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LARGER SAPPHIRE OPTICAL WINDOWS WITHIN REACH

Sapphire's optical transparency, strength, abrasion/corrosion/ temperature resistance, chemical inertness, and bio-compatibility make it ideal for high performance optical applications, such as, aerospace and defense. However, these rugged applications require optical-grade sapphire windows of greater size and thickness than have been available. This could change with the introduction of Bensenville, Illinois-based Rubicon Technology Inc.'s process of horizontally growing sapphire sheets of sufficient size and thickness for defense and other applications that can leverage the material's optical and physical properties.

Rubicon Technology provides advanced electronic materials that it derives from its developing, manufacturing, and selling of monocrystalline sapphire and other crystalline products for light-emitting diodes (LEDs), radio frequency integrated circuits (RFICs), blue laser diodes, optoelectronics, and other optical applications. According to a news release, the company developed its horizontal growth process for sapphire, or Large-Area Net-shape Crystal Extraction (LANCE) project, with support from the US Air Force Research Laboratory.

"There is a real demand, today, for large sapphire windows in aerospace and defense applications," saidJonathan Levine, director of technical business development at Rubicon Technology. Sapphire

crystals are predominantly produced as large cylinders that are optimized for wafer and round optical products, explainedLevine. "The goal for the LANCE project (which produced the horizontal growth process) was to produce near net-shape rectangular windows of sufficient dimensions that require minimal processing. We are working toward a monolithic sapphire window size of 36 in. × 18 in., and up to two inches thick," said the executive.

The greatest challenge for the Rubicon Technology design team was scaling up to larger crystal sizes while maintaining crystal quality. "As the crystal size gets scaled up, the hot zone and all of its corresponding components also need to be scaled accordingly to maintain crystal quality.The challenge isn’t growing a larger crystal, it is growing a high qualitylarger crystal," stressed Levine, who credited the engineering team's decades of crystal growing experience, combining multiple platforms, materials, and heater types, with achieving this goal. "We were able to utilize our collective knowledge and an iterative design process to develop our final process," he said. Typically, large sapphire sheets are grown by the edge-defined film-fed growth (EFG) method, which involves pulling molten sapphire vertically through a die to create the sheet. Gravity and surface tension limit the sheet thickness that can be achieved by EFG processing. An additional drawback is that EFG has a very high thermal gradient, which results in a crystal of high stress and lower quality. By contrast, the Rubicon Technology LANCE process involves pulling a horizontal boat through a heater surrounded by thermal insulation. "Because the entire crystal is supported, we are able to grow sapphire sheets thicker than 2 inches, and of very high quality," noted Levine.

Due to sapphire’s superior strength compared to glass and other ceramic materials, it is ideally suited as a protective window in electro-optical surveillance and targeting systems that can be found on planes, helicopters, and ships. The material's resistance to corrosion and scratches, combined with excellent transmission in the visible through infrared spectrum, make it highly suitable for such demanding optical applications.

Additionally, sapphire is used as a component in transparent armor that offers reduced thickness and weight compared with standard glass and laminate composites used in ground vehicles. "Until now, some of the benefits of sapphire have been obtained by piecing together small windows. The monolithic sheet is a big advance in that it provides a large, seamless optical field," said the Rubicon Technology executive. The next step for the Illinois-based company toward commercializing its sapphire sheet growing process is to improve throughput to meet their own internal production standards and training their crystal growth operators for 24-hour operations. Rubicon Technology anticipates full commercialization in the next one to three years.

When asked about the lessons Rubicon Technology has learned while developing its horizontal growth process for sapphire sheet, Levine replied, "Any time we modify a growth process, we gain knowledge about how the crystal quality reacts to such changes that is beneficial for any further development. Seemingly minor changes, such as, replacing one material with another or even adjusting the position of some insulation can have wide ranging effects, especially when we’re operating above 2000 degrees C. So everything we did helped us

understand how to better scale up and develop new processes for future demands."

Levine opined that increased purity and surface quality (polishing) of optical windows are going to become more important as the technology for optical sensors continues to improve. "There will also always be further applications that require even bigger sapphire, so the goal of increasing the size of sapphire windows never really ends," he added. Levine noted that while polishing technology has made a lot of improvements recently, it is still difficult and expensive to achieve optical finishes on such large pieces. Developments in that area would be beneficial, as would be more efficient technology to slice large windows from grown slabs, he stated.

The Rubicon Technology executive reported that the US Armed Forces have already been working very closely with sapphire manufacturers to ensure sufficient communication from the front end to the back end of the technology pipeline."Through the Small Business Research Innovation (SBIR) program, the DoD [Department of Defense] has been funding and advising companies, such as, Rubicon to help develop the technology they will need in the coming years. The most important factor for next generation development is to maintain an open dialogue so that the original equipment manufacturers understand the capabilities and benefits of our sapphire and so that Rubicon understands their needs as well," said Levine, who described significant commercial opportunities for these large sapphire plates.

One specific example he cited is in semiconductor wafer production equipment. The size of latest generation silicon wafer is 450 millimeter

diameter (approximately 17.75 in.).This can be met by using LANCE sapphire, and several key sapphire components for these processing tools can now be fabricated. This option was not available before LANCE was developed.

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