Enlightening Possibilities: Plastics Expand Role in Vehicle Lighting Applications

Polymeric materials bring increased functionality, safety, and visual branding opportunities to automotive lighting

By Peggy Malnati

An innovative new headlamp system developed by Magna AutoSystems Division offers higher design flexibility, more efficient light output, and potentially higher safety (through increased driver visibility) while significantly reducing LED lamp complexity and offering new opportunities to optimize styling and performance. The D Optic system combines precisely molded high-temperature lenses (HDT=1090°C/2280°F) in Plexiglas HT-121 PMMA from Arkema Inc. The light pipe around the headlamp's perimeter uses the same grade. Courtesy of SPE Automotive Division (left) and General Motors Co. (right)

Automotive lighting is something that few people spend much time thinking about—that is until something stops working or someone’s eyes are blasted by another car’s high beams at night. While lighting is rarely the reason people buy cars, it plays an important safety role in all personal and commercial vehicles—both in terms of making a vehicle more visible to humans and animals as well as improving a driver’s ability to see potential problems in the vehicle's path. Not surprisingly, plastics play an important role in these applications and, in fact, are being used for visual branding on many passenger vehicles. Nominations for the SPE Automotive Innovation Awards Competition—organized by the SPE Automotive Division—show just how innovative lighting has become for increasing occupant comfort and safety, adding functionality, and making vehicles memorable to consumers.
The 2016 MY Cadillac CT6 luxury sedan (top right) sports a headlamp light curtain from system supplier Hella KGaA Hueck & Co. that appears crystal clear when unlit but glows homogeneously across the part when lit due to a special light-scattering additive in Acrylite LED LD96 PMMA from Evonik Cyro LLC. The special diffuser particles in the polymer deflect light rays while suppressing total internal reflection so light exits the lamp through the part’s surface. Courtesy of SPE Automotive Division (top left), General Motors Co. (top right), and Evonik Cyro LLC (bottom)

Forward Thinking in Forward Lighting

The 2018 model year (MY) Chevrolet Traverse sport utility vehicle from General Motors Co. was the first to use the D Optic LED headlamp system from system supplier Magna AutoSystems Division of Plymouth, Mich. The technology offers automakers a scalable, building-block approach to optimize both lamp performance and styling objectives by target market (e.g. using more elements for premium models and fewer on economy models). It does this while significantly reducing lamp complexity and potentially improving safety by increasing driver visibility. Versus conventional LED-optic systems—which feature separate reflectors, shields, and lenses that must be positioned precisely—with the new system a polymethylmethacrylate (PMMA) lens is paired with a 1x1 LED light source, eliminating typical component stack-up and the extra space that takes while increasing light-output efficiency. Lenses are produced via single-shot, thick-section injection molding held to extremely tight tolerances for high optical clarity using a highly polished tool (to meet sub-micron surface reproduction requirements).

Innovative single-collimator, all-plastic injection molded lenses for both low- and high-beam LED headlamp applications replaced multiple glass lenses on Ford F-150 pickups from Ford Motor Co. Customers benefit from a uniform light pattern on the road and light color that replicates daylight. The long-lasting LED lamps and lenses are designed to last the life of the vehicle. Courtesy of SPE Automotive Division (left) and Ford Motor Co. (right)
and laser degating. Magna reports that each side of each lens is created via an insert put together like a jigsaw puzzle to achieve a perfect fit with no flash. Lens thickness varies between 1.5-12 mm/0.06-0.47 inches. High-temperature Plexiglas HT-121 PMMA from Arkema Inc. was chosen over polycarbonate (PC) for higher light transmission (92 versus 89 percent at 3.2 mm/0.13-inch) and superior stress resistance, enabling very close (300-500 μm) positioning of the lens to the light source to maximize light capture without distortion. In the case of the Traverse, nine individual lenses and nine 1x1 LEDs were used to produce approximately 720 lumens of light on each headlamp. Three large, vertically integrated lenses (two low-beam and one high-beam) and six compact lenses (four low-beam and two high-beam) plus nine 1x1 LEDs were used to meet the design studio’s goals.

A homogeneously glowing headlamp light curtain produced by system supplier Hella KGaA Hueck & Co. of Lippstadt, Germany, on GM’s 2016 MY Cadillac CT6 luxury sedans is said to enhance safety due to large and more visible illuminated surfaces. When headlamps are off, lamps appear crystal clear, but when lit, light guides appear to glow thanks to a light-scattering additive used in the new injection-molded PMMA grade (Acrylite LED LD96 from Evonik Cyro LLC.) A previous version of the lamps in clear PMMA without light-scattering additives—Evonik’s Acrylite 8N—required both special molded structures (micro-optics) on the light curtain as well as multiple LEDs behind the part to achieve this effect. However, that technology suffered from bright spots when powered and a milky appearance when off. The new technology is edge-lit using just four LEDs, is aesthetically pleasing, and serves as a design enabler for achieving a homogeneous lit appearance. The technology works with any color LED, with or without 3D effects like molded logos, offering studios greater design freedom and providing consumers with premium headlamp styling. Since the additive eliminated the need to mold structures into the light curtain, tooling costs were reduced 10 to 15 percent.

Replacing multiple glass lenses, the single-collimator, all-plastic lens for both low- and high-beam LED headlamp applications debuted on 2015 MY Ford F-150 pickups from Ford Motor Co. and later transitioned to 2017 MY Ford Fusion sedans. Looking like a large-faceted gem and subsequently called Crystal Diamond Light, the efficient single-lens design achieved the same level of light output as previous glass systems, increased design freedom for stylists, freed up headlamp packaging space, lowered the carbon footprint, and saved $5 USD/vehicle—which, on high-volume platforms like the F-150, represents significant savings. Injection molder and toolmaker DBM Reflex of Laval, Quebec, made the high-precision, multilayer tool, which holds surface tolerances to 40 μm to accurately replicate the complex optical shapes/prescriptions. The molding cycle is 150 seconds, which is quite fast for such a
thick lens (45-mm/1.8-inch). Makrolon LED 22.4.5 PC resin supplied by then Bayer MaterialScience (now Covestro LLC) was selected for optical efficiency. DBM supplies the lenses to system suppliers OSRAM Licht AG, headquartered in Munich, Germany, and Flex-N-Gate Corp. of Warren, Mich. who produce complete headlamp systems. Compared to glass lenses, Ford reported over $1.5-million savings from investment and capital cost avoidance.

The headlamp shutter with integrated backlighting ring debuted on 2014 MY BMW 4 Series executive coupes from BMW AG and replaced high-temperature co-polycarbonate with a liquid crystal polymer (Vectra E531i-D3 from Celanese of Irving, Texas). The switch to the higher-performing LCP was made to solve heat problems caused by the “sunload effect”—namely formation of a hot spot on the shutter/trim ring generated by the projection lens, which acts like a magnifier. In some cases, temperatures are rising to 200°C or greater on part surfaces. The change was cost neutral but provided many benefits, including better mechanicals (very-high tensile strength and elastic modulus, 30-percent higher creep resistance at 10,000 hours), very-low moisture absorption (0.03-0.10 percent), higher dimensional stability at elevated temperatures, and higher thermal performance (continuous-use temperature (CUT) = 225°C/437°F @ 1.8 MPa/261 psi with peak operating temperature at 335°C/635°F). Other improvements included higher chemical and oxidation resistance, inherent flame retardance (UL 94 V-0 to 0.15 mm/0.01 inch), very-low fogging/outgassing, higher part quality, shorter cycle times, and 30 percent less scrap (sprue waste). A very-thin cold runner is used to inject the material into the tool, which was produced by molder and toolmaker Formplast Purkert, s.r.o. of Prague, Czech Republic. Cycle times are around 15 seconds versus 35 to 45 seconds for the high-temperature PC. System supplier Automotive Lighting Reutlingen GmbH of Reutlingen, Germany, produces the complete headlamp.
No Retreat with Rear Lighting

Headlamp light curtains aren’t the only form of lighting that benefit from special reflective additives. A good example are rear lamp reflectors on 2015 MY Dodge Challenger sports cars from FCA US LLC. Produced by systems supplier and molder Varroc Lighting Systems, the rear taillamps appear to glow homogeneously when lit thanks to the special resin additive coupled with multiple LEDs. A reflective white PC resin (Lexan Lux 2298 from SABIC of Houston) provides both highly specular and diffuse reflectance (>95 percent across the visible-light spectrum) plus a higher optical efficiency versus other materials. Due to a low yellowness index (YI), the polymer experiences minimal color shift and maintains its high reflectivity even after heat aging, eliminating the cost, scrap, and environmental burden of painting or plating, which are standard practices for taillamp reflectors. An ideal balance of properties is said to facilitate both moldability and design freedom. The result is enhanced aesthetics and a stylish appearance that is different when the lamps are lit/unlit, helping support safety and the rear signature branding of Dodge vehicles.

Another rear lighting system adds an additional safety twist by embedding the blind-spot information system (BLIS) in taillights on Ford’s 2015 MY F-150 pickups. A radar-based collision-avoidance safety feature, BLIS modules help drivers determine if anything is entering the sensor’s field of view (FOV)—extending rearward from exterior mirrors to 0.91 meters/3 feet behind the truck’s rear bumper. BLIS modules normally are housed behind rear radar-transparent thermoplastic bumper fascia, but this vehicle sports aluminum bumpers, which are opaque to radar and render the system unusable. The tail lamp features a protuberance in front of the sensor to maintain a minimum distance of 3 cm/1.2 inches between sensor and lens. The BLIS is housed behind two layers of Plexiglas V826 PMMA supplied by Arkema. The taillamp lens was injection molded via a three-color/three-shot process in water-clear transparent, transparent red, and specially formulated opaque red. A cast-aluminum service door, which also acts as a heat sink, allows the BLIS unit to be serviced. The combined part function reportedly saved Ford $10 per vehicle plus an additional $15 million in cost savings by eliminating hardware, covers, and modifications to the D pillar to accommodate the module in the bumper.
Lighting as Visual Branding

The last decade saw a significant increase in the use of innovative, plastics-intensive lighting not only to enhance functionality, customer comfort, and safety, but also for visual branding both inside and outside of vehicles. Perhaps no automaker did more of this than Ford. The automaker introduced color-changing LED ambient lighting in footwells, front and rear cupholders, and heating/ventilation/air-conditioning (HVAC) controls for 2009 MY Ford Flex cross-over utility vehicles (CUVs). Injection-molded light-diffusing Acrylite PMMA resin from Evonik Cyro provided uniform lighting without hotspots across the car using blended colors from red/green/blue (RGB) LED light sources. LED-based ambient lighting was said to reduce costs and power consumption while increasing use-life of interior lighting. Ford’s second-generation dual-lens cup holder lights debuted on 2011 MY Ford Explorer SUVs. The one-piece design integrated the primary illumination surface with the show-surface lens for improved craftsmanship and lower assembly and warranty costs versus earlier two-piece designs. Acrylite 8N-123-000 PMMA from Evonik Cyro was molded by system supplier Chicago Miniature Lighting, LLC of Novi, Mich. A third-generation illuminated beverage holder assembly was used on Ford’s 2015 MY Lincoln MKC and MKX luxury CUVs. The patented, package-friendly application combined PMMA’s optical transparency with geometrically mirrored part surfaces to move light efficiently upward from the bottom of the cupholder via a single cup/plate component. This reduced glare when a cup was absent from the holder, lowered scrap, and eliminated the need for a special press and tooling, thereby lowering costs.

Similarly, Ford used LED-based lighting as part of its branding scheme on illuminated door sills with vehicle/model logos starting with 2010 MY Ford Mustang sports cars, Lincoln MKZ sedans, and Ford MKT CUVs. Produced by Innotec Group of Zeeland, Mich., using PMMA from Serigraph Inc. of West Bend, Ind., and PC and acrylonitrile butadiene styrene (ABS) from SABIC, the sill plates were laser etched to create high-impact illuminated optics. Development time was reduced from months to weeks, also lowering costs. Ford was back with a different manufacturing process on 2013 MY Lincoln MKZ and MKS sedans and Ford MKT CUVs. Produced by Innotec with Lexan PC from SABIC, this time electronics were encapsulated in the PC resin and Multicolor LED-based illuminated door sills (top) debuted on 2010 MY Ford Mustang sports cars and Lincoln MKZ and Ford MKT vehicles. The application was said to be the auto industry's first to provide multicolor illumination from one LED light engine. Next-generation illuminated door sills (above) debuted on 2013 MY Lincoln MKZ and MKS sedans and Ford MKT CUVs. Packaging height also was reduced, eliminating the need to form depressions in the rocker panel or to make costly changes to the door's sheet metal to accommodate the illuminated sill plate. Courtesy of SPE Automotive Division

An illuminated articulating step assist (above) combined a flexible cast urethane light bar with an extruded and hardcoated PC lens profile to put light where occupants need it when entering/exiting GM’s 2015 MY Cadillac Escalade SUVs. The sealed light pipe was protected against heat, water intrusion, stone chips, and shoe impacts. The system was supplied by Magna International using material supplied and processed by
to protect them from electrostatic dissipation (ESD), mechanical shock, and other environmental damage. Insert molding eliminated the need for conventional conformal coatings or separate housing assemblies, which, in turn, simplified ESD testing and improved reliability versus conventional light-engine designs.

Another branded lighting application from Ford was the logo-projection lamp in lower door panels of 2013 MY Lincoln MKT Town Car sedans and limousines. Traditional door-panel lights use incandescent bulbs that take significant packaging space where there is little space, necessitating that lights be designed concurrently with doors. That location increases the risk of bulb damage since the panel housing the light can be kicked/bumped as people enter/exit cars. The new LED-based system projects a logo (instead of a point of light) onto the ground beneath right- and left-side doors when doors open. Holes in the panel substrate provide *poka yoke* (fail safe) orientation for the logo. Compared to earlier designs, the system took far less packaging space and eliminated metal fasteners. Furthermore, damage during ingress/egress was greatly reduced since the LED light was no longer exposed when the