New software optimelt sequence reduces microdefects in optical components

Freedom from internal defects for brilliant images

Injection molding of optical components is subject to strict requirements, including freedom from internal defects. Tomography analysis methods can identify even microdefects in the order of 20 µm. The main cause of these very small defects are gases that enter the melt either from the material or the environment. With new software, ENGEL intends to reduce gas inclusions during the processing of transparent plastics and ensures a consistent high melt quality.

Eyeglasses, cameras, or car headlamps – optical plastic components play an important role in our day-to-day lives. To ensure that plastics for optical applications can be processed in the highest quality, ENGEL has been conducting intensive research for many years. The starting point are the developments in the smartphone industry. Ever since these multifunctional devices arrived on the scene, the performance of their cameras has increased continuously. The pictures have become ever sharper and the compensation for lighting conditions ever better. While the sensor resolution of the first camera-capable cell phones was in the range of 0.3 megapixels at the beginning of the 2000s, the latest models from leading smartphone manufacturers now offer over 100 megapixels. In addition, the number of installed camera modules is increasing steadily to further increase the quality via software-supported combining of images. In view of the fact that individual camera modules in turn consist of a large number of optical lenses, it becomes clear how important the quality of these tiny components is.

High-performance transparent plastics, particularly polycarbonate (PC) and cycloolefin copolymers (COC), have superseded glass in this market segment. The crucial factors are the lower weight, reduced energy input for processing and the resulting lower manufacturing costs. In addition, it is possible to reproduce both very complex and very fine structures by injection molding.

In the manufacture of optical lenses, there are principally two risks of defects: First, on the surface, where streaks or other defects can occur. And second, the lens volume facilitates to the formation of small defects such as cavities.

While, in standard injection molding, the formation of cavities can be prevented by optimizing the process control, the risk of other small defects often state greater problems for the user. Particularly critical are so-called “microvoids,” microdefects of below 20 µm, which cannot be made visible via conventional light microscopy investigations. ENGEL therefore first had to find and evaluate a reliable measurement method for these kinds of defects, in order to subsequently optimize the injection molding process.

Making the Smallest Defects Visible

The trend toward ever higher resolution sensors with higher light sensitivity and camera modules that can be used for a very wide digital zoom range reduces the size of the acceptable defects to ranges that are no longer visible to the human eye, even under the microscope. To make these defects visible, special measurement methods are necessary for which optical coherence tomography (OCT) is a promising candidate regarding resolution and measurement time.

OCT is used for generating high-resolution 2D and 3D images in organic and inorganic materials and is regarded as an optical equivalent to ultrasound measurement. Via white light interferometry, it makes use of interferences between the reference beam and the light scattered from the sample to create a depth profile (**Fig. 1**). A light source (LS) passes through a beam splitter (BS), forming a reference beam (RB) and a beam to the sample. Interferences are detected after spectral separation by means of a diffraction grating (G) on the detector (CCD). Depending on the light source used, depth resolutions of 1 µm and lateral resolutions of 0.5 µm are possible.

OCT analyses pose their own challenges. The greatest are so-called “speckles,” which are created by the unavoidable forward scattering in the sample. They are apparent on the recorded images as white dots, very similar to the sought microvoids. Based on preliminary work by the Research Center for Non Destructive Testing GmbH, ENGEL, together with the Institute of Polymer Injection Molding Technology and Process Automation at Johannes Kepler University, Linz, Austria, worked out an evaluation routine that can reliably distinguish between speckles and microvoids. It is only through this procedure that the problem of microvoids in smartphone lenses can be quantified.

With the OCT measurement of an arbitrarily selected lens (**Fig. 2**), the lens cross-section can be seen schematically in the center of the graphic. To make the microvoids visible and ultimately countable, the volume scan is subdivided into layers (Fig. center). By application of an algorithm, speckles can be identified and removed, which allows the microvoids themselves to be seen (Fig. right).

The OCT measurement, in conjunction with a corresponding evaluation algorithm, makes it clear that conventionally produced smartphone lenses, which appear flawless under the light microscope, are permeated by microvoids with diameters from 10 to 20 µm. In the tests, over 1000 microvoids were counted per lens.

Customizable Plasticizing is the Key

Microvoids are the result of gases, which occur in the process despite careful material conditioning and feeding. Two main causes can be identified [2]: first, the distribution of non-dissolved larger air inclusions and second the agglomeration of even smaller voids. The aim of the development work was therefore to find ways of freeing the melt from gases or preventing gas inclusion.

In conventional injection molding, even a compression relief before and after dosing often does not offer enough flexibility to eliminate gases present in the melt. According to Henry's law [3], there is a direct relationship between the pressure acting on the plastic melt and the amount of gas that can be dissolved in it. It is therefore an obvious step to eliminate the presence of gas by suitable process and pressure management during processing, in order to avoid the formation of microdefects. The aim was therefore to create additional possibilities for applying pressure to the melt. Because of the large number of different materials and customer-specific production conditions, this means customizing the plasticizing process to a high degree.

The result of the development work is the optimelt sequence software, which makes a variety of new modules available to the process for extending the plasticizing process (Info box). In the first expansion stage, the software offers modules for customizing the machine se-

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quence. The core element of this is the freely configurable plasticizing sequence, which can be programmed into the workflow as an additional sequence. Herein, steps such as dosage, screw retraction for closing the active-closing nonreturn valve (type: SmartShut by ENGEL) or compression reliefs are programmed. Two options for applying the backpressure are available. This pressure application can be arbitrarily adjusted in terms of level, duration, and onset time.

Variability in the Melt Compression

Besides the backpressure generation via an axial screw advance (backpressure via screw position), pressure can also be generated by screw rotation (backpressure via screw rotation) (**Fig. 3**). While, in the case of the backpressure variant via screw position, an axial stroke is executed, in the variant via screw rotation, the screw is axially stationary. It should be noted that these workflow sequences are only examples. They represent a great simplification of an actual sequence and are only one of many possibilities of how the modules can be used. With the aid of the modular system, the user can design and adapt the workflow flexibly as required.

The accuracy with which the backpressure generation by means of screw rotation takes place should be emphasized. The flow processes during this kind of pressure generation are diverse and, even with the simplest consideration, pressure flows toward the feed zone are opposed by drag flows toward the space in front of the screw. This does not take into account any leakage flows via the screw flights and the role of the shut-off ring. However, electrical injection units from ENGEL are able to keep the backpressure within an interval of ±1 % of the setpoint value over an arbitrary time period. The optimelt sequence software is currently available for electrical injection units.

Number of Microvoids Significantly Lower

The benefit of the software during injection molding of optical lenses has been investigated in numerous series of experiments. OCT analyses have all confirmed that adaptation of the pressure management to the particular requirements drastically reduces the number of microvoids. In the results presented here (**Fig. 4**), one lens in each case per cycle (per shot) was characterized. The individual bars reflect the variation of the process parameters, such as the level and duration of the pressure application and the time point during melt processing. The numbers indicate the number of microvoids detected per lens in each case. The illustration makes clear that the additional pressure application made possible with optimelt sequence can significantly reduce the number of microvoids. The variability made possible by the software permits an additional process and application-specific optimization.

To gain a better understanding of what the purely numerical representation means in reality, we turn back to practice (**Fig. 5**). In the layers from OCT measurements, the microdefects can be clearly identified by means of the white dots. While the left image shows a lens generated by a standard injection molding process, a customized workflow using the new software was chosen for manufacturing the lens in the right-hand image.

Outlook: Light Guides and Mechanically Stressed Parts

Since the reduction of defects can always lead to an improvement of the optical properties, the new software opens up great potential for manufacturing optical products from transparent plastics, apart from smartphones in medical technology, for example. ENGEL is evaluating other fields of application for the technology, which overall lead to an improvement of the internal structure of injection-molded parts. Among other applications, light guide structures, thick-walled lenses as well as head-up displays are being investigated in detail. Especially in the case of light guides, in which the light must cover long distances within the part, significant improvements can be expected by reducing microdefects. For example, it may be possible to reduce the problematic loss of blue light along the light guide.

Another field of application of optimelt sequence may be in mechanically stressed parts. Under cyclic loading, cracks often propagate from smallest defects in the material. Reducing just these defects might improve the fatigue strength correspondingly.

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References

[1] https://tu-dresden.de/med/mf/ksm/ressourcen/dateien/OCT_Anleitung.pdf?lang=de

[2] Michler, G. H.; von Schmeling, H.-H. K.-B.: The physics and micro-mechanics of nano-voids and nano-particles in polymer combinations. Polymer 54 (2013), pp. 3131–3144

[3] Sanchez, I. C.; Rodgers, P. A.: Solubility of gases in polymers. Pure and Applied Chemistry 62 (1990) 11, S. 2107-2114. https://doi.org/10.1351/pac199062112107

The quality of photos taken with the smartphone increases with each new generation of devices. As a consequence thereof, the requirements for plastic optical lenses are increased. (Picture: iStock)

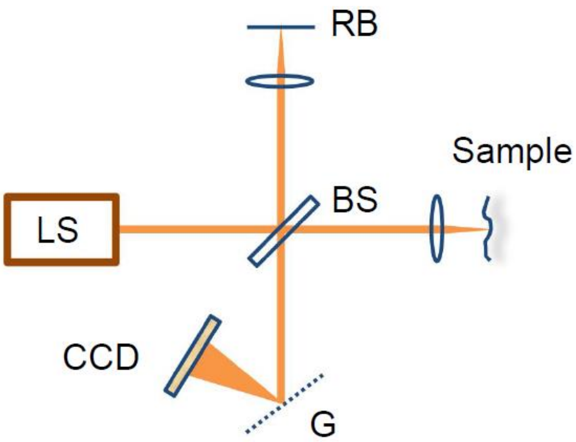

Fig. 1. Optical coherence tomography (OCT) provides two- and three-dimensional images from light-scattering samples with micrometer resolution.

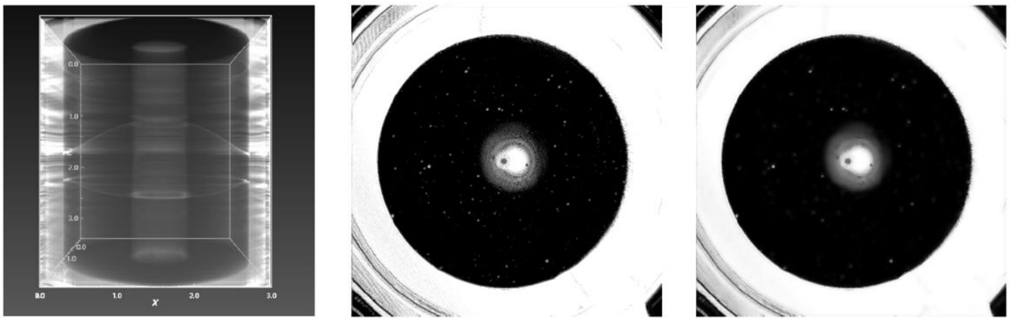

Fig. 2. Volume rendering of an OCT measurement (left) – width of the measurement range: 3 mm – allows the lens cross-section to be identified. XY layers are derived from this. The image right illustrates the microvoids after speckle removal.

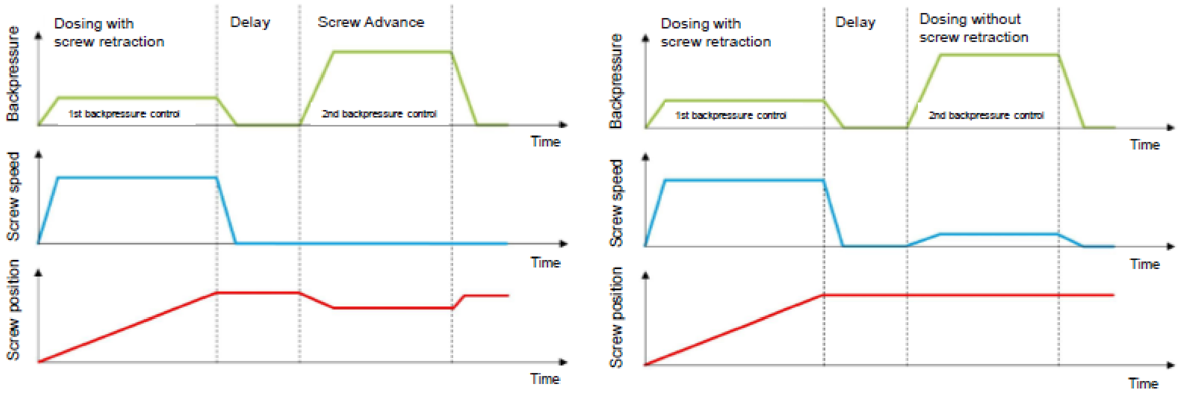

Fig. 3. Flow diagram: besides the backpressure generation by means of an axial advance of the screw (backpressure via screw position, left), pressure can also be generated by screw rotation (backpressure via screw rotation, right).

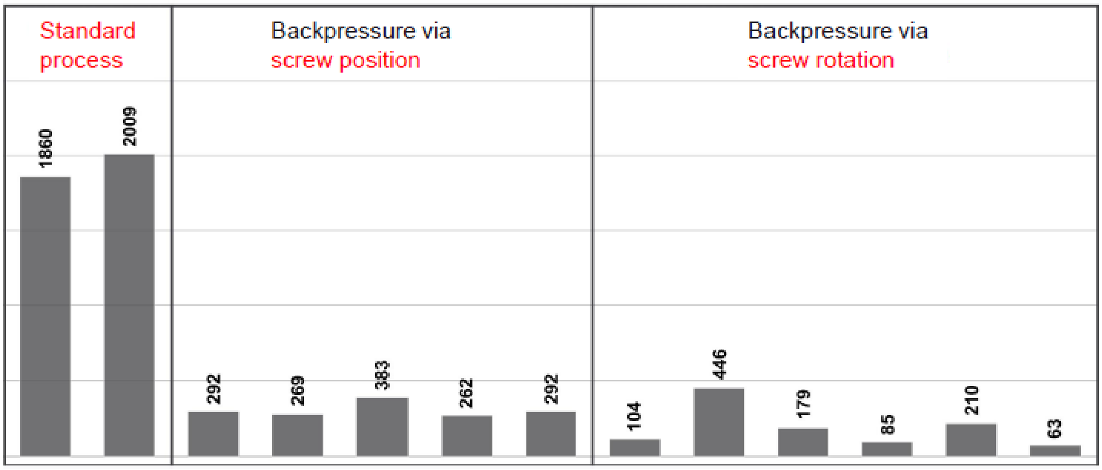

Fig. 4. The numbers indicate the number of microvoids detected per lens in each case. The diagram makes clear that this number can be significantly reduced with optimelt sequence and the additional pressure application.

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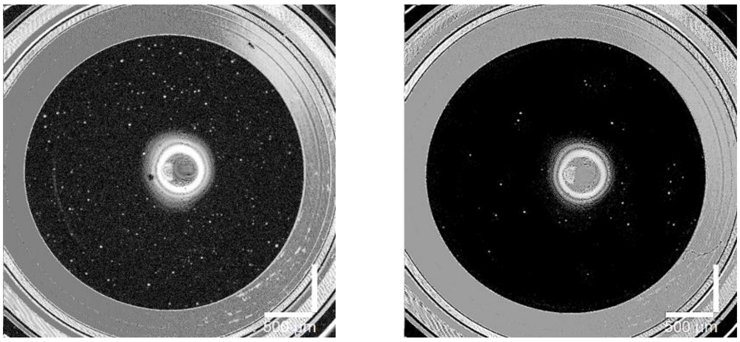

Fig. 5. With the use of optimelt sequence, the plastic lenses have significantly fewer microdefects (right). The lens in the OCT cross-section left was produced by standard injection molding.

Pictures: ENGEL

<<Text Box>>

New Software optimelt sequence – Fully Featured

The software provides the users with modules for extending the plasticizing process. The aim is to customize the machine sequence. A synopsis of the functionalities:

- Multiple plasticizing sequences configurable
- Plasticizing sequences interchangeable
- Own overview page with the most important setting parameters
- Visualization of the plasticizing sequences

optimelt sequence – Base Version

Additional steps in the sequence of the freely configurable plasticizing sequence:

- Dosing up to dosing volume
- Compression relief after dosing
- Screw reverse rotation with SmartShut
- Backpressure via screw position
- Backpressure via screw rotation
- Additional timer settings

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