

Precision Molded Lens Arrays Made of Glass

Lens strips simplify the design of compact light sources and optical systems

• The market for high-brightness Light Emitting Diodes (LED) is expected to grow strongly in the near future. In order to meet the rising demand, suppliers are developing new ways of manufacturing components on a larger scale. SCHOTT has now patented a precision molding process for producing strips and arrays of mini lenses made of highly refractive glass. Multiple LEDs can thus be positioned side by side and very closely together to allow for a strong and defined light beam to be formed. The precisely shaped lenses enable compact designs of light sources as well as optical systems.

With nearly 3,000 registrants from 38 countries, "Strategies in Light", the largest business conference on high-brightness light-emitting diodes and lighting, was held in Santa Clara, CA, USA, from February 10-12, 2010. Bob Steele, Conference co-chair and Director of the Optoelectronics Programs at the photonic market research institute Strategies Unlimited, presented an extremely positive market forecast. Overall, Steele predicts a 53% surge in the High-Brightness (HB) LED component market for 2010 to a total of \$8.2 billion, and growth to \$20.2 billion by 2014, driven mainly by the market for liquid-crystal display (LCD) backlights and a variety of lighting applications.

In many cases, lighting applications require aligned light, for instance in automotive, architectural and stage lighting, machine vision lighting, UV curing or medical technology. Since LEDs emit light hemispherically, reflectors or aspherical lenses, sometimes even a combination of both, are needed for collimation. However, if multiple LEDs are to be arranged densely side by side, these solutions become difficult to apply: Reflectors require a considerable amount of space and the mounting and adjustment of single aspherical lenses is extremely time-consuming. A strip or array of lenses that collimate the light of many LEDs in an efficient manner makes processing much easier.

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While lens arrays made of plastic are widely available, those made of highly refractive glass are still rare. Plastic lens arrays can be produced rather cheaply. However, they have downsides: plastic is not resistant to either high temperature or moisture. Additionally, UV light is either not transmitted at all or leads to darkening of the material (solarization). Optical glass represents the better but more expensive alternative. It is resistant to temperature changes as well as moisture. By offering high light efficiency from 350 to 2,000 nm, it can be used in a broad range of appli-

cations while enabling a compact design of the light source due to its superior refractive index.

Lens Arrays Made of Glass

Glass lens arrays can be produced using lithography or precision molding techniques. The lithography process is commonly used, for instance, in the semiconductor industry. It also offers a good solution for producing small, rather flat aspheres (Figure 1). However, the maximum height of the lenses is only a few 100 µm and this, in turn, limits their

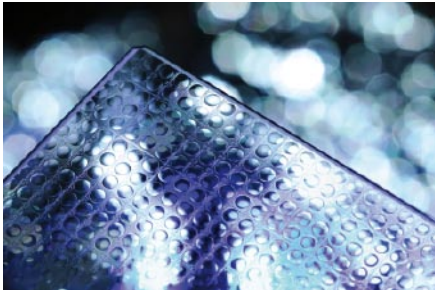


FIGURE 1: Hundreds of microscopic lenses formed on an array made of glass by using a lithographic process.

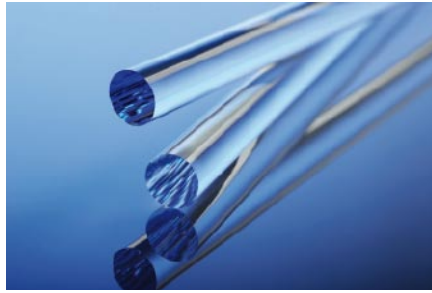


FIGURE 2: Highly refractive Low Tg glass rods with diameters of less than 1 mm and up to 1000 mm in length.

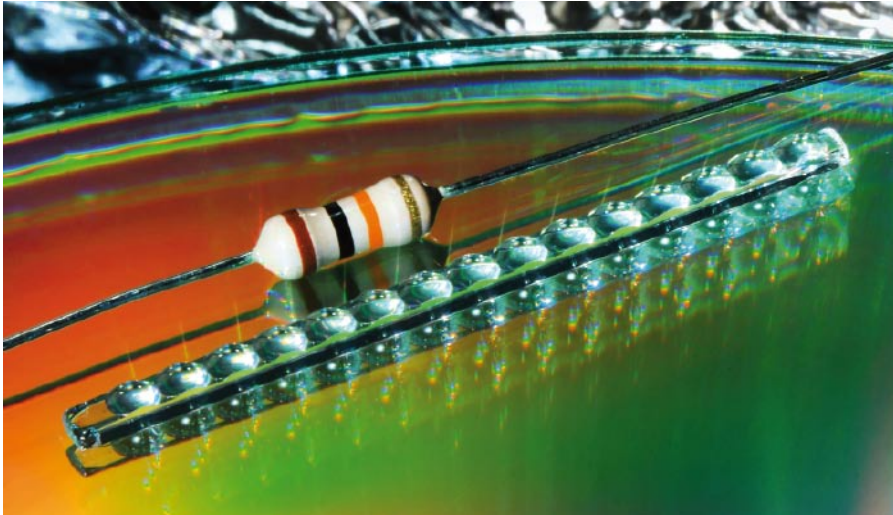


FIGURE 3: Manufactured strip of 15 high refractive index aspherical lenses.

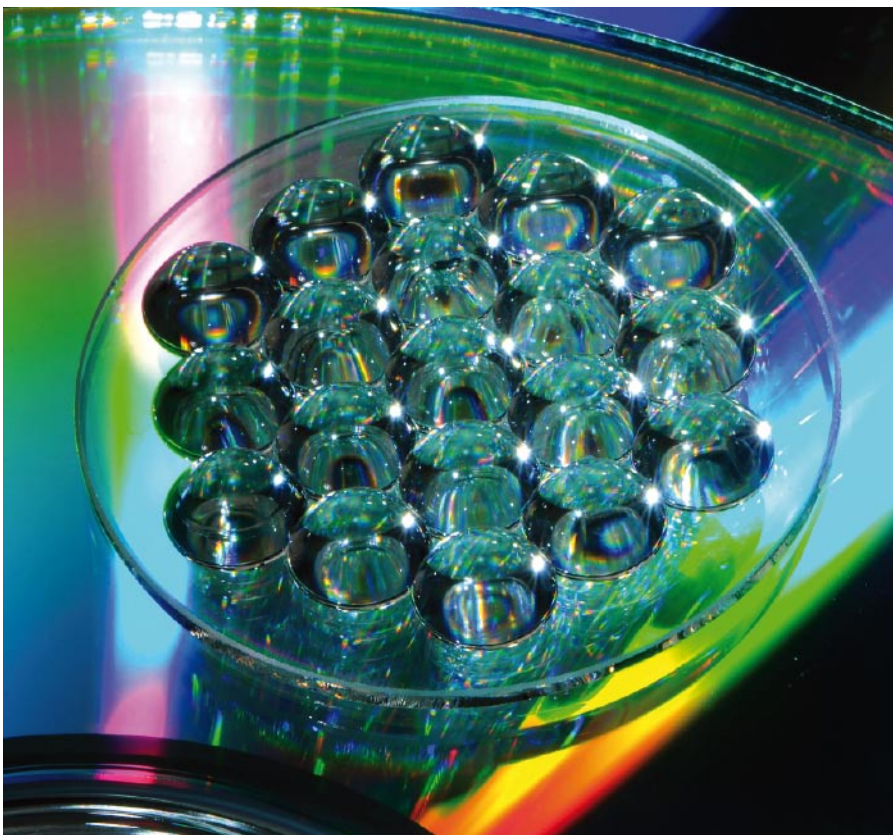


FIGURE 4: Lens array of 19 aspherical highly refractive glass lenses with a diameter of 25 mm. Each single lens has about 5 mm in diameter.

refractive power. The manufacturing costs are high and the processing times are quite long. This limits the technique to the production of small quantities. Mass production calls for a different approach to be used.

Precision molding allows for cost-efficient mass production of optical components. Hereby, a special glass is heated to a temperature at which it reaches a certain viscosity that makes it deformable. At this point, the glass is pressed into the final shape and gradually allowed to cool down. Correct thermal management of the cooling step is essential to ensuring the accuracy of the optical element. Furthermore, anti-reflective or filter coatings are often applied to these optical components. No additional grinding or polishing is necessary because the optical surfaces are of very high quality (i.e. $R_a = 5 \text{ nm}$) that can even be adjusted by modifying the processing speed.

Until now, however, strips and arrays of rotation-symmetric convex aspheres could only be realized by fusing a set of single precision molded lenses. Another way to produce lens arrays using precision molding is to use a vacuum process. However, molding lenses under a vacuum is rather expensive and leads to a slow process, which is not economical. Until now, it has not been possible to use a normal precision molding process. The reason is that air entrapments occurred during the molding process involving more complex structures with multiple cavities.

A solution to this problem has now been found: replacing the commonly used flat or ball-shaped blank with thin radial symmetric glass rods or fibers (see Figure 3). This allows for mass production of bubble-free optical components with a more complex structure. Glass rods are available with diameters of less than 1 mm and up to 1,000 mm in length. Single rods can be molded to lens strips (Figure 3); several fibers aligned side by side form an array (Figure 4). Besides being much easier to handle and cheaper than ball-shaped blanks, fire-polished rods have a defined thickness and offer high surface quality.

In relation to their small diameter, rods allow for the bubble-free production of lenses in higher volumes and steeper outlines than can be achieved with any other production method. This allows for geometrical accuracy of 300 nm or less to be reached. The precision molding process described here is extremely versatile and of particular benefit in producing small optical components with cavity structures of less than 3 mm and up to a maximum of 5 mm in diameter. It supports the mass production of aspherical, bi-convex, or bi-aspherical lens-

