In spite of the difficult economic situation, the symposium sponsored by Engel Austria GmbH at the end of May attracted 2,000 attendees to St. Valentin. One of the main speakers was Dr. Georg Steinbichler, Manager Research and Development at the Austrian injection molding machine manufacturer. His topic: Inspiration for Innovation – Chances for New Technologies and Machine Solutions. *Kunststoffe*'s editor Clemens Doriat used the opportunity to ask him about his vision of injection molding technology.

»Every Kilogram Saved May Cost a Bit More«

Georg Steinbichler on the revolutions in the optical and healthcare industries, smart plastics and the enormous potential in lightweight construction.

Kunststoffe: Mr. Steinbichler, you call optics one of the key technologies of the 21st century. What leads you to make this statement?
Steinbichler: Until now, optical components made of plastic have not really been considered competition for glass. It is only through an appreciation of how thick-walled plastic parts can be manufactured economically with a suitably high surface quality, additional degrees of freedom in design and functional integration that the opportunities that will revolutionize optics can be grasped. Studies confirm the numerous potential applications and the enormous market potential in the coming years. For instance, head-up displays such as those used by pilots in aircraft for years will be used in large quantities in automobiles to project important information in front of the windshield via plastic mirrors without posing a distraction while remaining readable under all lighting conditions.

Kunststoffe: Could you give us an example of other applications to be expected in the near future?
Steinbichler: This brings us to the field of polymer-based electronics. Take LEDs, which are already very highly developed: LED housings with reflector shells of glass fiber-reinforced LCP, for instance, are being injection molded onto pre-stamped conductive carriers. Following this, a semiconductor chip with an edge length of 0.2 to 1 mm is glued in the center as a light-emitting diode. To protect the chip and its delicate gold wire connections, the plastic housing is encapsulated. This requires use of injection moldable materials such as highly transparent liquid silicone or increasingly even thermoplastic resins. One of the requirements is to incorporate into the material encapsulating the electronics lenses to form beams of light. New materials make it possible to manufacture the LEDs very economically by means of injection molding.

Translated from Kunststoffe 7/2009, pp. 22–25
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE110152

Kunststoffe: Let's move on from materials to process technology – what is required here?
Steinbichler: It is a major challenge to control the injection molding process in such a way that, on the one hand, the semiconductor chip and the wiring elements are not damaged, while, on the other, the optical light-conveying components are formed precisely. The objective is to master the following balancing act: a low pressure to protect the electronics and precisely shaped surfaces where the light beams are formed to create the correct image.

Kunststoffe: How can the optical clarity be retained during processing?
Steinbichler: To ensure melt homogeneity from both the thermal and composition standpoints while avoiding loss of light due to clouding or discoloration of the material during the production process, we have developed special plasticating units for processing optical resins. Selection of the proper

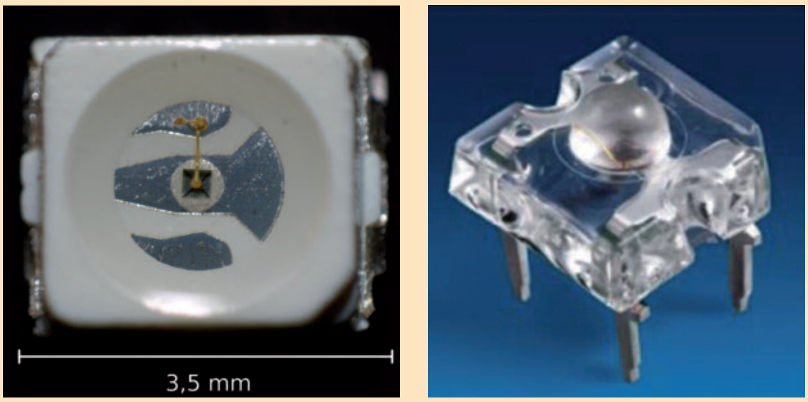
Head-up display: plastic mirrors project information into the cockpit (graphic: Continental)

screw and coating materials on the basis of the interaction between the plastics melt and the metal surface in conjunction with resin-specific and residence time-relevant optimization of the geometry is essential. Thermooxidative polymer degradation caused by oxygen in the air can be avoided by intentionally venting towards the back of the screw, flushing the feed zone with inert gas or applying a vacuum. At the same time, the pellets enter the screw flights via an air lock system. Using this approach, the transmission and thus the light yield upon passage through an optical component made of COC or PMMA can be increased significantly.

Kunststoffe: How much outside know-how is needed when it comes to applications with such a requirement profile?
Steinbichler: A great deal of experience comes together here. To define the limits of the processing conditions, it is necessary to know how much load the semiconductor electronics can withstand, both thermally and mechanically. The resin supplier must know the operating temperature of the light-emitting diode to exclude clouding of the lens is due to thermal degradation of the polymer, and applying the plastic enclosure to the prestamped leadframe presents a challenge to the moldmaker in order ultimately to have a fully automatic production cell. There will still be a lot of activity in this area; in the automotive sector, all lighting functions have only recently been achieved for the first time using LEDs in a front headlight.

Kunststoffe: What precision is possible in the injection compression process today?
Steinbichler: In the early phase of what were then hydraulically actuated toggle clamping units, we were able to achieve multi-step compression processes only through use of a floating piston. Later, we developed pressure pad solutions for compression on hydraulic tiebarless machines. For some time now, we have recognized the benefits of all-electric machines. Even at very low injection rates of 0.1 mm per second, the electromechanical drives of our injection units ensure the required reproducibility when it comes to filling cavities for thick-walled components without jetting. Thanks to the toggle's kinematics and a self-learning control system, the machines can operate very sensitively on the basis of speed, force or position control – extremely reproducibly shot after shot. The potential to improve quality has not been exhausted by far.

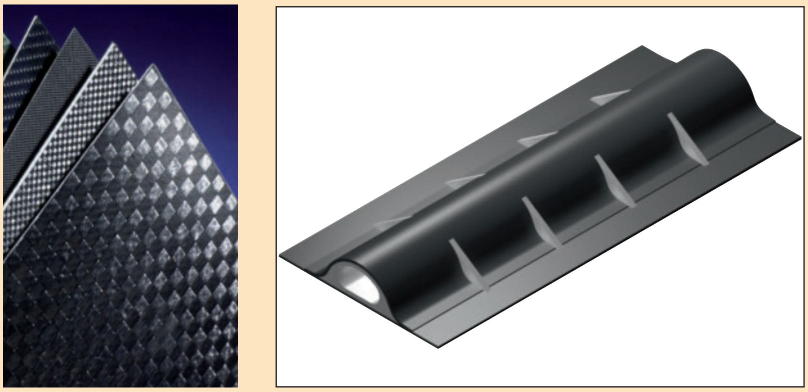
Kunststoffe: Where do you see the potential for multi-layer injection molding?
Steinbichler: Projects from customers to develop thick-walled optical components such as rain sensors, for instance, have shown us the need to find solutions for reducing cooling times and address basic questions: How must the layers be built up in order to manufacture such parts as economically as possible? Considering the attainable cooling time savings and the associated additional mold costs for each additional layer, how many layers are practical for a specified quantity of parts? There is no question about the potential of the process, because overmolding of additional layers can compensate for sink marks and other surface defects on the previously molded part. When producing a 30 mm thick plane-convex spherical collecting lens in PC, we can reduce the cooling time by 30 % with a symmetrical three-layer structure compared to that for a single-layer structure. We have developed simulation programs to design the layer thicknesses. However, we must still investigate what happens at the interfaces more closely and whether that presents obstacles for certain applications.



LED housing molded onto a prestamped metal carrier (left) and encapsulated LED with molded-on lens for light distribution (photos: Engel)

The electronics printed on the film are applied to an injection molded part and overmolded with a transparent, scratch-resistant cover layer of reactive polyurethane by means of the Clearmelt process (photo: plastic electronic GmbH)

The ultra-lightweight concept vehicle 1/X with body structures made from carbon fiber-reinforced plastics weighs only 420 kg (photo: Toyota)



Hybrid high-performance composites integrating hollow profiles can be created by forming and combining organic sheets (photos: Bond Laminates GmbH /LKT, Erlangen-Nuremberg University)

Kunststoffe: An important topic in optical applications is replication of micro- and nanostructures. What resolution is attainable today with injection molding with regard to surface structures?
Steinbichler: From the newest injection molded optical data storage medium, the Blu-ray Disc with a storage capacity of 25 GB in a single layer, we know that structures with a minimal pit length of 0.15 micrometer – with depths on the order of only 0.1 micrometer – can be replicated reliably. The challenge is to advance further in the third dimension and achieve a greater aspect ratio (depth/width, comment) in these structures. This is best achieved when the mold surface has the same temperature as the melt, so that no solidified skin forms as the melt enters the mold. The second essential point: the melt flows over the depressions without any pressure buildup; the component fills volumetrically, but in a sense only two-dimensionally. To replicate such structures, it is thus advantageous to inject the melt very quickly at high mold temperatures and then to apply the compression force suddenly via the clamping system, for instance, by 500 kilonewtons in less than 0.15 seconds. As soon as the structure has been replicated, the force should be reduced in order to prevent molded-in stresses in the part. The flow characteristics of today's thermoplastics permit replication of nanostructures with an aspect ratio of ten at a spacing of 100 nanometers. It also helps if the cavity is evacuated beforehand.

Kunststoffe: Where do you see important applications for this in the future?
Steinbichler: There is a great deal of activity targeted at developing a "Lab on a Chip". In the future, blood and other bodily fluids will probably not be sent to laboratories for examination, but will be processed directly in the doctor's office. It is not unusual to find that developments in other areas are derived from optical data storage media. Experts are thinking about a bio-CD that is used to conduct such analyses in a kind of CD player by separating individual components into the microstructures.

Kunststoffe: This example must surely be counted as part of the frequently touted revolution in healthcare. The charm of plastic is that in general it permits integration of intelligent functions into a component. What developments do you see on other fronts?
Steinbichler: In the matter of how intelligent mechatronic optical systems can be created and the interaction between optics, mechanics and electronics organized, research is only beginning. Plastic engineering has enormous potential here. The development of so-called smart plastics where electronic functions are printed on film made from electrically conducting or semiconducting polymers is highly advanced. This technology can be used to produce so-called RFID tags. It will probably not be long before the scanner checkout becomes reality and it is no longer necessary to empty the shopping cart. With our new Clearmelt technology, we are attempting to apply such smart plastics for sensors, displays and even solar cells on injection molded part surfaces and then protect them with a scratch-resistant cover layer. This is accomplished by overmolding the preshot with a reactive polyurethane mixture in a second mold station.

Kunststoffe: What are the benefits of such a process?
Steinbichler: Polyurethane is a material with very good flow characteristics that will not damage even delicate electronic structures. As with the LEDs, we can apply very thin cover layers over large areas using very low pressures, which is not possible with conventional thermoplastics.

> » *It is necessary to achieve greater weight savings – we simply have to succeed here in view of the pressing problems.* «

Kunststoffe: Popular belief in the energy shortage has become a megatrend. How can injection molding technology contribute to solving global problems in this area?
Steinbichler: Essentially, the question is how to produce plastic parts more efficiently in modern injection molding machines that operate at higher efficiencies through use of energy-saving drives and with reduced heat loss to the surroundings, and how to create lightweight designs through additional use of plastics to save energy and conserve resources, for instance, in automotive engineering. Unfortunately, the manufacturing opportunities used by the aircraft industry for many fantastic lightweight components cannot be used for large quantities in the automotive industry. This can be explained by the high prices for carbon fiber-reinforced composites. We are seeking answers to the question of how to cleverly combine fiber reinforcement over partial or entire surfaces and then put the technology into practice in fully automatic production processes. I view heating, forming, combining and molding functional elements onto semi-finished products such as organic sheets as only the beginning of an interesting development. The objective must be not to rely on a semi-finished product, but rather to place delicate fabric structures into the cavity with appropriate draping and then consolidate everything with the aid of extremely easy-flowing polymers.

Kunststoffe: What approach are you taking in this regard?
Steinbichler: We first need appropriate textile technologies to produce such fabric structures in three dimensions, and naturally materials that do not have the high viscosities characteristic of today's thermoplastic melts. The ideal material has almost water-like properties during the filling phase so as not to damage the delicate fabric structures while ensuring good penetration and impregnation of the fiber structures. This is quite essential to achieve the mechanical properties. Such easy-flowing materials with a viscosity that increases only after entering the cavity and then exhibit the characteristics of good thermoplastics are not a pipe dream. We are already working on concrete solutions with research partners.

Kunststoffe: What are they like? Are you modifying common materials?
Steinbichler: The principle is known from cast polyamides, for instance, where components containing an activator and catalyst are combined in the melt state and mixed. Polymerization then takes place in-situ in the mold cavity.

Kunststoffe: In terms of lightweight design, Toyota has set a standard with the 1/X. This concept vehicle based on the Prius weighs just 420 kilograms. How far away is volume production?
Steinbichler: The bar that Toyota has set is simply fantastic. It is almost hard to believe: A vehicle model that weighs merely one-third of the actual production vehicle. A small two-cylinder engine and a hybrid battery provide the desired performance. The hope is to achieve a consumption of only 2.2 liters per 100 kilometers. However, we know from Formula 1 racing what the potential is for ultra-lightweight body structures made from carbon fiber-reinforced plastics. While this is not something that will be put into high-volume production in the next ten years, the subject will gain momentum.

Kunststoffe: To what extent?
Steinbichler: New solutions using fiber-reinforced composite designs were always of interest to automobile manufactures, but simply too expensive. In the meantime, as in the aircraft industry, we have a situation where every kilogram saved may cost a bit more. I believe the pressure will increase even further when I think about the expression "fleet consumption". This is precisely the opportunity to incorporate even more plastics and intelligence solutions.

Kunststoffe: But carbon fibers are still an expensive proposition …
Steinbichler: And that is exactly why they probably will not be used in large quantities in high-volume production in the next few years. We have been discussing this subject in the industry for several years already, but we have as an alternative not only glass fibers available, but also a variety of other fibers. Polymers have the ability to form fiber-shaped structures for self-reinforcement without generating additional costs. Many problems can be solved simply with clever processing.

Kunststoffe: What is your personal vision – even though it may be unattainable for years?
Steinbichler: It would be wonderful to build a vehicle in the future that weighs 50 or 60 % less, or to incorporate energy storage systems with which a range of 200 kilometers could easily be achieved. But I am skeptical about whether this will be feasible in the next ten years. Nevertheless, it is necessary to achieve greater weight savings – we simply have to succeed here in view of the pressing problems.

Kunststoffe: How can we advance development?
Steinbichler: Work together, combine know-how and concentrate on putting ideas into practice, because we have all talked about it for a long time. ■

Dr. Georg Steinbichler

Born in 1955 in Rottenmann, Austria, Steinbichler studied plastics engineering at the University of Leoben, Austria. In 1982 he started his professional career in application and process engineering at Engel Austria GmbH. In 2003 he was named Manager Research & Development at the injection molding machine manufacturer. In 2008 Steinbichler received his doctorate from the Department of Plastics Engineering at the University of Erlangen-Nürnberg, Germany, and is now building up – in addition to fulfilling his responsibilities as part of Engel's management – the new institute for „Polymer Injection Moulding and Process Automation" at the Johannes Kepler University in Linz, Austria.