Lightweight to Fit in a Pocket

Composites Reduce Weight and Simplify Production of Electronics Housings

Continuous fiber-reinforced thermoplastic composites have also become established with thin-walled housings for consumer electronics and information technology. Not only do they offer high stiffness and help to reduce weight, but also enable the integration of classy appearance and functions. What is more, if the housings are produced using the hybrid molding process, costs, processing steps, and cycle times can be reduced.

The Carbon 1 Mark II smartphone from Carbon Mobile was developed in Germany. The matt-black carbon fibers lend the smartphone a classy high-tech look © Carbon Mobile

Hardly any other sector exhibits such high global growth rates as the consumer electronics and IT business, with smartphones, laptops, and tablets as their main application areas. According to investigations by the Indian market research and consulting company Mordor Intelligence, the global market for smartphones alone had a volume of almost USD 715 billion in 2020. With annual growth rates of about 11.2 %, it is expected to increase to more than USD 1.3 trillion by 2026. For these fields, plastics producer Lanxess has developed continuous-fiber reinforced thermoplastic compound materials.

Named Tepex, the composites are plate-shaped semi-finished products (organosheets) and are also used for lightweight structural components in the automotive industry. Their matrix consists of polyamide 6 (PA6), polypropylene (PP), polycarbonate (PC), thermoplastic polyurethane (TPU) or other thermoplastics, and is usually reinforced with continuous fiber fabrics of high-strength glass or carbon fibers, or with long-fiber mats or fleeces. The fibers are fully impregnated with the matrix plastic and contain practically no air bubbles (fully consolidated). Consequently, all the load forces are transferred from one filament to the next via the matrix. Usually, the fabric fibers are arranged at right angles to each other and are evenly distributed in both directions (balanced). Frequently, warp-strong fabrics are also used, in which most of the fibers are oriented unidirectionally. Therefore, the properties of the corresponding semi-finished products – such as stiffness, strength, and thermal expansion – are direction-dependent.

Meanwhile, hybrid molding is the preferred method for processing the semi-finished items. The procedure starts with a semi-finished pre-cut item, which gives an indication of the component's final shape. After heating above the matrix melt temperature, the item is positioned between the open halves of the injection mold. The mold closes and forms the pre-cut. Simultaneously, it is backmolded or overmolded with a short fiber-reinforced version of the matrix plastic (**Fig. 1**). As opposed to insert molding, thermoforming and injection molding are not separate stages, but occur in a single processing step. A separate forming tool is not necessary. The process is highly efficient, because the number of processing steps, the investment costs, and the cycle times are reduced. Another advantage of the semi-finished Tepex items is that they come fully consolidated. Therefore, consolidation in the mold is not needed – something that is not economically feasible with thermoplastics.

The inserts are heated in a separate oven and transferred to the open injection mold in the plastified state. In this step semi-finished items with a unidirectional orientation of the continuous fibers without transverse reinforcement are at a disadvantage, because they flow apart when the mold closes, whereby the fibers can be sheared off more easily (so-called mold slip). For semi-finished items with fabric reinforcement, the intermeshed warp and weft threads provide transverse reinforcement, which greatly simplifies the handling of inserts in the plastified state.

Off-Tool Parts with Demanding Surfaces

Housing parts for consumer electronics and IT in particular must exhibit smooth and usually glossy surfaces. Semi-finished composites fulfil these requirements, provided that they are produced in a hybrid molding tool with a controlled rapid heating/cooling system. This results in off-tool surfaces that hardly need any post-processing for subsequent painting steps. In contrast, die-casting metals, which are also used to produce e.g. tablet housings, mostly require smoothing with fillers, grinding, and polishing before being painted. Apart from the time and effort involved, this also produces more scrap. Hybrid molding with Tepex is considerably less energy intensive and has a lower CO_2 footprint than metal die-casting. »

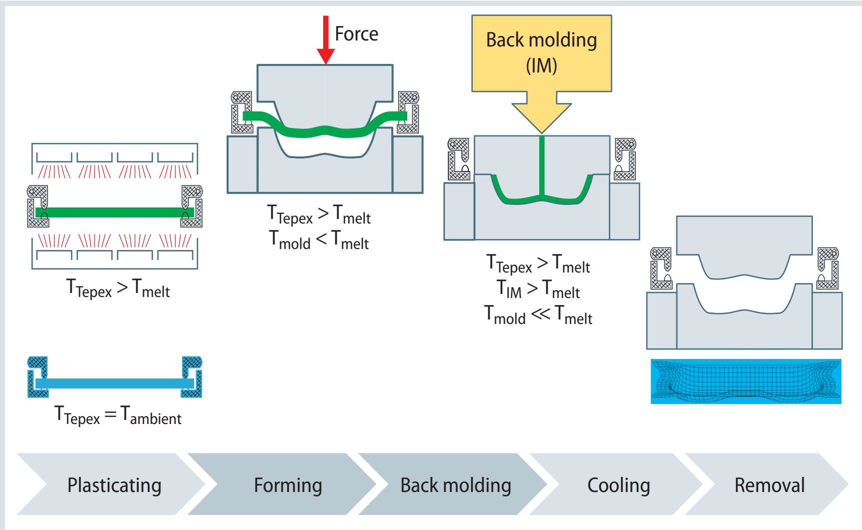

Fig. 1. Schematic of hybrid molding sequence with rapid heating/cooling temperature control: thanks to fast heating and cooling of the mold, the resulting component surfaces can be painted directly Source: Lanxess; graphic: © Hanser

Another substantial reason for the high suitability of Tepex for the production of housings for consumer electronics and IT is its high distortion resistance and stiffness with low material wall thickness. Both are significantly higher than for injection-molded thermoplastics, with which composites must compete mainly for small appliance housings. The specific bending stiffness when reinforced with carbon fibers is comparable with that of die-cast aluminum and magnesium, and the specific bending strength is significantly higher (**Fig. 2**). These properties are substantial contributions that enable housing parts, e.g. for smartphones, to be designed very thin and light, but also very stiff, thereby exhibiting a high resistance to deformation. This ensures good protection for the components of electronic equipment such as displays, circuit boards, and rechargeable batteries. For the manufacturers of such equipment stiffness is an important criterion and is verified by them in comprehensive system tests and/or force deformation tests of the finished component.

Reinforcing Ribs Produced Easily

If the housing part is hybrid molded, reinforcing ribs are very easy to injection mold. Because the composite matrix and injection material are the same a very strong molecular bond between ribs and housing shell is achieved. In addition to the composite material's specific stiffness this results in even higher stiffness which can be increased further by means of geometric elements such as e.g. beads or edges.

Among the first applications of Tepex in consumer electronics and IT were covers for smartphones from Research in Motion (RIM, still under the Blackberry brand name at that time). It was possible to design the covers stiffer and slimmer than conventional injection molded covers. The new covers were produced from a TPU-based semi-finished composite using the insert molding process. A visually very appealing element was the colored design that originated from regularly arranged colored glass fiber fabric in the compound material and was highlighted with a transparent lacquer coating.

A series application for Tepex is the A-cover for Dell business notebooks as substitute for die-cast magnesium components. Here semi-finished composites with PC matrix and reinforced with carbon and glass fiber fabrics are used. Apart from high stiffness and lower weight, further points favoring the use of composites instead of magnesium are better energy efficiency and safer processing and the very high off-tool surface quality of the components.

Particularly demanding are flame-retardant requirements: due to the high energy density in the processors, with corresponding heat generation, the semi-finished composites used must pass the UL 94 V0 flame-retardant test. For this, a halogen-free flame retardant concept was developed which does not influence fiber wetting and adhesion and therefore does not impair the composite's mechanical properties. An attractive appearance is created by the visible plain-weave carbon fabric.

The notebook covers are one of the first series applications of the hybrid molding process with rapid heating/cooling temperature control system. The applications already exhibit a wide range of injection-molded integrated functions such as reinforcing ribs, fixing elements, and guides. Carbon-free antenna windows, which ensure good sig-

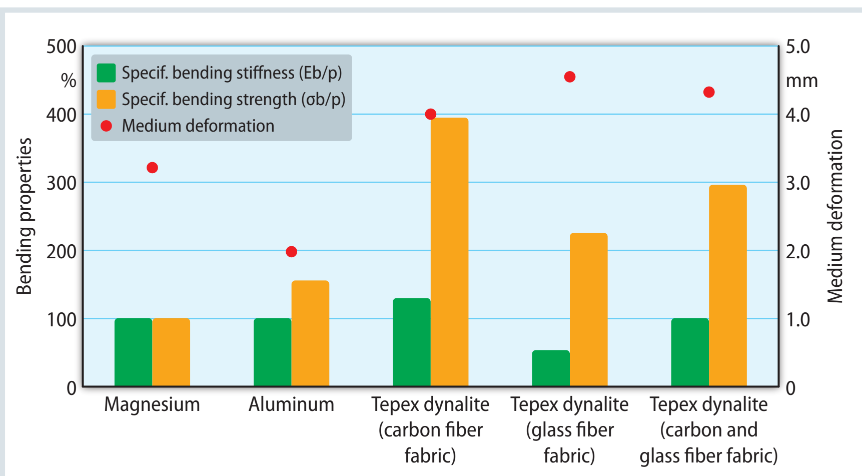

Fig. 2. Comparison of bending properties of standard materials for consumer electronics and IT equipment housings: Tepex dynalite semi-finished items with a halogen-free flame-retardant PC matrix are superior to die-cast metals, particularly in the system deformation test Source: Lanxess; graphic: © Hanser

nal transmission, are integrated by injection molding.

First Carbon Smartphone

The trend for functional integration in the consumer electronics and IT field continues. One outstanding example of this is the recently introduced world's first carbon smartphone: the Carbon 1 Mark II from the Carbon Mobile start-up in Berlin, Germany (**Title figure**). Previously, networked devices with carbon fiber housings were assumed to be impossible, due to the electromagnetic shielding of the fibers and the resulting blocking of radio signals. However, with Carbon Mobile's HyRECM (hybrid radio enabled composite material) technology, carbon fibers and an associated composite material are combined in such a way that the resulting compound allows radio signals to pass. Also integrated in the carbon fiber housing is a conducting 3D printing that assists the antenna function.

The housing is based on a semi-finished composite with TPU matrix. It is built as a single shell like the load-supporting chassis of Formula 1 racing cars. This monocoque design makes very good use of the carbon composite material's stiffness. Weighing just 125 g, the smartphone is about one third lighter than conventional mobile phones and with a height of only 6.3 mm it is 25 % thinner.

The demand for sustainable materials is also increasing for consumer electronics and IT. The aim is to reduce scrap and to recycle the resources from end-of-life components. As purely thermoplastic systems, Tepex organic sheets are easily recycled in the sense of closed-loop material cycles (**Fig. 3**). Tests conducted by Lanxess showed that under the right conditions, shredded scrap – singular or mixed with unreinforced or short fiber-reinforced virgin compound material – can be injection molded and extruded on standard machines without problems. The recyclate's mechanical properties – e.g. strength, stiffness, and toughness – are on the level of conventional short fiber-reinforced plastics with corresponding fiber contents.

Recently, Tepex semi-finished composites were introduced of which half the matrix is PC recyclate from the reclamation of returnable water bottles. The composites are aimed at applications such as laptop covers or housings for smartphones, tablets, e-book readers or mobile phones. For example, a halogen-free flameproof material with a chopped strand core of recycled carbon fibers is almost ready for series use in laptop covers.

Fig. 3. Tepex organosheets are easily recycled and subsequently reused for technical components. Strength, stiffness, and toughness of the recyclate correspond to those of short fiber-reinforced plastics with the same fiber contents Source: Lanxess; graphic: © Hanser

Fig. 4. Reusable water bottles are made of high-purity transparent PC, which is approved for foodstuffs contact. Tepex recyclates, which are used e.g. for laptop housings, benefit from these properties © Lanxess

Fully Bio: Semi-Finished Biopolymer Items with Bio-Based Reinforcement

Also ready for series production are semi-finished composites with polylactic acid (PLA) or PA11 as bio-based matrix, which are reinforced with continuous glass or carbon fibers. Their mechanical properties such as bending stiffness and e-modulus are comparable with those of similar PA6 and TPU grades.

Currently, Lanxess is also working on the use of bio-based reinforcing fibers in Tepex (**Fig. 4**). Special focus lies on flax fibers which are being discussed as a natural alternative for carbon fibers. Suitable semi-finished items with PP-matrix were investigated. Although their mechanical properties are significantly lower than those of their counterparts (reinforced with continuous carbon fiber or continuous glass fiber), they are still higher than those of injection molding materials reinforced with short carbon or glass fibers. Particularly sustainable is the combination of flax fiber fabrics with biomatrices. Entirely based on renewable materials, these semi-finished items produce surfaces with an appealing biocarbon look and feel. ■

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Service

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