Seven optical elements are combined in this point-of-care diagnostic.

Free-form optics for automotive applications: Design freedom says something for the use of plastic.

Plastic with crystal-clear optical advantages

Why polymers have huge potential in LEDs, photodiodes, eyeglasses, LiDAR, head-up displays, smartphone lenses and consumer optics

Plastics are in constant competition with many other materials. In optical applications, they rival above all with glass. K-PROFI spoke to Bernhard Willnauer, Managing Director of Viaoptic GmbH, which like its sister company Leica Camera is based at the traditional Hessian location of the optical industry, about the progress of substitution, new application opportunities for polymers and counter-movements.

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Feinwerktechnik Wetzlar GmbH produced its first plastic optical component in 1965 for the brightest viewfinder of an SLR camera. This is noted in the history of Leica Camera AG's sister company, today's Viaoptic GmbH in Wetzlar. While the actual imaging optics of camera lenses are still made of mineral glass, plastic optics have since conquered every new fields of application. "We are surprised every day by the ideas customers bring to us," reports Managing Director Bernhard Willnauer. Customised optics made of COP/COC, PC and PMMA for the automotive industry, sensor technology and medical technology are the three big drivers at Viaoptic. A high degree of design freedom, low weight, break resistance as well as economical large-scale production are the decisive advantages of plastic over glass.

"I see the design freedom as the biggest advantage," says Willnauer. For example, optical applications benefit from free-form lenses and so-called aspheres, i.e. lenses with an elliptical rather than spherical basic geometry, which can bring an optical system consisting of several spherical lenses down to one lens. While these are extremely difficult or impossible to realise in glass, they are just as easy to produce in plastic as a spherical lens "as soon as the tool is set up". This is because, in contrast to the geometric limitations in glass processing, the introduction of free-form surfaces into injection moulds is standard. And through ultra-precision machining in toolmaking, the high demands on accuracy and surface roughness of the optical plastic systems can be met.

The simple integration of fastening, centring and spacing elements is another aspect of design freedom. Just like the possibility of combining an infinite number of optical surfaces in one component. The classic glass lens (biconvex, plano-convex or concave) has two optical surfaces, a ground prism has a maximum of four. "Plastic optics with seven or eight optical surfaces, such as those used to steer the laser in a computer mouse, cannot be manufactured in glass at all". Plastic also allows the production of optical microstructures. Structures that are finer than the wavelength of light can be used to control the diffraction of light in such a way that very flat elements can be used to achieve effects similar to refractive optics, in which the light is refracted rather than diffracted. The production of plastic micro-lens arrays, where many small lenses are arranged on one surface, also has much fewer restrictions than the glass version.

Ahead by a nose in spectacles

Plastic is inferior in terms of scratch resistance, temperature resistance and (imaging) accuracy: "The achievable precision is significantly higher with glass, mainly due to the low thermal expansion".

In terms of dispersion and refractive index, plastics also cover a less extensive spectrum than glass.

Despite these limitations, plastics have prevailed especially in spectacle optics. In 2019, the share of mineral lenses in total sales of spectacle lenses in Germany was only 4%, compared to 12% in 2010. "Glass has all but disappeared here," Bernhard Willnauer discerns, even though Viaoptic is not active in this business sector. Break resistance and weight are the decisive aspects. Thanks to anti-reflective and scratch-resistant coatings, plastic lenses are "almost on a par with mineral lenses". In addition, there is a wide range of colouring options for filter functions or fashion purposes.

LED and laser diode cause growth boom

Plastic optics have experienced exponential growth in technical applications since the 1990s. With the emergence of LEDs (low heat generation) and laser diodes (adjustable radiation intensity), the range of applications expanded rapidly. "Gas discharge, xenon or halogen lamps, as used before in surgical lights, generated too much heat for plastics. In car headlights, too, plastic lenses have been introduced with the LED. For the older halogen and xenon lamps, glass lenses were the only option because of the enormous temperature produced." In the new generation of matrix headlights with beamer technology, a glass-plastic combination solves the issue, because there "the temperatures are a little higher again and the requirements for resolution and precision increase."

In addition to lighting optics, the automotive industry offers a large playing field for the use of plastic optics in sensor technology (for example LiDAR) and in imaging applications such as head-up displays. "On the other hand, in cameras used for vehicle assistance systems, glass has reasserted itself, partly because the temperature range for testing the components has now been extended to 130°C".

Viaoptic Managing Director Bernhard Willnauer on the range of applications for plastic optics: "We are surprised every day by the ideas customers bring to us".

In medical technology, especially in endoscopy and microscopy, plastic has so far not been able to hold its own against glass. "There are frequent attempts with plastic optics in disposable applications, but usually the imaging quality is not sufficient for the desired imaging". In contrast, the optics used between the laser and the eye in laser eye surgery are typically produced in form of a sterile disposable plastic component. Bernhard Willnauer also considers optical assemblies for near-patient laboratory diagnostics (point-of-care testing), commonly called rapid tests, to be predestined for plastic. "The demand is great, the processes are complex, and many optical components are needed. Plastic enables here a reduction in costs".

Optics built into smartphones represent a huge consumer market. In new top models, up to five lenses with multiple lens elements are built in. "The penultimate and last generation relied on plastic lenses with a glass element to compensate for the temperature effect. Current models have pure plastic lenses, and in the next generations a

Miniature optics made of plastic: The smaller the more difficult is the manufacture of glass lenses.

Optics for a high-end photo flash unit made of high-temperature plastic.

glass-plastic combination will be used again," reports Bernhard Willnauer. "Mineral glasses simply offer more possibilities in imaging optics in terms of refractive index, dispersion and temperature range. But since glass cannot be ground into aspherical lenses on the scale of mobile phone lenses, a lot of research and development is currently being invested in pressing the smallest lenses".

Into the future with even higher precision

But development is not standing still in plastic optics either, shown in the example of virtual reality headsets. The Viaoptic managing director reports on numerous new areas of application for plastic optics, such as sensors used in the smart home sector. And beyond navigation devices for surgeries, these also might include quite ordinary applications such as new signal displays in public transport for improved side visibility and colour diversity.

And even 3D printing is headed towards optics. "There is a vision that in future the optician will print the individual lenses in his back office directly after testing the eyes. The process itself still has limitations, but there are already many ideas on how to solve these. I think this will come at some point," Bernhard Willnauer is convinced.

The big challenge at Viaoptic and other manufacturers of technical plastic optics is a further increase in precision. "For the mass products used in optical systems, such as LEDs, photodiodes, chips, etc., the manufacturers specify relatively large tolerances across the board. If higher precision is required for the application, even more precise plastic optics are supposed to compensate for this. However, we can only achieve higher precision through better measurement technology. Therefore, we invest in inline 100-per cent-inspection with camera control and specific measuring technology, as it is used for the selection of mobile phone lenses. This trend towards higher precision through 100-percent-inspection and selection is seen in many areas".

Other areas of application may also be possible with special plastics, such as the OKP polyesters from Osaka Gas Chemicals in Japan. Compared to COP, PC and PMMA, these have enhanced dispersion and birefringence properties, as well as a higher refractive index, and are used for smartphone lenses, among other things. "However, some of these materials are so scarcely available that they only go into consumer optics and are difficult to obtain here in Europe".

www.viaoptic.de