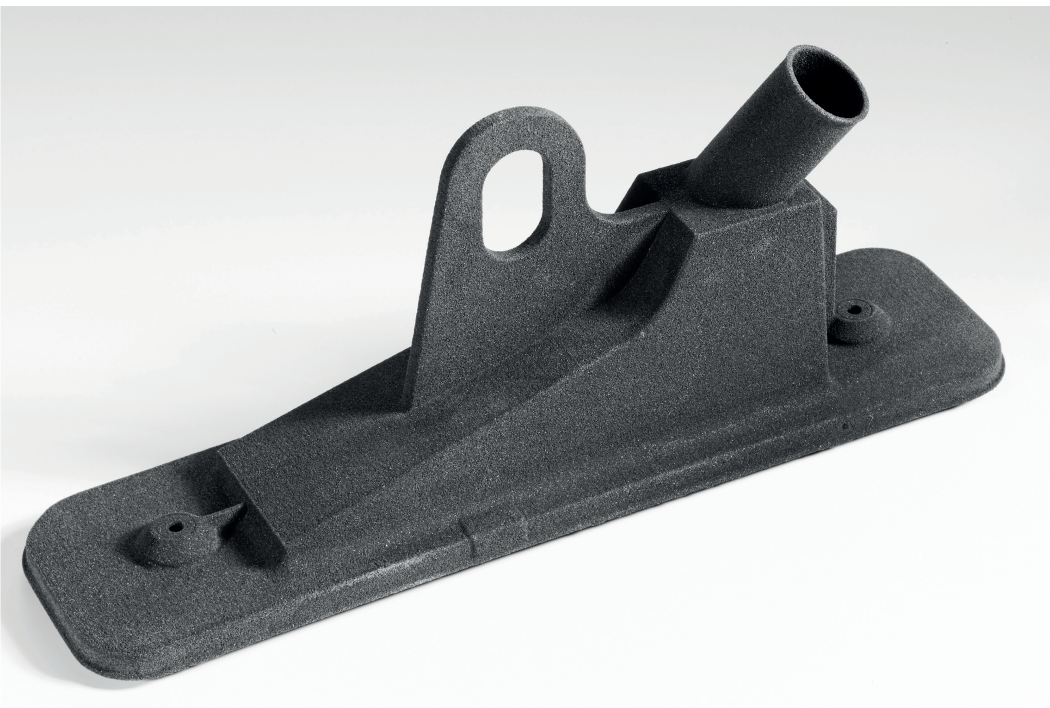
From Injection Molding to Additive Manufacturing

PA66 and PBT for Laser Sintering

The implementation of series applications in laser sintering is currently still hindered by an insufficient variety of materials. Many important engineering materials from traditional plastics processing have only been available for the process to a restricted extent up to now. PA66 and PBT considerably expand the field of applications for laser sintering by showing better properties than classic PA11 and PA12 materials in most cases.



As a temperature-resistant and flame-retardant material with high mechanical properties, PA66 opens up new application possibilities for laser sintering, such as its use as a sensor holder © Airbus

Additive manufacturing of plastics, and laser sintering in particular, has developed into a series production process in recent years. The production of millions of mascara brushes [1] and tens of thousands of glasses frames [2] are examples of this and show that even large quantities can be produced cost-effectively and in high quality. A major advantage of laser sintering is that standard thermoplastics can be processed with high part quality and close to injection molding properties. Although the process has become well established, the choice of materials is still limited. Various materials, especially semi-crystalline ones, are meanwhile available, but most of these are still niche products.

The market is currently still dominated by polyamide 11 (PA11) and PA12. With these polymers, the process has reached a good technical maturity. However, both are not dominating materials in traditional plastics processing. Plastics such as polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC) and acrylonitrile butadiene styrene (ABS) have significantly larger market shares. Even among polyamides, PA6 and PA66 dominate over PA11 and PA12, making them niche materials in classic applications.

For this reason, the step into additive manufacturing remains unavailable for many classic application areas due to a lack of suitable materials, although many interesting application areas would be available, for example, in the automotive, aerospace, electronics and electrical and mechanical engineering sectors. However, many companies hesitate to change the manufacturing process and material in one step. The effort required to in- »

troduce additive manufacturing is often considered too high to consider a second variable in the form of a previously unused material. As a result, many potential series applications remain closed, even though the number of units and the area of application would be suitable in principle.

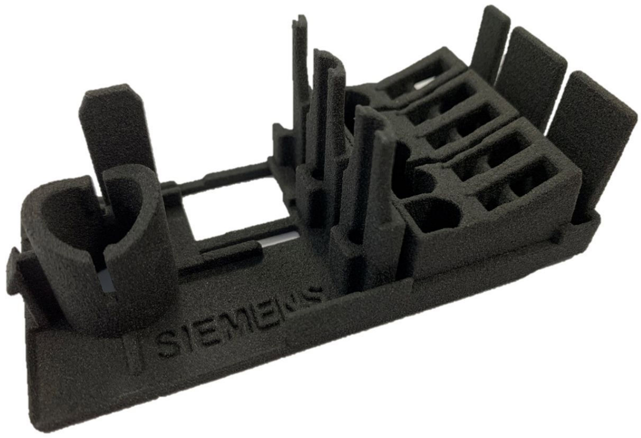


Fig. 1. Functional demonstrator of an electronic component made of PA66 produced by laser sintering: the material offers itself as an alternative to PA11 and PA12 in many areas © Siemens

Alternatives to PA11 and PA12 Required

A rethinking process has therefore taken place in the industry in recent years. Developments using additive manufacturing are being planned and initiated, claiming a clear break with widely available PA11 and PA12. The focus of this trend is additive manufacturing with the materials that have already been used for the application. The requests for additional materials for additive processes are therefore becoming louder.

However, the development of materials for laser sintering or powder bed fusion is usually very complex. The requirements for the materials and the manufactured components are based on the reference materials for injection molding. However, both processes differ fundamentally with respect to the required material properties and are usually even contrary with respect to these requirements (for more details [3, 4]). While rapid solidification and short crystallization times are desired in injection molding, these complicate processing in laser sintering. In addition, there is the need for a wide processing window between melting and crystallization, which only a few semi-crystalline materials provide as standard. Further complications arise from the lack of process pressure to support forming, and the difficulty of producing powders with good flowability and suitable particle size distribution. The combination of these requirements has in the past, and still currently, resulted in many materials with poor processing or part properties. Poor experience among users has often led to rejection of alternative powder materials to PA11 and PA12, thus hindering the necessary market distribution.

Traditional Plastics for Additive Manufacturing

AM Polymers has addressed this problem in particular, developing well-known standard thermoplastics and engineering plastics from injection molding for laser sintering with a focus on plug-and-play solutions. Over the last few years, this has resulted in various powder materials based on thermoplastic polyurethane (TPU), PE, PP, PBT and PA6, which are distributed under the brand name Rolaserit. They are characterized by part properties comparable to injection molding and good processing behavior with high elongation at break and good batch-to-batch reproducibility. Special focus is placed by the company on short run-in times of just a couple of days through support with extensive processing know-how, so that customers can quickly go into part production.

Fig. 2. Components made of PBT produced by laser sintering already have a very smooth surface after printing (left). Vapor smoothing can subsequently improve the surface quality even further (right) © AM Technologies

PA66 for Laser Sintering

With Rolaserit PA66–01, AM Polymers is now announcing for the first time a PA66 powder material for the laser sintering process. Compared to other polymers, PA66 is characterized in particular by high heat deflection temperature and aging resistance. At the same time, the material exhibits high hardness and stiffness as well as good abrasion resistance. These properties make the material particularly suitable for molded parts subjected to high mechanical and thermal stresses in electronics as well as in mechanical engineering, automotive applications and apparatus manufacturing. Typical components made of PA66 can be coil bodies, plain bearings, gears, coupling parts, but also coverings and housing parts [5, 6].

The material was developed as part of the Flatisa joint project funded by the German Federal Ministry of Education and Research (BMBF) via the Projektträger Jülich as part of the Promat_3D call (funding reference number 03XP0099F) in cooperation with Airbus and Siemens. It has already been successfully tested at the last mentioned companies for the production of demonstrators for the aerospace and electronics industries (**Title figure and Fig. 1**).

The material exhibits PA66 typical component properties with an elastic modulus of 3100 MPa, a strength of 75 MPa and an elongation at break of up to 15 % in dry state. In addition, the material meets a fire protection classification according to UL94 V2. In a first commercialization step, the material will be made available to the user market as part manufacturing on equipment from AM Polymers. The material shows very good processability on a laser sintering system (type: ST252P, manufacturer: Farsoon Europe) and also allows fine details due to its good ductility. Due to the high melting temperature, suitable machines with sufficiently high processing temperatures are required for processing. Such machines, however, are not yet very widespread. The range of suitable machines available from various machine manufacturers is increasing steadily, however. In the future, it can therefore be assumed that PA66, like other materials for laser sintering, will be widely available on the market.

PBT Processable on Standard Machines

As a further new product development, different PBT grades for use in laser sintering were jointly developed by AM Polymers and Mitsubishi Chemical. PBT as a polymer is characterized in particular by good slide and wear properties, good electrical insulation properties independent of moisture absorption, and high dimensional stability. Typical applications include plain bearings, valve moldings, rollers, pump housings, impellers, couplings and, in particular, applications in the electrical industry such as coil bodies, clamp and connector blocks [5, 6].

The typical melting temperature of PBT is 223 °C and thus normally requires powder bed temperatures above 200 °C for laser sintering. The material commercialized under the product name Rolaserit PBT01, on the other hand, can be processed on all standard types of laser sintering machines. The material has, for example, already been successfully processed on systems of type ST252P from Farsoon Europe, Vanguard HS from 3D-Systems, EOS P360 from EOS. Therefore, there are no restrictions with regard to the machine technology for a wide range of applications.

Compared to PA12, the material is characterized in particular by a higher stiffness of 2650 MPa at a strength of 48 MPa, as well as lower moisture absorption and thus moisture-independent material properties. Elongation at break of up to 15 % is achieved in laser sintering, which is about the same as for PA12. Even without post-treatment, the material has a high-quality, very smooth surface. This can be further improved by chemical post-processing through vapor smoothing (**Fig. 2**). The material also has very good electrical insulation properties. The surface resistance is $5 \cdot 10^{16}\,\Omega$m and the volume resistance is $3 \cdot 10^{15}\,\Omega$, which is a potency higher than that of classic injection molding materials made of PBT. These properties make the material very suitable for electrical and electronic parts, as illustrated by the application for a special connector (**Fig. 3**). Due to the high component ductility, it was also possible to produce fine details and snap-on connectors of suitable quality. This was confirmed by application and function tests.

Filled PBT Grades

On the base of this basic grade, further filled versions were developed, which again significantly extend the application spectrum of PBT for laser sintering. In a first step, glass fiber and carbon fiber filled grades were considered. For the first time, fiber-filled PBT-based materials were successfully introduced in laser sintering. Filling with fibers once again significantly improves the material properties. The stiffness could be increased to 5500-6000 MPa and the strength to up to 60 MPa, while the temperature resistance could be increased to 180 °C. By suitable preparation of the materials, it was possible to prevent any deterioration in processing behavior despite the use of fibers. Thus, a good powder spreading is given despite the use of fiber fillers.

Conclusion and Outlook

Additive manufacturing and in particular powder bed fusion processes such as laser sintering are becoming increasingly important for use as series production techniques. However, in many cases the use in series production requires the appropriate materials, which are already used today in injection molding in the corresponding applications. However, these are often only available for additive manufacturing to a limited extent. AM Polymers is addressing this point and making traditional injection molding materials with application-specific properties available for laser sintering. This should create a comparable range of materials for laser sintering in future. ■

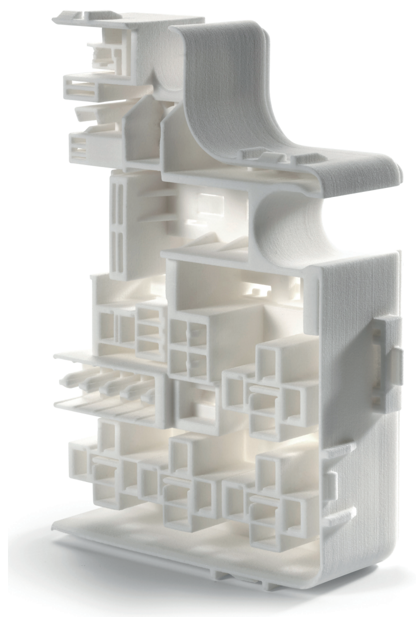


Fig. 3. Laser-sintered special connector with clips and thin connector elements made of PBT: due to its electrical insulation properties, the PBT type used is very well suited for such components © AM Polymers

The Author

Dr. Andreas Wegner is co-founder and CEO of AM Polymers GmbH; a.wegner@am-polymers.de

Service

References & Digital Version

- You can find the list of references and a PDF file of the article at *www.kunststoffe-international.com/archive*

German Version

- Read the German version of the article in our magazine *Kunststoffe* or at *www.kunststoffe.de*