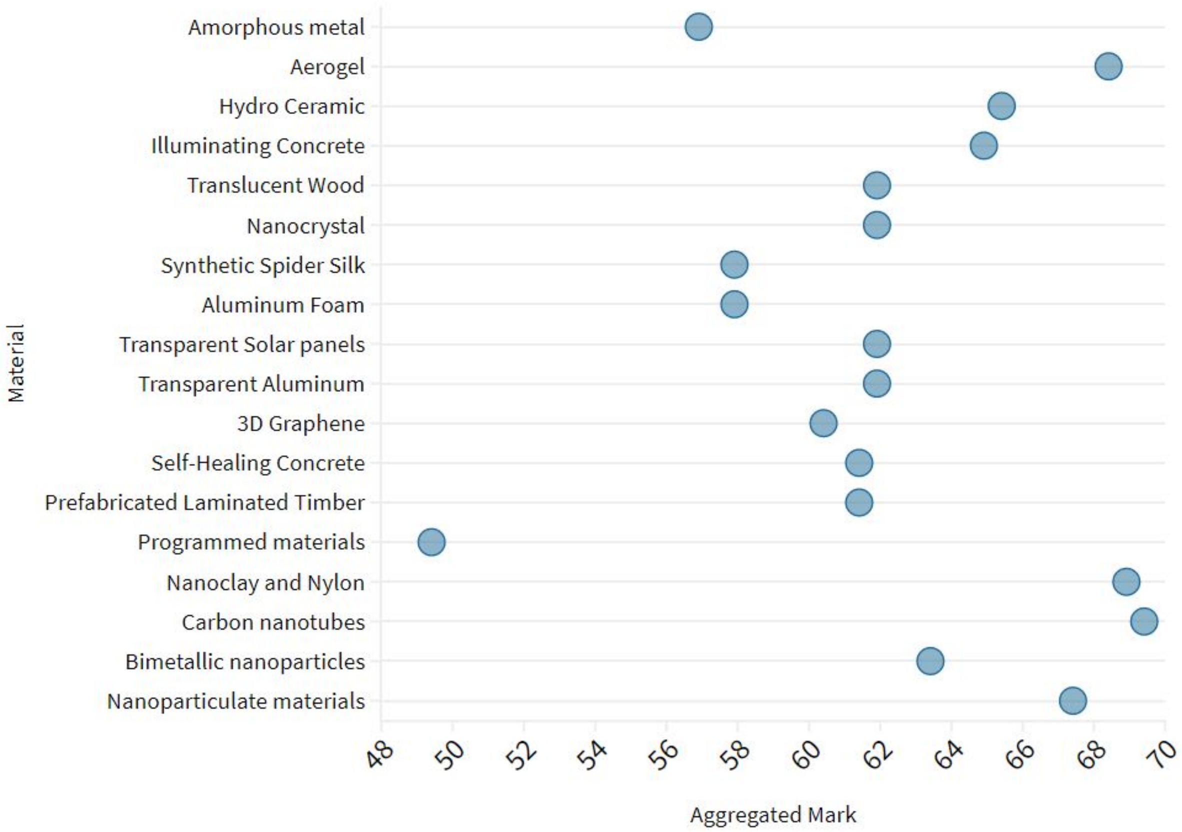
Construction Chemicals and Advanced Materials: Market Overview

The global construction CAMs (Chemicals and Advanced Materials) market is expected to grow from **$82.8B** in 2020 to **$98.5B** by 2023 with a CAGR **6.13%**. The highest contribution to the incremental growth from 2021 to 2026 will likely come from the **Asia-Pacific region**, specifically China, India, and SouthEast Asia (mainly Thailand, Vietnam, Malaysia).

Construction CAMs today, account for only a tiny fraction of the overall construction industry. For instance, they directly accounted for only **1.1%** of the $829 billion US construction industry, or **$9B** in 2019. Despite their small contribution, the role played by construction CAMs in reducing overall systems costs while maintaining the same or increased performance is considered very significant.

Segment	Market size, $B	CAGR (2021–2026)	Application
Concrete admixtures	15.4	9.30%	Admixtures are used to intentionally introduce and stabilize microscopic air bubbles in concrete. Air entrainment will significantly improve the durability of concrete exposed to cycles of freezing and thawing.
Adhesives and sealants	39.0	5.10%	Elimination of the effect of self-loosening caused by dynamic loads, sealing of areas to prevent oxidation and corrosion, waterproofing, etc. Sealants can be used as electrical or thermal insulators, fire barriers and products for smoothing, filleting or flying.
Protective coatings	12.0	7.30%	Two-component epoxy coating, hot dip galvanizing, powder coating.
Insulation materials	7.4	11%	Limitation of the transfer of energy between the inside and outside of a system. Insulation is used in buildings and in manufacturing processes to prevent heat loss or heat gain.
Polymer composites	9.0	7.5	Construction of structural parts for military aircraft, space shuttles, and satellite systems; performance footwear, sports equipment; chemical storage tanks, pressure vessels, pump housing, and valves

Construction Chemicals and Advanced Materials: Multiparametric Assessment



The assessment conducted for selected promising construction materials proved that some materials have great potential going forward only if some challenges are removed. For example, in the case of **polymer composites**, if their costs can be reduced, fabrication efficiency improved, and their different types standardized, they could find more applications in the construction and buildings space. Integration of **BIM, 3D printing, drone, and augmented reality** into the construction process will likely change the demand patterns for some key CAMs products. To enhance this trend, CAMs manufacturers should package their products and services together.

Construction CAMs companies have the opportunity to collaborate with customers on sustainability, overall systems cost reduction, and reduced project delivery time.

Construction Chemicals and Advanced Materials: Companies Profiling

Company: Basilisk Concrete

Segment: Concrete admixtures

Headquartered: Delft, Zuid-Holland, The Netherlands

Disruptive technology: The technology is based on bacteria or other microorganisms which, when mixed during concrete production, produce limestone. As a result, concrete structures become more durable while being able to autonomously repair crack formations. The autonomous repair system is developed for both new constructions as well as for existing structures. Currently, cracks of up to 0.8mm (0.03in) can be repaired.

Company: EPoS

Segment: Shape Memory Alloys

Headquartered: Rivoli, Italy

Disruptive technology: The company has a unique method for sintering, that can be processed to theoretical density in the air without oxidation, thereby, allowing lean production of simple components with reduced machining. The shape memory grades can be produced either with or without heat treatment after sintering.

Company: Green Earth Aerogel Technologies

Segment: Protective coatings, Insulation materials

Headquartered: Barcelona, Catalonia, Spain

Disruptive technology: The company develops carbon aerogels from rice wastes and silica aerogels from rice husk ash. These aerogels can be used for insulating pipes, tubes, and wires. Aerogel fine powders are used as paint additives and putty components to make fireproof and insulated protective coatings.

Construction Chemicals and Advanced Materials: Companies Profiling

Company: Betolar

Segment: Concrete admixtures

Headquartered: Kannonkoski, Western Finland, Finland

Disruptive technology: The company is offering a scalable AI empowered alternative construction material production with up to 80% less carbon emissions compared to using traditional cement. Betolar can also reduce the need for virgin raw materials by replacing aggregates with industrial side streams. The company has extensive knowledge in material physics knowhow which brings the team strong competitive advantage in the construction industry.

Company: KrossLinker

Segment: Insulation materials, Aerogels

Headquartered: Singapore, Central Region, Singapore

Disruptive technology: Krosslinker's aerogel fabrication process addresses the challenges of traditional aerogel manufacturing processes to produce silica aerogel insulation material with proprietary, first-of-its-kind platform technology for fabrication. Krosslinker's aerogel have been tested at a very low operating temperature range, all the way up to -196 C.

Company: Svenska Aerogel

Segment: Insulation materials, Aerogels

Headquartered: Gävle, Gavleborgs Lan, Sweden

Disruptive technology: Svenska Aerogel manufactures and commercializes the nanoporous material Quartzene® for various industrial applications. Quartzene can be adapted to a number of applications thanks to its extremely nano-porous structure and the hydrophilic (water absorbent) or hydrophobic (water repellent) properties of the material.

Advanced Functional Materials

The 5th Industrial Revolution

DEEP KNOWLEDGE GROUP

Advanced Functional Materials: General Overview

The advanced functional materials refer to a group of different compounds having superior properties created through the development of specialized processing and synthesis technologies. **Advanced functional materials have a wide range of applications in different end-use industries** including healthcare, electronics, aerospace, automobile and others.

Advanced functional materials can be found in all classes of materials: ceramics, metals, polymers and organic molecules. Functional materials are often used in electromagnetic applications from KHz to THz and at optical frequencies where the plasmonic properties of metals assume particular importance.

The most notable breakthroughs in advanced functional materials include:

Organic-inorganic hybrid crystals

The researchers combined the advantages of two-dimensional materials and hybrid perovskites—the eponymous mineral perovskite is well-known for its optoelectronic properties, and can be combined with other materials to improve these characteristics.

Polymers with dynamic bonds

This is adaptive polymeric materials with dynamic (reversible) bonds exhibit unique properties providing exciting opportunities for various future technologies. Dynamic bonds enable structural rearrangements in polymer networks in specific conditions. Replacement of a few covalent bonds by dynamic bonds can enhance polymeric properties, e.g., strongly improve the toughness and the adhesive properties of polymers. Moreover, they provide recyclability and enable new properties, such as self-healing and shape memory effects.

Photonic crystals with shaped light waves

The material takes advantage of nanoscale channels created naturally when the crystals are fabricated, and could find use in a host of optoelectronics applications. It’s the first case when researchers succeeded in steering light waves deep into “forbidden” regions of photonic crystals.

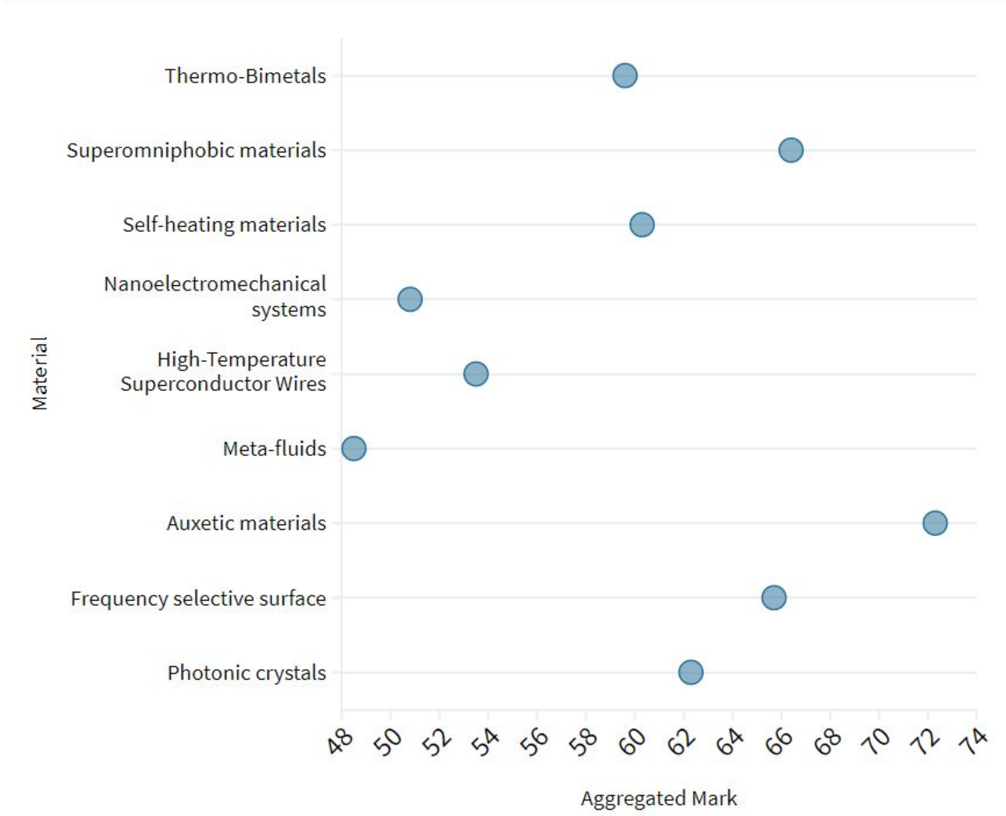
Advanced Functional Materials: Market Overview

The global advanced functional materials market surpassed USD **$86.02B** billion in 2019 and is expected to rise at a **CAGR of 7.6%** by the end of 2026.

50% of the market's growth is expected to originate from **APAC region** during 2021-2026. **China** and **India** are the key markets for advanced functional materials in APAC. Market growth in this region will be faster than the growth of the market in other regions. The increasing demand for automotive products and the presence of a large number of consumer electronic device manufacturers will facilitate the advanced functional materials market growth in APAC over the forecast period.

Segment	Market size, $B	CAGR (2021–2026)	Application
Advanced Composites	31.78	5.3%	Sectors that have traditionally used steel or aluminium structures are turning to composites for the competitive advantage they offer. In addition to application in aerospace, high performance yachting and wind energy applications, advanced composites are finding their way in medical applications, truck cabs, and many more.
Ceramics	10.30	5.0%	Advanced ceramics are able to withstand harsh environments and are used in numerous applications requiring high corrosion and wear resistance, high erosion resistance, high temperature capability and low electrical conductivity.
Energy Materials	27.40	6.3%	The application includes but is not limited to photovoltaic, batteries, fuel cells, nanostructured materials, and light sources.
Conductive Polymers	3.46	9.0%	Flooring, gelcoats & moldcoats, PU cast systems and coatings, powder coatings, tooling gelcoats.
Optical Materials	7.80	7.0%	As a rule, they include materials with good light transmission in some spectral ranges, exhibiting little absorption and scattering of light.

Advanced Functional Materials: Multiparametric Assessment



Advanced functional materials consist of two or more materials prepared using various manufacturing processes. Advanced functional materials can be prepared by casting processes, powder metallurgy, and surface modification techniques, and **their properties can be evaluated by mechanical and other testing methods**. In addition, the machinability of advanced welding techniques are essential to manufacture these components for end applications.

However, the discovery of new functional molecular materials is still limited by the need to identify promising molecules from a vast chemical space. When faced with the problem of developing a material to solve a specific need, a materials scientist conducts a series of time-consuming and costly physical and/or computational experiments to navigate the complex materials design space. Fortunately, recent advances in **materials genomics, AI** and **data science** make it possible to potentially discover relationships between materials features and performance through data-enabled approaches that can be further leveraged to accelerate the discovery of materials with optimal functionality.

Moreover, it can be expected that the emerging functional liquids will be one of the key materials trending in future. The emerging functional liquids include **liquid metals, ionic liquids** and **liquid crystals**.

Advanced Functional Materials: Companies Profiling

Company: 9T Labs AG

Segment: Advanced composites

Headquartered: Zürich, Zurich, Switzerland

Disruptive technology: With this new process, structural carbon fiber parts can be as accessible as metal to series production. To unlock the potential for customers, 9T Labs offers an all-in-one solution ready to be integrated in the production line of innovative companies. Now companies can design and produce previously impossible products that are stronger and lighter than metals.

Company: Boston Materials LLC

Segment: Advanced composites

Headquartered: Billerica, Massachusetts, United States

Disruptive technology: The company is working on commercializing its breakthrough three-dimensionally reinforced carbon fiber composite SuperPly™. SuperPly™ enables the production of significantly more impact resistant and durable composites. These composites are ideal for applications in the pressure vessel, wind turbine, aerospace, automotive, marine, and tooling industries.

Company: Cactus Materials

Segment: Advanced Ceramics

Headquartered: Tempe, Arizona, United States

Disruptive technology: The company design and develop advanced ceramic materials for semiconductor, optical, and medical applications (SiC, B4C, Nexcera), Ceramic thermal heater (BN, ALN)- the highest power density in the industry, and advanced sensors.

Advanced Functional Materials: Companies Profiling

Company: MicroR Systems

Segment: Advanced Optical Materials

Headquartered: Lausanne, Vaud, Switzerland

Disruptive technology: MicroR System is spin-off company from the Swiss, National Centre of Competence in Research "QSIT - Quantum Science & Technology" program and the École Polytechnique Fédérale de Lausanne. The company is focused on the commercialization of crystalline optical microresonators. A disruptive technology with applications ranging from advanced laser technology and radar to telecommunications.

Company: TALOSTECH LLC

Segment: Energy Materials

Headquartered: New Castle, Delaware, United States

Disruptive technology: The company produces advanced materials for battery manufacturers and develops advanced battery technologies for government agencies and commercial customers. In the past years, the company has achieved significant progress on commercializing and developing advanced battery technologies, sponsored by U.S. Department of Energy.

Company: TeXtreme

Segment: Conductive Polymers

Headquartered: Boras, Vastra Gotaland, Sweden

Disruptive technology: The company develops novel Spread Tow, Tape Weaving and Oblique Fabric Technologies providing ty in producing tow count-independent optimized carbon fibre reinforcements that are tailor-made to meet specific application needs. TeXtreme spread tow carbon fabrics achieved a considerable reduction in weight, at least 20%, increased strength and rigidness, as well as improved impact tolerance and superior surface smoothness.

Smart Materials

Smart Materials: General Overview

Smart Materials are defined as those materials that change significantly one or more of their physical or chemical native properties when subjected to changes in their environment, thus rendering them stimuli-responsive.

Smart materials are the basis of many applications, including sensors and actuators, artificial muscles, self healing materials, electroactive polymers etc. The range of application sectors is correspondingly large, including: information and communications technology, energy generation and storage transport, Healthcare, defence,consumer goods.

Many of the applications depend upon the use of multiple smart functional materials. Unlike many materials that are used in large volumes (such as, for example, building or packaging materials), **the value of most smart functional materials lies in their enabling capabilities**. Their **economic impact** comes from the effects of applying the devices and systems that use them, rather than the economic value of the materials themselves.

The potential future benefits of smart materials, structures and systems are amazing in their scope. This technology gives promise of optimum responses to highly complex problem areas by, for example, providing early warning of the problems or adapting the response to cope with unforeseen conditions, thus enhancing the survivability of the system and improving its life cycle.

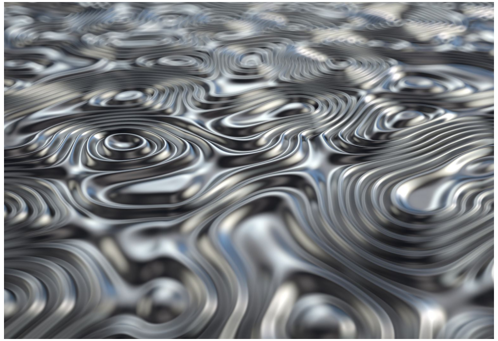
Self Healing Coatings

Not yet in use, but in the process of being tested by a group of scientists, is a self healing coating that could be applied to concrete. However, it's not yet ready for industrial use. This material has the ability to self heal when it cracks and is exposed to sunlight.

Shapeshifting Metals

Shapeshifting metals can undergo great stress and temporarily change shape, but they are designed to 'remember' their original form and revert back to it if altered in some way.

Practical use of this type of metal is largely still in the development phase, with scientists specifically studying how smart metal can be used across the variety of industries.



Source: Nadine Cranenburgh: Metals that change shape with temperature can revolutionise robotics

Smart Materials: Market Overview

Global Smart Materials market size valued at **$18.06B** in 2020 and is projected to reach **$28.80B** by 2026. The market is subject to witness a substantial growth due to **the growing demand of electronic devices** such as sensors and actuators in various end-user industries, and aerospace & defense sector. Globally, the smart materials industry is predicted to grow at **CAGR of 13.5%** in forecast period, providing numerous opportunities for market players to invest for research and development in the market.

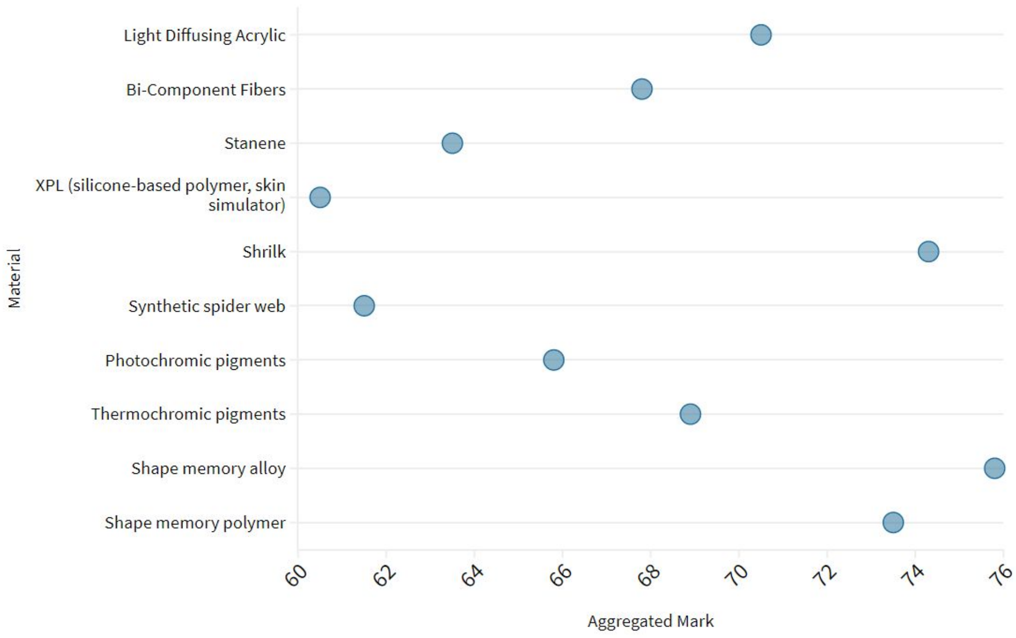
Region wise, **North America** held **39.54%** of market share in 2021 and is expected to keep its dominance over forecast period. **Europe** held the second-largest market share of the global smart materials in 2021, due to an increasing demand in developed countries such as the UK, Germany, France and Switzerland. **APAC** market is expected to experience outstanding growth over the forecast period, owing to the increasing demand from end-use industries in countries such as Japan, India and China.

Segment	Market size, $B	CAGR (2021–2026)	Application
Shape Memory materials	11.0	11.2%	Because of these excellent mechanical properties the application of these materials has been increasing day by day such as in the field of automotive, aerospace, mini actuators and micro electromechanical systems (MEMS) and biomedical.
Piezoelectric Materials	2.46	5.0%	Crystal oscillators, transducers, delay lines, medical ultrasound applications, gas igniters, displacement transducers, accelerometers.
Chromoactive Materials	1.85	4.3%	Invisible ink security, document detection, optics (lenses), labeling signaling, temperature-cold chain control, safety pipes and conduits, smart windows and screens.
Photoactive Materials	1.4	6.3%	Anti-counterfeiting inks, detection of biologic phenomena such as heart beat or brain activity, plasmon-enhanced photocatalytic applications, holographic applications, nonlinear optics.
Magnetorheological Materials	1.35	9.3%	Engineering applications: fluids, foams, grease, elastomers, and plastomers; tunable dynamic vibration absorbers, MRE force sensors.

Smart Materials: Multiparametric Assessment

Smart materials have been moving up the technological value chain, thereby **becoming a cheaper and a more powerful alternative as compared to traditional materials**. The property of smart materials to change one or more of its properties due to **external stimulus and increased investments in R&D** to innovate new smart materials have resulted in broadened applications of smart materials in the automotive, construction, healthcare, aerospace, and chemical industries. Technological advancements have resulted in the increased use of smart materials as compared to conventional materials, such as polymers, metal, and glass.

The use of smart materials requires high investments. Thus, various governmental and non-governmental bodies are focusing on increasing awareness and fuel uptake of smart materials. The further commercialization of innovations will potentially require dealing with industry's **barriers** involving the lack of market pull for material suppliers, high R&D costs, lack of economy of scale and environmental issues (e.g., possible regulations against the use of lead in PZT ferroelectrics).



Ultimately, smart materials **help in designing futuristic products** for a wide range of industries. They not only can capture data about the environment but also adjust their performance based on that data, and thus, they are starting to play an active role in designing advanced products.

Smart Materials: Companies Profiling

Company: Memetis

Segment: Shape Memory Materials

Headquartered: Karlsruhe, Baden-Wurttemberg, Germany

Disruptive technology: The company creates ultra-compact miniature actuators on the basis of shape memory alloys. The startup enables a memory effect in i the company cts materials, which are capable of sustaining extreme deformations, and later reverts to their original shape. This property supports the performance of the actuators even in small or dense installation spaces. Memetis offers solutions for consumer electronics, optical technology and mobility.

Company: Sorex Sensors

Segment: Piezoelectric Materials

Headquartered: Cambridge, Cambridgeshire, United Kingdom

Disruptive technology: The company develops high-sensitivity micro-electromechanical system (MEMS) sensors on silicon wafers using a thin-film piezoelectric material. The startup utilizes FBAR technology to create a piezoelectric effect, enabling it to accurately detect temperature and mass changes on a femtogram scale. This allows small-scale devices with low-power requirements to respond to external stimuli.

Company: Smarter Alloys

Segment: Shape Memory Materials

Headquartered: Waterloo, Ontario, Canada

Disruptive technology: The company develops a proprietary Multiple Memory Material (MMM) technology for precisely controlling the pseudoelasticity and shape memory effects. MMM locally programs any material properties into a single shape memory alloy. The phase transformation temperature of the material is set locally for achieving the prerequisite characteristics.

Smart Materials: Companies Profiling

Company: Magnesium Development Company

Segment: Magnetorheological Materials

Headquartered: Missoula, Montana, United States

Disruptive technology: The company produces fully absorbable magnesium-based biometal alloy devices for orthopedic applications. The body absorbs the proprietary magnesium alloy, in a controlled manner, and exhibits higher mechanical strength when compared to performance polymers such as polyether ether ketone (PEEK).

Company: TG0

Segment: Sensing Materials

Headquartered: London, England, United Kingdom

Disruptive technology: TG0 develops a material based on tactile sensing technology. It claims that its flexible touch-sensitive surface produces 3-dimensional controls that are ergonomic, intuitive and engaging. Their material will provide tactile sensing without the use of electronic sensors. It has application in gaming consoles, automotive interiors, personal computer, and electronic product controls.

Company: Omega Piezo Technologies

Segment: Piezoelectric Materials

Headquartered: Pennsylvania, United States

Disruptive technology: The company manufactures a wide range of piezoelectric and alumina ceramic products. Its piezoelectric products and services encompass piezoelectric components, contract device manufacturing and engineering support services. We manufacture piezoelectric ceramic components for a wide range of applications including sensors, transducers and actuators.

Nanomaterials

Nanomaterials: General Overview

Nanomaterials are engineered particles made to have extremely small dimensions to take advantage of unique physical and chemical properties that exist at the nanoscale. As a result of their unique size, the physical and chemical properties of nanomaterials differ from their larger-scale particles and may act unpredictably and in ways that are currently not understood.

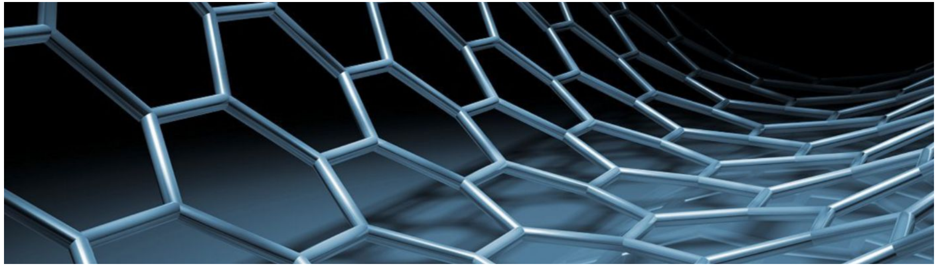
These materials, devices and systems **are made through control of matter at the range of 1-100 nanometers**. Using nanotechnology researchers and manufactures can fabricate materials literally molecule by molecule.

Nanotechnology has shown remarkable potential. The application of nanotechnology has great influence on the world in which we live. It is interdisciplinary or alliance of other applications such as consumer goods, electronics, computers, biotechnology, textile, food beverages, aerospace and defense, etc. Many sectors of economy are to be profoundly impacted by nanotechnologies.

Many nanomaterials exhibit various electrical, optical and mechanical properties themselves, but their small size means that they can also be incorporated into a wide range of composites and formulations, which is why their growth has been so vast.

Graphene

Graphene is a nanomaterial that comprises of a solitary sheet of carbon of the thickness of one atom. It is extraordinarily hard and has promising properties with regards to electricity conduction. Not just that, it's flexible as well.

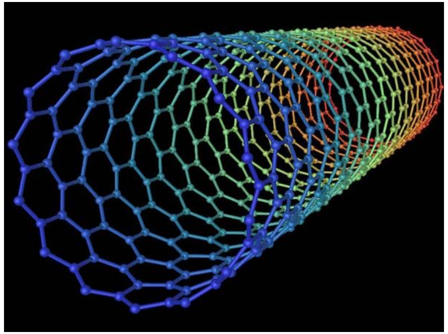


Source: The Innovator: Why Graphene Should Be On Every Executive's Radar

Carbon Nanotubes

They are only about a nanometer in diameter, but are molecules that can be manipulated physically and chemically in very useful ways.

They have unusual thermal, mechanical and electrical properties.



Source: Carbon Nanotube: The World Beyond Carbon-Fibre

Nanomaterials: Market Overview

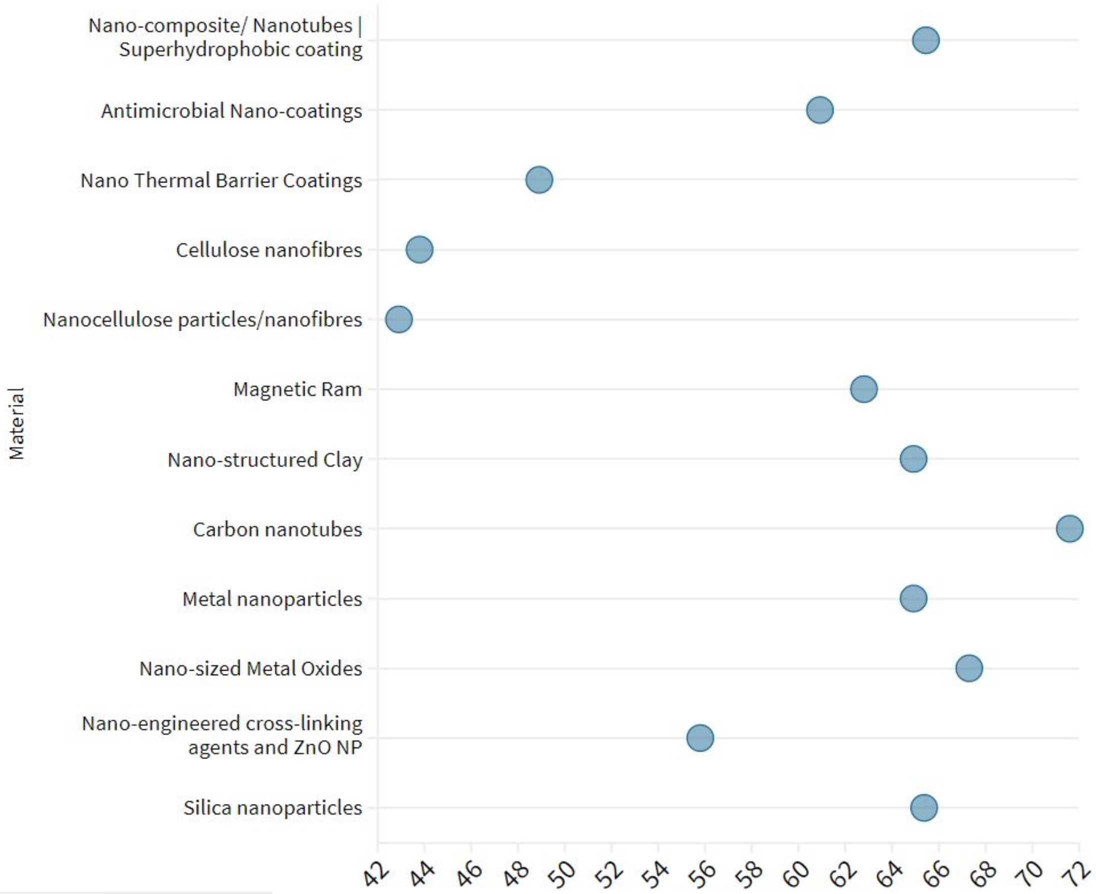
The global market size of nanomaterials is estimated at **$7.1B** in 2020, and is projected to reach a size of **$12.1**B by 2026, growing at a CAGR of 9.7% over the analysis period.

Asia Pacific region dominated the nanomaterials market in 2020 with a market share of 40.99% in terms of revenue. This region is expected to grow at the highest CAGR during 2021-2026, owing to an increase in demand for nanomaterials in multiple applications. **North America** holds the second largest share worldwide (30%).

The factors of nanomaterials market growth include by region: rising product application in **North America**; expanding mass production and price reduction of nanomaterials in **Europe**; ease of entry for new players due to the government financial support and increasing demand, along with rising environmental consciousness in **Asia Pacific region**.

Segment	Market size, $B	CAGR (2021–2026)	Application
Nanotubes	3.42	16.0%	Lithium-ion batteries, supercapacitor electrodes, actuators, composites with maximum strength, energy storage, bio-sensing, cancer treatment, hyperthermia induction, antibacterial therapy, tissue engineering.
Nanoparticles	2.06	12.3%	Synthesis of chiral nanoparticles (CNPs), antimicrobial applications, biosensing, imaging, and drug delivery, bioremediation of diverse contaminants, water treatment, and production of clean energy.
Nanofibers	0.70	17.5%	Automotive and transportation, drug delivery, water filtration, biomedical application, energy storage protective clothing, and air/gas filtration, tissue engineering.
Nanoclays	0.65	6.8%	Bone cement, tissue engineering, drug delivery, wound healing, enzyme immobilization.
Nanowires	0.27	16.4%	MOS field-effect transistors, nanowire sensors for detecting viruses, heat transfer enhancement, transparent conductive electrodes, creation of artificial protein-coding DNA, photodetectors, chemical and biological sensors.

Nanomaterials: Multiparametric Assessment



Advancements in nanotechnology show that the characteristics of materials at a nanoscale differ from those of their bulk equivalents. The proliferation of **nanofibers, nanotubes, allotropes, quantum dots (QD)**, and other nanostructures enable an almost infinite source of value-addition, in the form of strengthened performance of industrial products, retained at an atomic level. By leveraging the power of nanoparticles, modern companies secure their competitive edge, specifically in the **electronics, energy, mobility, and manufacturing sectors.**

While advanced materials were in existence before nanomaterials became commercialised, the recent boom towards using advanced materials has largely been due to **commercial production of different nanomaterials**, being able to utilise new nanofabrication technologies, and being able to convert already-used bulk materials into different nanoforms. As a result, nanomaterials are becoming a popular option as an additive in some industries (e.g. composites) but **can also be a stand-alone material** as well.

Nanomaterials: Companies Profiling

Company: Nanolumi

Segment: Nanocrystals

Headquartered: Singapore, Central Region, Singapore

Disruptive technology: The company intends to overcome the weaknesses of QD technology for electronic displays with its reliable and safe perovskite nanocrystals. The startup combines the advantages of cadmium-free origin, broad light spectrum coverage, purer color performance, and high-volume mass-production suitability. Nanolumi's product also intends to supplant conventional perovskite nanocrystals and QDs for premium electronics.

Company: BNNano

Segment: Nanotubes

Headquartered: Cary, North Carolina, United States

Disruptive technology: The company manufactures boron nitride nanotubes with superhydrophobic, high electrical insulation, and high thermal & mechanical stability characteristics. The company offers powders, master alloys, masterbatches, and custom mixes to enhance the performance of aerospace, automotive, defense, and textile applications, as well as for radiation protection and thermal management.

Company: RadiSurf

Segment: Nanolayers

Headquartered: Aarhus, Denmark

Disruptive technology: The company provides molecular adhesion technology for the materials industry. The startup grows polymer brushes with the help of a two-step process using proprietary nano primer chemical kits. Polymer brushes that are tethering with other surfaces act as a chemically bonded polymeric nanolayer to provide a completely new set of surface functionalities.

Nanomaterials: Companies Profiling

Company: Graphitene

Segment: Graphene

Headquartered: Scunthorpe, UK

Disruptive technology: The company produces graphene for buildings and construction. It has a unique and clean production process for graphene that does not require high temperatures. The process exfoliates graphene from naturally occurring graphite flakes using only mild chemicals and conditions that yield pure graphene.

Company: NanoScientifica

Segment: Nanoparticles

Headquartered: Gothenburg, Sweden

Disruptive technology: The company focuses on developing nanoparticles using automated method and leveraging its years of research experience. The automated method used by the startup develops nanomaterials 30 times quicker than conventional processes. The start-up produces high-quality metallic nanoparticles with tight size and shape control in an environmentally sustainable way.

Company: Tandem Nano

Segment: Nanoparticles

Headquartered: Liverpool, UK

Disruptive technology: The company develops nanoformulation delivery solutions using a broad range of techniques to develop Solid Drug Nanoparticles (SDN) that targets protein or tissues. The startup also provides solutions to agriculture industry as it develops agrochemicals.

Challenges along the Development of the Advanced Materials

High prices create lower demand

Some of the advanced materials like Nanomaterials have their average prices of around $1000 per gram. For example, carbon fiber reinforced polymers are used in various end-user industries like aerospace, energy and sports owing their excellent mechanical and thermal properties. Although they have many advantages, the demand for carbon fiber is more likely to reduce as its production is several times expensive than its conventional counterparts.

Lack of general awareness

There is a certain lack of acceptance of advancements in advanced materials R&D. Sometimes this is just driven by lack of knowledge about technologies in general, and materials potential in particular. In order to eliminate this, methods of co-creation and engagement of citizens need to be developed and applied in step with technology advances. Many groups of society must be involved in defining technological solutions and their benefits for society – without ignoring risks, dangers, possible side effects and people's concerns.

Parallel development of methods

A challenge for the future advancement of advanced materials is the development of robust, large-scale, fully integrated and flexible manufacturing methods. While applications of advanced materials are expected across the range of manufacturing sectors, it's essential to emphasize the frontier technological development.

Exponential R&D Expenses

The materials innovation processes require ongoing support for capital equipment for experiments, measurements, and testing. Given that materials development often requires more than a decade of work, it can be very difficult for companies and research organizations, particularly smaller ones, to maintain ongoing research activities. RDD&D supports, to collaborations, to resource sharing of leading edge tools and expertise from the national laboratories will be crucial while dealing with this challenge.

Key Takeaways

Advanced materials provide numerous opportunities to make our lives better in many ways, such as:

1. Making products more durable or energy efficient;
2. Offering superior performance, new features, or more attractive design;
3. Lowering the cost of goods and services we consume;
4. Lessening our dependence on imports of strategic value and critical materials or minerals;

The biggest change in the definition of advanced materials comes in regard to sustainability, which was not nearly as central of an issue in 1987 as it is in 2021. Advanced materials are an essential factor in helping us build a more sustainable economy.

Venture investment in Advanced Materials increased steadily in both deal count and dollars invested in the 2013-2020 time period. On a global scale, recent studies show that both public and private organizations are willing to invest in advanced materials industry.

Developing and commercializing an advanced material can take decades, sometimes with surprising results, and the process is rarely ever complete. The majority of materials development has occurred in the U.S. and Europe, with Japan and Korea contributing as key players. More recently however, China has become a key contributor to the advanced materials value chain.

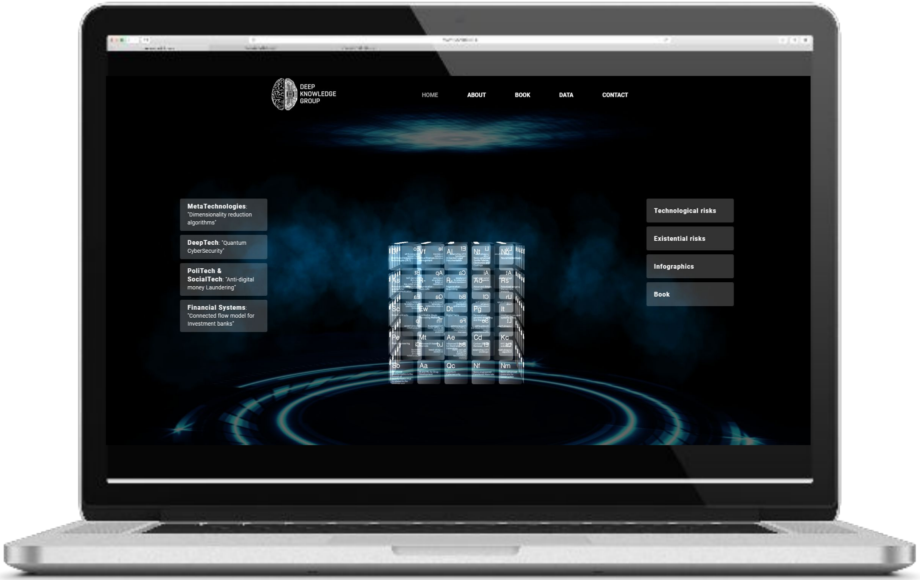
Key obstacle that impact the research, production and sales of advanced materials are:

1. Prices of advanced materials are very high compared to their traditional counterparts;
2. The materials innovation processes require ongoing support for capital equipment for experiments, and testing;
3. Development of robust, large-scale, fully integrated and flexible manufacturing methods;
4. There is a certain lack of acceptance of advancements in advanced materials R&D;

About the 5th Industrial Revolution

The 5th Industrial Revolution is a cutting-edge technological project developed by Deep Knowledge Group and its subsidiaries in order to promote and enhance the development of the important technologies, bringing the future closer!

5th Industrial Revolution possess an exhaustive overview of the existing technological spectrum in AI, Biotech, Finance, Energy and other areas. Our analytical reports along with the assessment framework allows to define potential disruptive solutions and use such insights as a competitive advantage.



Legal Disclaimer

This information and all additional materials provided in connection therewith (this "Information") is indicative and for informational purposes only and is furnished on a confidential basis in order to provide information about certain activities (the "Activities") to a limited number of interested parties. It may not be copied, released, revealed or distributed by any recipient (and its employees, advisors and/or affiliates) to any third party without Deep Knowledge Group's prior written consent.

Deep Knowledge Group doesn't not offer investment advice and nothing in the document should be construed as investment advice. The information contained in the document is not, and should not be read as, an offer, solicitation or recommendation to buy or sell any securities. The document is not, and should not be seen as, a recommendation to use any particular investment strategy. The Activities referred to herein are tentative and certain information contained in this document is based on current market statistics and conditions, and therefore, is subject to verification, material updating, revision and amendment.

Deep Knowledge Group

info@dkv.global

www.dkv.global