Advanced Ceramics and Green Coating Markets

Market Scenario and Competitive Landscape

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Introduction and Methodology

"Market Scenario" is a customized and organized analysis to gather information about target markets and competitive landscape in a particular sector.

"Market Scenario" provides relevant information to identify and analyze market needs, market size and competition in the fields of interest of the customer. A technology or a product developed by the customer can be characterized according to the sectors and potentiality of application, target market, competitive advantages and potential partners of the technology. The analysis is performed with the application of technology and business intelligence tools. The research in the information providers is usually based on the use of keywords or by thematic area, according to the specific topic of interest.

The results of the assessment are data about the target or global market potential, market value and applicability of the technologies or products developed by the customer, the trends of the market of interest, the segmentation of the market (e.g., by application, geography or indication), the supply chain and the competitive advantages of products or technologies, the key players active in the market of interest and the possible direct or indirect competitors of the customer.

Context

Chapter 1 of this analysis reports data about the global market for **advanced ceramics**, the main trends and dynamics in the period 2022 – 2027 and references to the market segmentations by material, application, end-user, region and the competitive landscape.

In **Chapter 2** is provided an overview about the **green coatings** market, with detail about the trends and dynamics in the period 2022 – 2027 and the segmentations by technology, application, region and the competitive landscape.

1 Advanced Ceramics

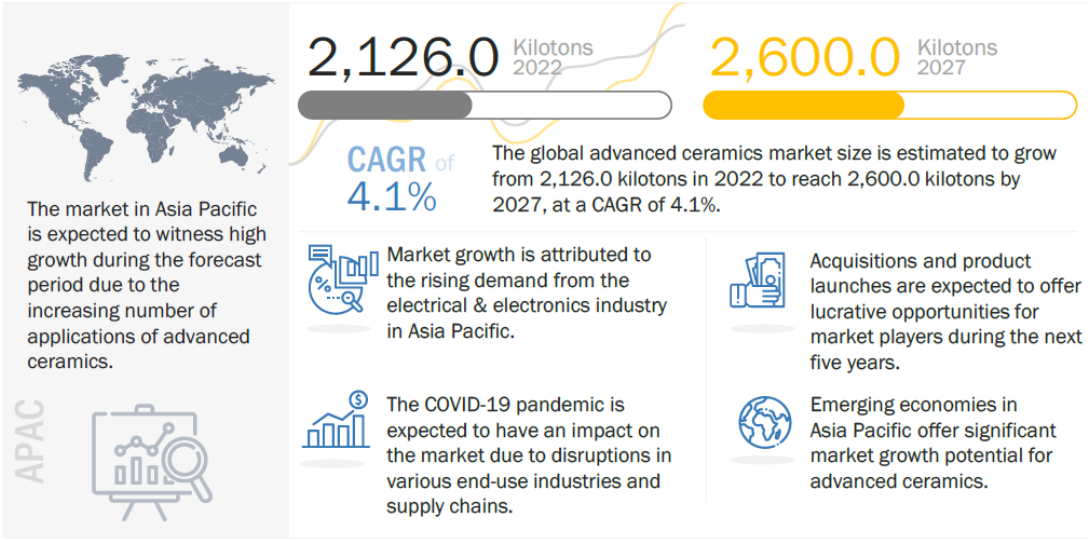
Advanced ceramics are the high-performance subset of the ceramic materials family, which are also referred to as technical ceramics, engineered ceramics, or industrial ceramics. Advanced ceramics are highly developed inorganic and non-metallic ceramics with excellent high-temperature stability, hardness, low thermal expansion, and various electrical properties ranging from insulation to dielectric properties to high conductivity. The application of these ceramics helps in reducing energy consumption and pollution. Advanced ceramics are mainly used in electrical and electronics, transportation, medical, defense and security and environmental industries.

1.1 Global Market and Market Dynamics

The **global advanced ceramics market** size was USD 10.3 billion in 2021 and is projected to reach USD 13.9 billion by 2027, at a Compound Annual Growth Rate (CAGR) of 5.1% during the forecast period.

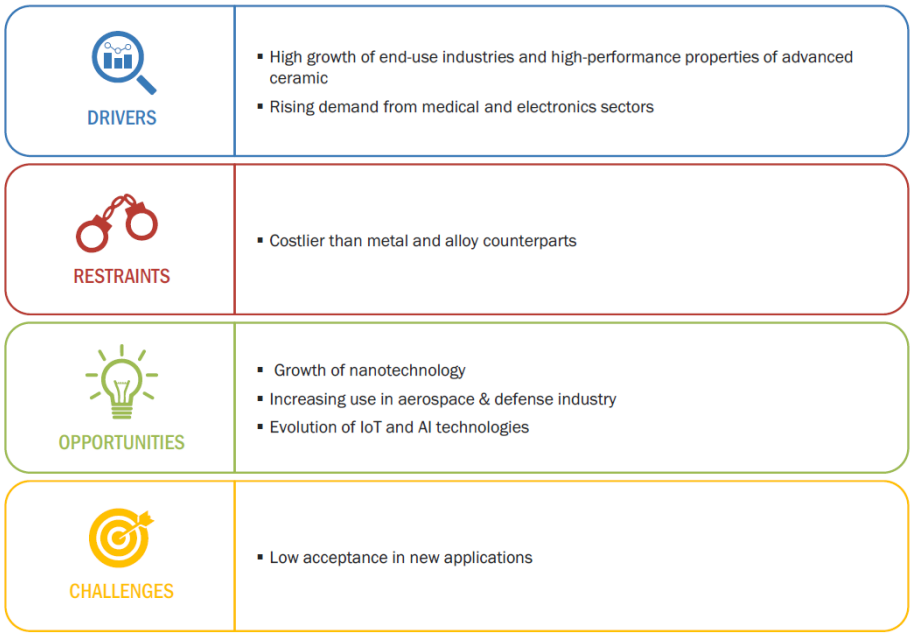
The market value and growth in Kilotons is reported in Figure 1.

Figure 1. Global Advanced Ceramics Market, in the Period 2022 – 2027 (Kilotons)



The demand for advanced ceramics is increasing owing to the growth in industrial activities in both developed and emerging economies. The market **growth** is driven by the growing demand for these ceramics in the medical and electronics industries and the suitability of advanced ceramics in a wide range of industrial applications (Figure 2). However, its higher costs than other metals & alloys and high customization requirement for end-use applications may **restrain** the market growth.

Figure 2. Drivers, Restraints, Opportunities and Challenges in Advanced Ceramics Market



1.2 Market by Material

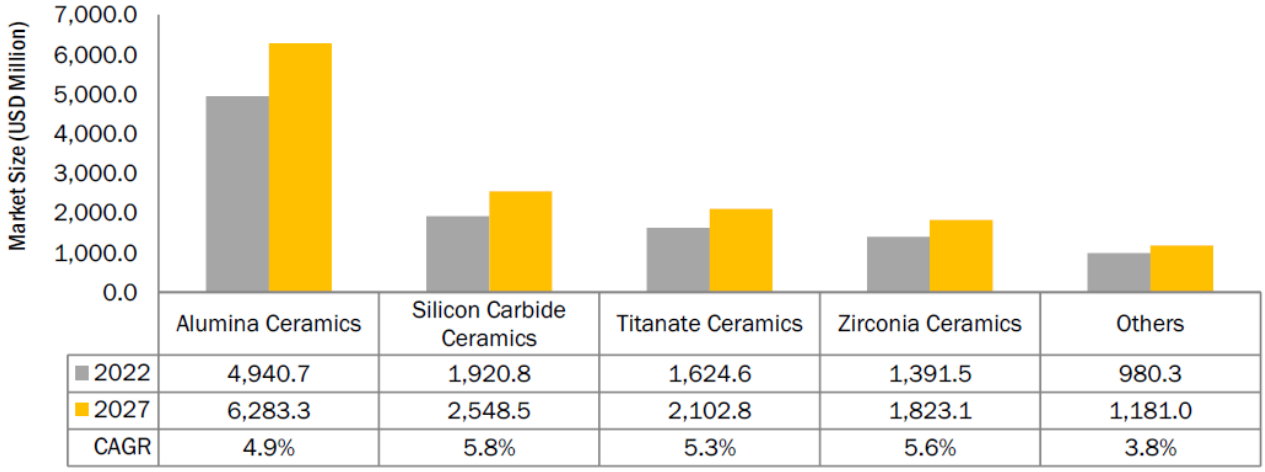
Advanced ceramics possess various characteristics, including mechanical strength, good electromagnetic properties, and thermal resistance. Depending on

the characteristics, these materials can withstand extreme conditions efficiently, such as high pressure and temperature and corrosive and chemical exposure. They also have hardness and rigidity, wear resistance, fire resistance, chemical resistance, shock resistance, electric insulation, and bio-compatibility. Due to these properties, advanced ceramics are used in various end-use industries such as power, electrical & electronics, oil & gas, and chemicals.

Advanced ceramics are by **material** are currently divided into: **alumina, silicon carbide, titanate, zirconia and others ceramics** (include aluminum nitride, beryllium oxide, silicon nitride, magnesium silicate, and pyrolytic boron nitride) (Figure 3). **Alumina** ceramics led the advanced ceramics market in 2022. The **silicon carbide** ceramics segment was the second-largest material, in terms of value, in 2022. It is also the fastest-growing segment of the overall advanced ceramics market, projected to register a CAGR of 5.8%, in terms of value, between 2022 and 2027.

The high-performance properties of advanced ceramics, such as chemical, corrosion, and thermal shock resistance, are propelling the market.

Figure 3. Advanced Ceramics Market, by Material, in the Period 2022 - 2027



	Alumina Ceramics	Silicon Carbide Ceramics	Titanate Ceramics	Zirconia Ceramics	Others
2022	4,940.7	1,920.8	1,624.6	1,391.5	980.3
2027	6,283.3	2,548.5	2,102.8	1,823.1	1,181.0
CAGR	4.9%	5.8%	5.3%	5.6%	3.8%

**Others include aluminum nitride, beryllium oxide, silicon nitride, magnesium silicate and pyrolytic boron nitride*

1.2.1 Alumina Ceramics

Alumina ceramics are the strongest and stiffest of the oxide ceramics. Based on the purity grades, they can offer up to twenty times the thermal conductivity of other oxides. High purity alumina is usable in both oxidizing and reducing atmospheres up to approximately 4000 °F. It possesses various properties such as extreme hardness, high density, wear resistance, thermal conductivity, high stiffness, chemical resistance, and compressive strength. Moreover, it has excellent dielectric properties, good refractory properties, and thermal properties, which makes it a suitable material for a wide range of applications. High purity alumina (up to 99.99% purity) is used for manufacturing passive components such as multi-layer interconnection circuits, resistors, and capacitors in the electrical & electronics industry; mechanical components such as nozzles, frictional parts, and piston engines seals, which require high wear resistance; armor plating for the protection of tanks and helicopters, bullet-proof jacket in military & defense industry; and in ceramic parts for orthopedic and dental surgery.

Common types of alumina ceramics are mentioned below:

- Alumina ceramic (94% alumina);
- Alumina ceramic (96% alumina);

- Alumina ceramic (99.9% alumina).

Alumina is the most utilized advanced ceramic in the aerospace & defense industry. It is used for body armors due to its hardness, modulus of elasticity, and low cost compared to other commercially available technical ceramics. It is used for the outer protection of aircraft in the form of panels, which are exposed to high-temperature variations, vibration, and other extreme mechanical conditions. Blades, combustion liners, igniters, seals, nozzles, connectors, and many other components in aerospace and defense equipment are made using advanced ceramics.

Alumina ceramics are lighter than metals that enable faster speed, larger payloads, and lower fuel consumption. These properties make them popular for automotive applications.

1.2.2 Zirconia Ceramics

Zirconium oxide or ZrO_2 is also known as **zirconia**. It is a material with very high resistance to crack propagation and excellent abrasive properties. ZrO_2 has excellent strength and high fracture toughness, along with a very high thermal expansion. It is considered a material of choice for bonding ceramic and steel. It delivers high performance owing to its extremely high purities, which are mostly metal compounds combined with oxides, carbides, or nitrides. Components manufactured from zirconium oxide are significantly more expensive than alumina ceramics, although they can increase product lifespan, increase efficiency, reduce overall maintenance costs, and improve performance.

Zirconium oxide ceramics have wide applications in various industries. It can be used for manufacturing compressors, pumps, and sealing technology (seal rings, bearings) for mechanical operations; bearing technology in automotive engineering; as a material for crowns and bridges in dental science; and as an auxiliary in welding processes.

Zirconia is a biocompatible material that can be used in the medical field for a wide range of applications. It is commonly used to produce dental substructures such as crowns and bridges. It has excellent wear resistance, strength, and flexibility; hence, it is used in a wide range of end-use industries.

1.2.3 Titanate Ceramics

Titanate ceramics can be further segmented, based on their **properties**, into **technical ceramics** and **functional ceramics**. Technical ceramics include ceramics that serve advanced applications, whereas functional ceramics are piezoelectric ceramics. The piezoelectric property is a functional phenomenon that occurs when the electric charge domains in the piezoelectric material are displaced under stress. Piezoelectric ceramics are ferroelectric materials. Ferroelectric is a subset of piezoelectric that possess a spontaneous polarization property and can be reoriented by the application of an electric field. The most famous piezoelectric ceramic is lead titanate, commonly known as PZT. Barium titanate and sodium bismuth titanate are lead-free titanate ceramics.

Based on the **base material**, titanate ceramics are further segmented as lead **zirconia titanate, barium titanate, sodium bismuth titanate, and others**.

Lead zirconate titanate is an inorganic technical ceramic also known as lead **zirconium titanate** (PZT). It is a ceramic material with a marked piezoelectric effect. It is suitable for applications that include compound changes in shape when subject to an electric field. It is used in applications such as ultrasonic transducers, actuators, and piezoelectric resonators.

Barium titanate is a lead-free titanate with piezoelectric properties. It is used in microphones and other transducers. As a piezoelectric material, it can be used as a lead-free replacement for PZT ceramics. High-purity barium titanate powder is a key component of barium titanate capacitor energy storage systems used in electric vehicles. These ceramics are highly biocompatible and are employed as nanocarriers for drug delivery.

1.2.4 Silicon Carbide Ceramics

Silicon carbide is a non-oxide ceramic. Silicon carbide ceramics are the most corrosion-resistant, lightweight, and hardest ceramics, which can maintain their strength at up to 2552°F. They are advanced ceramic materials containing silicon and carbon with strong covalent bonds. These ceramics have numerous application areas, and they are also ideal for use in demanding conditions in various sectors such as nuclear energy, space technology, automobile, marine engineering, and electrical & electronics. They are toxicologically safe and can be used in the food & beverage industry as well.

They are considered the most promising material for manufacturing rocket nozzles, gas turbines, and engine components in the aerospace and automotive sectors. They are also used in the manufacturing of cutting tools, bearings, seals and pump parts, corrosion-resistant containers, and other parts and components required in power, OEM, oil & gas, and chemical industries.

1.2.5 Others

Beryllium Oxide Ceramics

Beryllium oxide (BeO), commonly termed as Beryllia, is an advanced ceramic having a combination of thermal, electrical, optical, and mechanical properties. BeO is a thermally conductive and electrically insulating material that possesses high electrical resistivity and offers excellent strength with high specific stiffness properties. It offers significantly higher thermal conductivity than alumina.

It is suitable for a range of applications in multiple sectors, including thermal management systems in electronics, high-performance refractory components for nuclear reactors, gas lasers for DNA and tissue analysis in healthcare, industrial laser, and metal cutting equipment, semiconductor handling equipment, and radar & guidance module in aerospace & defense.

Aluminium Nitride Ceramics

Aluminum nitride (AlN) is a ceramic material, which has high thermal conductivity, along with strong electrical resistance and good metallization capacity, making it a highly acceptable material for use in the electronics industry. It allows electrical and electronic systems to dissipate heat quickly to achieve maximum efficiency. Aluminum nitride is primarily utilized in power and microelectronics applications. It is used as a circuit carrier (substrate) in semiconductors, as a heat-sink in LED lighting technology, and in high-power electronics. It is an alternative to beryllium oxide (BeO) in the semiconductor industry due to its non- hazardous nature. It also offers superior insulation properties, which is similar to a silicon wafer material.

Aluminum nitride has various applications in optoelectronics, heat sinks, liquid cooling systems, dielectric layers in optical storage media, electronic substrates, circuit boards, and others. It is also in demand in consumer & household, automobile & transportation, microelectronics & telecommunications, and other industries.

Silicon Nitride Ceramics

Silicon nitride (Si_3N_4) is an advanced engineering ceramic, which features an excellent set of properties such as thermal shock resistance, low coefficient of thermal expansion, chemical and thermal stability, mechanical fatigue and creep resistance, and high fracture toughness at varied temperatures. Due to the combination of good tribological properties, it makes silicon nitride ceramics for different applications in a wide range of end-use industries.

Components such as bearings, cutting tools, heavy-duty ceramic forming tools, and automotive components are subject to high stress. Silicon nitride is suitable for use under such high-stress conditions. It is also used to manufacture engines,

gas turbines, and turbocharger rotors. It is in high demand to manufacture reciprocating engines for combustion components and wear parts.

Common types of silicon nitride ceramics are as follows:

- Reaction–Bonded Silicon Nitride (RBSN);
- Hot Pressed Silicon Nitride (HPSN);
- Sintered Reaction–Bonded Silicon Nitride (SRBSN);
- Sintered Silicon Nitride (SSN).

Boron Nitride Ceramics

Boron nitride is an advanced synthetic ceramic material holding unique properties such as high thermal conductivity, corrosion resistance, and good thermal shock resistance. It possesses good lubricity, a low dielectric constant, and superior dielectric strength. It is also an excellent electrical insulator with a higher oxidation temperature.

Due to its excellent machinability and low-friction properties, it is used in various applications such as heat sinks in high-power electronic applications, plasma arc welding, precision machining and grinding, diffusion source wafers, and interface materials used in various molten metal processes.

Magnesium Silicate

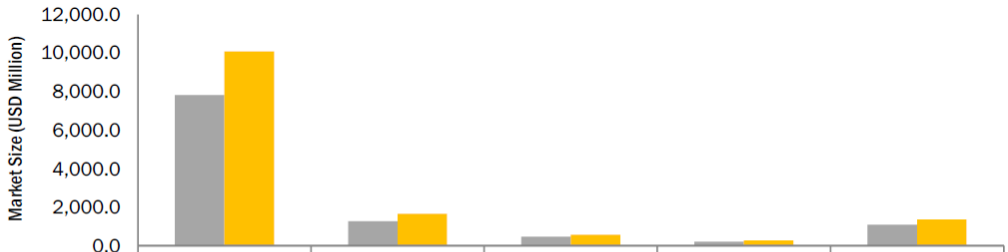
Magnesium silicate ceramics are composed of various chemical materials such as silica (SiO_2), magnesia (MgO), and traces of alumina (Al_2O_3). Steatite and cordierite are the two types of magnesium silicate ceramics that share an identical chemical structure but have different densities and melting points. Cordierite ceramics are manufactured at a lesser cost than steatite, providing better electrical properties, and are often considered a material of choice in the electronics industry. Magnesium silicate offers good electrical resistance, moderate mechanical strength, and temperature resistance. It has been utilized in electrical insulation for several years in both large-scale electrical systems, electronics, and domestic appliances.

1.3 Market by Application

Advanced ceramics are developed to overcome the limitations of traditional ceramics. These ceramics are mainly used for engineering and industrial applications owing to their unique properties such as low density, hardness, high mechanical strength, dimensional stability, resistance to wear and corrosion, high working temperature, low and high thermal conductivity, good electrical insulation, and dielectric and ferroelectric properties. Advanced ceramics, based on their application, are mainly segmented into: **monolithic ceramics, ceramic matrix composites, ceramic coatings, ceramic filters and others** (include multilayer ceramics and advanced coatings) (Figure 4).

The advanced ceramics market was dominated by the monolithic ceramics segment in 2022. The **ceramic filters segment** is projected to register the highest CAGR of 5.5%, in terms of value, between 2022 and 2027. Recent technological developments are enabling the manufacturing of thin ceramic coatings, ceramic filters, and ceramic membranes that meet the requirements of a wide range of end-use industries.

Figure 4. Advanced Ceramics Market, by Application, in the Period 2022 - 2027



	Monolithic Ceramics	Ceramic Coatings	Ceramic Matrix Composites	Ceramic Filters	Others
2022	7,817.1	1,280.9	461.9	210.5	1,087.5
2027	10,073.7	1,654.4	576.8	274.5	1,359.4
CAGR	5.2%	5.3%	4.5%	5.5%	4.6%

Ceramic filters are tiny pores on the ceramic surface to filter bacteria and sediments. Ceramic filtration is a natural method of filtration that uses a network of pores to remove bacteria and contaminants. It is an economical method of filtration that suits domestic and light industrial applications.

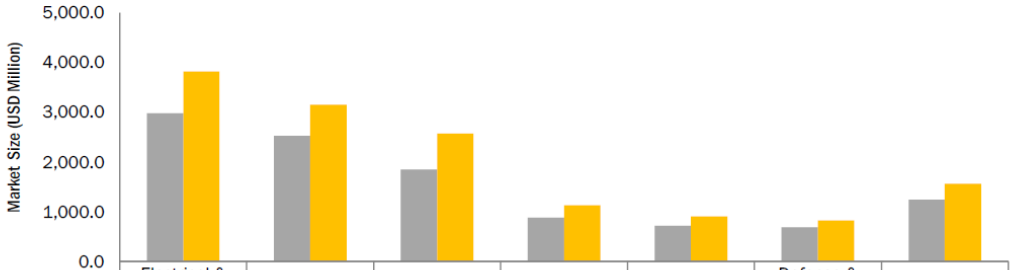
These filters can easily remove bacteria, sediments, and turbidity. They can be combined with activated carbon or ion-exchange resins to improve performance and enhance functionality. When combined with activated carbon, ceramic filters are capable of removing chlorine and VOCs, whereas a combination of ceramic filters and ion-exchange resins enables the removal of heavy metals. The combination of ceramic filters with different filtration materials supports a multi-stage filtration process.

1.4 Market by End-Use Industry

Advanced ceramics are used in various end-use industries due to their corrosion resistance, excellent shock resistance, high stiffness, physical stability, extreme heat resistance, chemical inertness, bio-compatibility, and superior electrical properties. The market for advanced ceramics is segmented based on various end-use industries into: **electrical & electronics, transportation, medical, defense & security, environmental, chemical, and others** (includes the marine, mining, and textile industries) (Figure 5).

The advanced ceramics market was led by the electrical & electronics segment in terms of value in 2022. Advanced ceramics play a critical role in the electronics, telecommunications, manufacturing, transportation, medicine, and defense and space exploration industries.

Figure 5. Advanced Ceramics Market, by End-Use Industry, in the Period 2022 - 2027



	Electrical & Electronics	Transportation	Medical	Environmental	Chemical	Defense & Security	Others
2022	2,980.2	2,522.6	1,845.6	874.4	714.2	679.6	1,241.2
2027	3,814.8	3,150.8	2,569.6	1,126.3	900.8	820.2	1,556.3

1.4.1 Environmental

The use of advanced ceramics in power generation technologies has reduced environmental pollution. Advanced ceramics are used in nuclear fuel storage, solar hydrogen technology, solid oxide fuel cells, and others. These ceramics have energy-efficient properties; therefore, their use results in the conservation of the environment. Advanced ceramics are utilized in both conventional and non-conventional sources of energy generation.

Ceramic materials ensure safe, low emission, and efficient use of resources in many areas of energy supply and environmental technology. Technical ceramics are used in advanced nuclear technologies, biofuels, carbon sequestration, coal gasification, environmental remediation, green building technologies, high-capacity energy storage, and solar and wind technologies for sustainable energy generation and to achieve environmental sustainability.

Conventional

In power engineering, the major concerns are power generation, transport, and storage. The prime objective is to minimize resource consumption and the environmental impact while maximizing efficiency. Applications of ceramic materials and coatings are often found in energy-efficient plants and machinery exposed to high mechanical, chemical, and thermal stresses. Oil and gas companies are utilizing silicon nitride and zirconia ceramics having good wear resistance and corrosion and thermal resistance characteristics. These ceramics possess low weight and heat tolerance properties, which are replacing traditional metal components. Ceramic coatings are also used in the hot gas area of stationary gas turbines and in corrosion-resistant dielectrics in molten carbonate fuel cells.

Nonconventional

Ceramic materials can withstand extreme temperatures and mechanical stresses in various applications. Advanced ceramics are used in energy generation power plant engines, turbines, solar thermal energy conversion, and wind & hydropower generation. The demand for solar energy is rising, resulting in the development of new and advanced materials such as a ceramic-metal composite of zirconium carbide and tungsten. These composite materials are now being used in solar power plants as heat exchangers and high-temperature absorber coatings in metallic solar receivers. In the nuclear energy sector, ceramics can be used in fuel disposal for immobilizing and storing nuclear waste, fuel cladding for various fuels in reactors, optimizing surface features, and creep resistance of reactor components.

1.5 Market by Region

The advanced ceramics market is divided into five major regions: **Asia Pacific, North America, Europe, South America, and the Middle East & Africa** (Table 1).

The North American and European countries are experiencing slow growth compared to the Asia Pacific, the Middle East & African, and South American countries because of the mature industrial base in the former two regions and the growing demand from emerging economies such as India, Brazil, China, and Malaysia. Most of the key players are focusing on regions that can offer them a sustainable demand and help them increase their revenue. Developing countries such as China, India, Malaysia, and Saudi Arabia, have high growth opportunities owing to their growing economy. Asia Pacific has a higher potential for advanced ceramics than other regions owing to the presence of a huge untapped market.

Asia Pacific led the advanced ceramics market, in terms of value, in 2022. China was the largest market for advanced ceramics in Asia Pacific, in terms of value, in 2022. The market in China is projected to register a CAGR of 6.7% between 2022 and 2027.

North America was the second-largest market for advanced ceramics, in terms of value, in 2022. The market in the region is driven by the large industrial base of the US. South America, the second-fastest growing market, is projected to register a CAGR of 5.8% in terms of value, between 2022 and 2027.

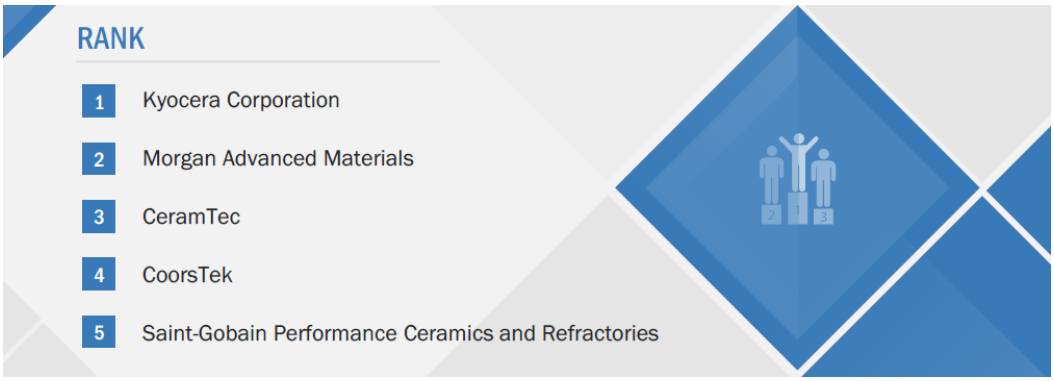
Table 1. Advanced Ceramics Market Size, by Region, 2022–2027 (USD Million)

Region	2022	2023	2024	2025	2026	2027	CAGR (2022–2027)
Asia Pacific	4,387.1	4,667.5	4,960.0	5,264.6	5,581.3	5,922.6	6.2%
North America	2,674.1	2,772.8	2,871.7	2,970.6	3,069.2	3,174.2	3.5%
Europe	2,376.3	2,489.2	2,604.3	2,721.4	2,840.5	2,967.6	4.5%
Middle East & Africa	545.0	576.5	609.0	642.7	677.4	714.7	5.6%
South America	875.4	927.8	982.2	1,038.5	1,096.8	1,159.5	5.8%
Total	10,857.9	11,433.7	12,027.2	12,637.9	13,265.3	13,938.7	5.1%

1.6 Competitive Landscape

Kyocera Corporation (Japan), CeramTec (US), CoorsTek (US), Saint-Gobain Performance Ceramics & Refractories (US) and Morgan Advanced Materials (UK) are the **main players** in the market (Figure 6). These companies have invested in new product launches, expansions, joint ventures, agreements, partnerships, and mergers & acquisitions of small players between 2018 and 2022 to dominate the advanced ceramics market. The major players in the market are also investing heavily in improving their R&D capabilities to develop new products that will expand the applications of advanced ceramics.

Figure 6. Ranking of Top Five Players in Advanced Ceramics Market (2021)



The advanced ceramics market consists of a large number of small firms. These firms are not major players, but they collectively have the largest share in the market. The market is very scattered with the presence of local and global players. Hence, there is a considerable competitive rivalry among the existing players. Additionally, manufacturers are aiming to differentiate their products from their competitors.

Other players globally include: 3M (USA), Advanced Ceramic Materials (USA), AGC Ceramics (Japan), Bakony Technical Ceramics (Hungary), BCE Special Ceramics (Germany), Blasch Precision Ceramics (USA), COI Ceramics (USA), Dyson Technical Ceramics (UK), Elan Technology (USA), Ferrotec (Japan), Maruwa (USA), International Syalons (UK), Materion (USA), McDanel Advanced Ceramic Technologies (USA), Momentive Technologies (USA), Oerlikon (Switzerland), Paul Rauschert GmbH & Co. (Germany), Ortech Advanced Ceramics (USA), Superior Technical Ceramics (USA), Techno Cera Industries (India).

1.6.1 Company Evaluation Matrix

This section provides an overview of the company evaluation scenario in the advanced ceramics market. The company evaluation has been carried out based on the outcome of the qualitative and quantitative analyses of various factors such as the product portfolios, technological innovations, market presence, revenues of companies, and opinions of primary respondents (Figure 7). The companies mapped have been categorized into **star**, **emerging leaders**, **pervasive** and **participant** companies.

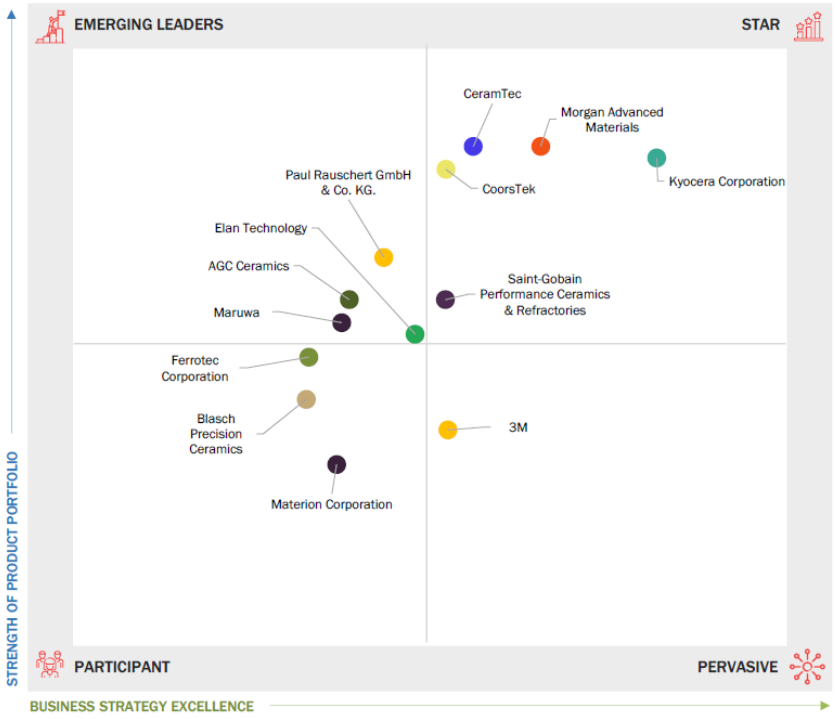
Star companies are leading players that undertake more strategic activities in the market. Kyocera Corporation, CeramTec, CoorsTek, Saint-Gobain Performance Ceramics & Refractories, and Morgan Advanced Materials are recognized as the stars in this market. They have a strong product portfolio and adopt robust business strategies to achieve continued growth.

Paul Rauschert GmbH & Co. KG, Elan Technology, AGC Ceramics, and Maruwa are identified as **emerging leaders** in the advanced ceramics market. These companies have a strong product portfolio and geographical presence. They have the potential to strengthen their business strategies to compete with other key market players.

Pervasive companies are established vendors with strong business strategies. However, they have a weak product portfolio. They generally focus on a specific type of technology related to a specific product. These companies provide comprehensive technical support to their customers and have a strong geographical presence. 3M is recognized as a pervasive player in the advanced ceramics market.

Participants have focused product portfolios. However, they do not have strong strategies for overall business growth compared to the stars. Ferrotec Corporation, Blasch Precision Ceramics, and Materion Corporation are recognized as participants in the advanced ceramics market.

Figure 7. Advanced Ceramics Market: Company Evaluation Matrix



1.6.2 SMEs Evaluation Matrix

This section provides an overview of the **small and medium enterprises** evaluation scenario in the advanced ceramics market. The company evaluation has been carried out based on the outcome of the qualitative and quantitative analyses of various factors such as the strength of the product and the business strategy excellence, and the players have been categorized into: **responsive**, **progressive**, **starting block** and **dynamic** companies (Figure 8).

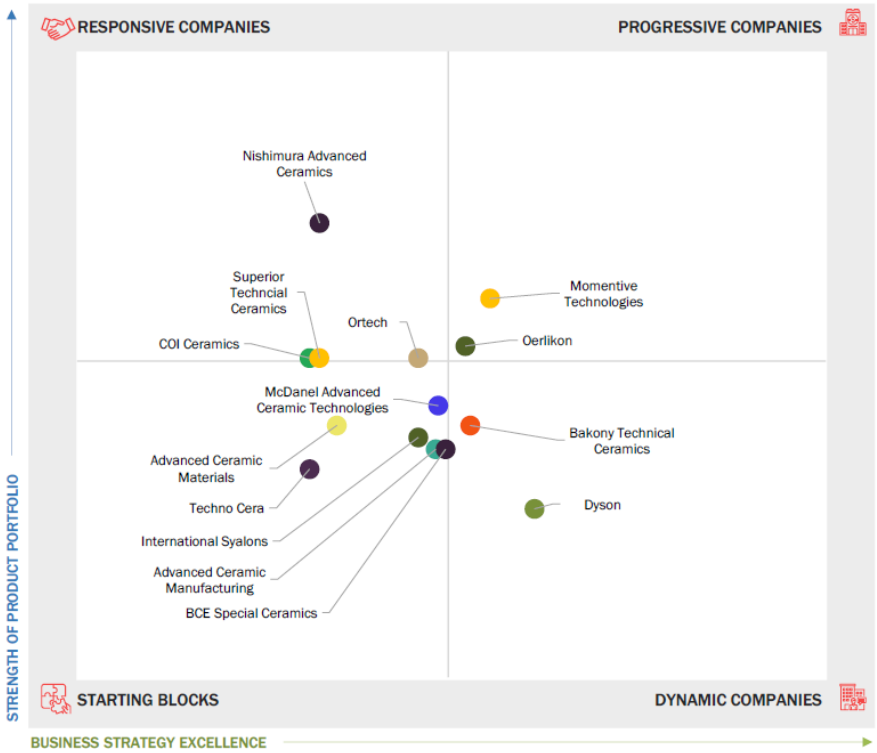
Oerlikon and Momentive Technologies are **progressive** companies. These companies provide a diverse range of products that perform exceedingly well and adopt robust business strategies. These companies have been achieving growth and have attained high partner attractiveness.

Nishimura Advanced Ceramics, Ortech, COI Ceramics, and Superior Technical Ceramics are the **responsive** companies in the market. They offer highly innovative product offerings compared to their competitors. They focus on the constant development of their product/service portfolios and bringing innovations into the market.

BCE Special Ceramics, Advanced Ceramic Materials, International Syalons, Advanced Ceramic Manufacturing, McDanel Advanced Ceramic Technologies, and Techno Cera are **starting block** start-ups with niche offerings and have started gaining their position in the market. They do not exhibit strong business excellence and product excellence compared to other start-ups. However, they are working to capitalize on opportunities for the consolidation of their market space.

Bakony Technical Ceramics and Dyson are recognized as **dynamic** companies in the market. They are new entrants in the market that provide differentiated products. They require some more time before they get significant traction in the market.

Figure 8. Advanced Ceramics Market: Company Evaluation Matrix for SMEs



2 Green Coatings

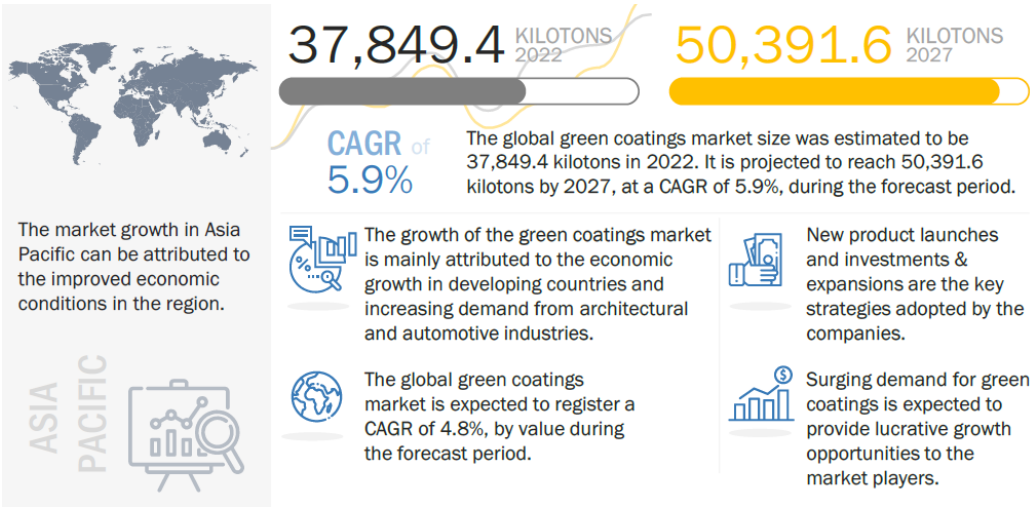
Green coatings are user- and environmentally-friendly coatings that emit nearly no volatile organic compounds (VOCs) during production. These coatings are usually expensive as compared to conventional coatings available in the market but provide higher performance properties than the latter.

The construction industry's demand for environment-friendly and healthier coating systems and the increasing need to improve performance, durability, and aesthetics are the key factors contributing to the growth of the green coatings market. The rising demand for renewable raw materials is expected to create growth opportunities for the market players globally, driving the demand for green coatings during the forecast period. However, developing synthetic technologies that possess little or no toxicity to human health and the environment is a potent challenge.

2.1 Global Market and Market Dynamics

The **global green coating market** is projected to reach USD 156.0 billion by 2027, at a CAGR of 4.8%, between 2022 and 2027 (Figure 9).

Figure 9. Global Green Coating Market, in the Period 2022 – 2027 (Kilotons)



The construction industry's demand for environment-friendly and healthier coating systems and the rising need to improve performance, durability, and aesthetics are the key factors contributing to the **growth** of the green coatings market (Figure 10). The increasing demand for renewable raw materials is expected to create growth **opportunities** for the market players globally, driving the demand for green coatings during the forecast period. However, developing synthetic technologies that possess little or no toxicity to human health and the environment is a potent **challenge**.

The market is expected to witness a shift toward **waterborne coatings** during the forecast period. Waterborne coatings have been a trend in the coatings industry, mostly witnessed in the decorative coatings segment. The recent developments in the European Union (EU) legislation regarding environmental and health considerations have pushed for a wider application of waterborne coatings in the industrial segment. The increasing demand for green products has also created the need for green raw materials for coatings, most notably, waterborne resins. Alkyd coatings found widespread use in several applications until the increasing regulatory VOC restrictions led to a sharp drop in the demand for these traditionally solvent-borne resins. Recently, advancements in waterborne alkyd technologies have enabled the production of virtually zero-VOC alkyd resins with the same performance as that of conventional alkyd resins.

Figure 10. Drivers, Restraints, Opportunities and Challenges in Green Coatings Market

2.2 Technology Analysis

Below are reported some new and innovative technological developments in coatings.

UV-curable coating technologies are considered the future of the Paints & Coatings industry. Since UV-cured coatings are in line with many environmental regulations, the technology is rapidly gaining a foothold over water or solvent-based coating technologies. A few application-related advantages include the absence of lower energy costs, pot-life issues, and faster-curing speed. One-component UV-curable coating positions itself as the fastest-growing coating chemistries available in the present industry. There is also a growing demand for polyaspartic technology in the industry owing to its weather-resistant capabilities.

Corrosion Protection Coatings: Corrosion causes costs of about 3–4% of each country's gross domestic product, and due to climate change, the corrosion rates on infrastructure are likely to increase further in the future. For corrosion protection, hard chrome plating (HCP) is commercially used since the early 20th century. Yet the biggest drawback concerns environmental protection, since toxic and carcinogenic hexavalent chromium Cr6+ is used.

Thermal Spray Coatings: Thermal Spray (TS) is increasingly used from the last 20 years. Nevertheless, the coatings are technologically-constrained with regard to high porosity, low material efficiency and poor bonding to the base material. Therefore, the demand for an environmentally friendly and economical process that produces high-quality coatings is increasingly coming into the research focus.

Eco-friendly coatings: One of the biggest trends today is the increased availability and demand for environmentally-friendly coatings with low or no-**VOC**. This formula protects house owners from various health issues associated with harmful chemicals and contributes to green building and remodeling. The industrial maintenance market is dependent on multiple resin technologies, including epoxy, polyurethane, alkyd, acrylic, polysiloxane, and hybrids combining these various chemistries, based on the type of performance criteria needed. The selection of resin relies on a variety of performance criteria driven by end-use industries, but the overall resistance to corrosion and UV degradation tends to be

the primary driver. **VOC regulations** and the need for longer lifetimes impact the use of alkyds. There is an increase in demand for its waterborne acrylic and alkyd dispersions compared to the demand for urethane hybrids and 2K systems. With VOC reduction as an important trend, high solids, ultra-high solids, and waterborne products are more often used today than in the past.

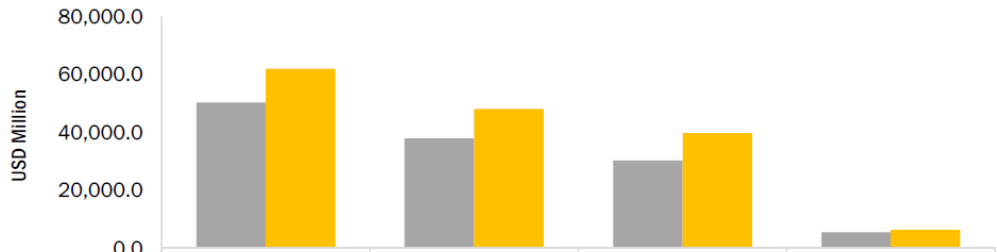
2.3 Market by Technology

The green coatings market is segmented into four coating technology types: **waterborne coatings, powder coatings, high-solids coatings, and radiation-cure coatings** (Figure 11). Environmentally-friendly coating technologies are based on reformulations of conventional organic coatings to reduce their VOC content, or modifications to application or curing techniques that allow for reduced, or in some cases, zero VOC content. They also reduce the generation of paint waste by improving the efficiency of coating transfer to the substrate.

Coating technologies rely on covering a substrate material with an organic film having the desired protective, mechanical, optical, aging, and adhesion properties. Conventional organic coating technologies use diluted solutions of alkyd, polyester, epoxy, polyurethane, acrylic, vinyl, and other resins in volatile organic solvents. In conventional coating formulations, an organic solvent performs the function of promoting desired flow characteristics, thereby facilitating the coating application. Once applied, the solvent evaporates, leaving the resins and pigments behind to polymerize and form the dry coating.

The **waterborne segment** accounted for the largest share in the green coatings market, in 2022. Waterborne coatings have various applications, such as industrial protective coatings, wall primers, sealants, interior flat and semi-gloss wall paints, and interior and exterior trim finishes. The availability of almost all types of resins in the waterborne version is driving the waterborne green coatings market. Low risk of fire, less VOC emission, and easy-to-clean properties drives the demand for waterborne green coatings.

Figure 11. Green Coatings Market, by Technology, in the Period 2022 - 2027



	Waterborne Coatings	Powder Coatings	High-Solids Coatings	Radiation-Cure Coatings
2022	50,179.2	37,855.1	30,204.3	5,370.3
2027	61,979.9	48,103.3	39,663.6	6,223.0
CAGR (2022-2027)	4.3%	4.9%	5.6%	3.0%

In recent years, the market has witnessed a shift toward **waterborne coatings**. Waterborne coatings have been a trend in the coatings industry, mostly witnessed in the decorative coatings segment. The recent developments in the EU legislation regarding environmental and health considerations have pushed for a wider application of waterborne coatings in the industrial segment. The increasing demand for green products has also created the need for green raw materials for coatings, most notably, waterborne resins.

Alkyd coatings found widespread use in several applications until the increasing regulatory VOC restrictions led to a sharp drop in the demand for these traditionally solvent-borne resins. Advancements in waterborne alkyd technologies have enabled the production of virtually zero-VOC alkyd resins with the same performance as that of conventional alkyd resins.

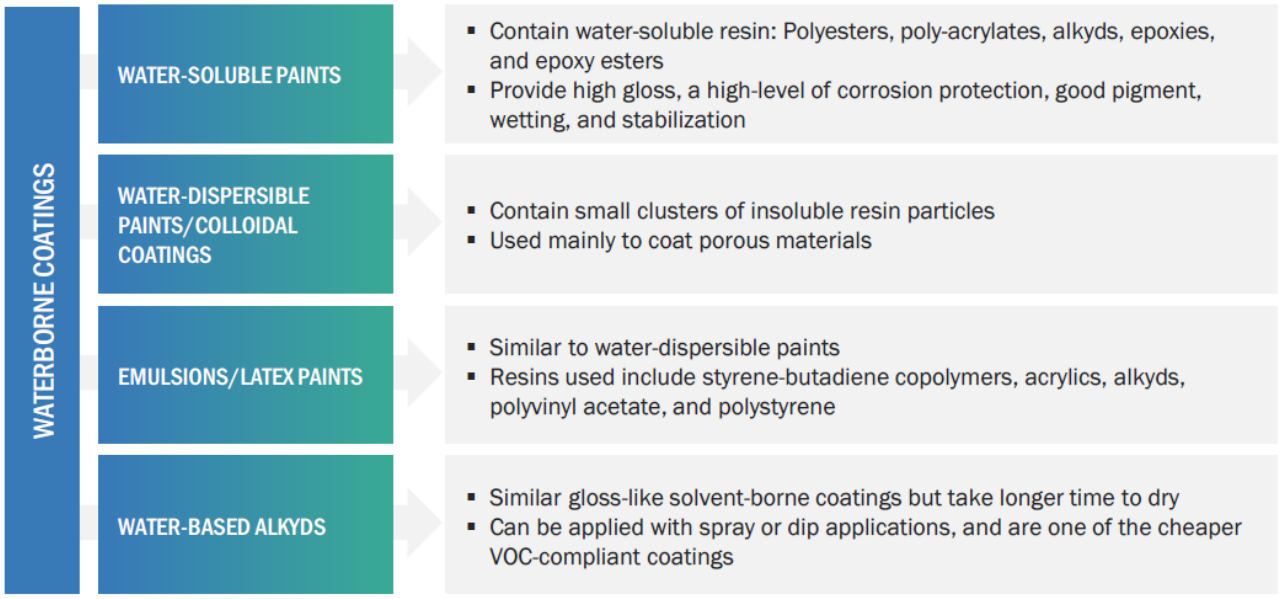
Waterborne coating systems primarily use water as the solvent to disperse the resin. It is an eco-friendly and easy applicable coating that contains up to 80% water with small amounts of other solvents, for instance, glycol ethers, alcohol, and other oxygen-containing solvents that are soluble or miscible with water. Advancement in the waterborne coating performance contributes to its use in a wide range of applications.

Most resins are available in the waterborne version, such as vinyl, acrylic, epoxies, polyester, styrenebutadiene, amine-solubilized, carboxyl-terminated alkyd, and urethanes. Waterborne coatings are classified based on how the resin is fluidized. The three **main types of waterborne coatings** can be considered (Figure 12):

- Water-soluble/water-reducible (solutions);
- Water-dispersible/colloidal (dispersions);
- Emulsions (latex) paints (the most commonly used form);
- Water-based alkyds.

The physical properties and performance depend on the type of resins used within each category.

Figure 12. Types of Waterborne Coatings



Alkyd, acrylic latex, vinyl, epoxy, acrylic/epoxy hybrid, styrene-butadiene, amine-solubilized, polyurethane, polyester, and other resins, such as polystyrene and polyvinyl acetate are used in the formulation of waterborne coatings.

- Alkyd coatings are commonly used for general finishing applications.
- Acrylic resins are also used frequently for finishing applications.
- Water-soluble epoxy esters and alkyd dominate the automotive components area.
- Water-reducible epoxies are often used as primers that can be top-coated with most other coatings.
- Water-reducible epoxy primers are frequently top-coated with polyurethane when good corrosion resistance and high-performance properties are required.

Water-based coatings are primarily used as architectural coatings and industrial finish coatings because they are easy to apply and adhere to damp surfaces, dry rapidly, and lack solvent odor. Most architectural coatings are water-based; water-based architectural coatings include:

- Wall primers and sealants
- Interior flat and semi-gloss wall paints
- Interior and exterior trim finishes
- Exterior house paints
- Industrial protective coatings

Water-based coatings have not been fully accepted in the industrial sector. However, stringent regulations are leading to the increasing demand for primer and topcoat industrial finishes.

In addition to **reducing VOC emissions** during applications, waterborne coatings reduce the risk of fire, are easy to clean (creating less hazardous residues), and result in fewer workers being exposed to organic vapors. However, special equipment might be required for the application, as water in the formulation can cause corrosion. For example, water-based paints can corrode plain steel or attack aluminum. Humidity must also be controlled to achieve the best film formation.

The main **drivers and restraints** in the waterborne coatings market segment are reported in Figure 14.

Figure 13. Drivers and Restraints in Waterborne Coatings Market

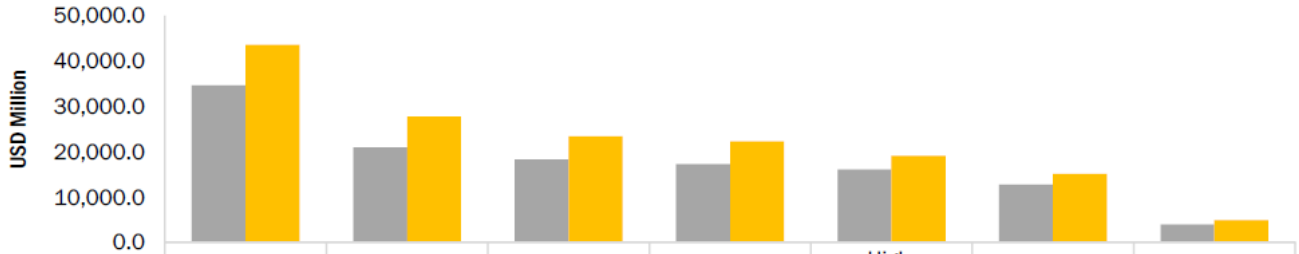
2.4 Market by Application

The green coatings market is developing and has different applications, including **architectural, automotive, industrial, high performance, wood, packaging, and product finishes** (Figure 14). These include decorative paints, exterior, and interior house paints, sealers, primers, stains, and varnishes. Green coatings are now getting recognized in the automotive segment, wherein commercial vehicles, and marine vehicles are being coated using green paints and coatings.

The demand for green coatings in woodworking and packaging applications is expected to witness a boom during the forecasted period due to the increased customer awareness about their health and environment and increasing regulations in the food & beverage industry.

The **architectural** application segment accounted for the largest market value of the overall green coatings market in 2022. The large market size is owing to the increasing residential construction and improved home remodeling practices.

Figure 14. Green Coatings Market by Application, in the Period 2022 - 2027



	Architectural Coatings	Automotive Coatings	Industrial Coatings	Wood Coatings	High-Performance Coatings	Product Finishes	Packaging Coatings
2022	34,577.3	20,944.3	18,280.5	17,183.6	16,050.4	12,680.4	3,892.3
2027	43,523.5	27,756.4	23,382.6	22,199.2	19,078.1	15,147.3	4,882.6
CAGR (2022-2027)	4.7%	5.8%	5.0%	5.3%	3.5%	3.6%	4.6%

Architectural Coating

Architectural paints & coatings, also known as decorative paints & coatings or building paints, are applied to the interior and exterior walls of all types of residential, commercial, industrial, and institutional buildings. Apart from their decorative features, architectural paints & coatings also possess some protective features. For example, exterior architectural paints & coatings protect a building from extreme rain, sunlight, and wind. An increase in environmental awareness among consumers and manufacturers has led to technological innovations in the coating industry to provide quality products that are biodegradable and environmentally friendly, affordable, of high quality, possess value-added features, and meet global trends.

The growing safety and health standards have raised the demand for green coatings in the segment. Architectural coatings possess various favorable properties, such as high corrosion and temperature resistance, increased durability of end-products, and low fire-hazards risk; and thus, are preferred for use in various commercial and industrial applications. With the growing population and increasing migration of population to the developed nations, the construction industry is estimated to develop substantially in the near future.

There is an interest in alternative of raw materials, the quality, performance, and cost of architectural coatings, where green coatings come into picture. Different development activities have led to various green building blocks becoming available for use in powder coating resins which, with careful formulation, can deliver the required performance. There is also a drive for green solutions with some paint companies which are specializing in these solutions.

Industrial Coating

The general **industrial coating** market has diverse end users and is linked to multiple industries. The drivers of the general industrial coatings market are population growth, improved standard of living, infrastructural growth, and recovery and growth in the construction industry. According to World Atlas, in 2016, China had the world's largest industrial output, worth USD 4.56 trillion.

The stable retail sales, rapidly growing export market in the country, and strong factory output have helped the country achieve the top position in the global market. China was followed by the US, Japan, Germany, India, South Korea, and the UK.

High-Performance Coating

High-performance coatings are typically used in environments where structures and surfaces require enhanced abrasion and chemical resistance and added durability. They are designed to meet the requirements of their primary function, which is to protect the surface that they are coating. In some cases, the coatings may protect surfaces from excessive use and abuse—for instance, flooring in an automotive shop garage or on the steps, railings, and in hallways of a large sports arena. In other cases, they may protect surfaces from corrosion caused by simple exposure to the elements or aggressive environments that may include corrosive chemicals. Regardless of the case, high-performance coatings enhance the overall durability of whatever they coat. This added protection is provided to ensure the safety of not only the people who make the structures but also the immediate physical environment surrounding the structures. Nowadays, manufacturers as well as painters have gained knowledge toward the health and environment and started opting for greener options in high-performance coatings.

High-performance coatings have a secondary function, which is to enhance the aesthetics of a structure or space. Coatings may be used in many ways: to downplay a space (e.g., a neutral tan or grey), to highlight a key feature (e.g., a bright red or yellow fire hydrant or holding tanks colored to indicate different contents), or to beautify or brand a space (e.g., high school lockers, or a transit system bus or subway car). Whatever the case, high-performance coatings can be seen everywhere.

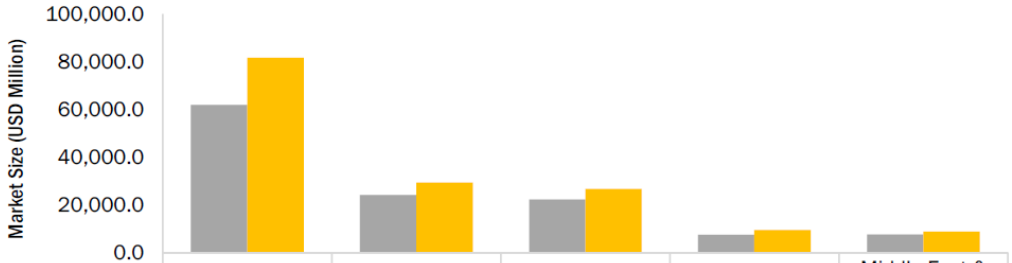
2.5 Market by Region

The green coatings market is divided into five major regions, namely: **Asia Pacific, North America, Europe, the Middle East & Africa, and South America** (Figure 15). Asia Pacific is the largest market, followed by Europe and North America. It is the fastest-growing market and is projected to register a CAGR of 6.5% during the forecast period, in terms of volume. This is due to high economic growth, improving the standard of living, an increase in disposable income, and a strong surge in the building & construction, appliances, and automotive industries.

Various manufacturers are shifting their manufacturing units to Asia Pacific because of the availability of raw materials, low labor cost, and favorable government policies in emerging markets, such as India, Thailand, and Singapore. Rising standards for environmental protection, increasing construction activities, growing urbanization, and housing construction expenditure are the important drivers of the global green coatings market.

The market in most of the developed countries, including the US, Germany, the UK, France, and Japan, are witnessing steady growth in comparison to developing countries as it has reached maturity in these countries.

Figure 15. Green Coatings Market, by Region, in the Period 2022 - 2027



	Asia Pacific	Europe	North America	South America	Middle East & Africa
2022	61,994.8	24,188.3	22,246.0	7,546.3	7,633.5
2027	81,686.0	29,319.3	26,694.3	9,474.4	8,795.7
CAGR (2022-2027)	5.7%	3.9%	3.7%	4.7%	2.9%

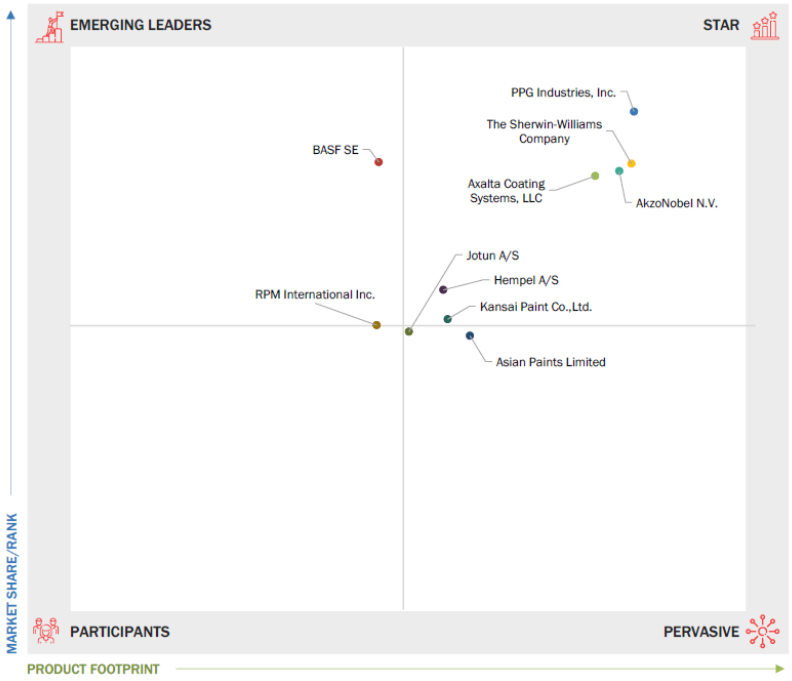
2.6 Competitive Landscape

The **top five manufacturers** in the green coating market can be considered: **PPG Industries, Inc., Axalta Coating Systems, LLC, AkzoNobel N.V., BASF SE, and The Sherwin-Williams Company** accounting for 45-50% of the total market, while the rest is secured by SMEs.

2.6.1 Company Evaluation Matrix

The company matrix analysis provides information about the main players that offer green coatings. This analysis provides information about the performance of green coatings manufacturers in terms of market share/rank and product footprint. The emerging companies are classified into: **emerging leaders**, **star**, **participant** and **pervasive** companies (Figure 16).

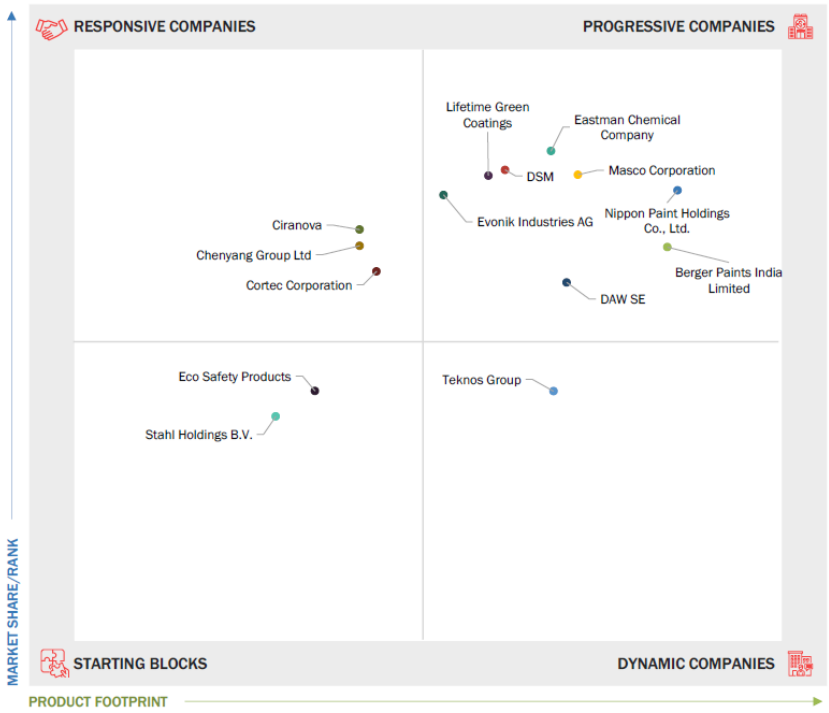
Figure 16. Green Coatings Market: Company Evaluation Quadrant Matrix



2.6.2 SMEs Evaluation Matrix

The **Small and Medium-sized Enterprises** (SME) Matrix analysis provides information about the emerging players that offer green coatings. This analysis provides information about the performance of green coatings manufacturers in terms of market share/rank and product footprint. The emerging companies are classified into four categories: **responsive**, **progressive**, **starting block** and **dynamic** companies (Figure 18).

Figure 17. Green Coatings Market: SMEs Competitive Leadership Mapping



In the company section of the report consulted **no references about photocatalytic coating in the visible light** have been found. For this reason, a general **overview of the main players** active in the market is reported in Table 2.

Table 2. Players active in the Green Coating Market

Company	Location	Description	Website
AkzoNobel N.V.	The Netherlands	AkzoNobel N.V. is a chemical company that specializes in coatings, adhesives, specialty materials, and bonding materials. AkzoNobel N.V. is one of the leading coating manufacturers and offers various coatings, such as wood coatings, powder coatings, protective coatings and coil coatings	https://www.akzonobel.com/
Axalta Coating Systems	USA	The company provides green coatings i.e. waterborne or powder coatings through the Performance Coating segment	https://www.axalta.com/corporate/en_US.html
BASF SE	Germany	BASF SE is one of the market leaders in the paints and coatings industry	https://www.basf.com/it/it.html

Company	Location	Description	Website
Ciranova	Belgium	Specializes in the development and manufacturing of finishing products for furniture, parquet, and other wooden objects. The company is also a major supplier of wood preservative to the wood processing industry	https://www.ciranova.eu/en
Cortec Corporation	USA	Cortec Corporation is a pioneer in the application and distribution of VCI (Vapor Corrosion Inhibitor) technology. The company also provides green coatings with low VOC emissions	https://www.cortecvci.com/
Daw SE	Germany	Developer, producer, and seller of innovative coatings systems	https://www.daw.de/en/home
Evonik Industries	Germany	The company develops the product Visiomer: Low-VOC Coatings	https://corporate.evonik.com/en
Hempel A/S	Denmark	Manufacturer and developer of coating solutions for marine, protective, yacht, container, decorative, and industrial segments	https://www.hempel.com/
Jotun A/S	Norway	Manufacturer of paints and performance coatings. The company operates through four segments: Marine Coatings, Protective Coatings, Powder Coatings, and Decorative Paints	https://www.jotun.com/it-en
Lifetime Green Coatings	USA	Provider of natural and highly durable floor coatings. The product portfolio includes garage floor coatings and commercial coatings	https://lifetimegreencoatings.com/
PPG Industries	USA	The company specializes in manufacturing and distributing coating, paints, and specialty material.	https://www.ppg.com/en-US
RPM International	USA	Manufacturer of sealants, building materials, coatings, and other related services	https://www.rpminc.com/
Stahl Holdings	The Netherlands	The company provides green coatings or low VOC coatings, such as Relca and Picassian	https://www.stahl.com/
The Sherwin-Williams Company	USA	Diversified coating company that supplies powder coating & liquid technology. The company is one of the market leaders in industrial and architectural coatings with a wide portfolio	https://www.sherwin-williams.com/

3 Conclusions

Advanced ceramics are highly developed inorganic and non-metallic ceramics with excellent high-temperature stability, hardness, low thermal expansion, and various electrical properties ranging from insulation to dielectric properties to high conductivity. Advanced ceramics are mainly used in electrical & electronics, transportation, medical, defense & security, and environmental, among other end-use industries. The **advanced ceramics market** is projected to reach USD 13.9 billion by 2027, at a CAGR of 5.1% during the forecast period.

Kyocera Corporation (Japan), CeramTec (US), CoorsTek (US), Saint-Gobain Performance Ceramics & Refractories (US), Morgan Advanced Materials (UK), and 3M (US) are some of the prominent players in the market.

Green coatings are user- and environmentally-friendly coatings that emit nearly no volatile organic compounds (VOCs) during production. These coatings are usually expensive as compared to conventional coatings available in the market but provide higher performance properties than the latter. The **global green coatings market** is projected to reach USD 156.0 billion by 2027, at a CAGR of 4.8%, between 2022 and 2027.

The construction industry's demand for environment-friendly and healthier coating systems and the rising need to improve performance, durability, and aesthetics are the key factors contributing to the growth of the green coatings

market. The increasing demand for renewable raw materials is expected to create growth opportunities for the market players globally, driving the demand for green coatings during the forecast period. However, developing synthetic technologies that possess little or no toxicity to human health and the environment is a potent challenge.

Green coatings are widely used because of their eco-friendliness and low VOC emissions. Asia Pacific is the biggest market, and the per capita consumption in the region is rising significantly.

The market is expected to witness a shift toward **waterborne coatings** during the forecast period 2022 - 2027. Waterborne coatings have been a trend in the coatings industry, mostly witnessed in the decorative coatings segment. The recent developments in the European Union (EU) legislation regarding environmental and health considerations have pushed for a wider application of waterborne coatings in the industrial segment. The increasing demand for green products has also created the need for green raw materials for coatings, most notably, waterborne resins. Alkyd coatings found widespread use in several applications until the increasing regulatory VOC restrictions led to a sharp drop in the demand for these traditionally solvent-borne resins. Recently, advancements in waterborne alkyd technologies have enabled the production of virtually zero-VOC alkyd resins with the same performance as that of conventional alkyd resins.

Green coatings are widely used in the **architectural application**. These are also used for transportation, woodworking, and packaging applications. This architectural application is the largest segment of the green coatings market and is estimated to account for the same in 2027 in terms of value.

4 Sources

MarketsandMarkets Knowledge Store - Multisectoral database that collects market research reports in various technological fields and designed to process some information interactively. More than 1,200 market reports are published each year (https://www.mnmks.com/)[1]. The information presented are contained in the Reports:

- "Advanced Ceramics Market – Global Forecast to 2027", July 2022;
- "Green Coatings Market – Global Forecast to 2027", October 2022.

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