Polymers & Lasers

Laser Application Center

Evonik. Power to create.

Performance Polymers

Laser Application Center

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Performance Polymers

Introduction

Application possibilities for laser systems used in processing plastics are virtually unlimited. Fast, flexible, and precise, laser technology is more cost efficient than conventional processes; moreover, this advanced technology brings innovative ideas to rapid implementation and adds years to the life of processed materials.

Where products are marked with barcodes, contour sharpness is important, as is contrast. Only if the marking stands out clearly from the material surface can it be correctly read by a bar code scanner and processed further.

The miniaturization of components and their increasingly complex geometries require welds of such fineness that conventional welding processes can obtain them only with great difficulty, if at all. The laser-welding process, on the other hand, makes it possible to do even three-dimensional welding in a single workstep. In the manufacture of sensors for medical engineering, the laser can produce the finest welds in the most confined of spaces. The conventional manufacture of three-dimensional circuit substrates depends on product-specific tools for creating the printed circuit structure on the component, which severely limits the flexibility of the processes when designs are changed. Further miniaturizing printed circuit structures on MID components requires additional time and cost. Using special molding compounds in conjunction with the appropriate laser-structuring technology offers a flexible and cost-effective alternative.

In design studies, modeling, and even in very small-scale production, parts are still often produced manually because the high cost of tools rules out the fabrication of injection-molded parts. Laser-sintering offers an economical alternative here. The parts need only be developed on a CAD system and then constructed as hardware in a subsequent rapid prototyping process.

The scope of application of plastics depends strongly on their material properties and their compatibility with the laser wavelengths used in the various systems. Not all of the currently used thermoplastics absorb laser beams equally well. But thanks to special additives developed and patented by Evonik's Performance Polymers and Inorganic Materials Business Units, our molding compounds can be adjusted for use in an extremely wide range of applications.

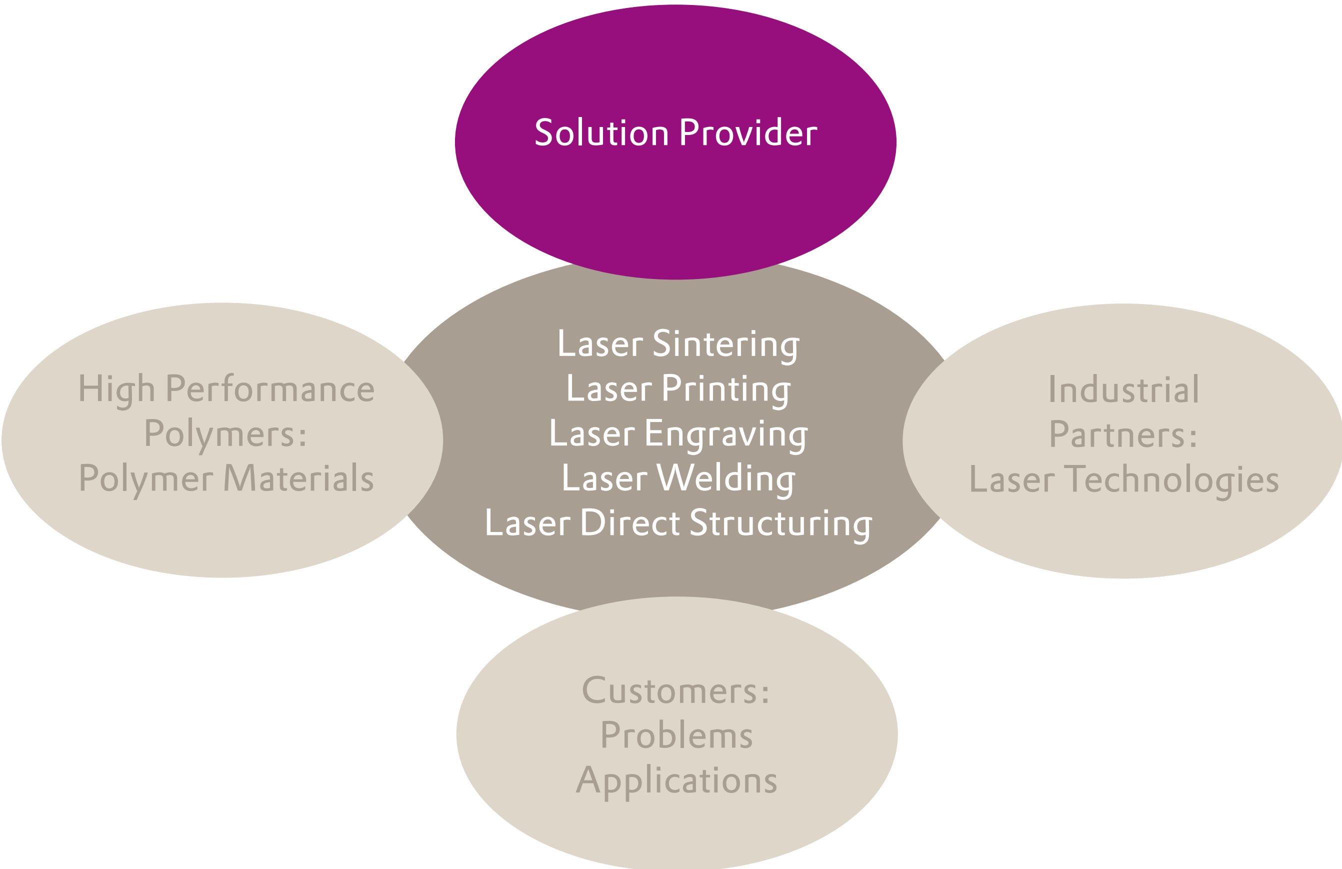
The components made from these molding compounds ensure good laser weldability of two transparent materials and, for laser-marking, dark lettering of the highest quality, even for highly transparent and colorless plastics. Moreover, the High-Performance Polymers Business Line offers various black and dark-colored products that can be laser-marked to give light-on-dark images with good contrast.

For the selection of a suitable laser-processable material, the requirements profile for the molded part must be known. The following table of laser-processable molding compounds from our high-performance polymers product range will help you draw up a short list of suitable materials. We recommend that you consult us as your knowledgeable partner before beginning a new project. Our Laser Application Center has the skills to select the molding compounds that are optimal for you, and to identify fast and economical processing options when these materials are used.

High Performance Polymers from Evonik

VESTAMID®	polyamide 612 (PA 612) polyamide 12 (PA 12)
TROGAMID®	polyamide 6-3-T (PA 6-3-T)
VESTODUR®	polybutylene terephthalate (PBT)
VESTAKEEP®	polyetheretherketone
VESTOSINT®	polyamide 12 (PA 12) powder
VESTAMELT®	copolyamide hot melt adhesives
PLEXIGLAS®	polymethyl methacrylate (PMMA)
ROHACELL®	polymethacrylimide (PMI) foam
EUROPLEX®	polyphenylsulfone (PPSU)
VESTENAMER®	trans-polyoctenamer (TOR)

Laser Application Center



The Laser Application Center of High Performance Polymers offers support in the use of lasers with polymers, in the form of:

- comprehensive advice,
- state-of-the-art technology, and
- quality testing

Polymers & Lasers

The Laser Application Center supports you in choosing materials for all relevant laser processes.
You are welcome to try out the following laser applications at the Center:

- Laser-marking (2D and 3D)
- Laser-welding
- Laser-sintering
- Laser-structuring

Quality

In our testing and analytical laboratories, we can perform a wide range of tests on lasered and unlasered materials to check and safeguard our high quality standards. These include

- transmission measurements,
- haze,
- scanning electron microscopy (SEM),
- transmission electron microscopy (TEM),
- light microscopy, and
- tensile testing

as well as many other physical and chemical tests.

Laser Technology

What is laser radiation?

The word laser is an acronym for Light Amplification by Stimulated Emission of Radiation, and describes a physical process leading to the production of laser radiation.

In the first step, atoms[1)] of a laser medium (the active medium) are excited by supplying them with energy, a process known as "pumping" (see diagram). The active medium may be a liquid, solid, or gas.

Depending on the active medium, the energy can be supplied by electrical gas discharges, flash lamps, an applied voltage, or another laser. The excited atoms emit photons (light particles), thereby returning to the non-excited state. If these light particles collide with other atoms in the excited state, the latter also emit light particles of the same wavelength, phase, and direction as the incident light particles. This process, known as "stimulated emission," is what occurs in an optical resonator.

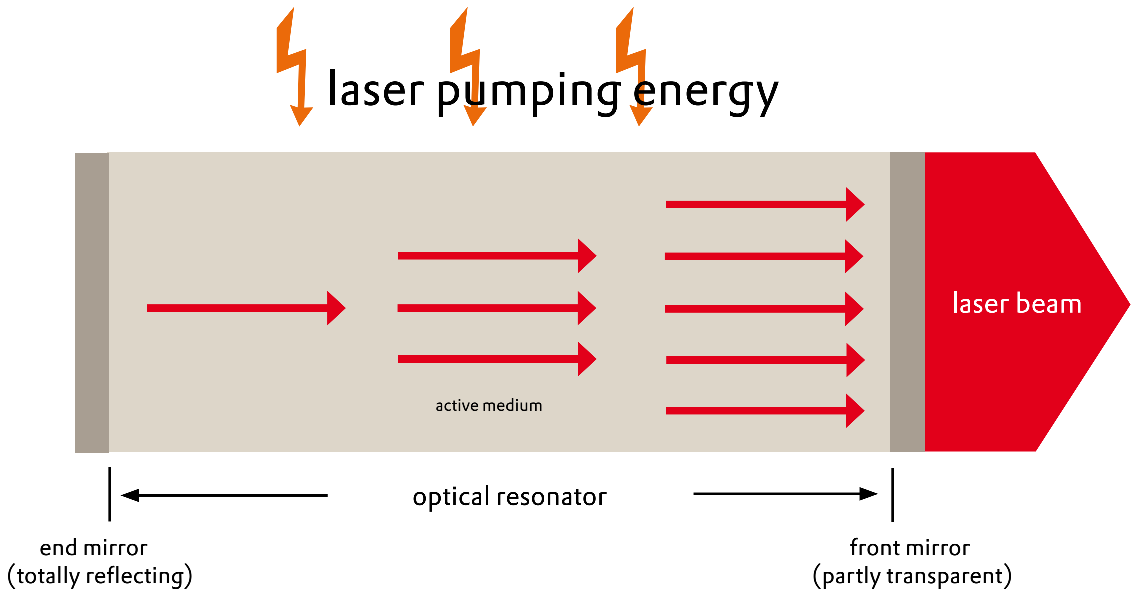
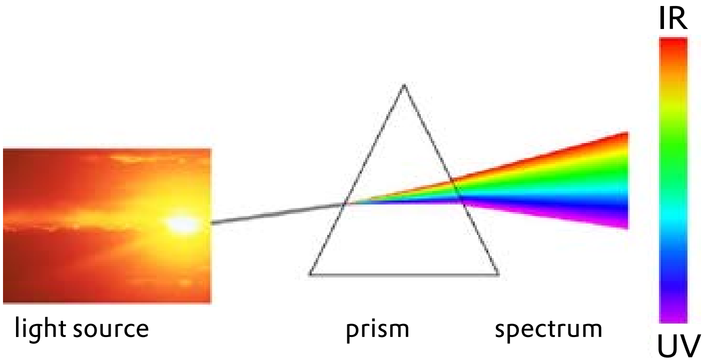


Fig. 1: Structure of a laser

The resonator may be, for example, a (gas-filled) tube or a solid (such as ruby, or a semiconductor), at both ends of which a mirror reflects the radiation. This therefore traverses the active medium many times, stimulating further atoms to give up their light particles on each pass. One of the two mirrors is partly transparent, so that part of the radiation can emerge from the tube.
Laser radiation differs essentially from radiation emitted by conventional radiation sources, such as incandescent lamps, in the following ways:

- coherence: the waves possess a constant phase difference; they are temporally and spatially coherent;
- monochromatic light: laser radiation has exactly one wavelength;
- low divergence: lasers emit bundled, almost parallel radiation.

[1)] These may be atoms, molecules, or ions; for the sake of brevity they will be referred to in the following as atoms



- “white” light, emitting a broad spectrum
- luminous power of the order of mW to W
- not coherent
- omnidirectional radiation

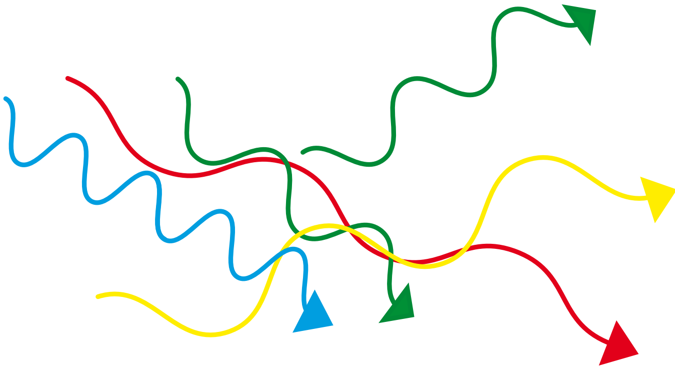
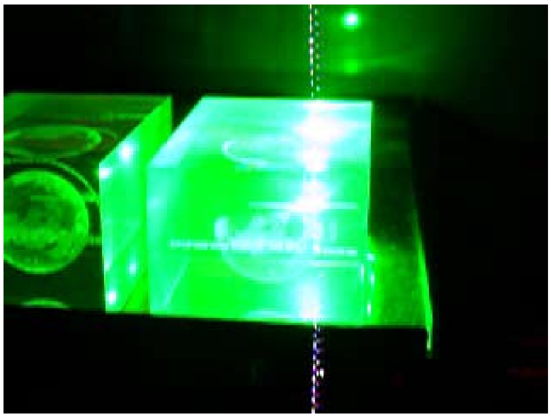


Fig. 2: Normal light



- monochromatic (a single color)
- luminous power of the order of mW to MW
- spatially and temporally coherent
- directional “laser beam” radiation
- good bundling (focusing) of the beam

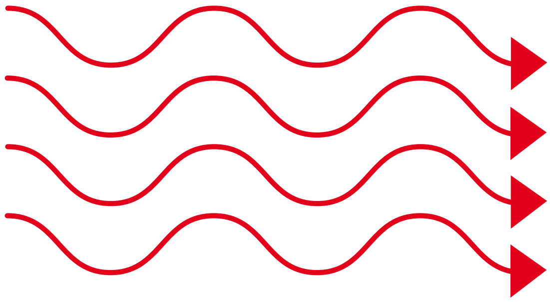


Fig. 3: Laser light

In practice, this means that laser beams can be strongly bundled and easily focused on the smallest spaces. This property is exploited in every CD player, for example, to read out the microscopically small structures on the CD. On the other hand, laser beams also allow enormous energies to be bundled at a single point, for example, for very precise cutting, marking, or welding of materials.

Because lasers are used for a wide range of different purposes, they differ also in their structure. The wavelengths range from the far infrared (IR) region through visible light to the ultraviolet (UV) region (see Fig. 4).

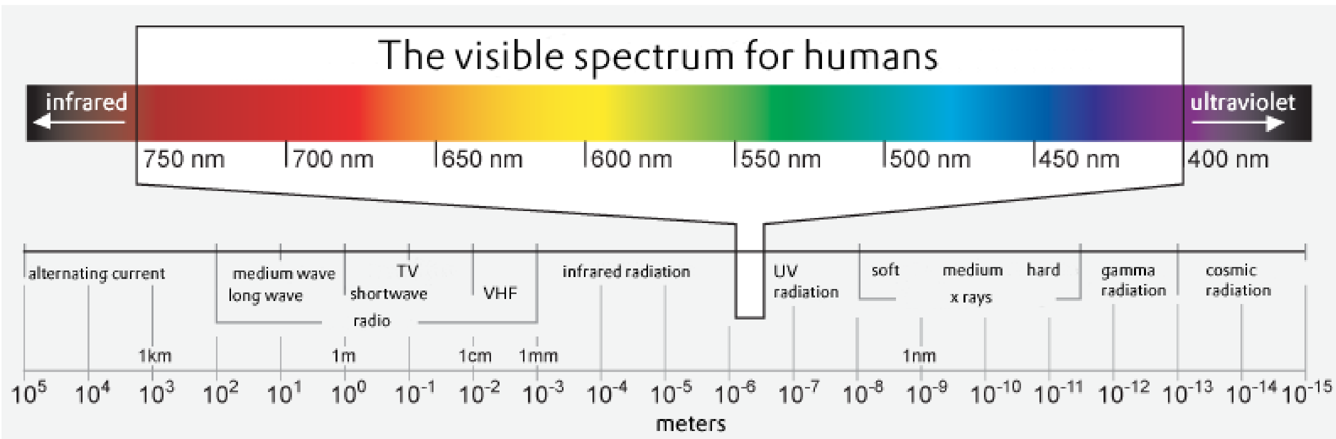


Fig. 4: The electromagnetic spectrum

Types of Laser

Lasers are categorized and named according to the type of the optically active material used; they may be gas, solid, or liquid (or dye) lasers (Fig. 5).

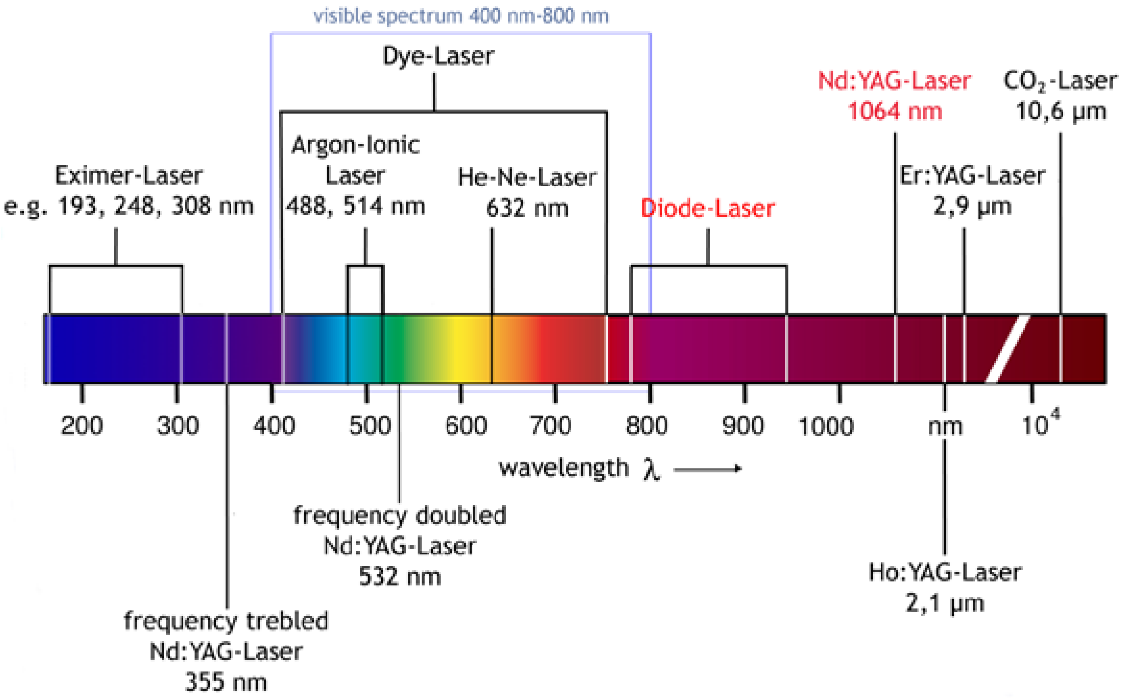


Fig.5: Typical lasers and their wavelengths

Lasers can also be classified according to whether they radiate continuously (cw (continuous wave) lasers, Fig. 6) or operate in a pulsed mode. Lasers radiating for a period exceeding 0.25 s are known as continuous wave lasers. Pulsed lasers emit radiation pulses at regular intervals; the duration of these pulses may range from a few femtoseconds to 0.25 seconds (Fig. 7).

P_L = laser power (W)
T = pulse period

P_S = peak power (W)
t_p = pulse duration

P_m = mean power (W)

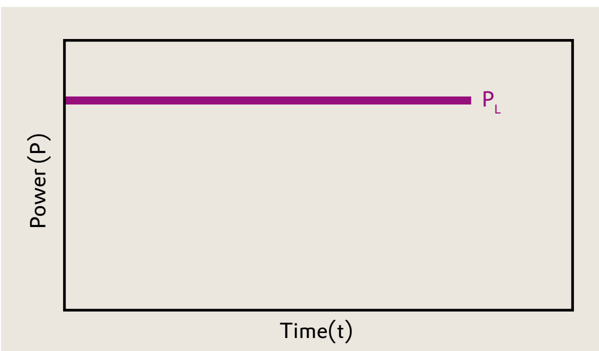


Fig. 6: Continuous wave (cw) laser

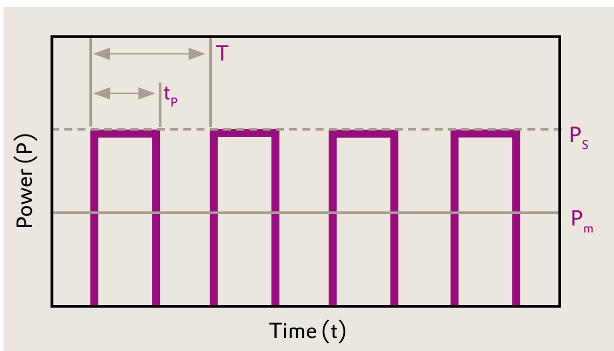


Fig. 7: Pulsed laser

Solid-State Lasers

The first working laser was a ruby laser, made from ruby (chromium-doped corundum), developed by Maiman in the year1960.
Solid-state laser materials are commonly made by doping a crystalline solid host with ions provide the required energy states. Embedded in the host material, these ions form the actual active medium. Their orbitals do not participate in chemical bonding. The carrier material (host crystal or glass) therefore has only a small influence on the properties of the ions.
Solid-state lasers are distinguished according to the type and form of the host material and the doped elements.

Examples of host or carrier materials

- Glass (in the form of rods or fiber lasers)
  - Advantage: simple to produce, even in large dimensions
  - Disadvantages: low thermal conductivity, low strength
- Al_2O_3 (corundum, sapphire; e.g., ruby laser (chromium doped), titanium:sapphire laser)
  - Advantages: high thermal conductivity, high strength
  - Disadvantages: relatively high absorption; expensive
- YAG (yttrium aluminum garnet laser: see Nd:YAG laser), doped with Nd, Er, Yb
  - Advantages: high thermal conductivity, high strength, low absorption
  - Disadvantage: expensive
- Yttrium vanadate (YVO_4), doped with Nd

Examples of Doping Materials

- The doping material in the first ever laser, the ruby laser (694.3 nm, red), was chromium. Because of its low efficiency it is now rarely used.
- Neodymium, is used in the most important commercial solid-state lasers, Nd:YAG at 1064 nm (infrared) and double frequency at 532 (green). Nd:glass and Nd:YLF are also possible.
- Ytterbium, allows high efficiency (>50%) in laser operation, but needs narrow-band pumping with laser diodes (940 nm). The most important material with this dopant is the Yb:YAG laser, for example, highly doped as a thin disk laser with a wavelength of 1030 nm.
- Titanium; an important mode-coupled solid-state laser is the titanium:sapphire laser, 670-1100 nm (red-infrared), which due to broadband amplification is suitable for pulses in the fs range.
- Erbium, 3 µm, pumping with diode laser at 980 nm; known as the eye-safe laser, this is used for laser range finders and in medicine.

Types of Active Media

- Rod lasers
- Microcrystal lasers
- Slab lasers
- Fiber lasers
- Thin disk lasers

Semiconductor Lasers

In semiconductor lasers, the active medium is the diffusion zone of the charge carriers in a p-n transition[1)] of a semiconductor crystal. The optical resonator can be formed here by the end faces of the semiconductor crystal, because the high refractive index of the crystal results in high reflectivity.
Laser diodes are directly electrically pumped lasers. The power of laser diodes lies between < 1W and 10W. The beam quality declines with increasing power.
A number of individual diodes can be assembled side by side on a single narrow chip (approx. 0.1 x 1 x 10 mm). These "bars", as they are known, can supply more than 50 watts if mounted on a heat sink, with the individual diodes electrically connected in parallel. The mounted bar is also known as a "submount." By coupling a number of bars or submounts in a stack, outputs in the kW range can be achieved, with correspondingly poor beam quality. By the use of different (normally up to 3) wavelengths and polarization directions, up to 6 stacks can be optically added with low losses and without deterioration of beam quality. For optical pumping of solid-state lasers by laser diodes, the pump wavelength must be matched exactly and wavelength coupling is therefore not possible. However, the diode lasers need not be combined here into beams with high power density.

Diode lasers with wavelengths in the range of approx. 800 nm to 1000 nm are now, in addition to Nd:YAG lasers (1064 nm), the most important industrial lasers for processing of plastics.

Other semiconductor lasers include:

- optically pumped semiconductor lasers, including semiconductor thin disk lasers,
- quantum cascade lasers,
- surface-emitting lasers (VCSEL) (optically as well as electrically pumped), and
- tunable lasers (tunable laser source, TLS) with adjustable wavelength.

Gas Lasers

In gas lasers the active medium is gaseous. Gas lasers are usually electrically pumped by a gas discharge in the active medium itself.
The most important gas lasers used in the processing of polymers are:

- the carbon dioxide (CO_2) laser, with wavelength approx. 10.6 µm (mid-infrared), an important industrial laser for cutting and marking, and
- the excimer laser, for example, KrF (248 nm), XeF (351-353 nm), ArF (193 nm), XeCl (308 nm), and F_2 (157 nm), for marking and fine drilling; all these are ultraviolet.

Other Types of Laser

Other types of lasers include, for example, dye lasers, color center lasers, and free-electron lasers (FEL).

[1)] **p-n (positive-negative) transition** is the boundary layer between a p-conducting and an n-conducting region in a semiconductor. The strong concentration gradient of the carriers at the boundary layer causes some holes to diffuse from the p- to the n-conducting layer, and some electrons in the reverse direction, where they then recombine with the respective carriers.

Polymers and Lasers

Requirements

Virtually any plastic can be laser processed, but material- and process-specific restrictions must be taken into account.

Plastics do not absorb laser radiation in the region extending from the near ultraviolet to the near infrared. Conversion of laser energy into heat (of fusion) is therefore possible only if the polymer has been appropriately "laser sensitized" by addition of an additive.

In the absence of laser additives, therefore, polymers can be processed only in far ultraviolet light, for example, with excimer lasers, and in far infrared light, for example, with CO_2 lasers (Fig. 8).

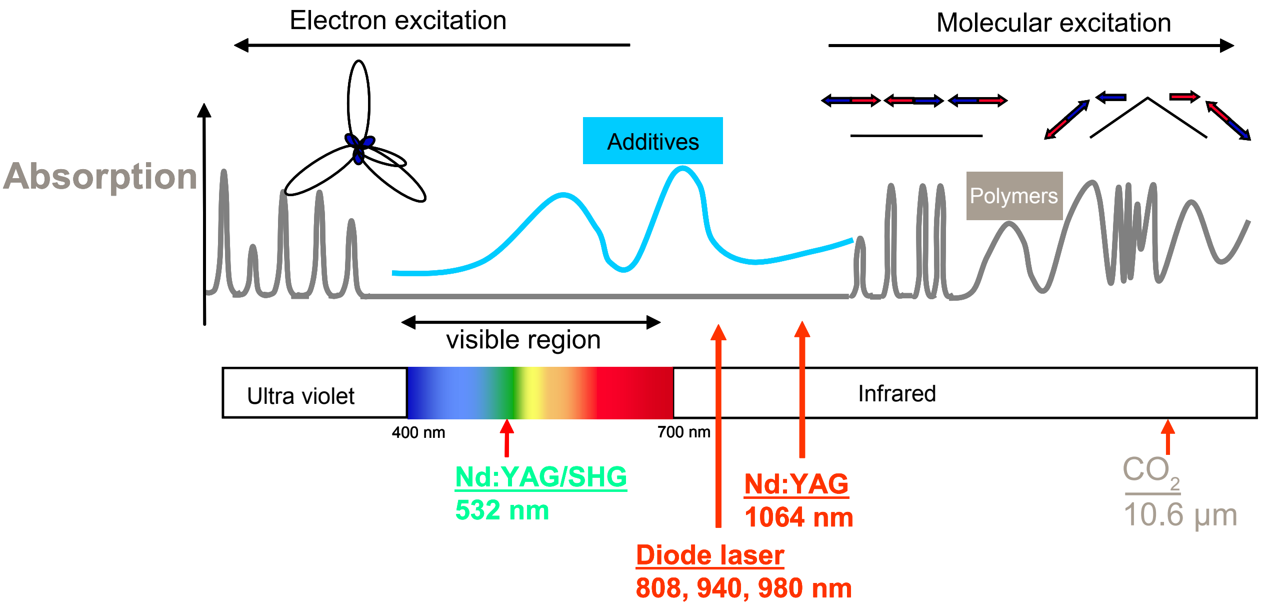


Fig. 8: Light absorption of polymers and laser wavelengths

If plastics are used for laser-welding, the material-specific properties of the various types of plastics must be taken into particular consideration.

Thermoplastics, whether amorphous or semicrystalline, are easily fusible and have a fusion temperature range above which they decompose (Fig. 9).

In addition to morphology, fillers, such as glass fibers, also affect welding properties.

Factors Influencing Laser-Welding of Plastics

Crosslinked plastics of the thermoset and elastomer class (except for thermoplastic elastomers, TPE/TPU) are not fusible. They are therefore not suitable for laser-welding. They can, however, be used for laser-marking.

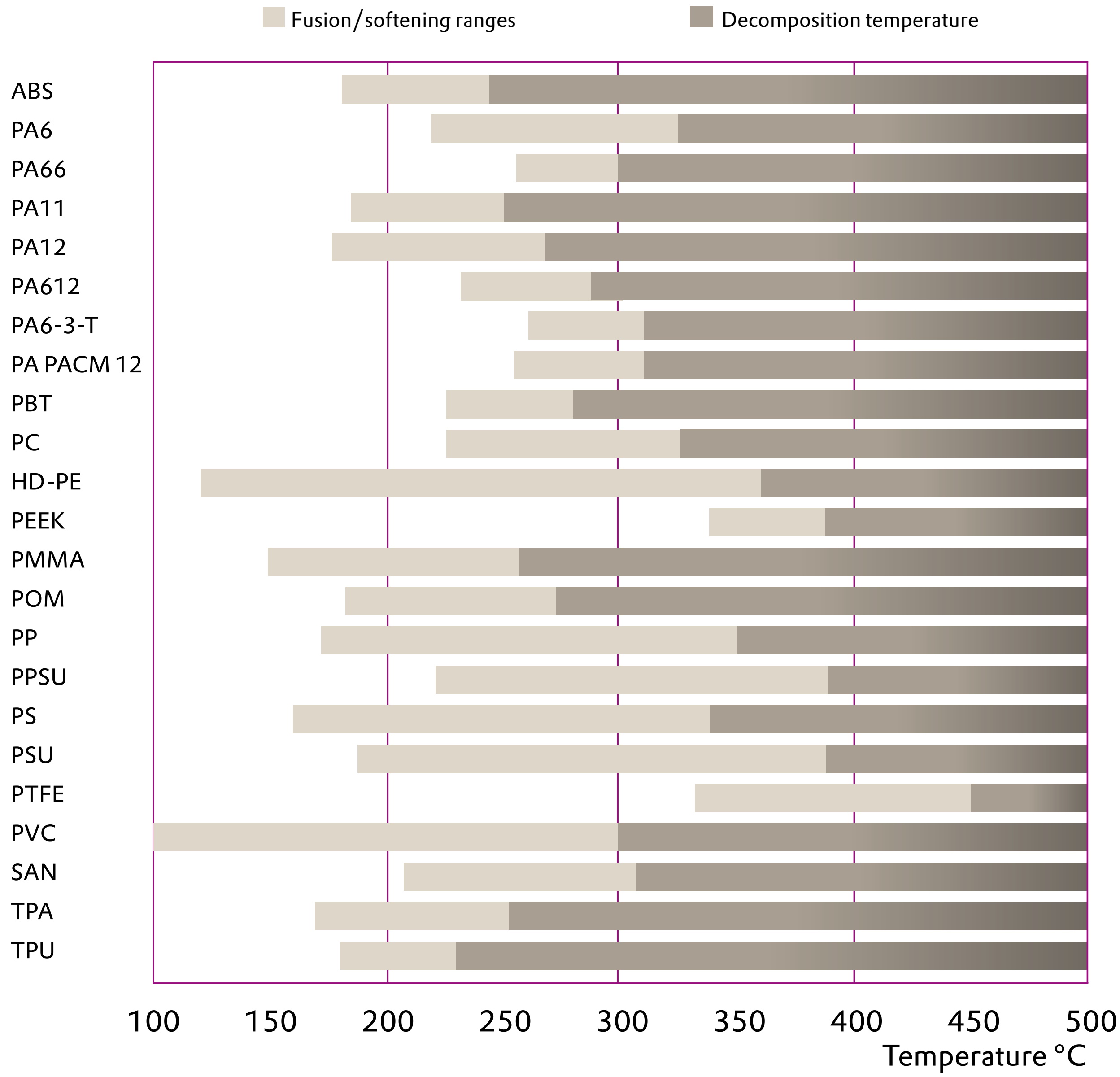


Fig. 9: Fusion and softening ranges of plastics

Optical Properties of Plastics

When a laser beam strikes a plane interface between two media with different refractive indices, it is partly reflected at the interface and partly absorbed on penetration, the remaining radiation then being transmitted. The proportion in which these effects occur depends on the material properties of the obstacle; the sum of all radiations is always 100%.

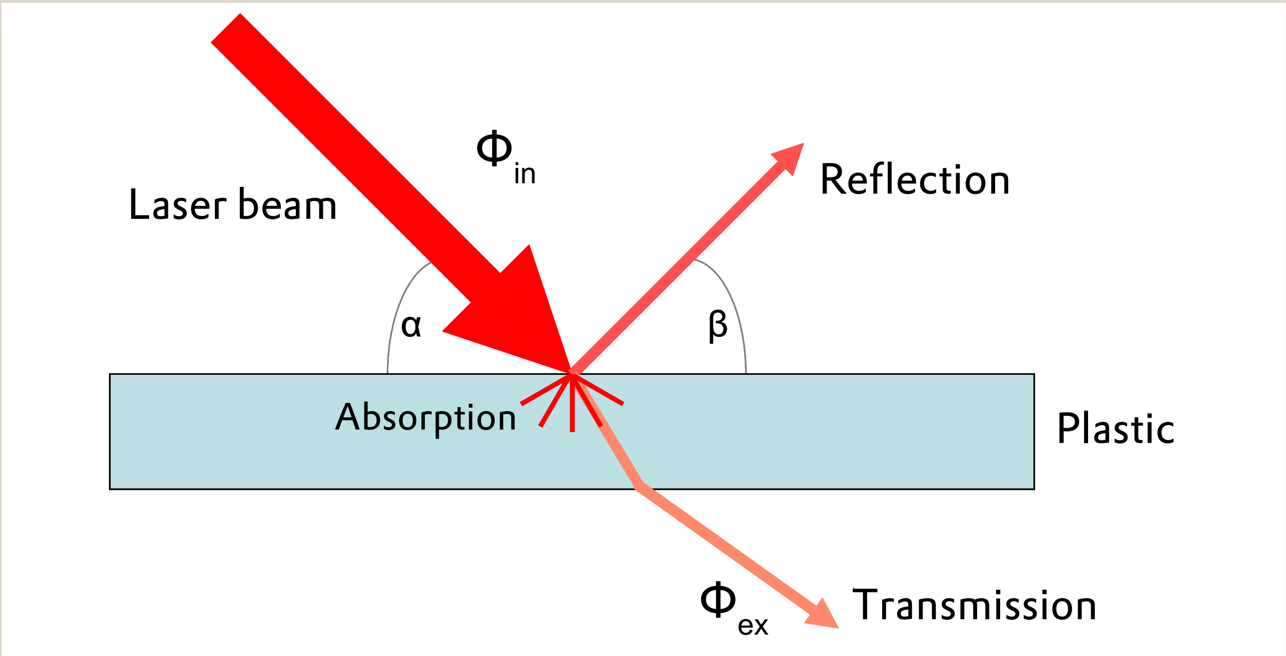


Fig. 10: Optical properties of plastics

Absorption
Absorption (from the Latin *absorptio*) occurs when power from the light beam is transferred to the plastic. The absorbed fraction of the light is generally converted into heat, but may also be lost through scattering at defects (air, etc.) in the structure of the material (Fig. 10).

Polymers do not absorb laser radiation in the region from the ultraviolet to the infrared. Conversion of laser energy into heat (of fusion) is therefore possible only if the polymer has been "laser sensitized" by addition of an appropriate additive (Fig. 8).

Reflection
Reflection (from the Latin reflectere, to bend back, or turn) occurs when, for example, electromagnetic waves are bounced back from a surface (Fig. 10).

The ratios of the refractive indices and absorption coefficients of the plastics determine the intensities of reflection and transmission. For reflection, the following simple law (for plane surfaces) applies: the angle of incidence (α) of the light beam equals the angle of reflection (β).

Scattering
Scattering of electromagnetic waves occurs mainly at defects in the structure of materials, caused by, for example, poor distribution of additives, bubbles (air pockets), etc.

Haze
Haze is the scattered component of the transmitted light in transparent plastics. Low haze values therefo-re indicate high transparency.

Transmission
Transmission (from the Latin *trans* (through) and *mittere* (send)) is a measure of the transparency of a medium to, for example, electromagnetic waves (light, etc.) (Fig. 10).

Transmittance

In optics, transmittance is the proportion of the incident radiation or light flux that completely penetrates a transparent component. The transmittance τ is defined as the quotient of the radiant flux of the emergent (transmitted) light beam (Φ_{ex}) and that of the incident beam (Φ_{in}).

$$\tau = \Phi_{ex}/\Phi_{in}$$

The transmittance depends on, among other factors, the wavelength and therefore the frequency of the electromagnetic radiation, that is, on the color of the light, and on the angle of incidence of the wave.

Transmission Spectra

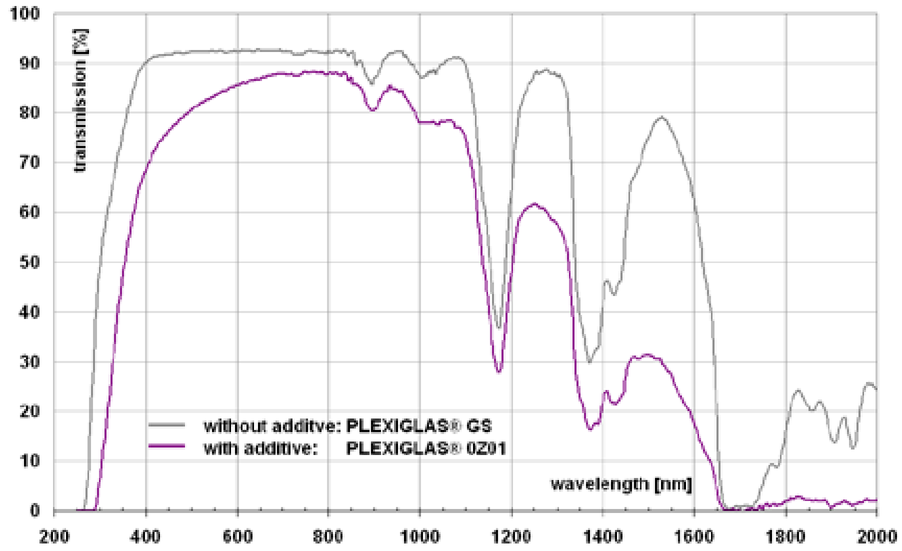


Fig. 11: Transmission spectrum of nanomodified PMMA

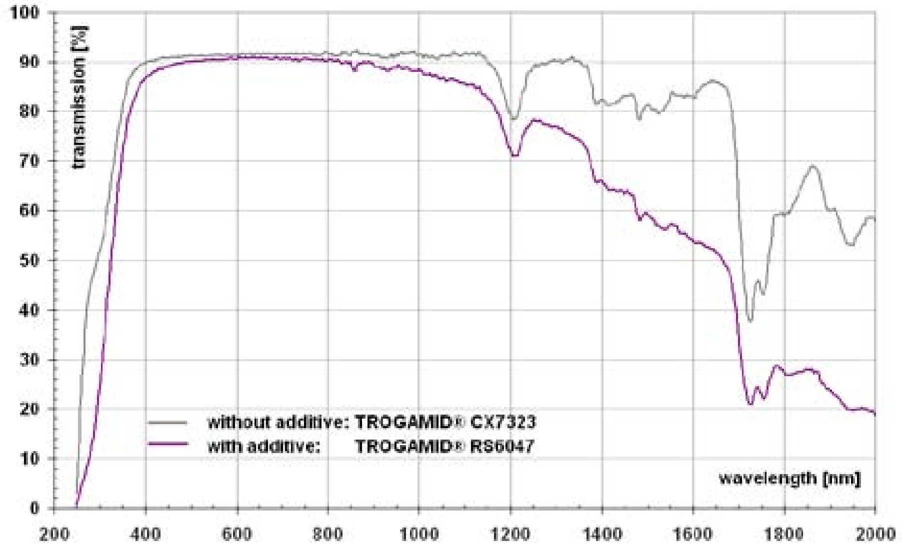


Fig. 12: Transmission spectrum of nanomodified TROGAMID® CX7323

Laser-Marking

The range of potential applications for laser systems in the marking of plastics is virtually unlimited. Fast, flexible, and precise, laser technology is more economical than the conventional printing and injection molding processes; moreover, this advanced technology guarantees the durability and contour sharpness of the marking.
For marking products with a barcode or data matrix code, contrast is important, as is contour sharpness; only when the marking stands out clearly from the material surface can it be correctly read by the bar code scanner and processed further.

The contrast and contour sharpness of laser markings depend on the material properties of the plastics used and their compatibility with the various laser systems and their wavelengths. Not all of the commonly used thermoplastics absorb laser beams equally well, and this can negatively impact the contrast or suppress it altogether.

Marking plastics in the UV, visible, and IR ranges is possible either directly or with the use of laser additives.
Because the Nd:YAG laser (1064 nm, Fig. 13) is the most commonly used in practice, most molding compounds for laser-marking are now formulated for the wavelength of this laser. Exceptionally high contrast is achieved when the materials contain special additives developed and patented by Evonik's High Performance Polymers Business Line. Laser additives designed specially for transparent plastics have also been developed by the company's Inorganic Materials Business Unit.
In non-transparent plastics, these laser additives ensure dark markings of the highest quality on almost all light-colored formulations, irrespective of the pigmentation of the plastic and even for in-house coloring by customers. Additionally, the High Performance Polymers Business Line offers various dark-colored and black products that can be laser-marked in light colors with good contrast.

Highly transparent plastics from Evonik that contain laser additives are distinguished by their absolute colorlessness and very low haze. In this case also, the lettering is of the highest quality, with very good contrast.

To choose an appropriate laser-markable material, you must know the requirements profile for the part to be marked.

Factors Impacting Laser-Marking

The markability of a plastic depends only on its material properties and any laser additive used. Marking effects such as color change, foaming, and carbonization depend on the reciprocal effects of material properties and laser wavelength. The characteristics crucially important for high-quality marking are homogeneity of the molding compound, excellent distribution of the laser additive, and appropriate selection of laser parameters.

Fig. 13:
Nd:YAG marking laser
1064 nm (from Baasel-Lasertechnik)

Laser-Marking Non-Transparent Plastics

Marking Lasers

Writing laser

The writing laser offers flexibility. The laser beam is deflected in the x- and y-directions by two computer controlled galvanometer mirrors, and is focused with a lens on the part to be marked. An area of approximately 10 x 10 cm can be marked at any required point. It is possible to provide every single part in a production line with an individual marking, such as a serial number.

Mask Laser

The mask laser is not as flexible as the writing laser, but is considerably faster. The laser beam, a few square centimeters in area, passes through a lens, imaging a mask on the part to be marked. This process allows up to 200 markings per second.

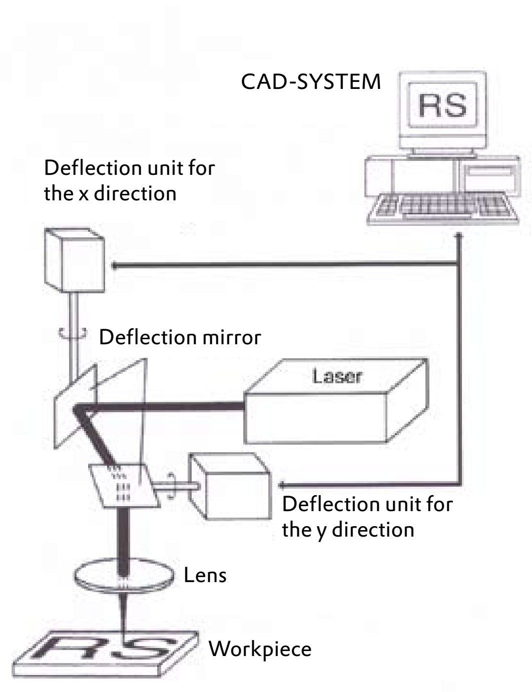


Fig. 14:
Writing laser

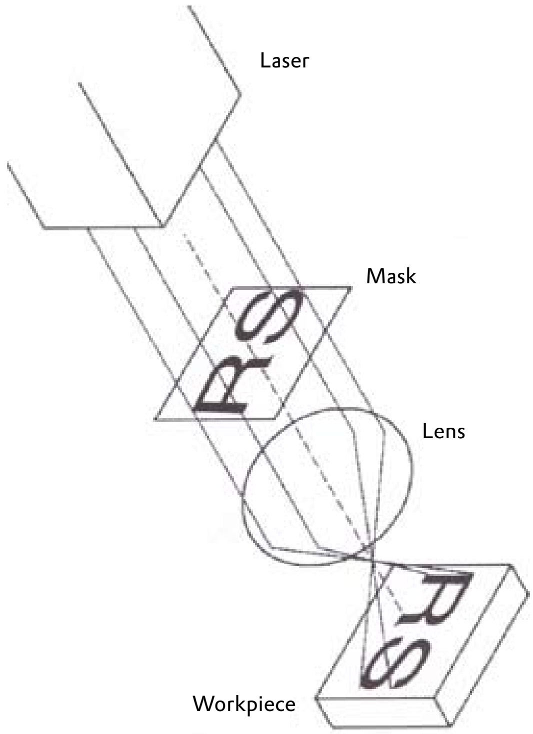


Fig.15:
Mask laser

Dot-Matrix-Process

In the dot matrix process, a laser beam is "chopped" by a rotating mirror. By movement of the part to be marked, a marking consisting of a number of individual points is produced, in the same manner as on an inkjet printer. This process represents a special form of laser-marking of plastics because it can be used for only a few thermoplastics.

The Dot-Matrix-Process is suitable for batch date marking at high speed. The size of the marking is restricted, however, and marking is possible only with moved parts.

Lettering and Contrast on Non-Transparent Plastics

The staining depth and foaming height can be determined from light microscopic images of thin sections (Fig. 16, 17, and 18). The staining depth [a] should be at least 100 µm, and the foaming height [b] should be as low as possible. The most important parameter characterizing the marking is the legibility, which can be quantified in terms of contrast; this can be determined using a luminance meter.

To eliminate gloss angle effects, the measurement point is illuminated by an integrating sphere with a luminosity of 200 lux. The luminances of the background (BL) and characters (CL) are determined, and the contrast C is defined by the ratio BL/CL. The GS-VWSG7 test standards of the Employers' Liability Insurance Association specify that for characters on key caps C must be > 3.

Fig. 16: Contrast without additive

Fig. 17: Contrast with additive

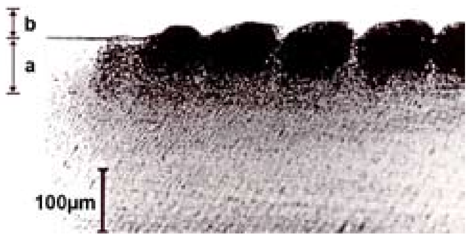


Fig. 18: Characterization of laser-marking by evaluation of staining depth (a) and foaming height (b)

Fig. 19: No additive; high foaming height

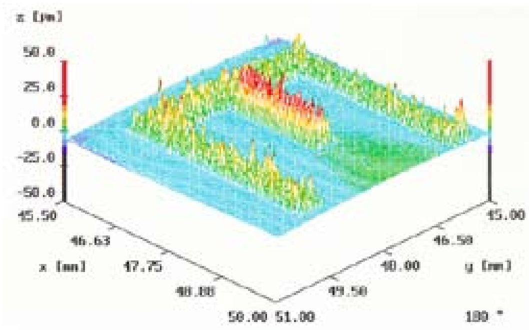
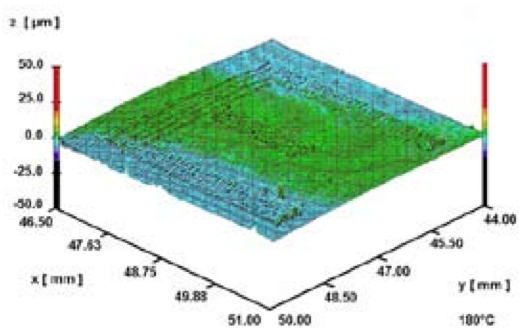


Fig. 20: Low foaming height achieved by use of an additive



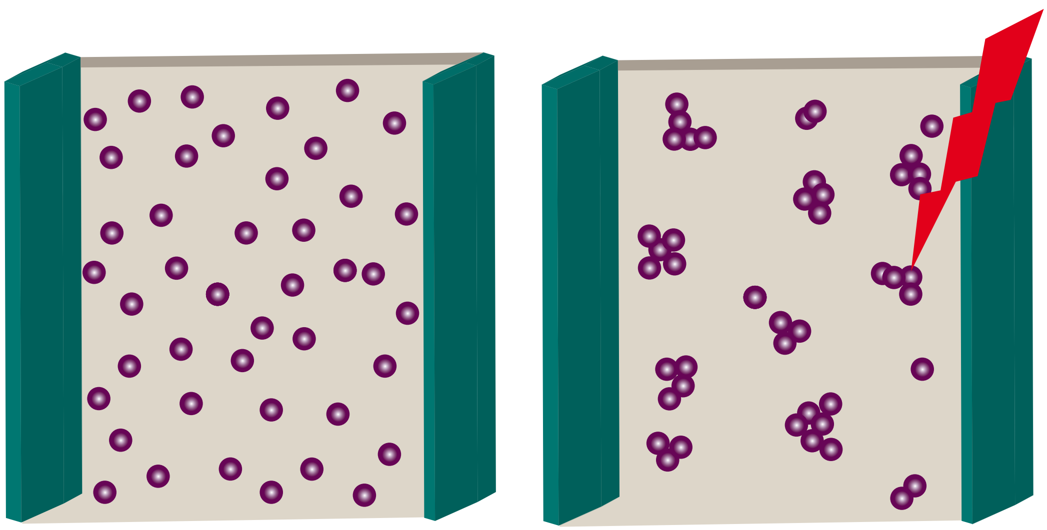
Surface profile of the letter "E" with the same laser energy

Laser-Marking of Transparent Plastics

Laser-marking of transparent plastics has so far been restricted to colored thermoplastics; selective coupling in of the laser energy was not formerly possible in transparent plastics. The problem could be solved by the use of suitable additives or pigments, but at the cost of transparency and colorlessness. Evonik's technicians have now overcome these difficulties and have succeeded in extending the process also to transparent polymers.

Laser-Marking by NIR Absorbers

A technology has been successfully developed for laser-marking transparent plastics, which are otherwise difficult or impossible to mark with lasers. This uses nanoscale metal oxides, which, on account of their small particle size, do not scatter visible light but absorb the wavelength of the laser in the near infrared (NIR) region. Because the Nd:YAG laser (1,064 nm) is most commonly used in practice, the additives have been formulated for the wavelength of this laser. The skill in the incorporation of the metal oxides lies in controlling their tendency to agglomeration and dispersing them as homogeneously as possible in the polymer matrix. Only under these conditions can high-contrast markings with the highest resolution and contour sharpness be obtained. These infrared absorbers are dispersed in PLEXIGLAS® (polymethyl methacrylate, PMMA) and TROGAMID®, a transparent polyamide, new compounding processes being used for this purpose.If a laser beam now falls on the metal oxides, they absorb the energy and heat their immediate environment, which results in foaming (by formation of gaseous degradation products in the micrometer region) or carbonization (degradation to carbon). The result is a locally confined change of refractive index, rendering the marking, such as an inscription, visible. The additives do not produce a color change, but appear in a shade of gray ranging from white to black, depending on the polymer and the choice of laser parameters. In both PLEXIGLAS® and TROGAMID®, markings can be obtained with layer thicknesses of less than 100 micrometers. Multilayer designs are also possible in which the laser-sensitive layer is embedded between two transparent covering layers.



Well-dispersed laser sensitive additive   Aggregated laser-sensitive additive

Fig: 21
Dispersion of NIR absorber

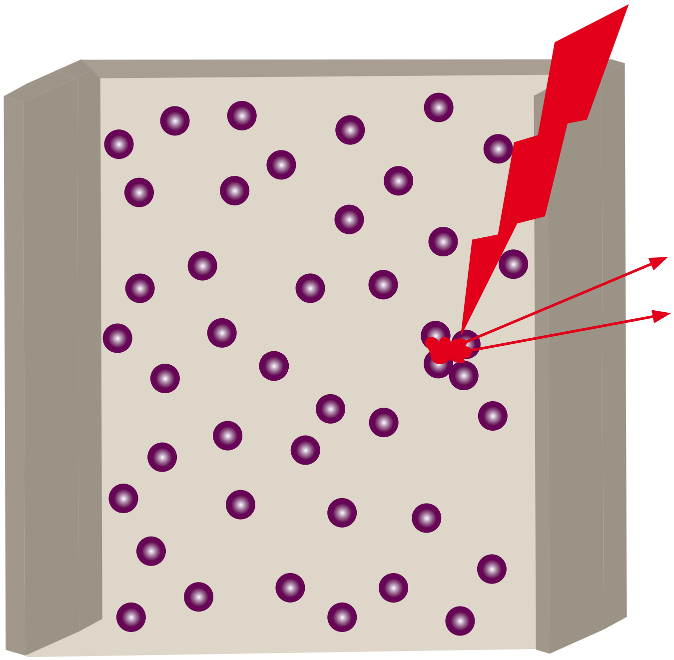


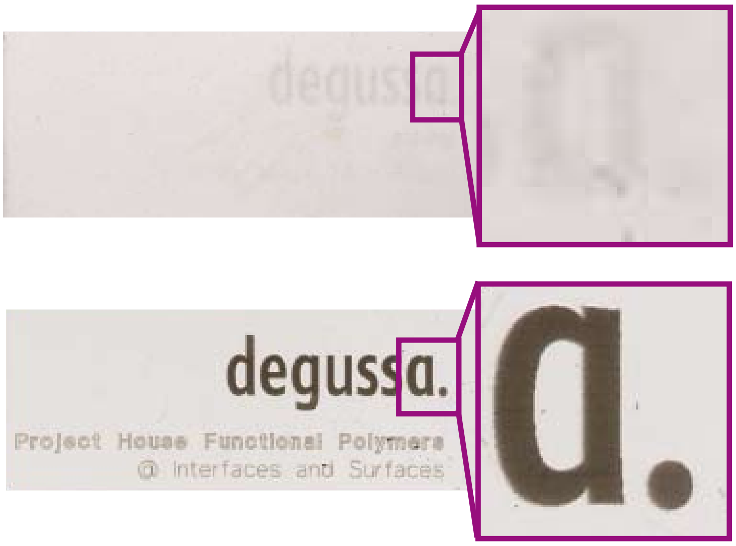
Fig. 22: Mechanism of laser-marking and sub-surface engraving by NIR absorbers

The possible fields of application of this new technology for laser-marking (highly) transparent plastics are many and varied. Because the marking is forgery-proof and highly durable, it is suitable for, for example, identity cards, barcodes, and pharmaceutical packaging. Medical technology could also benefit from this contactless process because, in contrast to other marking processes such as printing or milling, there are no impurities and no contamination with chemical compounds or abrasion particles.

Entirely different fields of application, such as personalized art objects or inscriptions for office doors, are also conceivable. Evonik is now stepping up further development in cooperation with customers.

2D Laser-Marking of Transparent Plastics

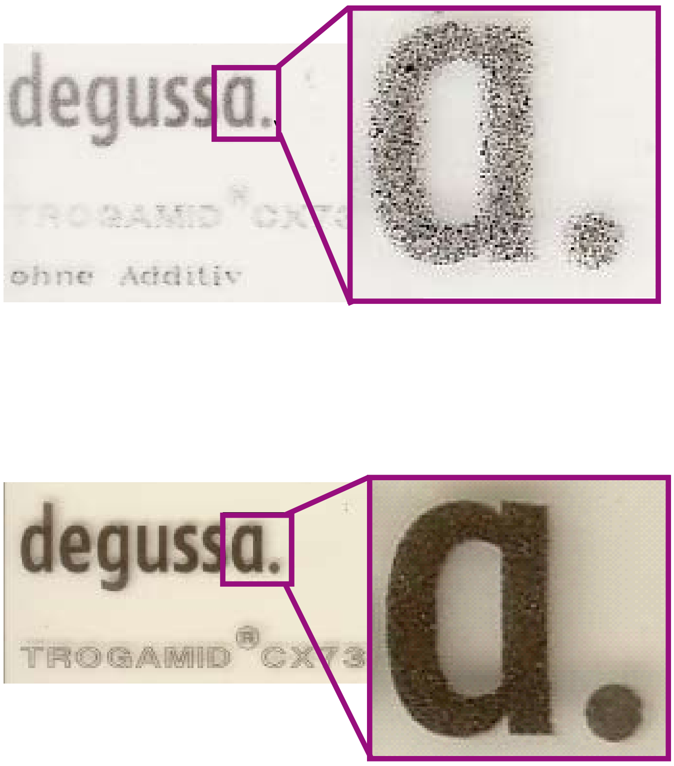
2D laser-marking of nanomodified polyamide or PMMA gives good contrast and excellent contour sharpness.



unmodified PLEXIGLAS®

nanomodified PLEXIGLAS®

Fig. 23: 2D laser-marking of PLEXIGLAS® (PMMA)



unmodified TROGAMID®

nanomodified TROGAMID®

Fig. 24: Laser-marking of TROGAMID® (PA)

3D Sub-Surface Laser-Engraving of Transparent Plastics

For many years, lasers have been used for sub-surface engraving of glass to produce 2D or 3D motifs (e.g., from CAD applications), logos, patterns, and photos. The amazing possibility also exists of imaging faces with 3D face scanners to produce realistically and accurately engraved 3D motifs in glass blocks. This technology works because a 3D scanner can capture the face of a person in seconds. This "face scan" is then prepared for the laser process by special software, the photo being transformed into a dot cloud. The laser, normally a frequency-doubled Nd:YAG laser (532 nm), burns hundreds of thousands of pixels into the glass in just a few minutes, reproducing the surface and the texture of the face, hair, eyes, and other features. A high-resolution 3D representation demands optimal matching of software, laser unit (hardware), and material.

3D motifs can be laser-engraved in normal, commercially available acrylic glass, but resolution and brilliance are significantly poorer than in silicate glass. The poor quality of sub-surface laser engraving has so far prevented the use of acrylic glass for this purpose. Evonik has now succeeded in developing a special type of acrylic glass in which, just as in silicate glass, 3D motifs of high quality can be laser-engraved (Fig. 25). This is achieved by nanomodifying of highly transparent plastics. The excellent dispersion necessary for the nanomodification is the basic prerequisite for obtaining high transparency of the plastic and producing an image with high resolution and brilliance.

In principle acrylic glass, such as PLEXIGLAS® from Evonik, offers many advantages over silicate glass, such as significantly lower specific weight, easy moldability and mechanical workability (affording greater design freedom), and higher resistance to breakage. It is well known that on improper handling or long storage, microcracks in silicate glass can increase in size to the point of breakage. This does not occur in acrylic glass.

Moreover, acrylic glass, unlike silicate glass, is easily colored, and permits significantly greater laser penetration depth (approx. 500 mm for PMMA), allowing sub-surface laser-engraving even of large objects.

In nanomodified acrylic glass, very high resolution is achieved. Sub-surface laser-engraving of unmodified acrylic glass results in optically and mechanically objectionable microcracks; in nanomodified acrylic glass, on the other hand, well-defined "points" are produced, as is clearly seen in the dot cloud of Fig. 26.

If at first sight this technique appears to serve no more than a decorative purpose, it has potential for improving the visual aesthetics of transparent plastics, as in architectural applications. The possibility of engraving high-resolution 3D motifs in components exists not only for acrylic glass but also for other highly transparent materials like TROGAMID® (semicrystalline polyamide).

Basics of 3D Sub-Surface Laser-Engraving

Production of a three-dimensional image with a CAD system or by stereo photography.

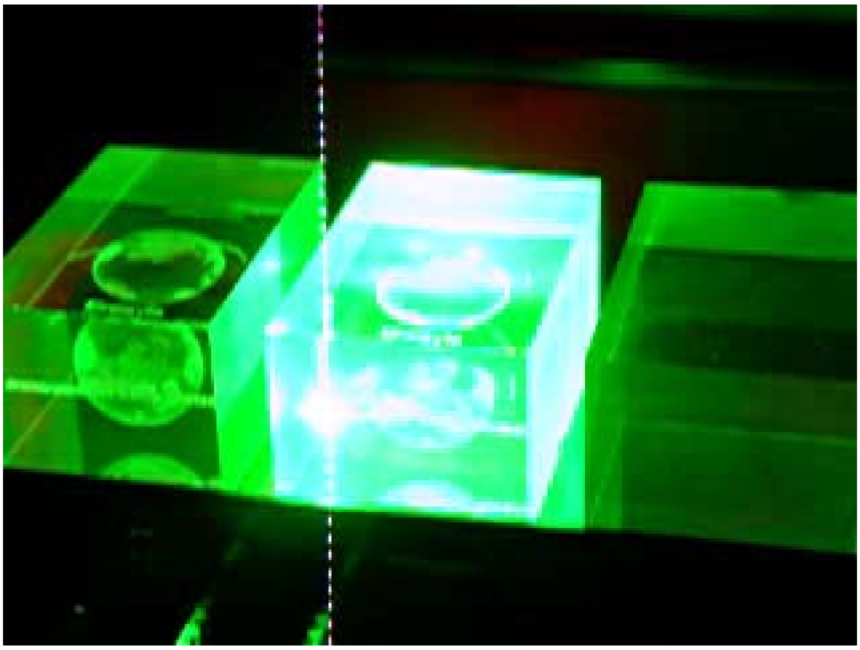


Fig. 25: Laser-marking of PLEXIGLAS® (PMMA)

The object from the CAD file must be transformed into a dot cloud, in which process the x, y, and z coordinates of each point are calculated and stored. In contrast to the normal writing laser, the 3D laser can laser only discrete points, but at very high speed.

Each individual point is then engraved into the transparent polymer by a highly focused, frequency doubled Nd:YAG laser (532 nm). For PMMA, this process produces micro bubbles, while for PA the plastic is carbonized (blackened).

Fig. 26: Dot cloud

3D Laser for Sub-Surface Engraving

The 3D laser for sub-surface engraving offers high flexibility in three- dimensional design. The laser beam is deflected in the x, y, and z directions by two computer controlled galvanometer mirrors, and focused on the part to be marked by a (preferably flatfield) lens. A field of approximately 10 x 10 x 20 cm can be marked at any desired point. Larger objects must be divided up ("tiled") and composed in several stages, as in a puzzle.

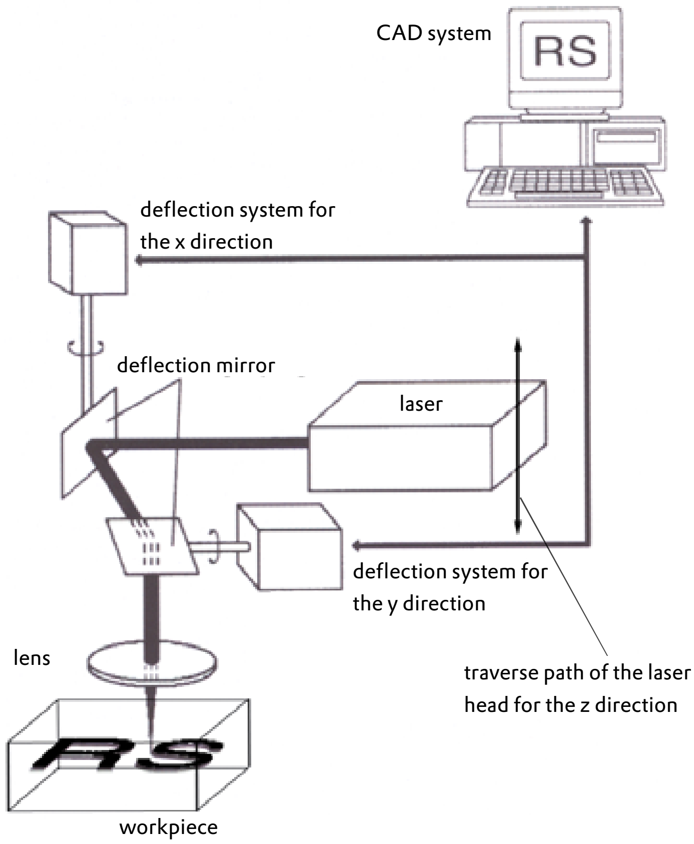


Fig. 27: 3D laser for sub-surface engraving

PLEXIGLAS® without additive | PLEXIGLAS® with laser additive | PLEXIGLAS® without additive | PLEXIGLAS® with laser additive

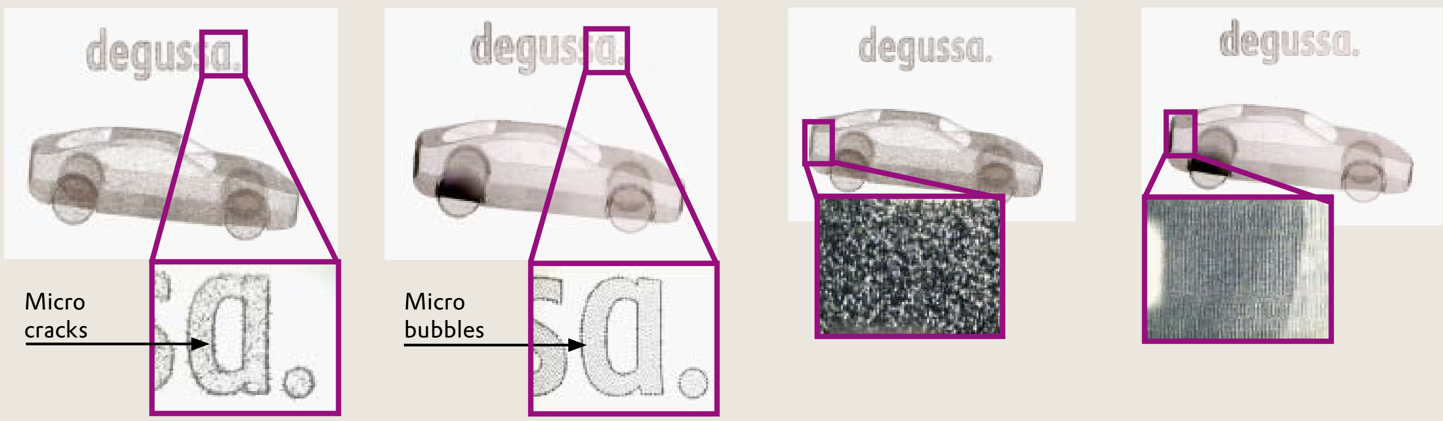


Fig. 28: 3D laser-marking of PLEXIGLAS® (PMMA)

Application Fields of Laser-Sensitive, Transparent, Colorless Plastics

Sub-surface lasering in (highly) transparent, colorless, and laser-sensitive plastics allows forgery-proof labeling, for example with serial numbers. Penetration depths of up to 500 nm can be attained in PMMA. Even deep lasered barcodes and data matrix codes can be read out without problems; only the penetration depth of the reader is important here.

Nanomodified PLEXIGLAS® now provides a good alternative to marked and sub-surface engraved glass.

Advantages of Laser-Sensitive, Transparent, Colorless Plastics

To make colorless, (highly) transparent polymers laser-markable and sub-surface engravable, nanoscale laser absorbers are required with a very narrow particle-size distribution and highly homogeneous distribution of the nanoabsorbers. Only in this way can excellent high-resolution markings with good contrast be achieved. These nanoabsorbers can be adjusted for the laser wavelength required.
For deep lasering, the surface of the object on the side where the laser beam penetrates is also required to be perfectly plane. If, for example, the surface is waved on a macroscopic scale, the text obtained is also visibly wavy.

Fig. 29:
The CERION C1 jet 3D laser
(from CERION)

Advantages of Laser-Marking

- **Fast**

Writing speeds of up to 2000 mm/s or 200 characters/s are possible.

- **Flexible**

Layouts can be prepared and stored using standard CAD programs and can be retrieved in any desired order, thus allowing fast changes.

- **Precise**

Even the smallest characters or symbols with very small line thicknesses can be accurately positioned and are clearly legible.

- **Clean**

No additives, and in particular no solvents, are required.

- **Contactless**

Marking is possible not only on smooth, uneven, and textured surfaces and surfaces difficult to access, but also through transparent covers.

- **Abrasion resistant**

Penetration depths of up to 200 µm are possible, so that the marking is both abrasion-resistant and forgery-proof. This is particularly important in regard to product liability.

- **Transparent**

To make colorless (highly) transparent polymers laser processable, nanoscale laser absorbers with very narrow particle-size distribution are required. Only in this way can excellent weld seam quality and high-resolution markings with good contrast be achieved. These nanoabsorbers can be adjusted in accordance with the required wavelength.

- **Resistant to chemicals**

The marking is resistant to cleaning agents, cosmetics, and perspiration with which it comes into contact.

- **No pretreatment necessary**

Because there are no adhesion problems, surfaces can be marked directly, without any special pretreatment.

- **Low operating costs**

Particularly for large runs, the process is highly cost effective. No additional materials are required, and there are no cleaning and disposal costs for colorants or chemicals. Labor costs are eliminated by integration of marking into automatic production processes, and no storage of dies, masks, etc. is needed.

- **Quality**

The process is characterized by a very high degree of reproducibility.

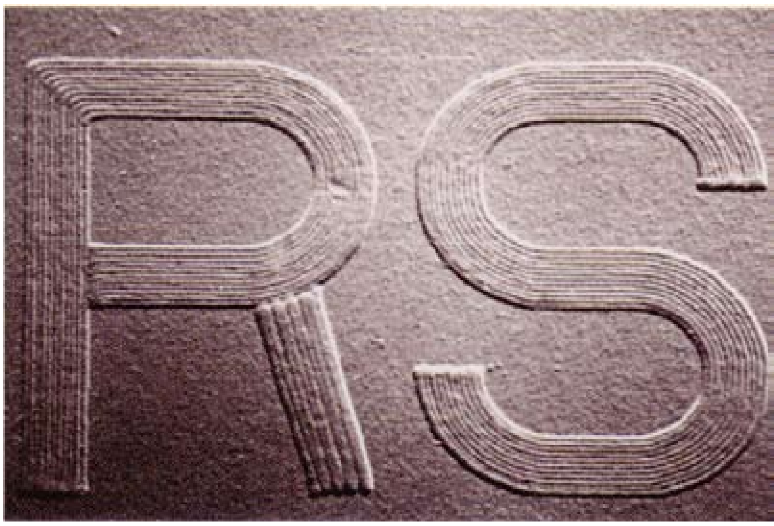


Fig. 30: SEM micrograph line structure

Laser-Welding of Plastics

Laser-welding of plastics consists in the bonding of thermoplastics under heat and pressure.
The bonded surfaces must be in the thermoplastic state. Plastics that can be laser-welded with or without additives are listed in the table below.

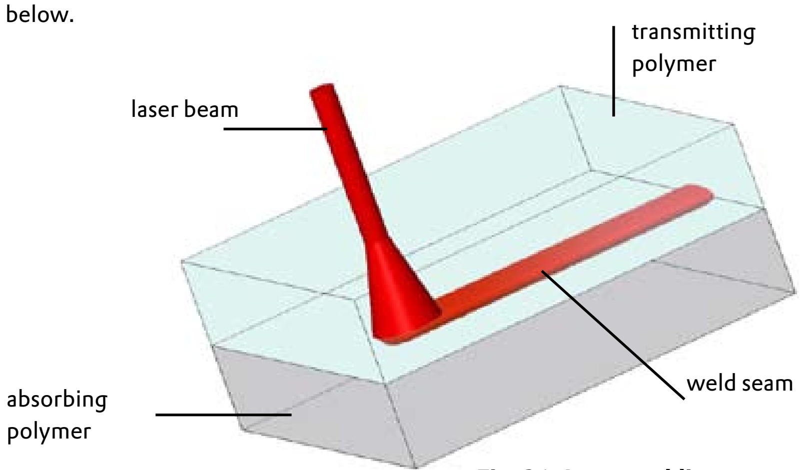


Fig. 31: Laser-welding (schematic representation)

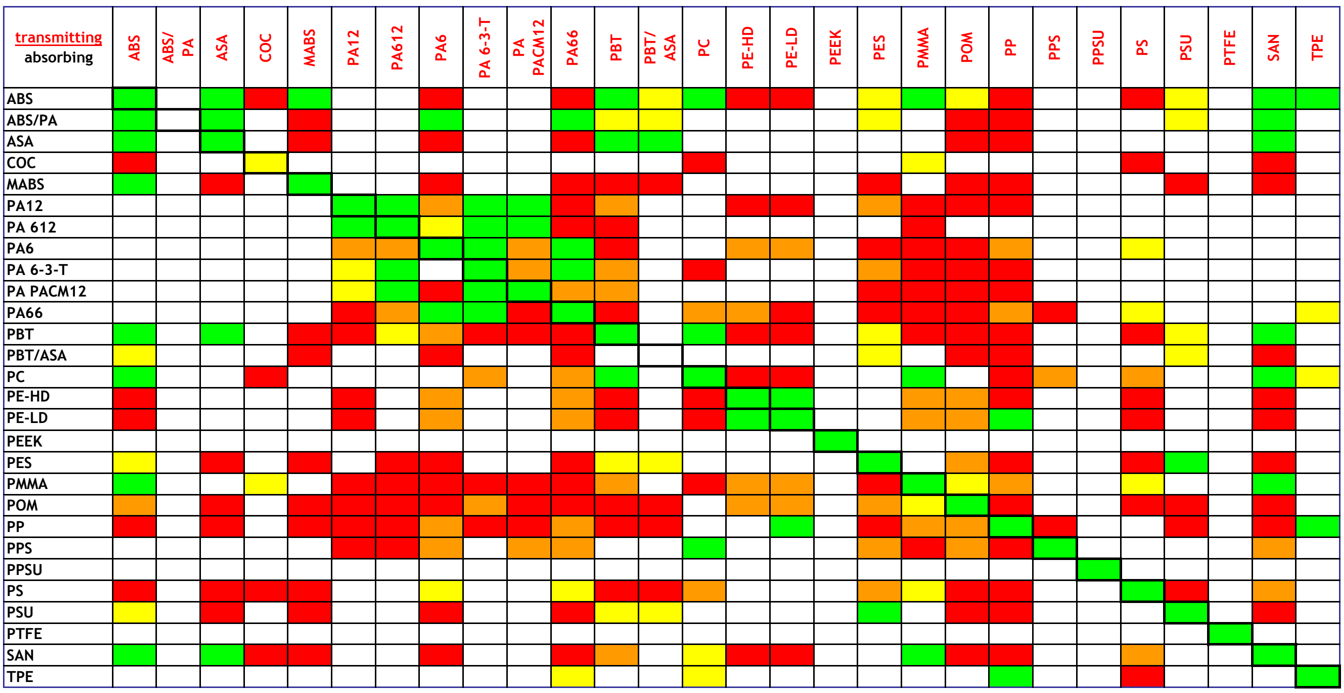
good welded joint

satisfactory welded joint

poor welded joint

no welded joint

no information available



The data in the table can vary, depending on the laser wavelength.

Fig. 32: Welding matrix

Laser-welding of plastics is possible only with fusible polymers; in general, all amorphous and semicrystalline thermoplastics, as well as thermoplastic elastomers (TPU) can be used. Elastomers and thermosets, on the other hand, are not suitable for laser-welding. The fusion temperature regions (Fig. 9) of the plastic parts to be bonded should overlap, and the melts should be mutually compatible. The laser-absorbent join partner should be able, possibly with the use of an additive, to convert the laser energy into heat at the wavelength used.

Degrees of Difficulty in Laser-Welding

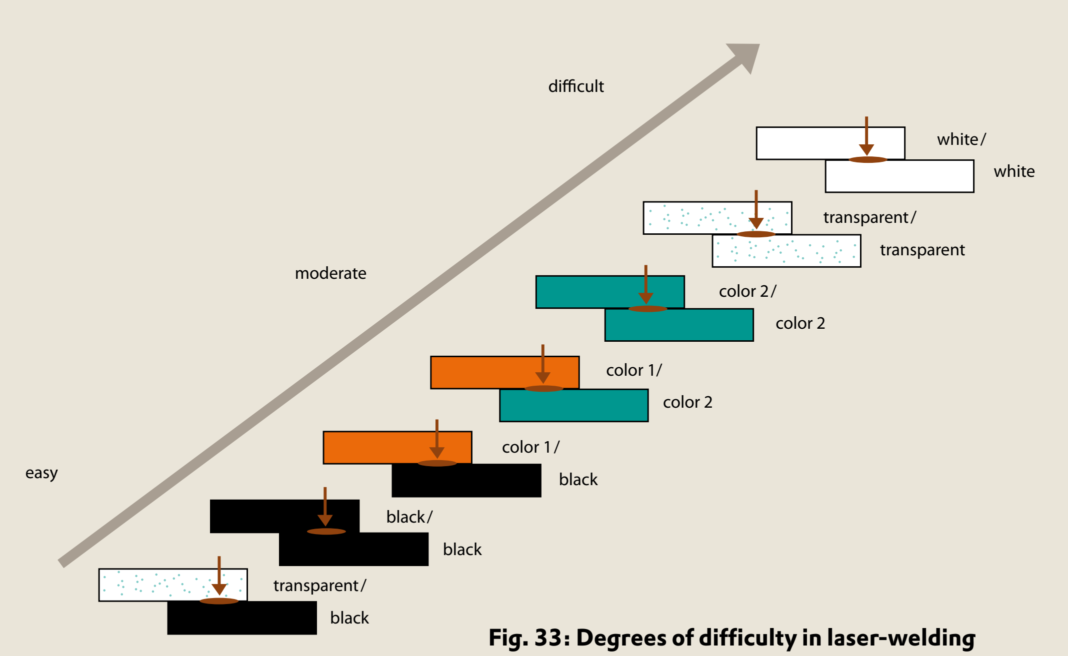


Fig. 33: Degrees of difficulty in laser-welding

The degree of difficulty in laser-welding depends on the laser transparency of the upper and the laser absorption of the lower of the two join partners. The better the upper join partner transmits the laser energy and the better the lower partner absorbs this energy, the easier is the welding process.

The requirements for the procedure increase in the order black, colored, transparent, and white. Applications with a black join partner as the absorber are normally easy to realize or are already available as standard solutions. Welding of colored plastics requires pigment combinations in laser-transparent and laser-absorbent form. Welding of light colored or transparent plastics is possible by using laser-absorbing high-performance additives.

The Laser-Welding Process

Laser-welding of plastics is usually performed in the overlap process. Two join partners are used, the separation (bridged gap) of which should be less than 100 µm. The upper join partner is a laser-transparent thermoplastic, selected according to the laser wavelength, which heats up very little, if at all, on the passage of the laser beam. For a weld seam to be produced, the second join partner must absorb the laser radiation. The absorbing medium can be, for example, a laser-transparent thermoplastic doped with laser additives (such as carbon black (approx. 0.3 wt%), metal oxides, or special dyes); alternatively, dark colored thermoplastics may be used. When this substance absorbs energy it begins to fuse and transmits its energy to the upper partner.

In order that the energy can actually be transmitted to the partner, the bridged gap should be < 100 µm. The partners must be pressed together; otherwise a secure bond (weld) cannot be guaranteed, despite the application of energy. The pressure required to join the plastic components should be applied as close as possible to the weld; only in this way can the externally applied compaction pressure cause the melts to blend and the plastic parts to weld to each other.

Diode lasers are frequently used here because the beam quality for this welding process does not usually need to be exceedingly high.

The laser passes through the upper join partner and is absorbed in the lower join partner (A). The laser energy is converted into heat and a melt is formed (B). This now heats the upper join partner in the area of the seam to the extent that the material here also melts (C). Due to the external compaction pressure on the two join partners the melt cannot escape, and the parts are welded (D).

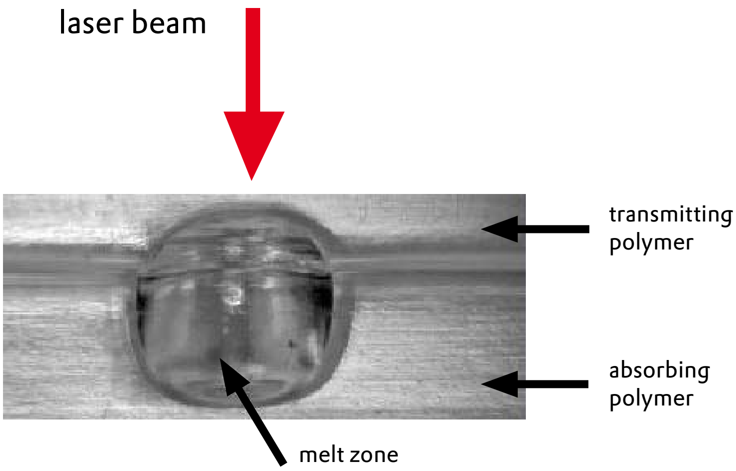


Fig. 34:
Laser transmission welding of plastics

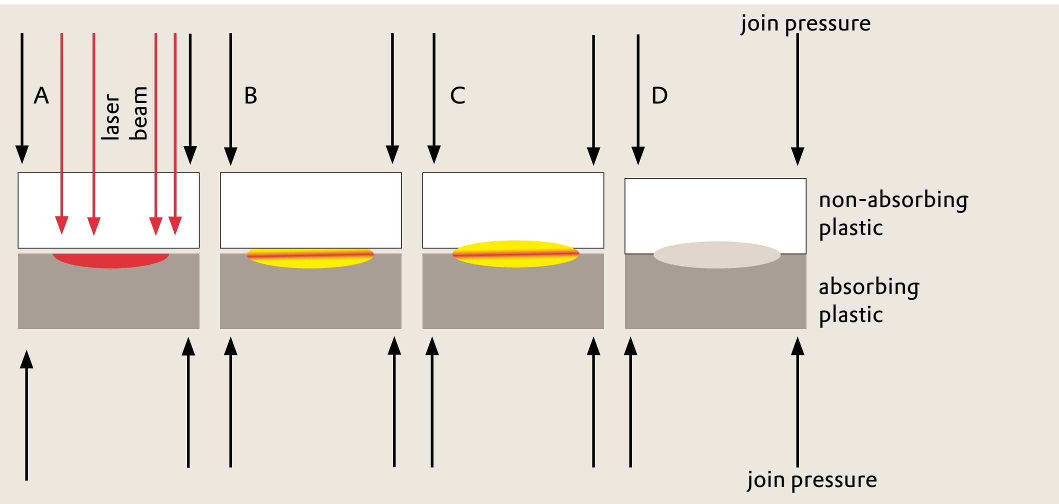


Fig. 35: Stages of the laser-welding process

Weld Seam Quality

Factors affecting weld seam quality in thermoplastics

A structured analysis of a production process is necessary to understand it and develop it further. Every production process is associated with a number of parameters that affect the result of the process. The result in this case is the weld seam between two thermoplastics. The parameters are of various kinds, and the extent to which they impact the result also varies. The Ishikawa diagram is a useful tool for the structuring and analysis of a complex production process in terms of its parameters (see also Fig.36).
The main branch of the diagram represents the entire process of laser-welding of thermoplastics, the result being the required quality of the joint.

The entire production process is influenced by certain factors that can be summarized under the heads:

- tool (laser beam, laser radiation)
- machine
- pre- and post processes
- material
- method, and
- people.

Some of these factors mutually influence one another. The heads can be further divided into (functional) subheads. The aim is to break down the structure to the extent that all the parameters directly affecting the result of the process are contained in the diagram. For reasons of clarity, the Ishikawa diagram is shown here only (roughly) to the first level of the functional subheads.

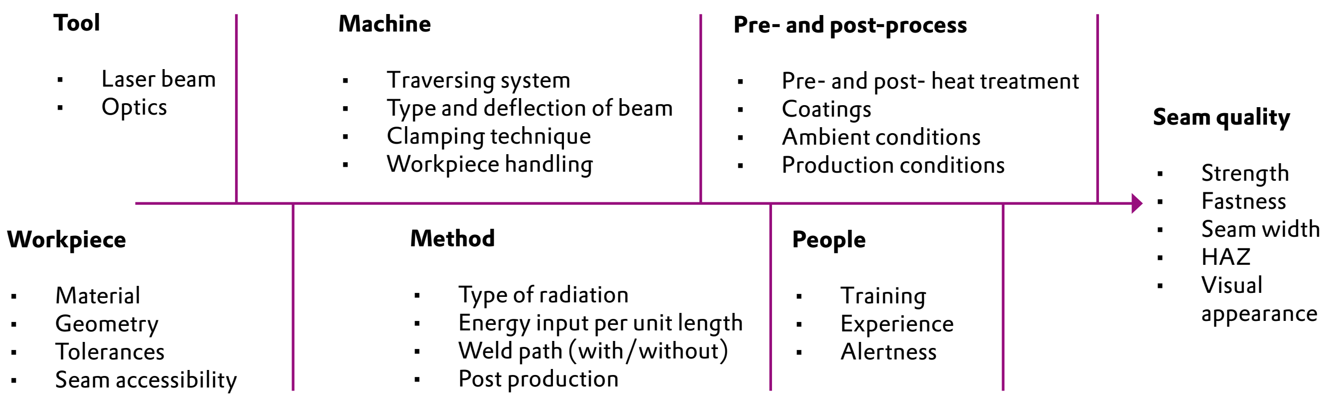


Fig. 36: Factors impacting seam quality in laser-welding of thermoplastics (Ishikawa diagram)

Source: Russek, Dr. U.A.: SKZ Seminar, Laser-Welding of Plastics, Würzburg, 2007

Laser-Welding Processes

There are four different variants of laser-transmission welding:

- contour welding,
- simultaneous welding,
- quasi simultaneous welding, and
- mask welding.

Contour Welding

This method allows the use of low laser power. In contour welding the laser beam traverses the entire join plane of the welding parts, so that relative movement of the laser beam and welding part is necessary. This can be achieved by means of a robot, by a traversing motion of the laser or the part to be welded. One advantage here is that components with virtually any seam structure can be welded. The welding process is also very flexible, and if the welding part is changed, the traversing movement can be rapidly adjusted for the new weld geometry. This is currently the most widely used process.
In the future, quasi simultaneous welding will probably used for relatively small components and contour welding for larger components.

Simultaneous Welding

Simultaneous welding usually uses a diode laser system. The laser beam simultaneously scans the entire joint plane and can heat it with one or more laser pulses. No relative movement between the laser system and welding part is required.
Simultaneous welding is highly advantageous for large runs because welding times can be reasonably short. A further advantage is the absence of mechanical components such as robot arms and scanners, which require maintenance. Like quasi simultaneous welding, simultaneous welding also allows monitoring of the process via the setting path; however, the need to adjust the system for each welding part is a disadvantage. The high laser power needed means that several diode lasers may be necessary. Moreover, the system cannot be modified, which means that the same laser cannot be used for slight changes of geometry of the weld seam, or if the components are changed. For reasons of cost, therefore, only components with simple seam geometries are welded using the simultaneous welding process.

Fig. 37:
Contour welding

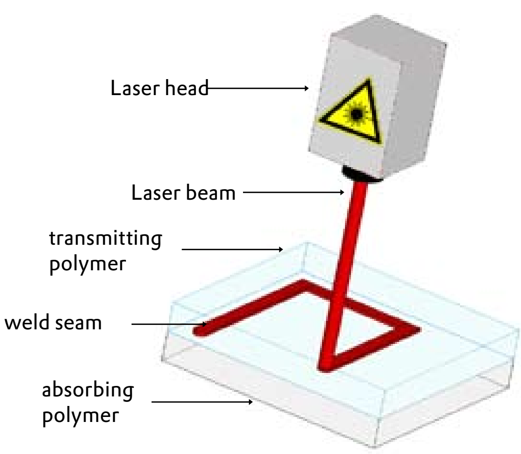
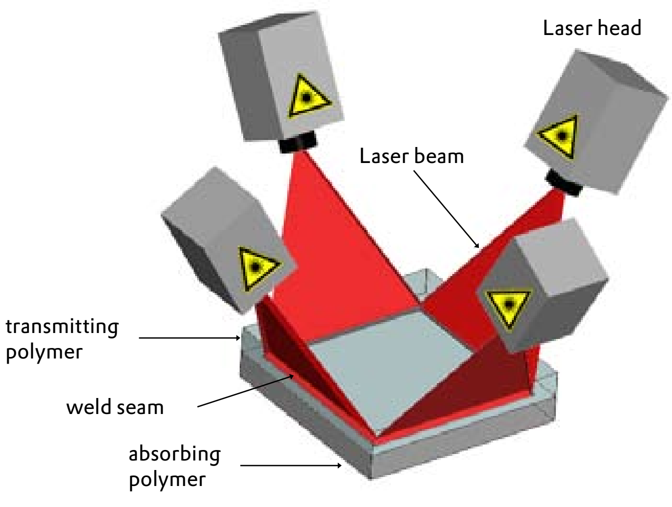


Fig. 38:
Simultaneous welding



Quasi Simultaneous Welding

In quasi simultaneous welding, the laser beam is guided along the seam using scanner mirrors. There is no movement of either the laser or the join partners; instead, the laser beam is deflected by the moving mirrors. Due to the high speed, the join surface can be traversed several times per second so that, despite the single-point energy source, the surface is heated and plasticized almost simultaneously. Both the join partners are kept under pressure. The advantage of this process it can be used flexibly, and components with three-dimensional seams can also be welded. However, 3D welding is possible only within narrow limits; in this case, a flatfield lens must be used.

A further advantage of quasi simultaneous welding is that higher path speeds are possible than for contour welding. However, higher laser power is also needed than for contour welding for the same energy input per unit length. A disadvantage is that the working space is restricted by the scanner, which limits the maximum geometry of the part. The quasi simultaneous welding process is used mainly for two-dimensional seam geometries. In the future, the technique is expected to find application for relatively small components, and contour welding for larger components.

Mask Welding

In this process, a metallic mask is placed between the laser and the parts to be welded. A laser beam is moved across the mask. The mask has cut-outs wherever welding is required. Areas adjacent to the join surface are covered by the mask. Mask welding allows realization on components of very fine seams that may also lie very close together (< 100 µm apart). Another important advantage of the process is the possibility of producing a variety of weld seam structures on a single component simply by changing the mask. The disadvantage is that at least one mask is necessary. Changes in the seam geometry require the production of a new mask, which results in low flexibility. The areas of application of mask welding include microsystem engineering, electrical engineering, sensors, and medical engineering.

Fig. 39:
Quasi simultaneous welding

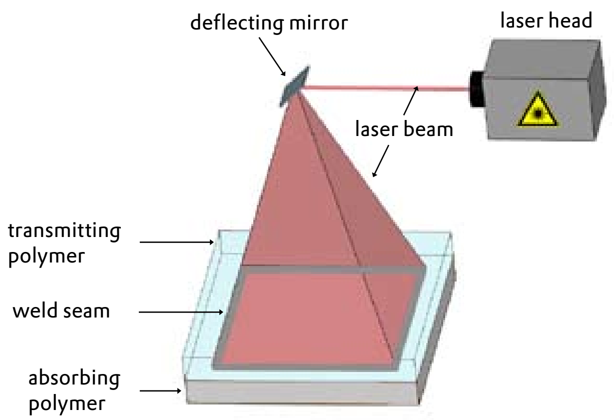
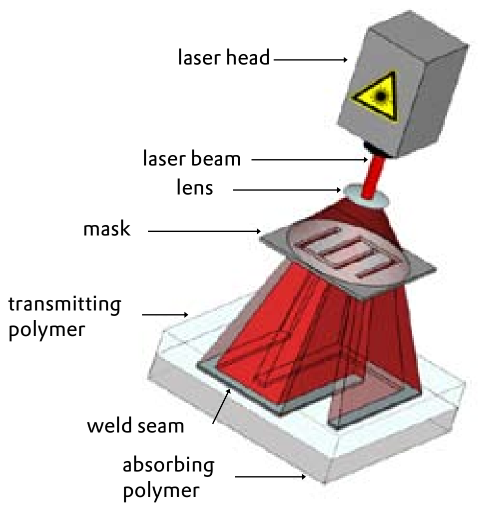


Fig. 40
Mask welding



Application Areas

Laser-welding could replace almost all the classical bonding techniques for plastics, such as adhesion, sealing technology, and ultrasound, vibration, mirror and hot-gas welding.

The miniaturization of components and their increasingly complex geometries require weld seams of a fineness that could be achieved with conventional welding methods only with great difficulty, if at all. Laser-welding offers the possibility of even three-dimensional welds in a single workstep. In the production of sensors for medical engineering, the laser can be used to produce the finest welds within a very restricted space.

The scope of application for plastics depends heavily on the material properties and their compatibility with the laser wavelengths used in various systems. Not all of the currently used thermoplastics absorb laser beams equally well. Special additives developed and patented by Evonik can equip our molding compounds for a very wide range of applications.

Components made from these molding compounds offer the advantage of high-quality (transparent/transparent) laser-weldability even with highly transparent and colorless plastics. The High Performance Polymers Business Line also offers a variety of colored products for non-transparent laser-welding.

Advantages

Advantages of using nanoscale laser absorbers

Colorless, (highly) transparent polymers can be processed using lasers. Excellent weld seam qualities are obtained thanks to the very narrow particle-size distribution of the nanoabsorbers. The nanoabsorbers can be adjusted for the laser wavelength.

Advantages over ultrasound, vibration, mirror, and hot-gas welding, sealing technology, and adhesion

No additional materials, such as adhesives, are necessary. Processing is completely particle-free. No interfering microparticles, adhesive residues, or roughness are produced. Thermal and mechanical stresses on the components are significantly lower. Despite the usually shorter cycle times, the long-term stability and quality of the joints are superior, as are the monitoring options. Lower costs for systems and tools are also an important consideration.

Laser-Structuring

Increasing miniaturization of components requires ever finer and more accurate tools to produce fine surface structures. The laser, with resolutions of < 1/10 mm, is the ideal tool for such tasks, and splendidly suited to producing the finest structures. It can remove material from plastic surfaces with great precision and selectivity.

Three-dimensional injection molded circuit substrates, or 3D MIDs (molded interconnect devices), open up a new dimension, in the true sense of the word, compared with conventional two-dimensional circuit boards, because they offer a high degree of design freedom. A new, laser-supported structuring process (the LDS process, from the company LPKF) for 3D MIDs considerably simplifies the manufacturing process. It allows, for example, antenna structures to be directly and cost effectively integrated into the housings of cell phones. Furthermore, sophisticated mechatronic systems that integrate mechanical and electrical properties can be realized for applications in automotive construction and medical engineering.

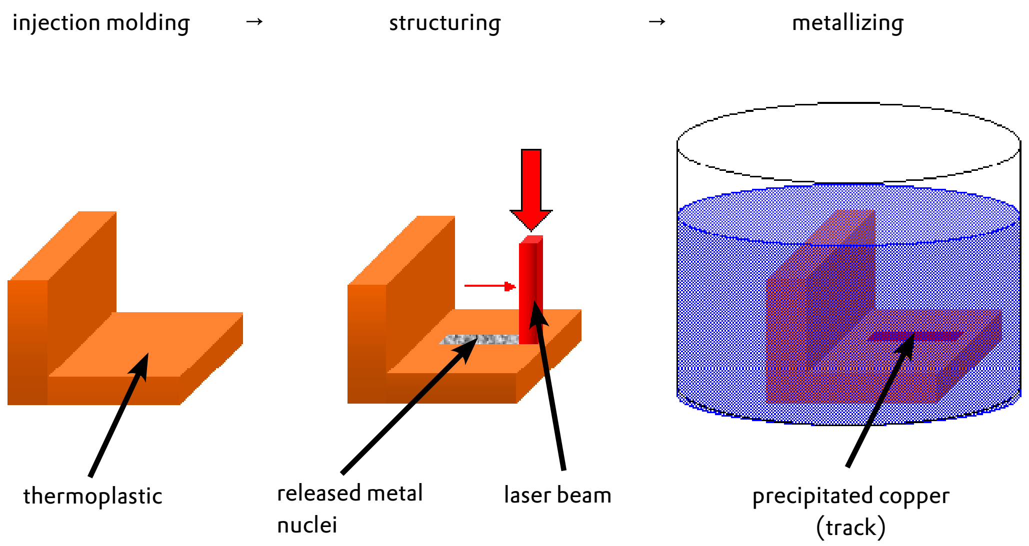


Fig. 41: The LDS process, from LPKF

Laser-Sintering

Selective laser-sintering (SLS) is a rapid prototyping process allowing layer-wise production of complex components on the basis of CAD data. This dispenses with the need for a molding tool. SLS is based on the principle of the layer-wise build-up of a structure by application of a polyamide 12 powder followed by selective heating by a laser beam, preferably from a CO_2 laser. In general, the process can be characterized as follows:

- specification of a three-dimensional model in the form of CAD data
- no use of molding tools
- processing of material in powder form
- generative build-up. Molding occurs not by removal of material, but by applying it.
- production by layer technology
- any desired geometry
- no supporting structure necessary

Fig. 42:
Intake manifold for LOTUS sports racing car

Requirements on Laser-Processable Molding Compounds

Application Profiles Laser-Marking

Functional marking

- Computer keyboards
  very good legibility; high abrasion resistance required, due to frequent use

- Barcodes on housing parts, electrical switches, etc.
  - one-dimensional barcode
  - two-dimensional data matrix code
    Contrast and contour sharpness are important for secure trans mission of coded information.

Information markings

- Name and address of producer/ owner, etc.
- Equipment type/product data
- Operating, setting, connection, safety, or installation instructions; test symbols
- Type of voltage supply/power rating of electrical components or appliances
- Circuit diagrams, scales, technical labels

Decorations

- Company logo
- Colored symbols and patterns with transfer film, some directly applicable

Application Profiles Laser-Welding

Medical technology

- Syringes
- Hose/tube connectors
- Pharmaceuticals packaging
- Pouches for liquids
- In-line filters
- Catheter tips
- Balloon catheters
- Sensors

Electrical Engineering

- Miniature relay housings
- Dust- and water-tight housings for electronic components

Requirements on Laser-Wor-kable Molding Compounds

Automotive engineering

- Front headlamp casing with reflector
- Rear lamp casing with reflector
- Dust- and water-tight housings for electronic components
- Electronic ignition key (remote control)

Requirements Profile Laser-Structuring

Electronics

- Tracks for MIDs

Medical Engineering

- Microfine channels in biosensors

Laser Additives

Additives for Non-Transparent Molding Compounds

In addition to high contrast, adequate staining depth and a surface as smooth as possible are also required. The intensity of the color change reaction increases with the content of laser-sensitive pigment, but the penetration depth of the laser radiation decreases simultaneously. For a low content, the penetration depth is very high, but the expected contrast is too low.

- The contrast increases with increasing laser intensity.
- The staining depth is reduced with increasing laser intensity
- The foaming height (which is a measure of the quality of the surface) increases with increasing intensity; a smooth surface is desired.

For the same quality of marking, the surface does not foam to the same extent when an additive is used, and is therefore more resistant to abrasion.
To ensure excellent marking, we have taken these effects into account in developing a laser additive that does not affect the coloration.

Laser-welding requires high weld seam strength. This should ideally attain the strength of the welded components.
For a good weld to be obtained, a laser-sensitive additive must be compounded into the absorbing join partner. The classic laser additive for this purpose is carbon black. If, however, the same coloration is required for the upper and lower join parts, color pigments or metal oxides adjusted for the laser wavelength can be used.

If plastics are to be laser-structured at the surface, for example, with CO_2 lasers, the use of additives is not absolutely necessary. Special molding compounds are required for production of three-dimensional circuit substrates with miniaturized track structures, for example, for insertion of MID components. The laser additive contained in these offers, after laser-structuring, the possibility of selective deposition of copper for the tracks.

Additives for (Highly) Transparent, Colorless Molding Compounds

With the special additives developed and patented by the Inorganic Materials Business Unit of Evonik, our (highly) transparent and colorless molding compounds can be equipped for the most diverse applications.
The laser additive has practically no impact on the haze of the plastics used. These molding compounds are therefore also highly suitable for deep lasering of markings or lasering of 3D CAD objects.

The laser additives ensure high-quality laser-weldability, even with colorless, transparent-transparent joins.

Laser-Processable Molding Compounds

VESTODUR®

Compound	Color	Filler	Tensile modulus	HDT	Flammability	CHARPY impact strength	Contrast Image[1] Light / Dark	Remarks
Test method:			ISO 527	ISO 75-1/2 (B)		ISO 179/1eU 23°C		
Unit:		%	MPa	°C	UL 94	kJ/m²		
X7061	natural	0	2700	160	0.8 (HB)	130 C	C 3.3 D	PBT-LV
	white						C 4.3 D	
	electric grey						C 3.2 D	
	yellow						C 3.6 D	
	green						C 2.5 D	
	red						C 2.0 D	
1003-FR3	natural	0	3100	185	0.8 (VO)	25 C	C 2.8 D	PBT-FR-LV
	white						C 3.5 D	
2002-FR3	natural	0	3100	180	0.8 (VO)	100 C	C 3.2 D	PBT-FR-MV
X7062	black	0	2600	150	0.8 (HB)	130 C	C 8.5 L	PBT-MV
GF12-FR3	natural	12	6000	223	0.8 (VO)	30 C	C 3.2 D	PBT-GFI2-FR-MV
	white						C 3.5 D	
G20-FR3	natural	20	8000	223	0.8 (VO)	35 C	C 3.2 D	PBT-GF20-FR-MV
	white						C 3.5 D	
RS1203	black	20	7500	220	1.6 (HB)	60 C	C 8.0 L	PBT-GF20-MV
X7095	black	20	7000	220	1.6 (HB)	30 C	C 8.0 L	low shrinkage
GF30	black	30	9500	220	0.8 (HB)	75 C	C 3.9 L	PBT-GF20-MV
X4877	black	30	5200	195	1.6 (HB)	80 C	C 8.0 L	low shrinkage
GF30-FR3	natural	30	11000	223	0.8 (VO)	55 C	C 3.2 D	PBT-GF30-MV
	white						C 3.5 D	PBT-GF30-MV-HI
X9402	black	30	9000	210	1.6 (HB)	70 C	C 10 L	PBT-GF30-FR-MV
X7212	natural	45	15500	225	0.8 (VO)	45 C	C 3.0 D	
	white						C 3.3 D	PBT-GF30-MV
X9405	natural	30	9000	210	0.8 (VO)	80 C	C 3.2 L	low shrinkage

VESTORAN®

Compound	Color	GF	Tensile modulus	HDT	Flammability	CHARPY impact strength	Contrast Image[1] Light / Dark	Remarks
Test method:			DIN ISO 527	ISO 75-1/2 (B)	Acc. To UL 94	ISO 179/1eU 23°C		
Unit:		%	MPa	°C		kJ/m²		
1900	natural	0	2000	190	1.6 (HB)	200 P	C 2.1 D	mPPE
	black						C2.2 L	
1900-GF20	natural	20	5600	191	1.6 (HB)	50 C	C 2.9 D	mPPE-GF20
	black						C 1.5 L	
X7342	natural	20	5700	170	1.6 (HB)	45 C	C 3.0 D	mPPE-GF20

TROGAMID®

Compound	Color	GF	Tensile modulus	HDT	Flammability	CHARPY impact strength	Contrast Image[1] Light/Dark	Remarks
Test method:			DIN ISO 527	ISO 75-1/2 (B)	Acc. To UL 94	ISO 179/1eU 23°C		
Unit:		%	MPa	°C		kJ/m²		
T5000	transparent	0	2800	180	0.8 (V2)	N	C 23 L	PA 6-3-T, MV
TX7389	black	0	2700	140	0.8 (V2)	N	C 23 L	PA 6-3-T, LV
CX7323	transparent	0	1400	130	0.8/1.6 (HB)	N	D	PA PACM 12
RS6047	transparent	0	1400	130	0.8/1.6 (HB)	N	D	PA PACM 12, ITO

VESTAMID®

Compound	Color	GF	Tensile modulus	HDT	Flammability	CHARPY impact strength	Contrast Image[1] Light/Dark	Remarks
Test method:			DIN ISO 527	ISO 75-1/2 (B)	Acc. To UL 94	ISO 179/1eU 23°C		
Unit:		%	MPa	°C		kJ/m²		
L2123	black	0	370	80	1,6mm (HB)	N	C 7.2 L	PA12-P, HV, HI
L2124	black	0	400	90	1,6mm (HB)	N	C 9.5 L	PA12-P, HV
L2140	black	0	1450	110	1,6mm (HB)	N	C 9.7 L	PA12, HV
L-GF30	black	30	6500	175	1,6mm (HB)	85 C	C 10 L	PA12-GF30, MV
L1670	orange	0	1400	120	1,6mm (HB)	N	C 3.4 D	PA12, LV

VESTAKEEP®

Compound	Color	Filler	Tensile modulus	HDT	Flammability	CHARPY impact strength	Schmelzbereich (DSC, 2. Aufheizen)	Remarks
Test method:		%	DIN ISO 527	ISO 75-1/2 (B)	Acc. To UL 94	ISO 179/1eU 23°C		
Unit:			MPa	°C		kJ/m²		
4000G	natural		3500	205	1,6 (VO)	N	ca. 335	PEEK
4000 GF30	natural	30	11000	>240	1,6 (VO)	70 C	ca. 335	PEEK-GF30
4000 CF30	black	30	23000	>240	1,6 (VO)	60 C	ca. 335	PEEK-CF30
4000 FC30	black	30	11500	>240	1,6 (VO)	45 C	ca. 335	PEEK-FC30
2000 G	natural		3700	205	1,6 (VO)	N	ca. 340	PEEK
3001 G	natural		3600	205	1,6 (VO)	N	ca. 340	PEEK
2000 GF30	natural	30	11000	>240	1,6 (VO)	55 C	ca. 340	PEEK-GF30
2000 CF30	black	30	23000	>240	1,6 (VO)	63 C	ca. 340	PEEK-CF30
2000FC30	black	30	11500	>240	1,6 (VO)	40 C	ca. 340	PEEK-FC30

Laser-Processable Semifinished Products

EUROPLEX®

Compound Test method: Unit:	Color	Density ISO 1183 %	Tensile modulus ISO 527 MPa	Vicat softening temperature ISO 306/850 °C	Notched impact strength (Izod) (Sample thickness: 3.0 mm) ISO 180/1A kJ/m²	Remarks
EUROPLEX PPSU	transparent (natural)	1,29	2350	222	50-60	PPSU

PLEXIGLAS®

Compound Test method: Unit:	Color	GF %	Tensile modulus DIN ISO 527 MPa	Flammability Acc. To UL 94	CHARPY impact strength ISO 179/1eU 23°C kJ/m²	Remarks
GS	transparent		3300	B2	---	PMMA
233; 222; 209						
GS 0Z01	transparent		3300	B2	---	PMMA+ITO
XT	transparent		3300	B2	---	PMMA
20070; 29070						

1) = Produced by Nd:YAG laser (1064 nm)
2) = Product with relatively high tracking resistance

HDT = Heat deflection temperature, Method B, 0.45 Mpa
C = Contrast, depends on the luminance of the color
LV = low viscosity
MV = medium viscosity
HV = high viscosity
fibers, and PTFE
FR = contains flame retardant
N = no break
P = partial break
C = complete break

HI = increased impact strength
GF = glass fiber content
P = plasticized
CF = carbon fiber content
FC = filler mix of equal parts of graphite, carbon

In addition to the compounds listed above, other variants, such as compounds of the VESTAMID® E Series (PEBA), can be supplied in laser-processable form.

Environmental Aspects

Emissions

In industrial laser systems, the small amounts of gaseous decomposition products that can be generated by the heat developed during laser-processing are drawn off by exhaust systems. The high efficiency achieved through the use of special additives in laser-processable molding compounds from Evonik makes the processes even more eco-friendly. The advantage is obvious: if the required contrast or fusion is achieved with less laser energy, fewer decomposition products are generated.

Recycling

All the laser-processable industrial plastics from Evonik listed here can be recycled without any problem. Sprues and unmarked moldings can be returned directly to the primary process as regrind. Only recycled materials from parts already marked should be used for a secondary application, due to their possible discoloration.

Quality

The High Performance Polymers Business Line of Evonik is EN ISO 9001:2000 and ISO/TS 16949:2002 certified, and therefore formally recognized as a reliable supplier.

Our products set high quality standards in the market. We offer you customized solutions specially tailored to your requirements profile.

Future Prospects

Wear resistance and protection against forgery are aspects that will promote the spread of laser-marking systems. Whether for product liability or future recycling of finished parts, laser-inscribed quality-relevant or production data leave no doubt as to the origin of a molding. Producer, production dates, machine numbers, and material batches can all be easily recorded.

For very small part geometries, the compact data matrix code (DMC) is the ideal solution; with the ongoing miniaturization of components, this will be the data code of the future. It encodes the data in the matrix both horizontally and vertically, so that thousands of items of information can be recorded on the smallest surfaces. In addition it is possible to mark data in private mode, which can be read only with the correct access authorization.

The use of the laser-marking and data matrix code technologies on suitable materials from our product range (see the tables on pages 40 to 42) allows product identification with an extremely high degree of security which practically eliminates the risk of substitution errors.

Laser-welding of polymers is still a relatively new joining technique. But in a number of sectors it is already well on the way to replacing conventional joining process such as ultrasound, vibration, mirror, and hot gas welding, sealing technology, and adhesion. Compared with conventional methods, however, laser-welding currently involves significantly higher investment costs.
In medical engineering, a particle- and emission-free working environment is very important. Medical sensors consist of components that are getting increasingly smaller, with complex joint geometries. The flexibility and speed with which even complicated weld seams can be produced and high quality standards are the outstanding properties of the laser-welding process.

Similar observations apply for electrical engineering. Tiny housings for fully encapsulated miniature relays and electronic components must be laser-welded because only this method ensures clean processing without generating particles that interfere with the mechanics or electronics.

In the automotive industry, headlamp and rear lamp casings are already being laser-welded. The partially three-dimensional geometries do not permit of any other joining technique.

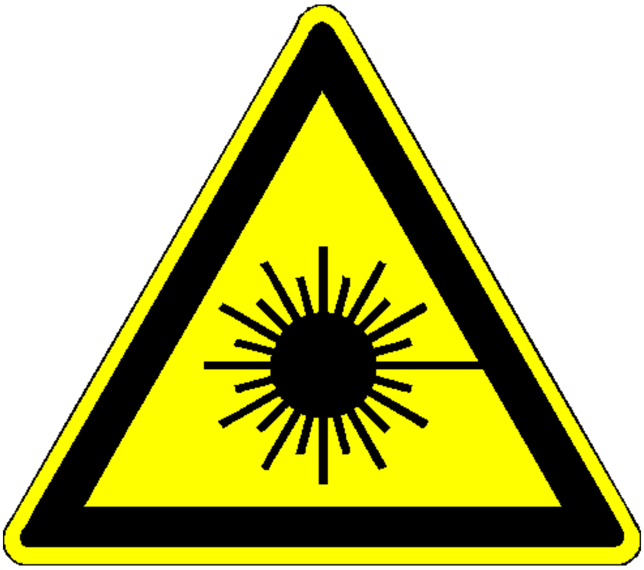
With the increasing use of plastics in automotive construction, new, fast, and flexible joining techniques are required that also meet the highest quality standards. No other joining technique currently satisfies these requirements as well as laser-welding.

Classes of Lasers

Laser devices are divided into classes depending on the biological effects of the laser radiation. Specification of the limit values up to which no damage is expected is of major importance for nationally and internationally defined laser classes. In addition to the U.S. ANSI standard, the International Commission on Non-Ionizing Radiation Protection has published limit values in the spectral region between 400 and 1400 nm.

The limits are defined primarily in terms of thermal power and non-ionizing radiation. Due to the optical focusing properties of the eye, the hazard increases in the visible spectral range. In the invisible range, there is an adjacent region in which the eye is still well focused and transparent.

DIN EN 60825-1 Classification
Lasers are divided into equipment classes depending on the hazard to humans. The DIN EN 60825-1 classification is specified by the manufacturer. (The old DIN VDI 0837 classification may no longer be used for new lasers.)



Laser Classes

Laser Class	Description
1	The accessible laser radiation is not hazardous. Example: CD player
1M	The accessible laser radiation is not hazardous provided that optical instruments such as magnifying glasses or binoculars are not used.
2	The accessible laser radiation is limited to the visible spectral range (400 to 700 nm). In the case of limited exposure (up to 0.25 s) it is not hazardous, even for the eye. Longer exposure is prevented by the natural blink reflex. (*)
2M	As for Class 2, provided that no optical instruments such as magnifying glasses or bino culars are used. (*)
3R	The accessible laser radiation is dangerous for the eye.
3B	The accessible laser radiation is dangerous for the eye, and under certain conditions also for the skin.
4	The accessible laser radiation is highly dangerous for the eye and dangerous for the skin. Even light from diffuse reflections may be hazardous. The laser radiation may cause fire or explosions

Fig. 43: Laser safety classes as defined in DIN EN 60825-1

*) Note on laser classes 2 and 2M: Scientific studies (at the FH in Cologne) have shown that the blink reflex (which occurs within 0.25 s; longer exposure damages the eye) occurred in less than 20 percent of the test subjects. The existence of the blink reflex for protecting the eye should not therefore be taken for granted. If laser radiation of class 2 or 2M enters the eye, the eyes should be deliberately closed or immediately averted. It must also be noted that the blink reflex occurs only with visible light. Laser radiation in the infrared range, for example, does not cause blinking because the radiation is not detected by the eye. Special care must therefore be exercised with invisible laser radiation.

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