Sapphire: The Ultimate High-Performance Manufacturing Material

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Sapphire, which goes by the mineral name corundum, is a crystalline form of Al2 O3 with a hexagonal structure. It boasts extreme physical, chemical and thermal durability, earning it an exceptionally broad range of applications in areas where resilience to extreme environments is required. Sapphire's high electrical resistance and optical transmission properties also lend it to applications in photonics and electronics.

In this article, we outline the properties of sapphire and take a look at how Edge defined Filmfed Growth is enabling the production of large and complex sapphire pieces that open up a range of previously impossible applications.

Although it is a naturally occurring precious gemstone, the sapphire used in high tech applications is usually synthetic. Commonly, applications of sapphire involve small

quantities – e.g. watch face crystals and small lenses. However, thanks to breakthroughs in Edgedefined Filmfed Growth (EFG), sapphire can actually be manufactured in large, continuous pieces to suit virtually any application.

In EFG, a single crystal piece of sapphire can be mechanically drawn from a liquid solution, enabling the production of complex shapes and very large single crystal pieces of sapphire: Luxium Solutions use EFG to produce the largest single-crystal sapphire tubes (up to 3" diameter) and windows (1 ft x 3 ft) in the world. Being able to control the shape and size of a sapphire crystal during its formation means that sapphire can now be produced for a much broader range of applications than was previously thought possible.

The increased manufacturability offered by EFG means that today, sapphire is more frequently being specified over commonplace but suboptimal materials that were traditionally easier to work with; such as quartz, silicon carbide and zinc sulphide.

Synthetic sapphire manufacturing is environmentally friendly and much less polluting than the production of many alternative materials. What's more, synthetic sapphire is highly pure, with minimal contamination, no grain boundaries, and minimal defects; giving it a range of desirable properties:

1. It's hard, stiff, and almost impossible to scratch.

Sapphire is one of the hardest materials on earth. Mechanical hardness is typically measured using the Mohs scale: glass generally has a Mohs score between 6 and 7, and hardened steel which comes in at 8 Mohs. Sapphire has a Mohs hardness value of 9, placing it just below diamond which has a hardness of 10 Mohs.

Furthermore, sapphire is very stiff. Its Young's modulus is 435 GPa, making it 6 times stiffer than quartz, so it can't be stretched or deformed easily.

These properties make sapphire one of the strongest and most durable materials on the planet.

2. It's chemically inert.

Sapphire's stable crystal structure means that it won't react with its surroundings. As a result, it can survive harsh chemical environments without damage.

3. It transmits light without interference.

Sapphire has a high refractive index and a broad transmission window spanning the UV,

visible, and infrared range. It also transmits Xrays.

4. It conducts heat but is an electrical insulator.

Sapphire's crystal structure makes it a superior thermal conductor (0.1 watts/cm°K at 1000°C) compared with ceramics and glass. It even maintains excellent conductivity at low temperatures (0.4 watts/cm°K at 25°C).

5. It is temperature resistant.

Sapphire has a melting point of 2050 °C, so it can withstand extremely high temperatures without damage.

Applications of Sapphire

Sapphire is a truly multifunctional material, so it's no surprise that it is already used in a wide range of hightech applications. In fact, it's difficult to find a branch of science or technology that doesn't use sapphire in some way. Here are some of the most demanding applications where sapphire proves its worth:

Semiconductor manufacturing components

The processes involved in semiconductor production are often extremely aggressive, requiring industrial strength acids, alkalis, fluorine based plasmas, and high temperatures. Quartz, alumina, and ceramics are frequently used in semiconductor manufacturing components, but these are quickly eroded by the aggressive chemicals meaning they must be replaced frequently.

Sapphire is highly resistant to the semiconductor manufacturing environment, making it durable and preventing contamination. As a result, sapphire is the ideal choice for production components, including windows, tubes, pins, rods, injector nozzles, and even more complex parts. Sapphire components can be used indefinitely, increasing productivity and through put by reducing contamination and reducing maintenance stoppages compared with other materials.

Protective Glass Windows

Sapphire is hard, durable, and scratch resistant, making it a superior option for transparent sapphire protection of high velocity (kinetic energy) projectiles.

Ground vehicles and aircrafts often use glass protection to stop high kinetic energy projectiles from entering the cab and or cockpit. But glass protection can be heavy and thick. On the other hand, Sapphire protection is 50% thinner and lighter than glass alternatives, while providing the same stopping power. What's more, it offers better abrasion and chemical resistance to outside threats.

Sensor protection

Sapphire's broad transmission range, thermal conductivity, abrasion resistance, durability and stiffness make it a fantastic material for sensor protection and windows in scientific equipment, autonomous vehicles, helicopters, air crafts, and even drones.

Sapphire windows can be used to protect with a range of spectral analysis solutions that rely on light transmission without affecting performance, including UVV is and IR sensors, vision systems, cameras, night vision cameras, navigation systems, protection systems, and LiDAR.

Transmission and ionization tubes

Sapphire tubes are strong and provide excellent light transmission. They are used in infrared countermeasure systems designed to protect aircraft pilots and passengers from heatseeking projectiles by firing infrared beams to confuse their tracking systems.

Sapphire tubes are also used as essential components in excimer lasers, replacing alumina tubes. Excimer lasers are widely used in medical technologies, scientific research and photo-lithography machines for microchip manufacturing.

Conclusion

Sapphire is a fabulous, multifunctional material that can help solve a vast range of complex engineering challenges. The demand and applications of sapphire are continually increasing. So, if you haven’t considered sapphire for your application yet, you may be falling behind.

To talk to the sapphire experts and find out how sapphire can improve performance, durability, and productivity in your application, head over to Luxium Solutions’ website.

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Our achievements include lifesaving medical technologies, game changing security capabilities and materials that have enabled revolutionary research — on this world and beyond.

At Luxium Solutions, our team of researchers and engineers comes through the door each day ready to drive materials engineering forward in pursuit of advanced capabilities, forward thinking technology, and a more fruitful future. With advanced techniques for harnessing the strength and precision of crystalline structures, we develop the materials that are powering the technologies of tomorrow.

This combination of solid science and bold ideas has allowed us to develop an industry leading portfolio of high performance, highreliability products including synthetic sapphire armor, precision scintillation crystals, Xray monochromator crystals and epitaxy substrates made of garnet.

We work closely with our clients to so they can take advantage of these innovative products and advanced capabilities — offering the support to develop ideas, the expertise to impact industries, and the vision to change the world.