

F R O S T & S U L L I V A N

2024 TECHNOLOGY INNOVATION LEADER

*IN THE NORTH AMERICAN
SMART GLAZING
INDUSTRY*

SCIENSTRY, INC.

F R O S T & S U L L I V A N

BEST
2024 PRACTICES
AWARD

Best Practices Criteria for World-Class Performance

Frost & Sullivan applies a rigorous analytical process to evaluate multiple nominees for each award category before determining the final award recipient. The process involves a detailed evaluation of best practices criteria across two dimensions for each nominated company. Scienstry Inc. excels in many of the criteria in the smart glazing space.

AWARD CRITERIA	
<i>Technology Leverage</i>	<i>Business Impact</i>
Commitment to Innovation	Financial Performance
Commitment to Creativity	Customer Acquisition
Stage Gate Efficiency	Operational Efficiency
Commercialization Success	Growth Potential
Application Diversity	Human Capital

Innovates Multifunctional and High-performance 3G Switchable Film

Smart glazing refers to materials that can dynamically respond to external stimuli such as heat, light, or voltage pulse and change their optical properties. This technology provides control over transparency, light transmission, and thermal conductivity, offering privacy, comfort, and energy efficiency benefits.

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**– Priya Madhuri K
Industry Analyst**

Smart glazing or switchable glass with variable tint or opacity for automotive and building exteriors has piqued consumer interest due to its potential benefits. There is an annual increase in the use of smart glass in the construction and automotive industries due to the emphasis on energy savings and the transition from traditional vehicles to electric or autonomous connected driving.

Polymer-dispersed liquid crystal (PDLC) technology forms the basis of the most popular form of smart glass.

A smart film comprises a polymer matrix that holds liquid crystal microdroplets dispersed in a solid polymer phase. The smart film is laminated between two glass sheets to form a smart glass that aligns in a particular fashion upon voltage application to provide a transparent view. In the absence of voltage, the liquid crystals orient randomly, causing an opaque appearance.

However, conventional PDLC technology faces challenges due to chemical instability toward ultraviolet

(UV) rays and narrow working temperatures, the two main factors limiting widespread adoption in outdoor applications. Other PDLC technology limitations include infrared instability, narrow viewing angles, high operating voltage, and short product lifetimes. Smart glazing technologies are also expensive to manufacture, with industries striving to reduce the direct, upfront production costs and expand the economies of scale.

In this context, US-based Scienstry Inc. has developed a new 3-Gen liquid crystal display (LCD) film known as the 3G Switchable Film™ to address the challenges above using a multidisciplinary approach based on materials chemistry, optics, and engineering for broader applications in automotive, architecture, and other technological areas.

Nonlinear polymer dispersed liquid crystal display (NPD-LCD) technology powers the 3G Switchable Film™. NPD-LCD smart film has a polymer matrix that comprises liquid crystal microdroplets dispersed in a non-linear or gradually changed polymer phase formed through a phase separation process. It requires only refractive index matching between the liquid crystal and the inner layer of the polymer phase, avoiding the optical matching necessary between the liquid crystal and the entire polymer phase. This technology allows the freedom to continuously improve the performance and add new features with optical, chemical, and physical modifications compared to earlier generation technologies.

Scienstry holds numerous patents on apparatus and methods of making the 3G Switchable Film™ and related smart glazing, as well as new apparatus of normal laminated glass and bulletproof glass with advantages in performance and cost. It is one of the few research-oriented companies relying solely on its technologies to produce and commercialize NPD-LCD-based smart glazing products. One of Scienstry's patented inventions, apparatus and methods is UV stabilization technology. Scienstry had a disruptive breakthrough to protect all of organic materials used in a smart film from UV damage by using UV absorbers. UV absorber has a super absorptive capability for UV rays and can be excited to its high energy state after absorbing UV energy and then returned to its ground state by releasing heat. UV stabilization technology started to be used in automobile paints in the 1990s and then people could hardly see the faded cars running on the streets. A similar technology is used in sunscreens to protect the skin. However, liquid crystals are very sensitive for molecular shapes, polarities, and colors and most UV absorbers do not have the required optical, physical, and chemical properties. Scienstry created a new kind of liquid crystal component, called liquid crystal-like UV stabilizer which has the liquid crystal's molecular shape, polarity, and colorless. So, the original performance and functions of the liquid crystals are not changed after adding the UV absorbers. When the UV absorbers are mixed with the materials in a smart film, the UV absorbers like a lot of molecular umbrellas to shield the liquid crystals. Similarly, different molecular shapes and reactivities of UV absorbers can be used to protect the polymers and film substrate. It is the first case that a UV absorber is used in an LCD optical system. Thus, the company adds new features and products to its portfolio with constant research efforts.

The 3G Switchable Film™ LCD technology has all the desired qualities and advantages over conventional PDLC films that are usually unsuitable for outdoor and projection applications. It is free of inherent chemical defects, with the chemical requirement for curing easily met to obtain a high degree of polymerization that results in high-purity liquid crystals. The high purity of LCs allows a wide operating temperature range from -30°C to 80°C or even wider, unlike conventional ones that can operate only from

0°C to 50°C. The technology's outdoor application capability indicates its high performance and is a major breakthrough in the LCD industry. The capabilities of front and rear projection and all-round visibility link LCD industry and glass industry together. The lifetime of these films have been extended 50–100 times with improvements in anti-plasticizer, anti-moisture, anti-heat, and anti-UV properties compared to its competitors' conventional PDLC technology. These features enable smart glazing applications in any part of the world. The feature of improved UV stability allows for standalone or laminated applications, unlike competing technologies. Scienstry's technology has further demonstrated enhanced product lifetimes, capable of operating for more than 30 years with 100 million on-off switches and a low driving voltage of 15 V. In contrast, conventional PDLC films have a lifetime of 5 years and 3-4 times higher driving voltage. The company has also developed an optical mechanism to increase the value proposition of its technology by making the 3G Switchable Film™ applicable for front and rear projections with unique feature of same brightness and clarity at any viewing angle (360 degree viewable), avoiding annoying surface reflections, virtually turning any window or a building surface into a giant display. Many innovations of improving visual effects on the projected images link the glass industry and the display industry together and have a great potential to play an important role in a converting between AI/metaverse systems and reality, especially for large displaying.

Frost & Sullivan's analysis indicates that Scienstry's technology breaks many limitations of conventional PDLC theory and holds multiple benefits, heralding a new era for outdoor, projection, and energy-saving applications. Outdoor applications are an important feature added to the smart glass industry. These are some special attributes of the 3G Switchable Film™ technology that competitors do not offer.

Automotive and architectural industries have been looking for smart windows with dark or colored tints instead of the conventional milky white tones that current PDLC technology offers. Colored or dark glazing usually uses dichroic technology or liquid crystal dyes with limitations such as UV instability, slow response time, short product lifetime, and high driving voltage. Since the most fundamental contradiction of dichroic display is instability of dichroic dyes, that is why in over 70 years, none of colored smart film and LCDs using dichroic dyes could be used outdoor. For this fundamental contradiction of dichroic display or a nature flaw of coloring function in dichroic display, Scienstry had a disruptive breakthrough by relocating position of the chromophores from liquid phase of liquid crystal to solid phase of PET film substrate as a new color filter layer, so that the instable dichroic dyes can be replaced with very stable inorganic dyes, nanoparticles, low-e materials, or pigments. Similarly, the colored smart glass can be made by lamination of colored or dark smart films. Scienstry's innovation overcomes these limitations with additional haze-free and wide viewing angle advantages. As such, Scienstry has extended its innovation to its Dark Films in the NPD-500-D1, NPD-500-D2, and NPD-500-D3 series, specially developed for automotive and architectural uses. This smart glazing has the same basic features and unique attributes of the parent technology, with differences only in tinting levels. The most amazing thing is that the color filter not only provide color options for smart film/glass, but also filter out IR and UV rays, making 3G Switchable Film even more stable for outdoor applications, thus further extending the product lifetime up to 100 times. Competing technologies do not offer this tinting feature and benefits. This marks the first time in the market that products have features of near haze-free and absolutely wide viewing angles added to low-e glass and even usable without lamination.

Frost & Sullivan considers this proof that Scienstry addresses various technological challenges with its innovation capabilities, opening emerging markets in outdoor applications for the smart glass industry.

Offers Customers Cost Advantages Through Efficient Production Processes and Strategic Business Solutions

Scienstry's innovations are game-changing breakthroughs with its new products and manufacturing processes. The company has invented Vacuum Liquid Resin Lamination (VLRL) and Vacuum Liquid Resin Laminated Glass (VLRLG), a new manufacturing process for producing laminated smart glass. This technology has significant advantages for making high-performance products in any place without using any large equipment. The VLRL technique virtually allows anyone, anywhere, to make any sized laminated glass at a fraction of the cost without needing any large equipment. This feature gives the company a considerable advantage over market competition.

In early 2023, Scienstry unveiled a new production line to produce wider switchable films with widths up to 1.65 m. It also announced another production line commencing to produce pre-shrunk 3G Switchable Film with a width of 2 m and a standard length of 2.8 m and a maximum of 6 m. The company solved a new challenge associated with the increased unit prices for producing wider films due to the expensive wide indium tin oxide substrates. Its patented innovation of developing machinery and processes with high production yield provides a healthy cost reduction. With a long-term technological innovations, Scienstry has kept prices unchanged over the past 15 years despite high inflation.

Scienstry always adheres to the highest industry standards to provide net benefits in its new technology. Unlike other smart film manufacturers, the company follows a strategic business solution by providing possible free licensing for making and selling its patented solutions, with registration for using the 3G-Switchable Film™ and its associated technologies for selected glass companies or early participants. This aspect can attract new participants to use the technology to easily address new markets and customer demands.

Frost & Sullivan recognizes Scienstry's efforts, which enlarge the application scope and attract more companies to leverage its technology.

Reliable Product Performance Leads to Diverse and Emerging Market Applications

Scienstry Inc. has implemented its technology in many world-class projects for outdoor applications across multiple industrial segments, ranging from cruise ships and luxury cars to architectural complexes. In contrast, competing technologies are either in the developmental stage or confined to specific industrial applications. Customers have used the 3G-Switchable Film™ for projects such as windows, sunroofs, building walls, cars, trains, yachts, and airplanes. Notably, those using this technology for about a decade have not observed any defects. In addition, certifications by third-party comprehensive testing facilities have gained widespread reputation and commercialization success for Scienstry's products. The company follows the practices of several field tests that 3G-Switchable Film™ has passed, building customer confidence. This led to the accomplishment of large projects that set world records in the smart glazing field.

Twenty-four major airports installed the 3G-Switchable Film™ and glass the largest being Beijing Capital

Airport and Shanghai Pudong Airport, during the Beijing Summer Olympics 2008. These films also received qualifications for exclusive use for many nations' pavilions at the World Expo Shanghai 2010.

In 2011, a super luxury cruise ship named SWIFT 141 was built in the United Arab Emirates, with 100% coverage of the 3G-Switchable Film™ with touch functions. The owners have not reported any defects since its launch despite the region's high temperature and humidity. A big win for Scienstry, this project set the record for the largest project in the smart glazing business.

The film passed comprehensive tests and obtained a certificate from the Chinese National Glass Quality Supervision and Inspection Centre (CNAS) for its applications in high-speed trains in 2012. Since then, several large companies have tried and tested the 3G-Switchable Film™ for automotive applications. It passed all the internal test requirements of large OEMs and technical specifications that comply with European automotive standards. Hundreds of cars in different countries, from cold regions such as Norway to hot ones such as South Africa, have used the technology without any defects.

Diverse applications of the 3G-Switchable Film™ include heads-up displays, traffic signs, building advertising, indoor projection screens, switchable projection glass, and 3D television/monitor. In 2013, traffic signs in Norway used these films, working well at -30°C. The company has since taken up the project of updating traffic signs in different European Union countries.

In 2016, building advertising with tens of thousands of square meters covered used the 3G Switchable Film™, turning architectural complexes in Manila, Philippines, into giant television displays with front projection in evening, allowing a 360° view. The project showed that the glass building surface is valuable and a new source of generating an additional 7% revenue through advertising, besides providing energy savings at daytime.

The 3G Switchable Film™ has also begun to gain traction in luxury cars; for example, the Rolls Royce Phantom created a privacy suite officially launched in 2019. The products were partition glass to form a privacy suite, dividing the front and rear of the cabin for controlled privacy. A soundproofing, a switchable projection glass, and an energy-saving window may be additional options. Rolls Royce has the highest standard for its product quality and strict product certifications. This opens numerous opportunities for other brands to trust and introduce the product in their vehicles, impacting its business.

The company's technology caters to various applications (e.g., active and dot matrix display, touch screen, heads-up displays, switchable projection glass/window, transparent TV, organic light emitting display TV, automatic fishing machine) in over 10 other industrial sectors. Frost & Sullivan finds that only Scienstry has explored application diversity while competitors' applications focus on a single industrial segment. It is amazing that a R&D oriented company uses its internal funding to support various research and development activities and offers many advanced technologies and products to the multiple industries worldwide.

Catering to Emerging Markets Has a Far-reaching Impact on Its Growth

Scienstry's technology has revolutionized the smart glazing field and exhibited its potential usefulness in many places, such as private homes and public spaces. The new features of the 3G Switchable Film™ have linked the glass and display industries, paving the way for emerging markets, especially outdoor

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applications.

Scienstry’s innovations breaks through over three decades of limitations on smart glass for outdoor applications. Due to natural properties of glass, market sizes of outdoor applications of the new generation of smart glass are much greater than smart glass made with PDLC technology for indoor use, because the new smart glass not only can be easily fused into existing glass products but also have several new structures of

glazing, new manufacturing methods and many new applications in over 16 industries. The growth potential for outdoor applications maybe 100 times bigger than the traditional smart glass market as the company’s innovation offers more than just a privacy glass with multifunctional benefits. Acknowledging that it is impossible to have new applications without a breakthrough in fundamental principles and properties, Scienstry has concluded that different technological innovations are necessary to meet the demands of various market segments.

The company does not face much competition due to the technology’s unique attributes, which competitors cannot provide. Frost & Sullivan envisions Scienstry having a leading role with its independent patent technologies that can meet the demand from the ever-expanding automotive industry while mid-sized glazing companies are not ready yet.

Conclusion

Scienstry is a leading innovator and manufacturer of liquid crystal switchable film/smart film. The company has immense technical know-how and a deep understanding of smart glass and LCD technologies. Combining materials, processes, and manufacturing equipment technologies, the company has developed a series of liquid crystal-based technologies that provide reliable and best-in-class solutions for smart glazing applications to address emerging market applications. It has invented many new technologies by solving some of the fundamental problems related to smart film and smart glazing and contributed to the most advanced features that paved the way for developing a superior 3G Switchable Film™ suitable for outdoor and projection applications. The significance and market potential of these results are very huge.

With its strong overall performance, Scienstry Inc. earns Frost & Sullivan’s 2024 North American Technology Innovation Leadership Award in the smart glazing industry.

What You Need to Know about the Technology Innovation Leadership Recognition

Frost & Sullivan's Technology Innovation Leadership Award recognizes the company that has introduced the best underlying technology for achieving remarkable product and customer success while driving future business value.

Best Practices Award Analysis

For the Technology Innovation Leadership Award, Frost & Sullivan analysts independently evaluated the criteria listed below.

Technology Leverage

Commitment to Innovation: Continuous emerging technology adoption and creation enables new product development and enhances product performance

Commitment to Creativity: Company leverages technology advancements to push the limits of form and function in the pursuit of white space innovation

Stage Gate Efficiency: Technology adoption enhances the stage gate process for launching new products and solutions

Commercialization Success: Company displays a proven track record of taking new technologies to market with a high success rate

Application Diversity: Company develops and/or integrates technology that serves multiple applications and multiple environments

Business Impact

Financial Performance: Strong overall financial performance is achieved in terms of revenues, revenue growth, operating margin, and other key financial metrics

Customer Acquisition: Customer-facing processes support efficient and consistent new customer acquisition while enhancing customer retention

Operational Efficiency: Company staff performs assigned tasks productively, quickly, and to a high-quality standard

Growth Potential: Growth is fostered by a strong customer focus that strengthens the brand and reinforces customer loyalty

Human Capital: Commitment to quality and to customers characterize the company culture, which in turn enhances employee morale and retention

