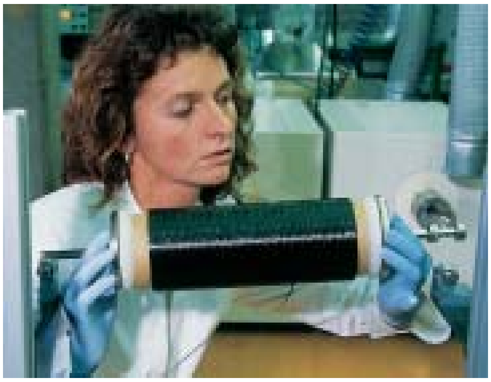
Klaus Jopp
Hamburg

Collaborations on Composites

After the glass industry, the aluminum industry has now discovered "Fortadur," a **fiber-reinforced glass** produced by Schott Medica. New research findings give reason to believe that this family of composites has a promising future.



Some years ago, Schott researchers developed a new material that Schott Medica now produces and markets with growing success under the brand name "Fortadur." This unusual material is a fiber-reinforced glass in which the ceramic fibers are made from either carbon (C) or silicon carbide (SiC). Thanks to these built-in "reinforcers," a glass is formed with tailored properties that are anything but typical of this normally brittle material. "Composites like this one are characterized by their unique breaking and flexural strength," says Hans-Hermann Leiß, Director of Production at Schott Medica GmbH in Wertheim. "Fortadur" also has a very high resistance to temperature changes and, depending on the type of glass and fibers, can withstand air temperatures of up to 450° C ("Duran"/C) or even 1,200° C (glass ceramic/SiC).

Interesting fields of application

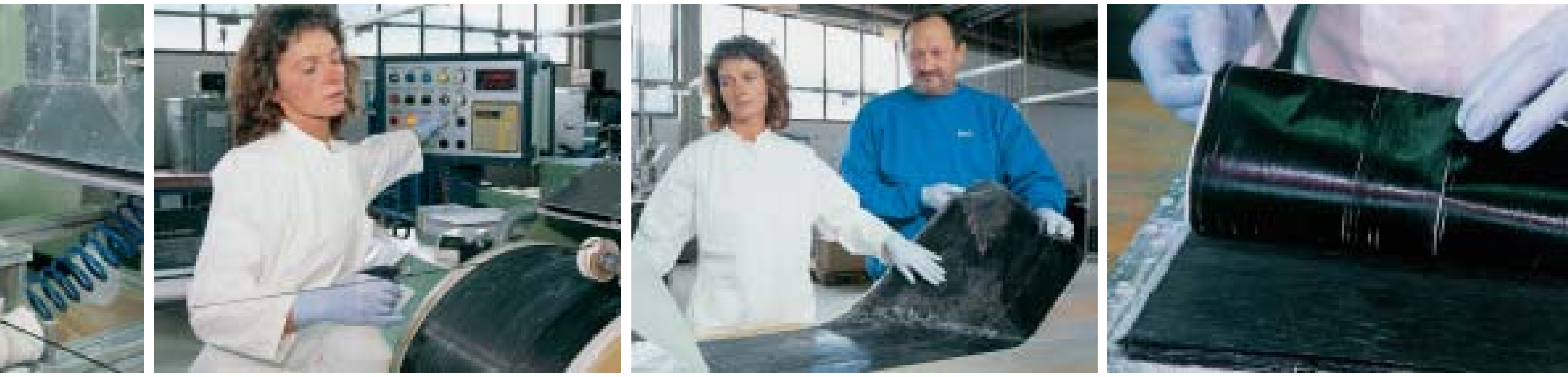
The glass industry was the first to utilize the enormous potential of this new class of engineering materials. When handling hot components, for example in bottle manufacturing, there are a number of tools and machine parts that are exposed to high temperatures. They must be sturdy, offer a good service life and ensure that no traces are left behind on the glass products.

The demands on the production of bottles and glass are enormous, especially considering the normal production targets of between three and five million pieces per day. For this reason, fiber-reinforced glass is an excellent choice as an engineering material for the fabrication of grippers, sliders, racks and transport devices. Metals cannot be used for this equipment because they would withdraw too much warmth from the bottles, which can result in cracks. Graphite is one alternative, but it is breakable. "Fortadur" is used both in glassworks and also in factories in which the glass is processed into a particular shape.

The characteristics that have been so successful with glass are also applicable to other materials, such as ceramics and metals. In the meantime, the aluminum industry has begun to use composites as well. The advantage of "Fortadur" in aluminum applications is that it is not wetted by the metal,

"Fortadur" has a very good breaking and flextural strength, tolerates temperatures of up to 1,200° C and can be used to produce components in complex geometries.

Continuous fibers are coated with glass powder in a whirlpool bath and wound on a reel to wide bands.



which, as a particularly lightweight engineering material, is growing in importance in automobile construction, in the aircraft and aerospace industries and in rail vehicles.

With composites, processes can be accelerated because conversion times are shortened and the service life is extended. The foothold in the aluminum industry succeeded through the production of piston rings. Other applications include hooks, stirrers and scoops. “We are actually supplying the aluminum industry more and more. ‘Fortadur’ is definitely a promising product,” confirms Armin Reiche, Managing Director of Schott Medica, which has one of the biggest hot presses in the world. And this device is responsible for the most important process step.

Continuous fibers are first coated with glass powder in a kind of whirlpool bath, then wound on reels in wide bands and cut into defined segments called tapes. These tapes are pre-dried in stacks (prepregs) and then fused in pairs at 1,000° C and 100 atmospheric pressure into the nearly poreless, finished composite. This occurs with an upper punch and lower punch; the compression ratio is about 1:4.

Searching for better production methods

Despite all the enthusiasm for this special kind of glass, one drawback has still not been overcome. The silicon carbide fibers produced by companis like UBE and Nippon Carbon are very expensive. So Schott is pursuing several strategies to come up with better solutions. For example, a new manufacturing process has been developed in which short, randomly distributed or matted fibers about one centimeter long are used instead of the continuous fiber. This is a technological improvement because it reduces production costs, while ensuring isotropic, i.e. identical in all directions, features. The mechanical properties, for example, remain virtually the same. Thanks to this isotropy, other geometries are possible, which increases the potential for new applications. “We are now working up to 80 or 85 percent with matted fibers,” says Leiß.

The Fraunhofer Institute for Silicate Research (ISC) in Würzburg under the supervision of Professor Gerd Müller, with whom Schott is also collaborating, has taken a different approach. Conventional reinforced fibers are often too expensive for the desired applications. For this reason, ISC is mainly searching for fiber types that will be more economical. Thus researchers are investigating $SiBN_3C$ fibers, which contain boron, nitrogen and carbon in addition to silicon. They differ from conventional silicon carbide types because of their improved oxidation and temperature stability.

A good starting position

No matter if it is reinforced with silicon carbide or with carbon, “Fortadur” is virtually black due to its high fiber content of 40 per-

The use of matted fibers is a technological advance. Compared with manufacturing methods based on continuous fibers, composites can not only be made more economically, but also permit the production of components with other geometries because of their isotropic features.

cent. If such composites were translucent or even transparent, they would have the potential for a much wider range of application, for example panes that can withstand shots and flying objects. “For this application, the glass and fibers must have an identical refractive index,” explains Schott’s materials expert Professor Wolfram Beier. In collaboration with the University of Chemnitz and the Technical University and Mining Academy in Freiberg, the Technical University of Ilmenau is researching various possibilities. The German Research Community (DFG) is supporting this project.

There are many options in this field. In fact, Schott itself is investigating the use of aluminosilicate glasses and “Ceran” type glass ceramics for fiber reinforcement. There are also other potential areas of application. For example, clutch disks and facings could be made from fiber-reinforced glass. The same is true of brake disks and linings. Such components could be used not only in street vehicles, but also in high-speed trains like the German ICE, the French TGV and the Japanese Shinkansen. The advantages of components made from composites are manifold: temperature stability, a high coefficient of friction, better wear resistance, good comfort behavior and lower prices compared with ceramic materials. With this in mind, it is clear that the future of fiber-reinforced glass has just begun. And Schott has a very good starting position. “We are the only company that already has marketable products,” says Armin Reiche. ◂

Fiber-reinforced materials:

Will they soon be translucent or transparent?

“Research has shown that the main prerequisite for translucence is a general harmonization of the optical properties of the composite components,” explains Professor Dagmar Hülsenberg, Head of the Institute for Materials Technology of the Technical University of Ilmenau. However, producing such composites is very tricky because one has to optimize the seemingly contradictory requirements for the desired maximum reinforcement and for the best possible transparency. This method is facilitated when intermediate layers made from, for example, titanium oxide or boron nitride are applied to the fibers by means of a chemical vapor deposition (CVD) process. The improved sturdiness and fracture toughness are tied to the efficacy of various reinforcement mechanisms. This is where the intermediate layers of about 30 nanometers (30 billionths of a meter) play a crucial role.

The Fraunhofer Institute for Ceramic Technologies and Sintered Materials (IKTS) in Dresden is also involved in developing transparent and extremely resistant materials. The researchers first focused on the development of halogen bulbs that have to withstand extremely hot plasma. Neither quartz glass nor the ceramic materials commonly used up to now can easily cope with the high internal gas pressure and even tend to burst. The IKTS found the solution with aluminum oxide, also known as alumina or corundum. Pure corundum, like its colored forms sapphire and ruby, has a melting point above 2,000° C. The problem is that it cannot easily be melted and subsequently cast or blown. The melt forms crystals when it solidifies, thus leading to undesirable mechanical properties. Existing production processes work with temperatures around 200 K below the melting point at which the powder grains sinter; in other words, they merely blend together on their surface. The particles grow and, as a result, the porosity diffuses light. This is the reason why these advanced ceramics are usually cloudy, like translucent glass.

The Fraunhofer Institute found one alternative as part of the “Starelight” project sponsored by the EU. “The most important factor in obtaining transparency is that the grain size of the raw materials should be well below one third of a micron. In the finished product the particles are not much more than half a micron, which is why they scarcely diffuse the light,” stresses Dr. Andreas Krell, Project Manager of the IKTS. This is possible at a sintering temperature that is 600 K below conventional temperatures. “We optimized the processes so that the final ceramic material is virtually poreless despite the low temperature, thus leading to transparence and good strength,” says Krell. This interesting approach with nanopowders may be able to be used with other systems, such as fiber-reinforced glass.

The future will bring transparent and highly resistant materials that have been investigated as part of an EU project.