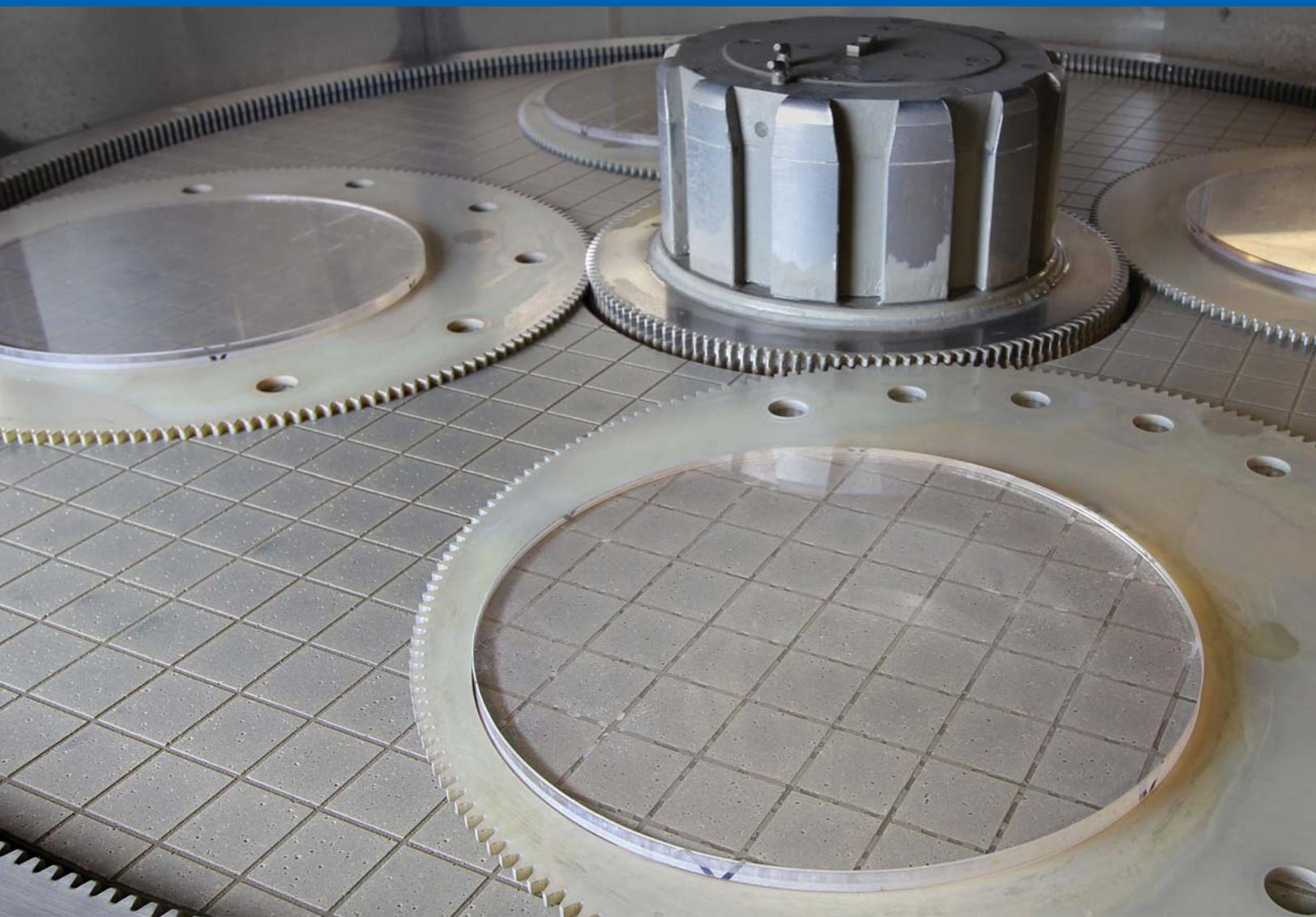


Selecting A Sapphire Window Manufacturer For High-Reliability ISR Applications: 6 Important Criteria



Selecting A Sapphire Window Manufacturer For High-Reliability ISR Applications: 6 Important Criteria

INTRODUCTION

As intelligence, surveillance, and reconnaissance (ISR) sensor technology evolves and mission requirements become more rigorous, increasing demands are placed on high-precision windows to deliver the highest levels of performance and reliability. ISR applications often use infrared (IR) and multispectral sensors to collect information from target locations and identify objects in high resolution. ISR windows must demonstrate superior performance to avoid compromising mission success. Because ISR windows need to withstand extreme operating conditions, careful control of the manufacturing processes is imperative to ensure strong windows and pristine optical surfaces.

Sapphire is extremely durable and transmits over a broad wavelength range of light, making it an excellent choice for ISR optical windows. Additionally, this scratch-resistant material can withstand severe environmental conditions and temperature changes. Sapphire demonstrates excellent chemical resistance and has a very high Knoop hardness.

Selection of a qualified window manufacturer is particularly important when using sapphire as the optical material because this material presents a number of challenges for manufacturers. Sapphire's extreme hardness, high strength, and fracture toughness make it difficult to turn an unfinished material blank into a high-performance optic using typical window fabrication processes.

To produce a superior product on time and within budget, the following criteria should be used to evaluate potential suppliers before placing an order for high-quality sapphire windows.

MATERIAL KNOWLEDGE

Sapphire material production technologies include the Kyropoulos method, Edge Fed Growth (EFG) method, and Heat Exchanger Method (HEM). These methods produce sapphire with different specifications such as size, thickness, and inclusions. The raw material blank's crystal orientation determines certain window characteristics. For example, a-plane sheets have historically been available in larger sizes than c-plane sapphire. However, a-plane sapphire is birefringent, while c-plane is not.

ZYGO is familiar with raw material characteristics and can help select the most appropriate material for the project at hand. We have a profound understanding of how raw material properties impact manufacturing processes and overall performance.

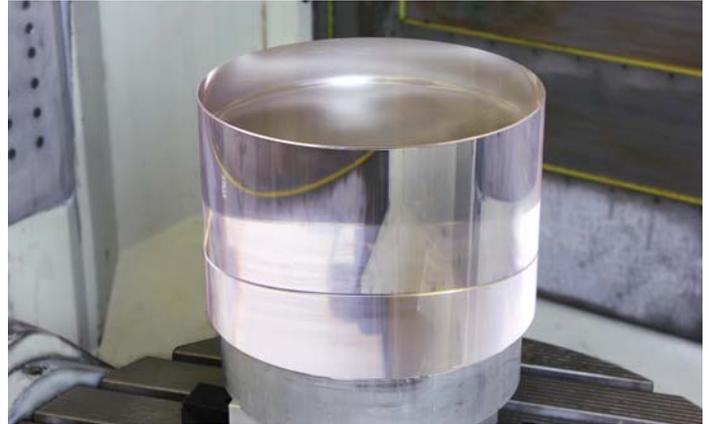


Figure 1: Sapphire cylinder being fabricated by ZYGO from a c-plane boule.

DESIGN EXPERIENCE

Custom windows used in mission-critical applications require careful engineering to ensure optimal performance under a wide variety of operating conditions, which therefore necessitates in-house expertise in both design and manufacturing processes. An experienced engineering team understands the effects of manufacturing processes on strength, optical performance, and reliability of the window. An ideal ISR window supplier can design tools, metrology fixtures, custom coatings, and assembly frames. Then a finite element analysis (FEA) is performed to ensure the window meets specification. The manufacturer should also be capable of performing strain measurements and proof pressure testing and assembling a detailed metrology budget to ensure the highest quality windows.

Our in-house design of proof pressure test fixtures and controls offers the unique capability to test virtually any window geometry, ramp pressure up/down, as well as test one or both sides of an

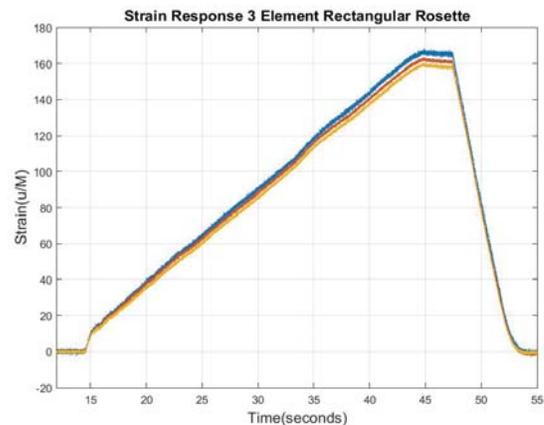
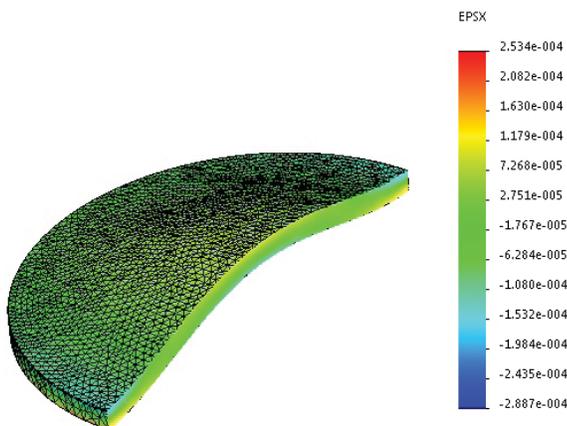


Figure 2: ZYGO Three-Element Rectangular Rosette strain response during pressure profile and FEA correlation of an ISR surrogate window

Selecting A Sapphire Window Manufacturer For High-Reliability ISR Applications: 6 Important Criteria

optic. Our engineering team has extensive real-world experience bringing ISR window designs to life. They understand the benefits and tradeoffs required to produce the highest-quality windows on time and within budget. We do not consider ourselves to be just a window supplier, but a true design and manufacturing partner.



Figure 3: ZYGO custom-designed proof pressure test fixture

FABRICATION PROFICIENCY

The methods used to process a piece of sapphire ultimately determine the strength of the window. Controlled processing must take place in order to minimize subsurface damage. For more information on the relationship between fabrication proficiency and sapphire window strength, please refer to the SPIE proceeding titled “Sapphire Statistical Characterization and Risk Reduction Program,” by Dan Harris et al.¹ and “Does Anyone Out There Know the Strength of Sapphire?” published by the U.S. Naval Air Systems Command².

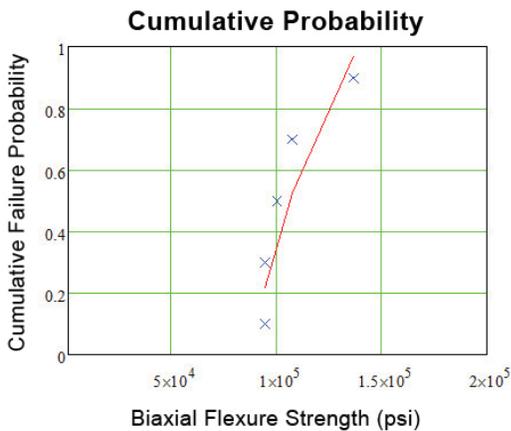


Figure 4: ZYGO strength analysis of an a-plane sapphire window

We have the unique ability to fabricate high-strength windows for tight transmitted wavefront and/or surface flatness, very good mid-spatial frequency, very low surface roughness, and less than one arc second parallelism. We qualify our sapphire manufacturing processes with ring-on-ring and ASTM flexural tests.

IN-HOUSE COATING EXPERTISE

A sapphire window manufacturer that possesses in-house coating design and deposition capabilities greatly reduces logistical issues for its customers in terms of lead time and technical difficulties. ISR window coatings must typically be able to withstand harsh environmental conditions. The coating designs, in most cases, are multispectral in order to take advantage of the broad wavelength transmission range of sapphire. When procuring large coated windows, ensure the manufacturer has the experience to guarantee thin film spectral uniformity over the complete clear aperture.

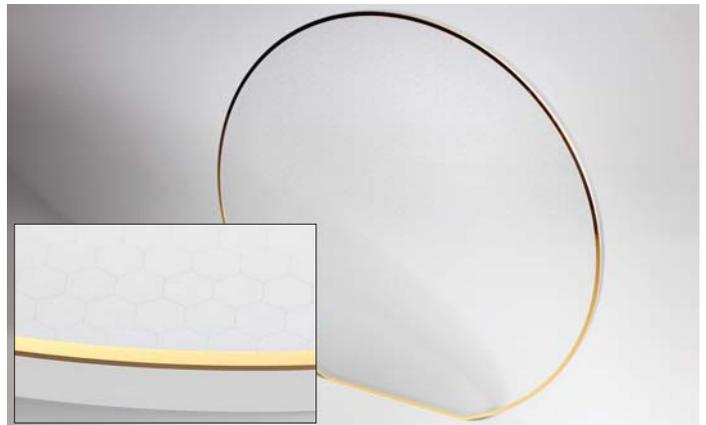


Figure 5: 300 mm diameter x 7.5 mm thick a-plane sapphire window with ZYGO coating applied and EMI gridding (inset image provides closeup view of EMI gridding applied to surface)

ZYGO designs antireflective and dielectric coatings for UV, VIS, MIR, and multispectral applications. Our coatings are qualified to meet RTCA/DO-160D or military specifications. Equipment includes several 72-inch coating chambers for large optical windows. We maintain an extensive library of designs and are also experienced with coating windows requiring EMI grids.



Figure 6: ZYGO's large coating chamber capabilities

METROLOGY PROFICIENCY

A manufacturer must possess sophisticated metrology equipment and the necessary expertise to utilize the equipment properly in order to develop or optimize processes and to guarantee a sapphire window meets specifications. Large-aperture metrology is

Selecting A Sapphire Window Manufacturer For High-Reliability ISR Applications: 6 Important Criteria

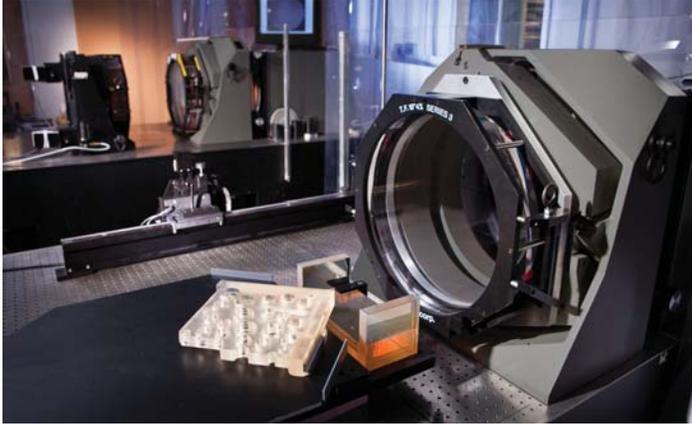


Figure 7: ZYGO is recognized worldwide for large-aperture metrology systems.

vital when characterizing large sapphire ISR windows. For complex designs, the manufacturer will work with its customer to develop metrology processes that support the customer's requirements.

We employ several large-aperture ZYGO interferometers (such as our Verifire™ MST line) for multiple surface testing. These instruments measure front and back surface, transmitted wavefront, material homogeneity, and wedge. This capability enables us to fabricate and measure windows to less than one arc second parallelism and produce matched window sets for line-of-sight applications.

VOLUME PRODUCTION AND ASSEMBLY CAPABILITY

A manufacturer of custom windows needs to have the ability and experience to scale up from prototype quantities to full production runs. In addition to the typical manufacturing resources, such as equipment and personnel, volume production requires detailed program management; consistent, well-controlled manufacturing processes; and well-thought-out tooling designs. Many ISR programs require samples to be made from the same sapphire boule and with the same manufacturing process as the actual window product. It is important to have processes in place

for document control and material traceability to maintain the fidelity of the project. A manufacturer that also possesses the ability to mount sapphire windows into frames and perform proof pressure testing of the assemblies adds tremendous value with this service, because incorrect installation will compromise the performance of otherwise excellent windows.

ZYGO's Electro-Optics business possesses extensive New Product Introduction (NPI) experience and Design for Manufacturing and Assembly (DFMA) capability. This reduces assembly cost and delivery times by reducing touch time and minimizing the warranty return rate.

CONCLUSION

Selection of a sapphire ISR window manufacturer must be based upon a supplier's technical competencies in a number of areas. To maximize product quality and long-term reliability, a window manufacturer needs to have the capability and experience to serve as a fully engaged design partner.



Figure 8: ZYGO polished the edges and bevels on this c-plane sapphire window.

References

1. McClure, D.R., Cayse, R., Black, D., Goodrich, S., Lagerlof, P., Harris, D.C., McCullum, D., Platus, D.H., Patty, Jr., C.E. and Polvani, R., "Sapphire statistical characterization and risk reduction program," Proc. SPIE 4375, (2001).
2. Harris, D.C., "Does anyone out there know the strength of sapphire?" U.S. Naval Air Systems Command, (2002).



www.zygo.com
(860)347-8506

ABOUT ZYGO

Zygo Corporation is a global leader in the design and manufacture of ultra-precise optical components and assemblies, as well as advanced optical metrology systems. ZYGO's Optics business fabricates high-performance optics for defense (ISR), high-energy laser (HEL), biomedical, semiconductor markets, and other industries.

ZYGO develops leading-edge technologies for manufacturing and measuring the most challenging, high-quality optical designs in the world. As a vertically integrated ITAR-registered company, ZYGO has the design, fabrication, coating, testing, production, and assembly experience to produce the highest-quality custom ISR sapphire optical windows. All ZYGO products are designed and manufactured in the United States. More than 40 years of experience are behind every optic made by ZYGO. ZYGO understands what is required to produce sapphire windows that deliver superior performance under the toughest conditions.

ABOUT THE AUTHOR

Michael Albrecht is the product manager for Zygo Corporation's Precision Optics business segment. He possesses extensive knowledge of optical materials and the processes involved in creating cutting-edge plano optics. Albrecht has been involved in numerous high-profile, complex ISR optics development programs. To learn more about ZYGO's sapphire fabrication, coatings, and assembly capabilities, contact Michael at michael.albrecht@ametec.com. He would like to acknowledge ZYGO team members Rich Boland, Ed Gowac, Matt Stevens, Marc Tricard, and Katy Zadrowicz for their contributions to this article.