Carbon nanotubes are responsible for the illumination of "light sticks." The Fraunhofer ICT compounds the electrically conductive material itself and then processes it by the APF process using the Freeformer (© Arburg)

Illuminating Idea

Fraunhofer ICT Processes Conductive Material in Additive Manufacturing

The Fraunhofer ICT has been involved with additive manufacturing since the 1990s. At the Fakuma 2017, the scientists amazed the trade visitors with glowing USB sticks made from functionalized PC/ABS. For this purpose, they had made the plastic conductive with the aid of carbon nanotubes and processed the composite using Arburg Plastic Freeforming.

The core competency of the Polymer Engineering Department of the Fraunhofer-Institut für Chemische Technologie (ICT) in Pfinztal, Germany, is application-oriented research into technical plastics. The Nanocomposites working group focuses on the development of functional composites with defined electrical, mechanical or thermal properties. The range of plants for formulation development extends from extremely small amounts to compounding lines in which the composite is prepared as pellet stock.

"To a large extent, we are concerned with thermoplastics and their processing through extrusion or injection molding. It therefore made sense to transfer this expertise to extrusion-based additive manufacturing processes in order to open up new application options," says Dr. Christof Hübner, Group Leader Nanocomposites at the Fraunhofer ICT. A Freeformer (manufacturer: Arburg GmbH + Co. KG, Lossburg, Germany) has also been operating in Pfinztal since 2016, processing standard pellet stock and applying the plastic in the form of drops onto the build platform. The inventors call the process Arburg Plastic Freeforming (APF).

Hübner continues: "The Freeformer and the APF processing afford us the freedom to process and parametrize the materials we develop in-house ourselves. We also eliminate the step of filament production, which makes material development more efficient and extends the range of composites we can use."

Sascha Baumann, APF expert from ICT, who has thoroughly familiarized himself with the Freeformer, adds, "In our project-related research work, we principally focus on functionalized materials, part concepts and process developments." He goes on to explain that he supports colleagues with free-formed components for test set-ups or functional prototypes, for example.

Conducting Paths and Housing Are Produced in an Additive Process

One innovation that the scientists presented at the Fakuma 2017 in Friedrichshafen, Germany, were so-called "light sticks", which demonstrate the new applications for functional compos- »

First, the black functionalized material with inserted LED, then the white ABS housing, is applied onto a build platform by an additive process (© Arburg)

In the processing with the Freeformer, the process parameters can be freely adapted to the material (© Arburg)

ites in additive manufacturing. The key here is the functionalized material: nanoscaled fillers are compounded into the base material PC/ABS. In this case, carbon nanotubes (CNTs) make the part electrically conductive so that an inserted LED lights up when an electric current is applied. In a further example, the Fraunhofer ICT has also implemented capacitive sensors, which, for example, transmit signals in a contact or proximity-sensitive manner.

Five Questions to ...

... Dr. Christof Hübner, group leader for nanocomposites at the Fraunhofer Institute of Chemical Technology in Pfinztal, Germany.

How high is the proportion of carbon nanotubes in the matrix material and how expensive is this material?
There's no simple answer to that question. The amount of CNT in the composite depends on the requirements that the part has to meet, the function it must perform, the matrix material as well as the type of CNTs used. In the Freeformer, we have by no means tested all the CNT composites that we consider we could use successfully. An amount of 5 % ought to be sufficient for many applications. The price of CNTs varies within wide limits, depending on the type. Commercially available multiwall CNTs cost around EUR 100 per kilogram.

What layer thicknesses do you apply for the conductor and the housing component?
The printed structures consist of five layers, each of 0.2 mm thickness. The height of the conductor tracks for the "light stick" varies between two and three layers, with thicknesses of 0.4 and 0.6 mm respectively. The housing component covers the conducting structure with at least two layers, or 0.4 mm.

What is the pros of CNT compared to metal conductors, printed, e.g., with silver ink on the part surface or injection molding with a tin alloy?
We see the main advantages in the fact that the finished parts do not contain metals, and can therefore be used in corrosive environments if necessary, and that the parts can be recycled without separating plastic and metal. Ultimately, however, the choice of a particular solution depends on the individual requirements made on the assemblies to be manufactured.

How did you manufacture a capacitive proximity-sensitive sensor in this way?
Such a sensor generally has a very simple design, since you only need an electrically conductive structure with a certain minimum conductivity. Our sensor for the trade show demonstrator therefore consists quite simply of an electrically conductive surface, which is embedded in two cover layers and has electrical contacts. The necessary electronics is state of the art, inexpensive and is available largely ready to use. Only certain modifications to the software are necessary.

How will industrial application be on the cards, and in what form?
Electrically conductive applications have already been in industrial application for some time. They are used, for example, for antistatic purposes or for housings that require electromagnetic compatibility. However, the availability of electrically conductive carbon modifications, CNT and graphene, which are now available in industrial quantities, together with the boom in additive manufacturing, have given the material class a new boost in recent years.

Dr. Christof Hübner (right), group manager for nanocomposites at Fraunhofer ICT, and APF expert Sascha Baumann (© Arburg)

Using the same principle, the Fraunhofer ICT has also realized capacitive sensors, which transmit signals sensitive to, e.g., contact or proximity (© Arburg)

For the manufacture of the "light sticks", a base plate made from ABS is placed in the Freeformer build chamber and an LED is inserted. The first discharge unit then applies a thin layer of a functionalized material, which anchors the LED mechanically into the part, while also acting as the electrical contact. The second component is an ABS housing. The Freeformer takes about 6.5 minutes for additive application of the conductors and the housing component.

"Particularly in the case of highly filled CNT composites, which are brittle and tend to break, or in the case of very soft materials, the Freeformer provides for better processability and process reliability than filament-based printing systems," explains Sascha Baumann.

Material Freedom Signifies Increasing Complexity

"We have no problems in processing standard geometries and materials with APF processing, especially as Arburg is continually developing the Freeformer software. But the material freedom comes at the cost of increasing complexity," says Dr. Christof Hübner, summarizing the experiences gathered to date. One challenge that he mentions is, for example, differently parametrized areas within a part, e.g. in order to implement zones with differing degrees of filling or densities. "If we encounter very complex issues, we resort to Arburg's expertise," says Dr. Christof Hübner. ■

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Service

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