



THE **POWERHOUSE**
OF **ADVANCED MATERIALS**

CERAMICS

How Technical Ceramics Outperform
Metals and Polymers

COORST[®]TEK



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INTRODUCTION

Information-age technology has advanced at an extraordinarily fast pace. From raw material production to end use, the requirements on industrial and commercial technologies and equipment have developed equally rapidly. Design engineers are consistently looking for ways to improve performance in systems where strength, extreme temperatures, electrical insulation, chemical resistance, and other demands are persistent factors.

While there have been major advancements in metal and polymer technologies, many of these materials still can't meet the stringent levels of performance expected from today's consumers, OEMs, and virtually every other segment of the supply chain.

ENTER TECHNICAL CERAMICS.

Ceramics can survive extreme temperature and corrosive environments that destroy metals and plastics. They are extremely hard and stiff, offering an overall longer life. Many ceramics offer outstanding performance as an electronic substrate since they can be both electrically insulative and thermally conductive at the same time, which is not possible with metals (electrically conductive) or plastics (thermally insulative). Ceramics can also be engineered to be as strong as metals, and outperform metals in many mechanically demanding applications.



“ WE ALL INTERACT WITH TECHNICAL CERAMICS ON A DAILY BASIS. ”

By definition, a ceramic is any non-metallic, inorganic solid. Items such as glass, cement, and earthenware fall under this category, but technical ceramics live in a category of their own. Developed over the last century by manufacturers such as CoorsTek, these highly engineered materials include compounds such as oxides, carbides, silicates, nitrides, and several specialty categories such as translucent or transparent materials and ceramic membranes.

Ceramic material compounds can be manipulated to meet application-specific requirements. There is no one particular property that makes technical ceramics worthy of being labeled the “powerhouse of advanced materials.” It is the combination of properties—along with the versatility and range of materials that set them apart.

And it's not just the basic material properties that matter. Manufacturability is key. There are numerous ways ceramics can be formed, fired, and finished to meet the needs of a given application. Ceramic manufacturing has advanced to enable solutions ranging from micro-molded components with fantastically tight tolerances to ultra-large components for metrology equipment.

Without knowing it, we all interact with technical ceramics on a daily basis. These extraordinary high-performance materials are literally a key component to many modern conveniences. Advanced ceramics can be found in your car, your dentist's drill, and the armor that protects our soldiers on the battlefield.

WHY COORSTEK?

For over a century, CoorsTek has been at the forefront of developing advanced ceramic materials. CoorsTek has grown into a multinational company with over 30 facilities across three continents. With over 400 advanced ceramic formulations, unparalleled ceramics expertise, and a dedication and commitment to researching and developing innovative

products, CoorsTek partners with our customers to make the world measurably better.

Ready to learn more? Read on to discover the mechanical, thermal, chemical, and electrical properties of technical ceramics, and how these materials outperform metals and polymers.

A POWERHOUSE MANUFACTURER

>400

Advanced Ceramic Formulations

61/118

Utilizing Over 1/2 of Earth's Known Elements

30+

Manufacturing Sites Worldwide

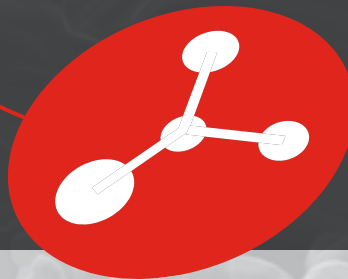


ABOUT COORSTEK

Since 1910, industry leaders have turned to CoorsTek for solutions to the world's most perplexing engineering and manufacturing challenges. We meet these challenges with unsurpassed expertise in ceramic materials engineering, broad research & development capabilities, operational excellence, and a commitment to building reliable, collaborative relationships.

At CoorsTek, our success is built upon a foundation of integrity. We continue to make substantial investments in developing advanced ceramic materials and processes for critical-to-function applications. Our highly qualified experts and dedicated staff work tirelessly to ensure consistent delivery of superior quality products and services.

PHYSICAL PROPERTIES



High Temperature Durability

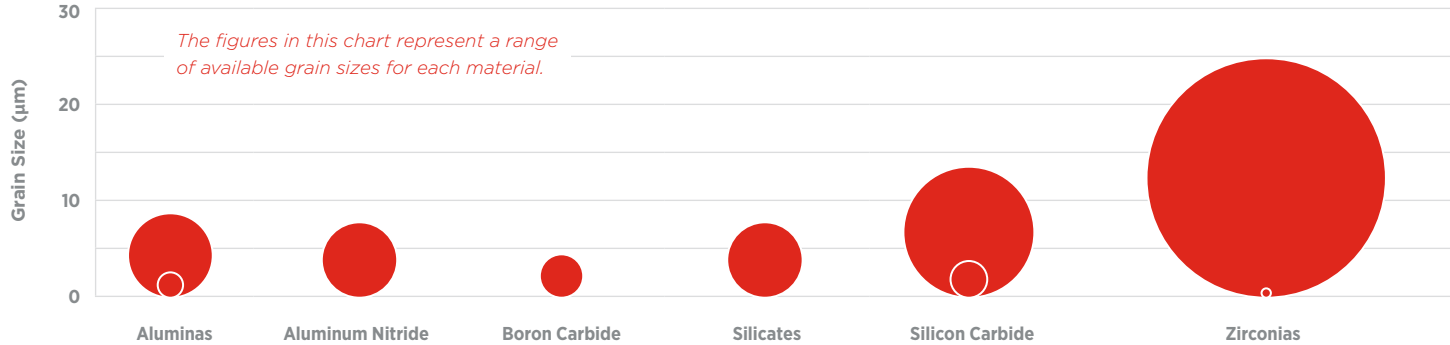
Many applications require reliable, high performance properties at elevated temperatures. At 1000°C (over 1800 °F) most metals will not even support their own weight and are permanently weakened by high temperature oxidation reactions. Advanced ceramics, on the other hand, can retain the majority of their room temperature strength, rigidity, and environmental resistance—essentially reverting to their original properties and dimensions when returned to ambient temperatures. Learn more about the Thermal Properties of technical ceramics on page 33.

Water Absorption and Gas Permeability (%)

Technical ceramics generally provide sealed performance with no measurable water absorption or gas permeability. However, CoorsTek can engineer application-specific materials which provide controlled levels of porosity or permeability to enable such solutions as fluid micro- or ultra-filtration, electrochemical conversion through proton conducting ceramic materials, synthetic bone substitute, 3D tissue culture growth, and more.

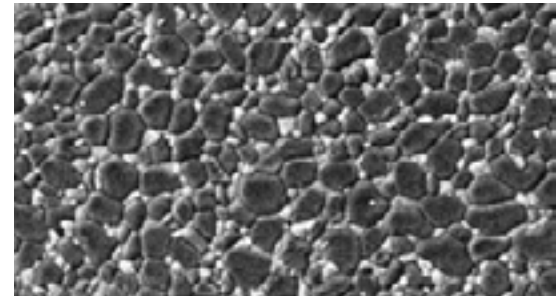
Color

CoorsTek technical ceramics come in a variety of colors depending on the type of material you choose. CoorsTek can engineer its ceramics to the color that is best suited for your application.



Grain Size (µm)

Although grain size is not a direct measure of performance, some material properties can vary with grain size. Generally, strength increases with decreasing grain size in a ceramic material's microstructure. Additionally, finer grain sizes may enable finer surface finishes, leading to improved performance in tribological or optical applications. CoorsTek engineers both raw materials and processing to control grain size and its resultant properties. Often we will distinguish and specify grain sizes, even for the same material, to correlate with expected hardness.



Scanning Electron Microscope (SEM) photo showing grain size



MECHANICAL PROPERTIES

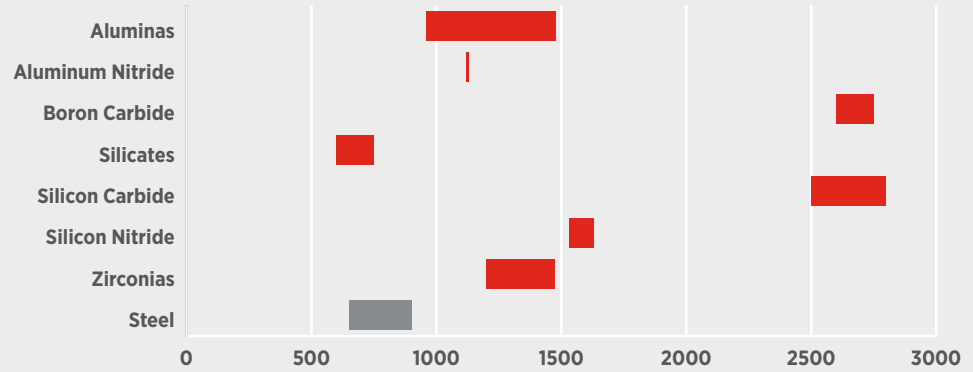
The most popular “superpowers” of CoorsTek technical ceramics are their mechanical properties. Advanced ceramic materials are engineered to outperform metals and polymers. Their high-performance mechanical strengths include hardness, wear resistance, rigidity, density, fracture toughness, and other application-specific mechanical requirements that often exceed steel, alloys, and plastics.

“ADVANCED CERAMIC MATERIALS ARE ENGINEERED TO OUTPERFORM METALS AND POLYMERS.”



HARDNESS

kg/mm²



CoorsTek technical ceramics are known for their extreme hardness. Our materials are harder than every metal and naturally-occurring material known, except diamond. That’s why CoorsTek ceramics excel in mechanical wear and abrasion. It’s not uncommon for ceramic components to extend wear life 10 to 100 times longer than conventional metals.

The harder a material, the more resistant it is to localized permanent deformation from indentation or abrasion. We observe “macro” hardness on surfaces we see, but it is generally associated with strong intermolecular bonds

at the “micro” level. Hardness is measured by quantifying the resistance to a microindentation. For hard materials like ceramics, scales like Knoop, Vickers, and Rockwell are commonly used to compare materials.

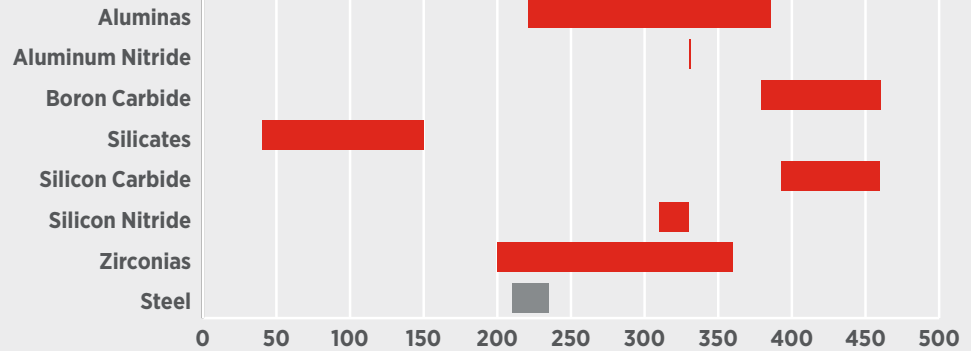


Silicon carbide paddle and wafer boat for semiconductor manufacturing



ELASTIC MODULUS

GPa



Advanced ceramics are highly rigid and do not bend easily. This means they provide exceptionally stiff, stable dimensional performance. In fact, CoorsTek ceramics deliver some of the highest stiffness-to-weight ratios available for use in demanding, lightweight applications. Metals frequently warp, creep, or distort during machining or thermal cycling. Polymers tend to flow under pressure and over time.

A material's rigidity is a measure of its resistance to elastic (non-permanent) deformation. Stiffer materials

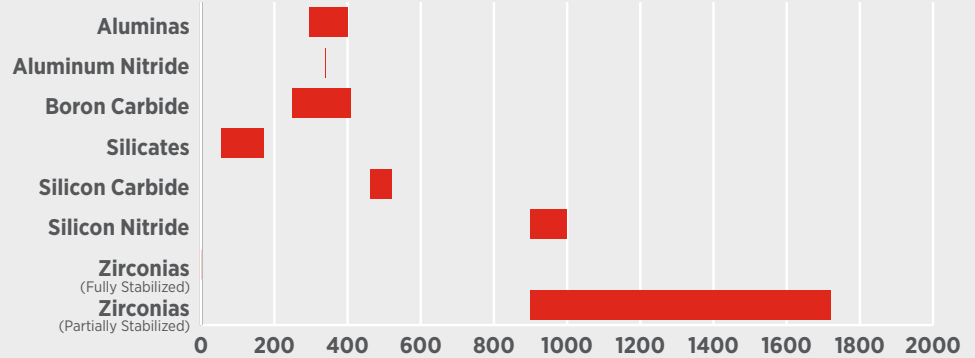
have a higher elastic modulus (E), also known as Young's modulus. Another measure of stiffness is Shear Modulus (G or μ), or the deformation of shape at constant volume.

Unlike metals and plastics, ceramics are perfectly elastic, meaning there are no mechanisms of plastic deformation. They deflect less under high load situations and will spring back to their original dimensions when unloaded.



FLEXURAL STRENGTH

MPa



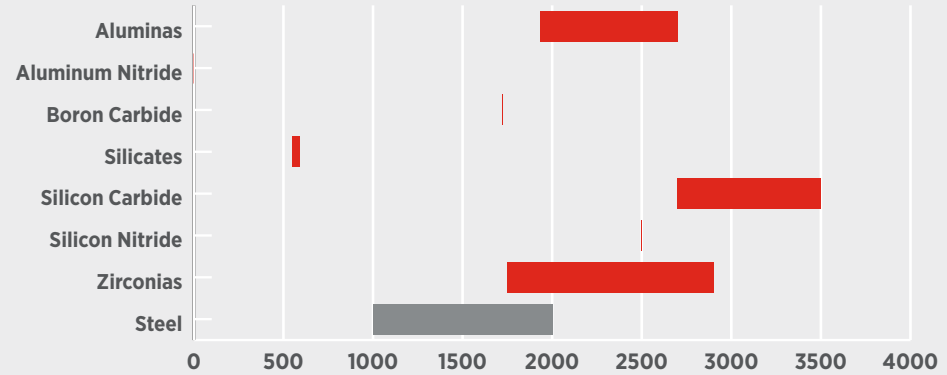
Because ceramics are stiff and unyielding, they are perfectly elastic to the point of failure. This permits ceramics to be easily characterized for strength using a bending, or flexural test, whereas metals and plastics need to be characterized using tensile testing. Yielding of metal and plastic materials in a flexural test results in redistribution of stresses, confounding test results. Because flexural testing is significantly more economical than tensile testing, flexural testing is commonly used for ceramic materials strength characterization.

In flexure testing, one of the faces will be in tension and the opposite side will be in compression. Because monolithic ceramics are substantially stronger in compression than tension, the failure will always initiate from the tensile face of the ceramic. Although tensile testing is rarely performed on monolithic ceramics, tensile strength can be estimated from flexural test results, and materials which are stronger in flexural testing will also generally be stronger in tensile testing.



COMPRESSIVE STRENGTH

MPa



Compressive strength is a measure of a material's ability to resist compression, a key value for structural design. Technical ceramics have exceptional compressive strength, so it is preferable to design assemblies in such a way that ceramic parts are in compression.

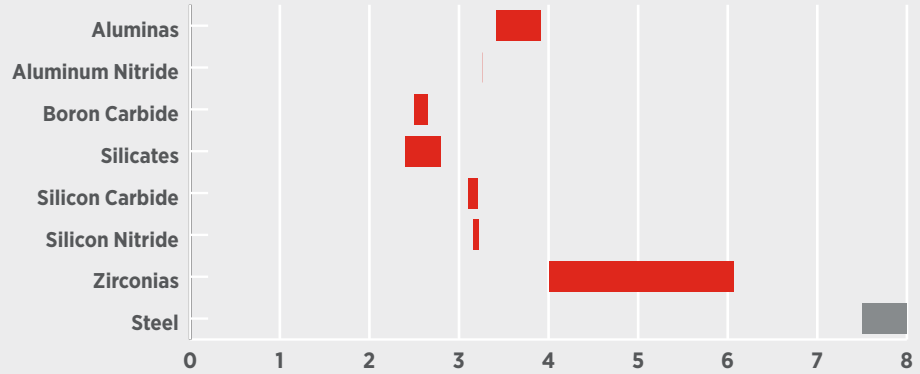


Cerbec® Silicon Nitride balls



DENSITY

g/cm³

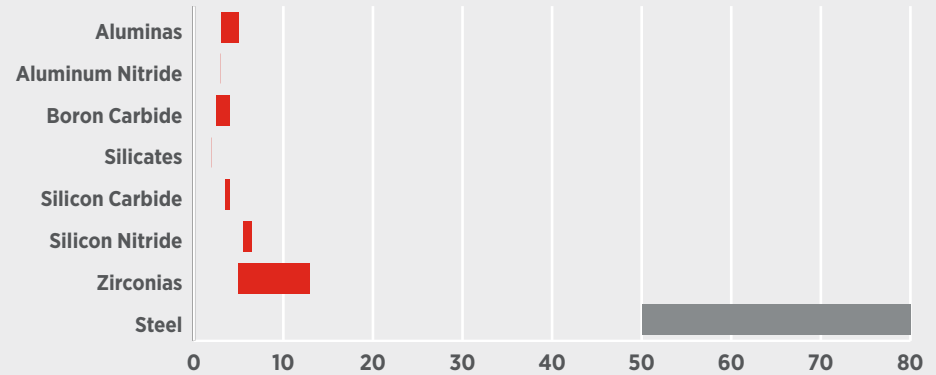


CoorsTek technical ceramics are significantly lighter than high-strength metals, typically weighing 50 percent of metal parts with the same volume. Many aerospace, automotive, machinery, and armor applications benefit from lower mass. Lightweighting vehicles improves performance, increases efficiency, and reduces energy costs over the lifetime of the vehicle. Reducing inertia in rotating equipment and machinery tools can dramatically reduce centrifugal forces, enabling higher speeds and longer life. CoorsTek advanced ceramics enable light weight body and vehicle armor, combining the light weight and superior hardness of ceramic materials to protect the lives of those who protect us.



FRACTURE TOUGHNESS

MPa M^{1/2}



Some advanced ceramics are engineered to enhance toughness – the ability of a material to resist fracture. Fracture toughness measures the amount of energy a material can absorb before fracturing. Toughness tends to be larger for ductile materials like polymers and most metals, because both elastic (reversible) and plastic (irreversible) deformations allow materials to absorb large amounts of energy.

Ceramics are sometimes unfairly thought of collectively as brittle materials. In everyday usage we think of “brittleness” as something that fractures easily; however,

this is really a combination of both brittleness and a lack of strength.

Materials like technical ceramics can be both brittle and strong. We develop advanced technical ceramics like zirconias, silicon nitrides, and ceramic matrix composites (CMCs) to improve fracture toughness for severe mechanical service environments. The design of CoorsTek Dura-Z™ zirconia, for example, incorporates a crack-arresting mechanism at the microscopic level which increases impact resistance, fatigue resistance, and endurance limits.



Example Applications Requiring High Performance Mechanical Properties

Our ceramics are frequently used in the following industries and applications:



AUTOMOTIVE

- Fuel injection systems
- Automotive electronics
- Pressure and temperature systems
- Automotive HVAC



AEROSPACE
& DEFENSE

- Space mirrors
- Control systems
- Jet propulsion
- Ballistic armor



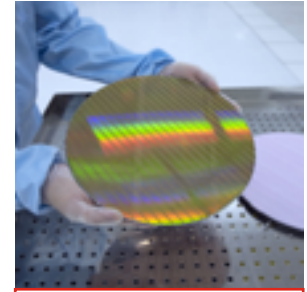
ENERGY

- Pump bushings
- Gas seal faces
- Ball valve assemblies
- Frac plugs
- Bearings



MACHINERY
& EQUIPMENT

- Bearings
- Bushings
- Fluid handling
- Roller guides
- Forming tools



SEMICONDUCTOR

- Semiconductor processing components
- Wafer chucks
- Chemical-mechanical polishing (CMP) plates
- Lithography stages



MECHANICAL PERFORMANCE



Aluminas | Wear Resistance

Aluminum oxides (Al_2O_3) are known for their versatile combination of mechanical properties including good hardness, wear resistance, and flexural strength. CoorsTek aluminas demonstrate excellent useful life-to-cost performance across a variety of industrial applications, and are available in a range of purity levels and formulations. Generally the higher the purity, the more robust the chemical and electrical performance.



Silicon Carbides | Hardness

Silicon carbides (SiC) are strong mechanical performers with exceptional hardness and rigidity at low density, valuable in applications which require a combination of light weight and mechanical strength. Some CoorsTek silicon carbides have extreme stiffness-to-weight ratios and are used when dimensional stability is critical.



Silicon Nitrides | Flexural Strength

Silicon nitrides (Si_3N_4) are distinguished by their high strength and toughness combined with superior thermal properties, which provide outstanding performance in severe thermo-mechanical operating environments. Silicon nitrides also offer excellent resistance to rolling contact fatigue, which combines with other material property advantages to make silicon nitride a material of choice for bearing applications.



Zirconias | Flexural Strength and Fracture Toughness

Zirconium oxides (ZrO_2) are durable ceramics with exceptional strength and fracture toughness. CoorsTek zirconias exhibit remarkable mechanical durability and impact resistance. Additionally, CoorsTek Dura-Z® offers superior cyclic fatigue resistance, exceeding the fatigue limits of high strength steels.

Pictured above (top to bottom): Alumina ring, Silicon Carbide wafer chuck, Cerbec® Silicon Nitride ball, Zirconia ball valve





ELECTRICAL PROPERTIES

“ENGINEERED CERAMICS EXHIBIT SUPERIOR DIELECTRIC ATTRIBUTES, COMPARED TO PLASTICS OR METALS.”

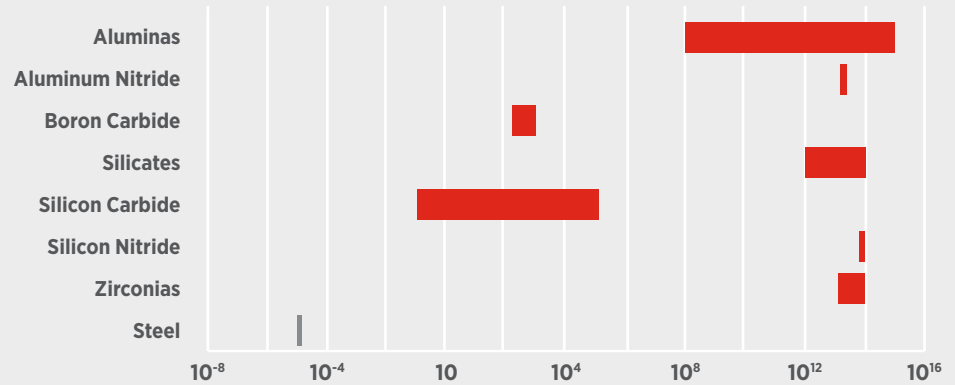
Engineered ceramics exhibit superior dielectric attributes when compared to other materials, like plastics or metals. The composition of engineered ceramics makes them highly effective electric insulators, which is how they are most commonly used – though ceramics can also be carefully processed and specified for conductivity to fit the application.

Most engineered ceramics have low dielectric loss, meaning the material can maintain high levels of electromagnetic energy with very little, if any, measurable dissipation of that energy. Although polymers, rubber, and glass can be excellent electrical insulators, they do not exhibit the same mechanical, thermal, and chemical properties of technical ceramics, making ceramics ideal for high strength, high heat, or highly corrosive electronic environments.



VOLUME RESISTIVITY

Ωcm



Volume (Electrical) Resistivity, is a measure of how well a material resists the flow of electrical current in a specified (dc) field. A material with high volume resistivity is an electrical insulator, and a material with low or no volume resistivity designates as an electrical conductor. The inverse measurement is electrical conductivity, which is the measurement of a material's ability to conduct an electric current instead of resist it.

Resistivity is dependent on a material's temperature.

Engineered ceramics tend to have high volume resistivity even at high temperatures, although some ceramic materials are engineered purposefully to allow some charge through (typically referred to as electrostatic discharge safe, or ESD safe ceramics), lengthening the life of the material or protecting sensitive objects it contacts.



DIELECTRIC STRENGTH

ac-kV/mm



There is only so much electrical voltage a material can withstand before it breaks down. This is quantified and measured by the material's dielectric strength. Dielectric strength is the maximum voltage that a dielectric (insulator) material can withstand without losing its insulating properties. It is defined as the breakdown voltage divided by the thickness of the sample. Dielectric strength is highly dependent on the sample thickness. Therefore, thickness should always be reported with dielectric strength.

Engineered ceramics often have high dielectric strength, adding to the list of dielectric properties that make ceramics superior insulating materials for electrical applications.

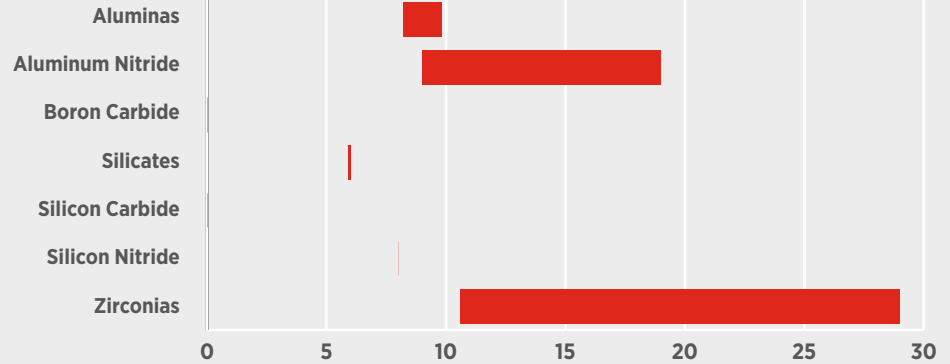


Aluminum nitride cooling box "heat exchanger" for rail vehicles



DIELECTRIC CONSTANT

25°C



Dielectric constant is the ratio of permittivity (or ability to store electrical charge) of a material to the permittivity of free space—understood as the amount of charge stored in a substance by an applied voltage relative to charge storage of the same dimension in a vacuum of the same dimension. The dielectric constant of ceramic materials vary widely, though many formulations offer a low constant. Having a low dielectric constant may be advantageous for use in semiconductor manufacturing and radio frequency (RF) transmitter applications.

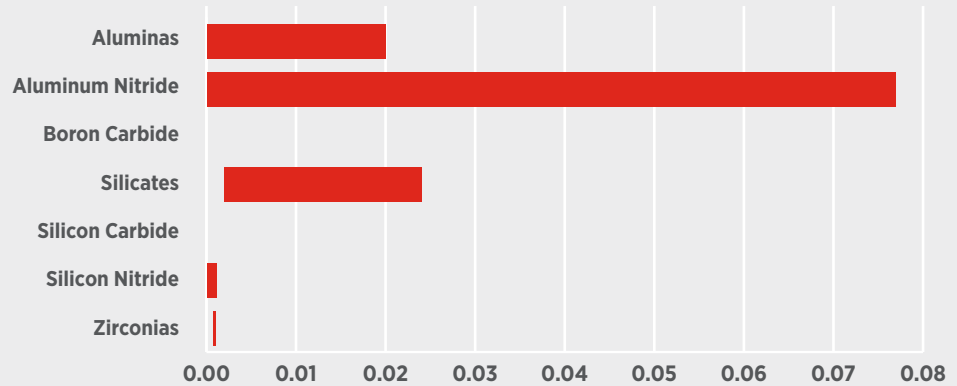


Glazed electrostatic anti-sway bar



DIELECTRIC LOSS

Loss Tangent: $\tan \delta$
25°C



Dielectric loss essentially quantifies the dissipation of electromagnetic energy in a dielectric (insulating) material. This dissipated energy, or inefficiency, manifests itself as heat. Technical ceramics are generally low loss materials, making them ideal for use in power generation and utility applications. CoorsTek has special grades of low loss materials for applications requiring exceptionally low loss or very tight control.



Electrostatic precipitator insulator



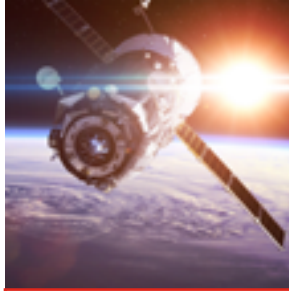
Example Applications Requiring Optimal Electrical Properties

Our ceramics are frequently used in the following industries and applications:



AUTOMOTIVE

- Carbon brushes
- LED lighting
- Automotive electronics
- PT sensors
- EV batteries



AEROSPACE
& DEFENSE

- GPS antenna components



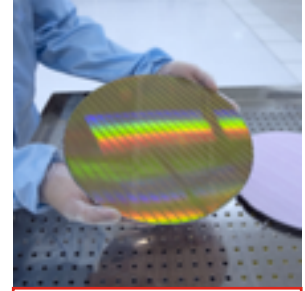
ENERGY

- Electrostatic precipitators
- Vacuum interrupters
- Insulators
- Switches
- Wind turbine bearings



MEDICAL

- Electro-implantable devices/pacemakers
- Cochlear implants
- Bioelectronic micro-implants
- Dental drills



SEMICONDUCTOR

- Plasma etch equipment
- Nozzles and focus rings
- Semiconductor wafers
- Microelectronic components





Alumina | Low Dielectric Loss

Aluminas (aluminum oxide, Al_2O_3) are a commonly used technical ceramic with a range of high performance properties, including excellent dielectric behavior. Specific formulations of CoorsTek aluminas are engineered for extremely low dielectric loss or other application-specific requirements.



Aluminum Nitride | Dielectric Strength with High Thermal Conductivity

Aluminum nitrides (AlN) are used in many electronic applications due to their unique combination of high dielectric strength and thermal conductivity, giving them a superior ability to dissipate heat quickly in electronic substrates and other electrical applications with thermal challenges.



Silicates | Electrical Resistivity

Silicates are often used for applications which require electrical resistivity and inertness, and are a cost-effective option for applications like chemical labware.

- Steatite has low dielectric loss combined with high dielectric strength, and is inexpensive to manufacture.
- Mullite has excellent dielectric strength and thermal shock properties.

Pictured above (from top to bottom): Electrostatic precipitator insulator, heat exchanger for rail vehicles, electrostatic precipitator insulator cone



Silicon Carbide (SiC) | Controlled Volume Resistivity

CoorsTek has carefully tailored the manufacturing process of silicon carbides for specific and variable volume resistivities. PureSiC silicon carbide, for example, is offered in several variants with high, medium, and low resistivities to fit a range of application-specific requirements.



Specialty Ceramics

The CoorsTek material portfolio includes a variety of specialty ceramics, engineered for the unique requirements of specific applications. Several of these specialty materials have excellent dielectric behavior.

- Titanate formulations are designed specifically for use as a dielectric resonator in antennas.
- ESD-Safe ceramics are engineered to protect sensitive microelectronic components from static electricity buildup by slowly dissipating the accumulated charge to prevent rapid discharge or arcing.
- Carbon and graphite, unlike many of the other ceramic materials discussed here, make excellent electrical conductors.

Pictured above (from top to bottom): Wafer planarization CMP plate, semiconductor handling blade





CHEMICAL PROPERTIES

“ COMPARED TO STEEL AND PLASTIC POLYMERS, TECHNICAL CERAMICS OFFER SUPERIOR CORROSION RESISTANCE. ”

Ceramics are chemically inert, allowing them to be used in applications that cause other materials to degrade. CoorsTek can tailor ceramic formulations and processes to meet your specific corrosion resistance requirements. When compared to steel and plastic polymers, technical ceramics offer superior corrosion resistance. In addition, ceramics outperform these materials on hardness and wear resistance, making them ideal for multiple applications with highly-corrosive environments.

Aluminum Oxide (Al_2O_3) and Silicon Carbide (SiC) ceramics are resistant to almost all chemicals and are used in applications that cause other materials to fail. Rarely will ceramics breakdown due to corrosion like metals, and they are resistant to acids and bases. However, some ceramics will perform better than others depending on specific corrosion resistance requirements. CoorsTek engineers are able to help you find the right technical ceramic material to meet your application needs.





PURITY

Measuring the purity of ceramics is critical for extremely corrosive environments, such as plasma etching (a semiconductor manufacturing process), as well as medical and food processing applications. Ceramic formulations for corrosion resistance have grain structures that are engineered to have a near perfect finish, maximizing their chemically inert properties that can be up to four times stronger than glass. By using chemical vapor deposition (also known as CVD), ultra-pure ceramics can be manufactured up to a purity level exceeding 99.99955%.



BIOCOMPATIBILITY

As a biological/chemical property, biocompatibility measures material performance in a specified application, identifying benefits or undesirable effects when combined with various biological hosts, such as body tissue or food material. High-purity ceramics are generally bioinert, and therefore ideal for medical applications – including both implantable and non-implantable devices such as high strength ceramic acetabular liners and femoral heads (hip joint components), and ceramic components in medical fluid monitoring systems.



CORROSION RESISTANCE

When it comes to the chemical resistance to acids and bases, ceramics are an ideal material for long-lasting performance resulting from their ability to withstand chemical breakdown. Corrosion resistance is measured by testing ceramics against other alternative materials, such as metals and plastics, that are chemically soluble.



Example Applications Requiring Exceptional Chemical Properties

Our ceramics are frequently used in the following industries and applications:



AUTOMOTIVE

- Fluid injection systems
- Automotive HVAC
- Pressure and temperature sensors



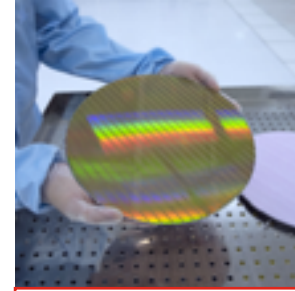
CHEMICALS

- Grinding media
- Crucibles
- Valves systems
- Pipe linings
- Seals and bearings
- Pump components



MEDICAL

- Orthopaedic implants
- Hollow-fiber membrane recirculation systems
- Body fluid management systems



SEMICONDUCTOR

- Silicon ingot production
- Chip processing
- Device manufacturing and assembly
- Plasma etching systems

CHEMICAL RESISTANCE



Aluminas | Wear and Corrosion Resistance

Aluminas (aluminum oxide, Al_2O_3) are the most commonly used technical ceramics due to their generally useful properties, good price/performance ratio, and suitability for most industry applications. Higher purity aluminas typically demonstrate enhanced corrosion and wear resistance.



Silicates | Corrosion Resistance

Silicate ceramics are multi-phase materials developed from natural silicate sources and are useful for cost-effective technical applications such as chemical labware. Porcelain is the company's longest running line of technical ceramics, and CoorsTek chemical and scientific labware has become an industry standard. After glazing, our porcelain labware resists corrosion and demonstrates superior thermal properties.



Silicon Carbides | Corrosion Resistance with Excellent Thermal Properties

Silicon Carbides (SiC) exhibit characteristically high corrosion resistance, hardness, wear resistance, and strength — even at high temperatures.



Zirconias | Corrosion Resistance with Superior Mechanical Durability

Zirconium oxides (ZrO_2) are durable ceramics with exceptional strength and fracture toughness. CoorsTek zirconias exhibit remarkable mechanical durability and impact resistance. Additionally, CoorsTek Dura-Z™ offers superior cyclic fatigue resistance, exceeding the fatigue limits of high strength steels.

Pictured above (from top to bottom): Ceramic bushing, crucible, pump bearings, ceramic discs





THERMAL PROPERTIES

“TECHNICAL CERAMICS
OUTPERFORM OTHER
MATERIALS IN APPLICATIONS
WHERE EXTREME
TEMPERATURES EXIST.”

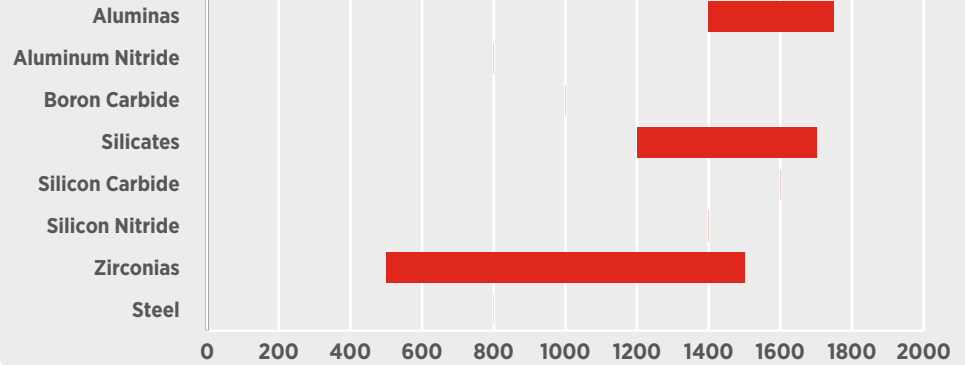
Technical ceramics outperform metals, alloys, and polymers in applications where extreme temperatures exist. Applications with extreme high or low temperature conditions require materials that can perform without failing through expansion, contraction, melting, or cracking. Ceramics cover a wide array of applications where high temperature strength, thermal stability, and thermal resistance are key to operational success and safety.

Thermal properties characterize how a material performs across a range of temperatures and reacts to changes in temperature. Many of our technical ceramics are ideal for specific thermal performance, including high- and low-temperature precision applications, by controlling the inherent material properties and structure. Many technical ceramic formulations can be tailored to fit application-specific thermal requirements, where operating temperature range, thermal conductivity, coefficient of thermal expansion, and thermal shock resistance are critical.



HIGH TEMPERATURE USE

°C



One of the key benefits of advanced ceramics is the ability to hold their other properties at extreme temperatures. Many technical ceramic formulations can withstand temperatures well beyond highly engineered polymers and metals, offering stable performance at up to 2400°C. In comparison, the maximum operating temperature of high end heat resistant plastics is around 250°C, and up to 1000°C for some metal alloys. In combination with other mechanical, electrical, and chemical properties, ceramics are the ideal option for mission critical applications where high and/or low temperatures are a factor.

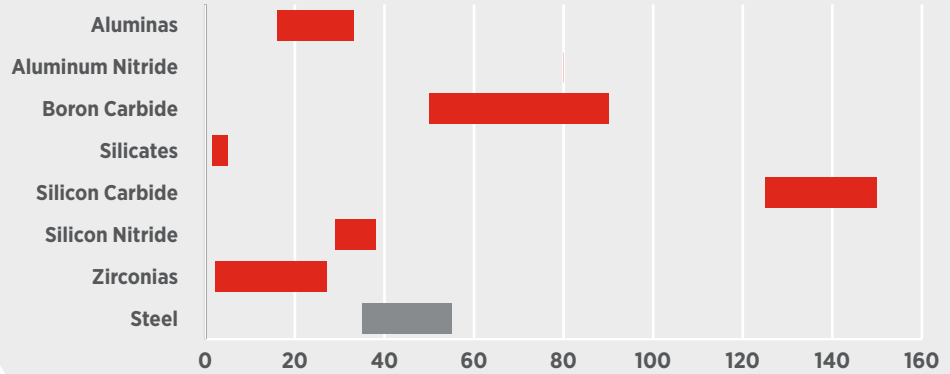


Half and whole arc tube envelopes



THERMAL CONDUCTIVITY

W/m*K



Thermal conductivity measures how well a material spreads heat within itself. Cooking pans have high thermal conductivity allowing evenly distributed heat to pass quickly into the food. On the other hand, insulative gloves are used to handle hot objects because their low thermal conductivity prevents heat from transmitting to sensitive hands. Technical ceramics are extraordinarily versatile, exhibiting a wide range of thermal conductivity.

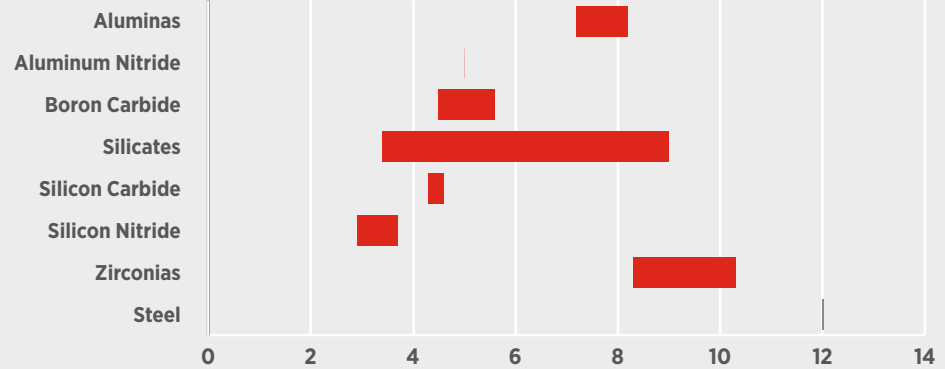


*Wafer planarization
CMP plate*



COEFFICIENT OF THERMAL EXPANSION

$1 \times 10^{-6} / ^\circ\text{C}$



Coefficient of thermal expansion defines how much a material expands or contracts based on external temperatures. Most materials swell with the application of heat because the energy causes the atoms to move more rapidly, stretching their bonds. Ceramics generally have a low coefficient due to their strong interatomic bonds, making them more stable across wide temperature ranges.

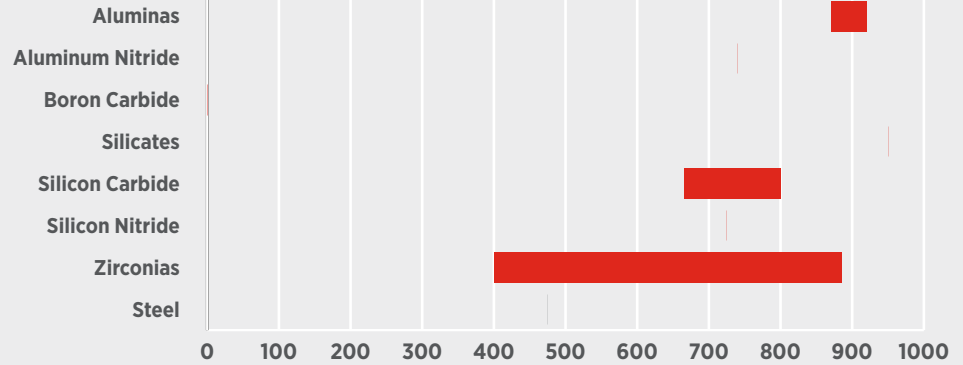


Ceramic heat sink and electrical insulator

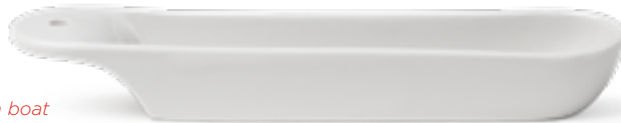


SPECIFIC HEAT

J/kg*K



Specific heat measures how easy or difficult it is to raise the temperature of a product. Although they exhibit a broad range of specific heat, technical ceramics generally have higher specific heat than metals, useful where regulating temperature is critical.



Combustion boat for laboratories

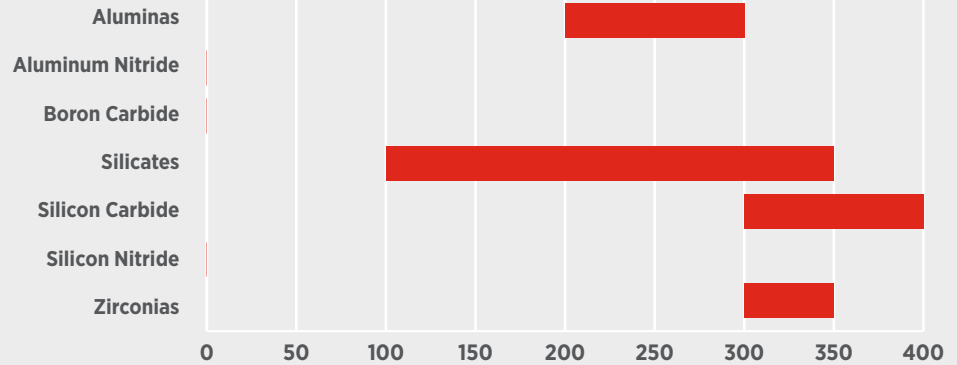


Set of various arc tubes



THERMAL SHOCK RESISTANCE

°C



Thermal shock resistance measures the ability to withstand dramatic and sharp temperature changes. During rapid cooling, the core of the product remains hotter while the surface cools, preventing uniform thermal contraction. Materials with low thermal shock resistance are prone to cracking with variations in temperature.

Refractory materials such as CoorsTek Glassun™ have excellent thermal shock properties since they have strain-tolerant microstructures combined with a low coefficient of thermal expansion.

Structural grade ceramics can also display excellent thermal shock properties, combining material strength and the ability to dissipate thermal stresses. Higher thermal conductivity, lower thermal expansion, and lower elastic modulus can contribute to lower thermal stresses.



Example Applications Requiring Exceptional Thermal Properties

Our ceramics are frequently used in the following industries and applications:



AUTOMOTIVE

- High-end automotive lighting
- Ceramic heat exchangers



AEROSPACE
& DEFENSE

- Aircraft engines
- Advanced propulsion systems
- Thermal insulating tiles
- Thermal barrier coatings
- Mirrors and optical systems



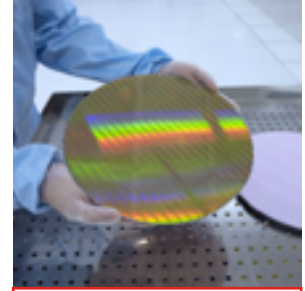
ENERGY
PRODUCTION & MILLS

- Power generation
- Chemical processing
- Steel mills
- Oil refineries



MACHINERY
& EQUIPMENT

- Centrifugal pumps
- Compressors
- Turbomachinery
- Foundry filters



SEMICONDUCTOR

- Semiconductor wafer processing
- Fabrication
- Packaging
- Crucibles



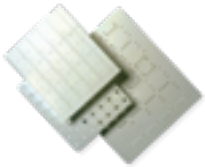
HIGH THERMAL PERFORMANCE



Aluminas | Thermal Resistance with Good General Use Properties

Aluminas (aluminum oxide, Al_2O_3) are the most commonly used technical ceramics with good all-around performance. CoorsTek has engineered over 100 aluminas for use across a wide variety of applications with thermal resistance of 1500°C or more.

- Zirconia Toughened Alumina is a specialized alumina designed for high thermal shock resistance and increased toughness.



Aluminum Nitride | High Thermal Conductivity

Aluminum Nitrides combine high thermal conductivity with strong electrical resistance. They are an excellent solution for many electronic applications, allowing electrical systems to dissipate heat quickly for maximum efficiency.



Quartz | Thermal Shock Resistance and Thermal Expansion

Synthetic quartz or fused silica (silicon oxide, SiO_2) ceramics exhibit excellent thermal shock resistance due to extremely low thermal expansion and extreme purity. These unique properties and thermal stability allow this technical ceramic to be used in rapid thermal processing applications.

Pictured above (from top to bottom): Lasered alumina substrate, Aluminum Nitride substrate for electronic circuit boards, quartz crucible





Mullite foundry filter

Silicates | Thermal Shock Resistance

Silicate ceramics are multi-phase materials developed from natural silicate sources such as clay, kaolin, feldspar, and soapstone. Today’s silicates are useful for technical applications such as electrical insulators and foundry filters.

- Steatite is used in manufacturing processes where high thermal performance is required.
- Cordierite combines great thermal shock properties with low thermal expansion rate, making this an excellent material for insulators.
- Mullite has excellent thermal shock resistance and dielectric strength, making it ideal for electronic components for manufacturing purposes.
- Porcelain is the company’s longest running line of technical ceramics. After glazing, porcelain demonstrates superior thermal properties.
- CoorsTek Glassun™ is a high-purity silicate refractory material with an extremely low coefficient of thermal expansion, strong thermal shock resistance, low thermal conductivity, and excellent corrosion resistance to chemicals and molten metals.

HIGH THERMAL PERFORMANCE



Silicon Carbide | Thermal Stability

Silicon Carbides (SiC) exhibit high hardness, wear resistance, corrosion resistance, and strength at high temperatures. CoorsTek has engineered a variety of silicon carbide processes and compositions which deliver properties and features optimized for specific application requirements.

- PureSiC® Chemical Vapor Deposition (CVD) Silicon Carbide resists corrosion in extreme environments and has an exceptional purity of 99.9995%, making it ideal for ultra-clean manufacturing. It is an excellent material for rapid thermal processing (RTP) used in semiconductor production, which needs excellent thermal shock resistance and the ability to withstand prolonged high-temperature manufacturing processes.
- UltraClean™ Recrystallized Silicon Carbide’s grain structure provides excellent thermal material properties for extremely precise manufacturing requiring high purity.



Silicon Nitride | High Temperature Strength & Endurance

Silicon Nitrides (Si₃N₄) have a unique grain structure which delivers high strength and toughness, along with exceptional thermal shock resistance. This material is ideal for applications with high dynamic stresses, thermal rigor, and demanding reliability requirements.

Pictured above (from top to bottom): Semiconductor edge ring, automotive fuel injection nozzle





Printing mandrels for can tooling

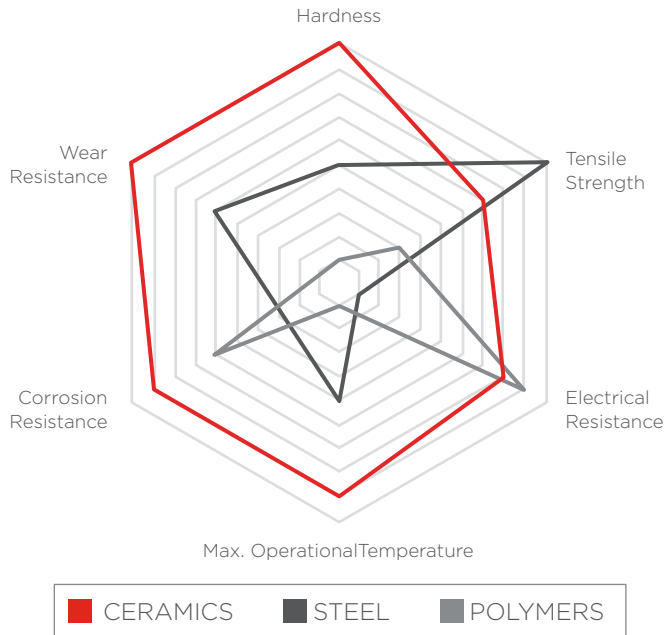
Zirconia | High Heat Resistance

Zirconias have a unique crystal structure which combines excellent strength, high fracture toughness, wear resistance, and high temperature resistance. Some zirconias have engineered crystal structures which expand when a micro-crack is formed, arresting crack growth and preventing brittle failure. These materials are ideal for extreme mechanical environments, particularly impact prone applications.

- Magnesia Partially Stabilized Zirconia is used in severe-service conditions where high-temperature resistance, durability, and corrosion resistant materials are needed, making it ideal for machinery parts and valves in severe applications.
- Yttria Partially Stabilized Zirconia components are very strong, and can be employed in extreme environments. This material excels in machinery and mechanical applications requiring insulative properties matched with fatigue resistance and impact loading excellence.



THE MATERIAL PROPERTY POWERHOUSE



The properties of advanced ceramics are impressive when viewed singularly, but it is not any one property that makes these materials stand apart. Ceramics are remarkable precisely because they are not a one-size-fits-all solution.

CoorsTek offers over 400 advanced ceramic compositions designed to meet individual specifications. Design engineers can start with their most demanding requirements and work their way back into finding the ceramic that will offer the correct combination of mechanical, thermal, electrical, and chemical benefits.

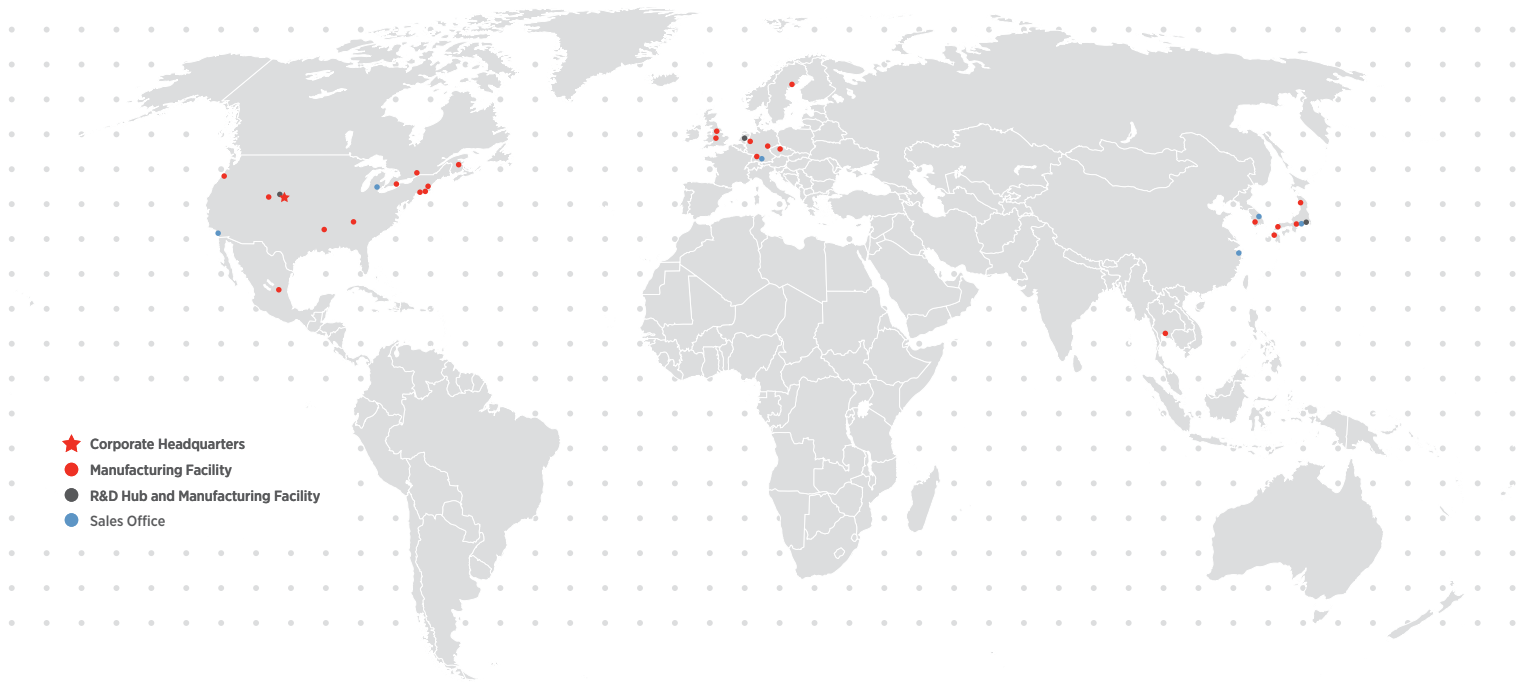
Design for manufacturability is also key. As a vertically integrated manufacturer with immense global capacity, unsurpassed expertise and extensive forming, firing, and finishing options, CoorsTek partners with customers to turn concepts into reality. Bring us your latest design challenge.



LOOKING FOR MORE?

Use our online Material Comparison Tool to compare multiple ceramic formulations and find the most suitable material for your particular application.

Visit [coorstek.com/engineered-ceramics](https://www.coorstek.com/engineered-ceramics)



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