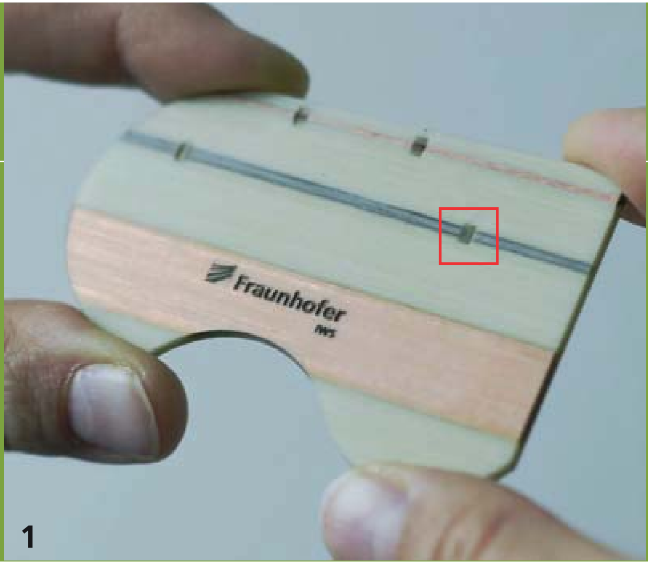

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PROCESSING OF GLASS FIBER REINFORCED POLYMER COMPOSITES WITH PULSED LASER SYSTEMS

THE TASK

Fiber reinforced polymer composites achieve high specific strengths due to the combination of high-strength fibers with lightweight polymeric matrix materials. Due to the use of thermoplastic materials, it is also possible to apply forming processes that are established for working with polymer materials. Examples include the thermo-forming of continuous fiber reinforced organic sheets and the formation of additional structures with injection molding. A task is to ensure a strong bond of the molded structures with the load carrying fibers throughout the service life of the component.

A specific characteristic of continuous fiber reinforced composites is their layered structure. The layering offers the possibility to tune the material thickness to strength requirements and also to integrate actors and sensors in between the layers. Such inserted actors and sensors are fixed in their position during the consolidation process of the composite. Later these inserts have to be locally exposed to attach electrical contacts.

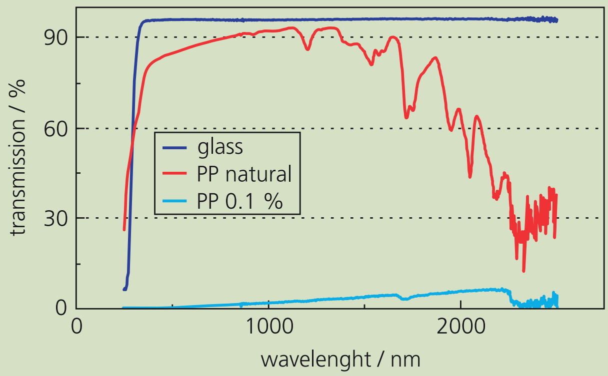
Both tasks require a tool capable of removing material at well defined locations and quantities. Fraunhofer IWS engineers tested various laser systems to qualify them for the selective and homogeneous ablation of fiber reinforced polymer composites.

OUR SOLUTION

The Fraunhofer Institute for Materials and Beam Technology has a broad spectrum of pulsed laser sources with various wavelengths and pulse durations. When selecting a laser system, the desired type of ablation has to be considered. Selective ablation means the complete removal of the polymeric matrix material while only minimally affecting the reinforcing fibers. Homogeneous ablation means the simultaneous removal of polymer matrix and reinforcing fiber.

The starting point of the investigations was the optical characterization of the composite material and its individual components. Optical spectroscopy was applied to determine the transmission spectra of the materials. In general, the polymer matrix and the reinforcing fiber have similar transmission properties. Well defined absorption properties can be tailored by incorporating additives into the matrix, which can be exploited during selective ablation of matrix and fiber materials.

Transmission spectra of reinforcing glass fiber and polymer matrix with and without additives for the wavelength range from 300 to 2500 nm



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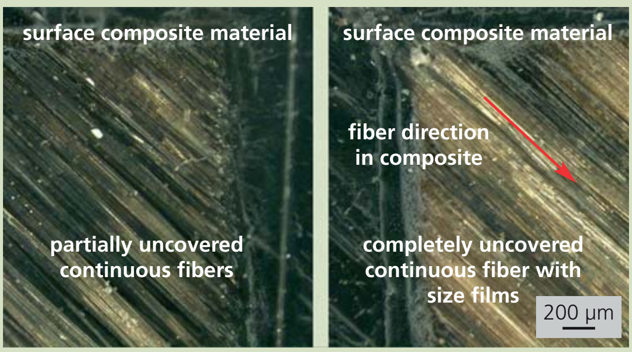
RESULTS

Matrix as well as fibers show low transmission in the UV and mid infrared spectral ranges. This means that there is only a very narrow process window for selective ablation when using lasers with wavelengths of 355 nm (frequency tripled Nd:YAG laser) and 10,600 nm (CO_2 laser). However, the entire composite can very well be homogeneously ablated. The uncolored matrix and the glass fibers have very high transmission in the visible and near infrared (Vis-NIR) spectral ranges. Thus, the selective and homogeneous ablation processes are very difficult with lasers in this wavelength range.

However, by introducing pigments to the matrix, selective ablation becomes possible with short pulse lasers in the VIS-NIR range. Research showed that under these conditions there is a broad process window to selectively remove the polymer matrix without affecting the reinforcing fibers (Fig. 4). At high powers the size film of the fibers can be completely removed. Thermal effects on the composite material depend on the laser pulse duration. The heat affected zone can be reduced to a minimum when using ultrashort pulse laser systems (USP) with pulse durations shorter than 10 ps. This approach also minimizes effects on the mechanical strength of the bordering regions. The physical effect of multiphoton absorption can be exploited to equally process uncolored and pigmented polymers with wavelengths in the VIS and NIR spectral ranges. By tuning the process parameters, USP laser systems are applicable for selective matrix removal as well has homogeneous composite ablation. Figure 1 and Figure 3 show laser generated electrical contact spots on functionalized fibers and the corresponding height profile.

Image of partially and completely uncovered continuous fibers in PP matrix after laser processing



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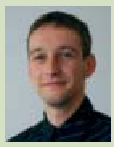
The here presented research was funded by AiF (FKZ: VP2097548TA3). Jointly with collaborators, the developed know-how for processing fiber composite materials is being used to develop specific applications. The selective matrix ablation process is being qualified for vehicle components to attach injection molded material to continuous fiber reinforced organic sheets.

1 *USP laser processed demonstrator component made from glass fiber reinforced polypropylene with Cu inserts and functionalized fibers. The component was produced in collaboration with the IPF Dresden.*

3 *Laser generated contact area*

CONTACT



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