New Laser Additives For Welding Polymers

by BASF, Treffert and Rofin

Laser welding of polymers has established itself as a promising and mature industrial joining technology during the last few years. In the medium term, market experts predict that approximately 10% of all welding systems will be equipped with laser technology. The majority of applications are currently found in the automotive industry, and involve processing dark coloured polymers. Up until now, the welding of light-coloured or transparent polymers still required significant improvement. Now, a new class of laser additives presented by BASF, Treffert and Rofin with which any coloured polymer can be welded, the Lumogen IR product line. This additive also allows to weld optically transparent and fluorescent coloured polymers and opens up new possibilities for innovative joining applications, particularly in the medical device and electronics industries and in the field of design.

Laser welding of polymers is achieved by overlap welding: the laser penetrates the upper polymer layer and is absorbed by the lower (Figure 1). The lower layer heats up and melts together with the upper layer material in a contact-free process. The resulting joints have almost the same strength as the base material, making them stronger than conventional joints. This motion-free and contact-free overlap welding technique simplifies assembly processes and produces welds without generating any micro particles on the component’s surface. Joints can even be made close to sensitive electronic components, micro mechanical parts or vibration-sensitive membranes.

Figure 1 – The concept of overlap welding: the laser beam penetrates the upper layer and is absorbed by the lower. The heat is transferred by conduction, melting the upper layer. After solidification, the bond is almost as strong as the base material.

Figure 2 - Most polymers (grey graph) absorb light in the UV and IR range. In the visible and near IR range, they are transparent or show a milky white translucent behaviour. In order to adjust the absorption performance for laser welding appropriately, absorbing systems have to be embedded into the polymer matrix.

Figure 3 - VIS/NIR absorption spectra of 3mm polycarbonate sheets, with an added 100 ppm of Lumogen IR 765 and Lumogen IR 788, respectively.
These benefits are the reason why more and more components in the automotive, electronics and medical device industries are laser welded. However, the colour range of components that can be laser welded has been very limited up to now. The extent to which the laser radiation is absorbed is usually determined by embedded absorbing additives such as pigments or dyes and not by the polymer matrix itself (Figure 2).

As these absorbing additives usually have an intrinsic colour of their own in the visible range (e.g. deep black) a compromise had to be found between technical design requirements and the demands of the marketing department with regards to colour.

The ideal laser additive, however, exhibits high absorptivity at the common laser wavelengths in the NIR range, no absorption in the visible range (i.e. no residual colour) and no optical scattering. Furthermore, it should not affect the mechanical characteristics of the polymer matrix, it must not be toxic and must be compatible with processing even at high die casting temperatures. BASF, Treffert and Rofin have introduced new additives, the Lumogen IR series, which meet all these needs.

**Highest flexibility for laser welding of polymers**

BASF has recently launched the new Lumogen IR product line, a result of a long term interdisciplinary research and development effort in the field of functional additives and colorants. The additives consist of highly efficient organic NIR absorbers based on proven BASF colorant technology. The first two products of the series, Lumogen IR 765 and Lumogen IR 788, exhibit thermo- and photostability at levels hitherto reserved exclusively to inorganic materials, coupled with a processability typical of classical organic polymer additives. A structural similarity to graphite is evident in the distinctive chemical resistance and the low reactivity of this class of compounds. In contrast to graphite, however, Lumogen IR 765 and Lumogen IR 788 exhibit good to excellent solubility in all common transparent and translucent thermoplastic polymers. Another important feature is their high NIR absorption efficiency together with only a slight, easy to compensate residual colour in the visible range (Figure 3).

Lumogen IR 765 and Lumogen IR 788 are non-ionic, free of halogens and heavy metals and non-toxic, making them ideally suited for medical device technology and other sensitive applications.

**From additives to laser optimised polymer**

The production of laser-suitable polymers with optimised colour characteristics usually requires a masterbatch producer. Since the mid-nineties, pioneering work has been done at Treffert
Polymer-Technologie on specific masterbatches (or compounds) for laser transmission welding of thermoplastics. Treffert was one of the first players to develop industrial, laser-transparent, black solutions for the automotive sector. Today, the company’s range of products comprises a large number of laser-transparent colour combinations, which fulfil other demands such as migration and heat stability, light and weather fastness.

The last great challenge, the production of laser-absorbing transparent or light-coloured polymers, which are primarily used in medical device technology and in high-tech products, has now been overcome with the new Lumogen IR additives. Many years of experience in optimum loading levels and application forms of NIR absorbers for laser transmission welding of two overlapping polymer materials has lead to the development of Lumogen IR 765 and Lumogen IR 788, in cooperation with BASF and Rofin.

These additives, used as absorbers for laser transmission welding, have been successfully tested for a wide range of polymers. The resin spectrum ranges from the standard polymers like polyolefins and polystyrene to engineering plastics like polyamides, ABS or polyester. The high absorption efficiency and the excellent thermal stability of these organic NIR absorbers even allow for their use in high quality polymers with high melting point, such as polysulfone (PSU), polyetherimide (PEI) or polyetheretherketone (PEEK). The low residual colour and the high transparency of these NIR additives enable the creation of nearly every desired transparent colour shade.

Almost all non-transparent or opaque colours can be reproduced - from intense colours to a white similar to RAL 9003. Lumogen IR 765 and Lumogen 788 exhibit excellent dispersion in all types of polymers. Compared to carbon black, the distribution in the laser-absorbing part is much more homogenous, resulting in more constant absorption along the welding path and a higher process reliability (Figure 4). Very low concentrations of the additives are required due to their optimal physical and optical characteristics, yet they can be easily mixed into polymers either as masterbatches or as compounds.

Lasers for welding with Lumogen IR

Due to their specific absorption characteristics, polymers with Lumogen IR are welded with diode lasers with a wavelength of 808 nm. Extremely high extinction coefficients of Lumogen IR absorbers allow welding with a laser power between 30 and 150 Watts for most applications. As Lumogen IR additives do not disintegrate during heating, several laser passes over the welding path are possible. This is extremely important for crossing-points in the welding path and quasi-simultaneous welding applications.

In comparison to other special laser absorbers, Lumogen IR shows high specific heat generation. This means that even polymers with high melting points such as transparent polysulfones can be welded. Moreover, the processing window is comparatively large, i.e. the danger of burned spots, bubbles or insufficient weld thickness, which are much more visible in transparent polymers, is considerably reduced.

Diode lasers for welding polymers

The laser producer Rofin offers diode laser devices and complete laser systems for welding polymers with Lumogen IR additives. The StarWeld Diode is specifically designed for plastic welding demands. The diode modules (optionally 75 or 140 Watts, 808 or 940 nm) are integrated in the 482mm power supply unit. An optical fibre cable delivers the laser radiation to the processing head, while also homogenising the beam (Figure 5).

Depending on the workpiece, fixed optics or scanner deflection heads can be used. As a rule of thumb, round parts are preferably welded with fibre-coupled lasers with fixed optics whereas flat parts are preferably welded with scanner deflection heads. The scanner deflection heads are programmed with a user-friendly and very flexible LaserCAD editor with DXF importing function. A number of standard industrial interfaces (e.g. profibus, network connection, serial or parallel ports) and also flexible customer interface solutions provide easy laser integration into existing production lines.

The diode modules are produced by Dilas, a member of the Rofin Group. Two beam-switching modes (power supply or external shutter) allow welding of complex interrupted seams while at the same time maximising the lifetime of the diode lasers. The laser has external air-cooling.
number of additional modules and options make the lasers more flexible: integrated pilot laser or camera viewing system for application adjustments, pyrometer or setting gap measurement for process control and integrated power control.

**Polymer welding using scanner deflection heads**

PolyScan is a complete system for polymer welding using scanner deflection heads. The system can be provided with a diode laser of the Starweld Diode series (808 or 940 nm) or a Nd:YAG laser of the StarWeld-YAG series (1064 nm) with all components integrated in the compact housing (Figure 6). The laser is operated via keyboard and integrated LCD monitor.

The LaserCAD program allows fast and flexible programming of the welding path, either for contour or quasi-simultaneous welding. Adjustment of the laser head and therefore the laser spot size can be set using the motor driven z-axis. This makes the system very flexible with regard to changes in materials or parts being welded. PolyScan is ideal for welding plastic parts in the development phase, for prototypes or in small volume production.

**Applications**

Small welding paths with widths between 0.5 mm and 2 mm can be realised achieving extremely strong and reproducible weld seams. The Lumogen IR dyes have been successfully tested in a large number of laser welding applications (Figures 7 and 8). Typical examples can be found in the medical device, electronics and sensor industries as well as in the field of household appliances.

Figure 8 - Lumogen IR dyes allow polymer laser welding throughout the complete colour range