



Plastic Welding Technology

R&D Center

1. General plastic welding technology

1.1. Hot plate welding technology

Hot plate welding is the welding method in which the welding parts are sufficiently melted after pressurizing, heating, softening, and melting the fixed parts at the upper and bottom side of the jig(fixture), using a heating plate slightly hotter than the material's melting temperature, than removing the heating plate and pressurizing each part, cooling until solidification occurs.

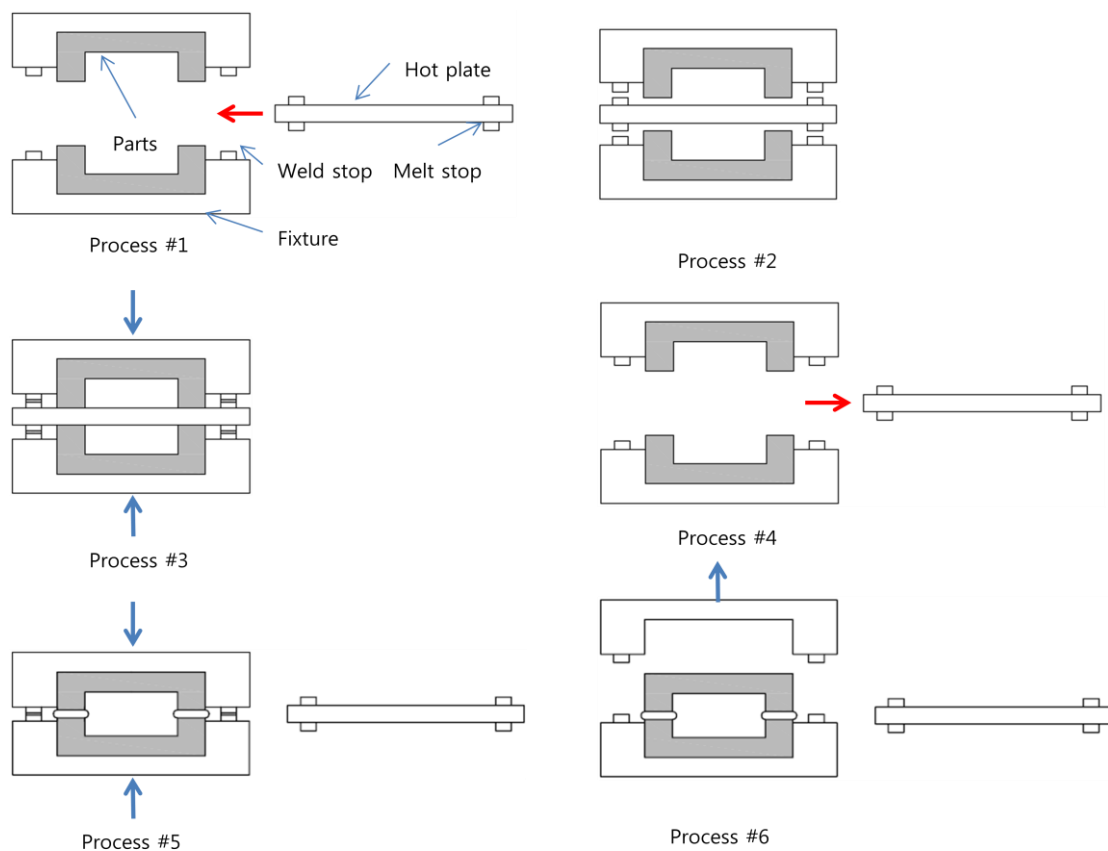


Figure 1. The process of hot plate welding

As figure 1 demonstrates, while the hot plate welding method, consisting of a 6-step process and principally welds two basic materials together, has superior bonding strength such that it retains the same cohesive strength after welding, it faces limitations for applicability and processing time according to parts' shapes, sizes and qualities, and a generally longer process in general than other welding methods. In addition, it carries the disadvantage of causing burrs or fluffing because melted material flows out as shown in figure 2.

Thus, during hot plate welding, as melted material flows out, proper welding part design is necessary in accordance with the priority of both use and appearance.

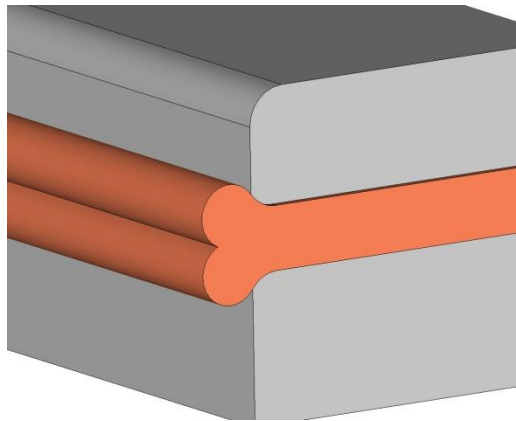


Figure 2. Appearance after hot plate welding

1.2. Vibration welding technology

Vibration welding is method in which melting resin using frictional heat coming from contacting parts through horizontal vibration(right and left) of upper jig pressurizing between two thermoplastic resins, and after proceeding sufficient melting performance, and ceasing vibration, materials are then arranged and welded through consistent pressurizing and cooling.

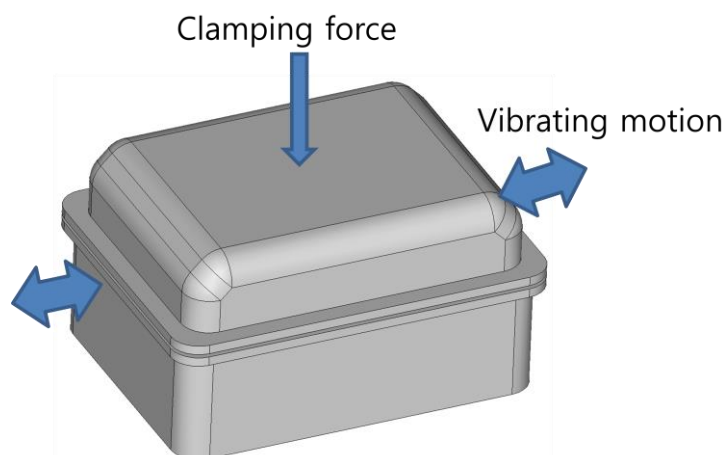


Figure 3. The principle of vibration welding

The vibration welding method by friction heat generated by the horizontal movement between upper and lower bases faces fewer restrictions in regards to material, size, and shape, but the welding principle is based on the bases material's friction heat, so if elasticity is relatively large or the flatness between the two bases has above a 10° difference, it's difficult to apply it. In addition, as shown in Figure 4, the melting materials overhang toward the base material's external parts after melting.

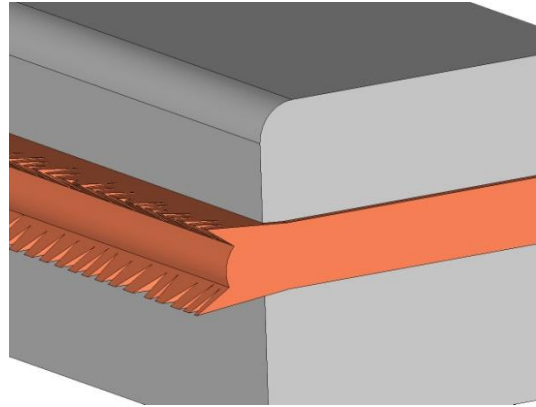


Figure 4. Appearance after vibration welding

1.3. Ultrasonic welding technology

When the ultrasonic vibration is applied, tiny asperities of the welding surface generate excellent heat very rapidly. This surface asperity receives much greater concentrated stress than elsewhere and consumes the majority of the large deformation and vibration energy, so the asperity of the welding area melts and heat transfers around it. At this moment, the melted layer is thinly formed at the entire welding surface, and the consistent vibration of the ultrasonic vibrations cause the spread in a short time, so that ultimately, it welds together.

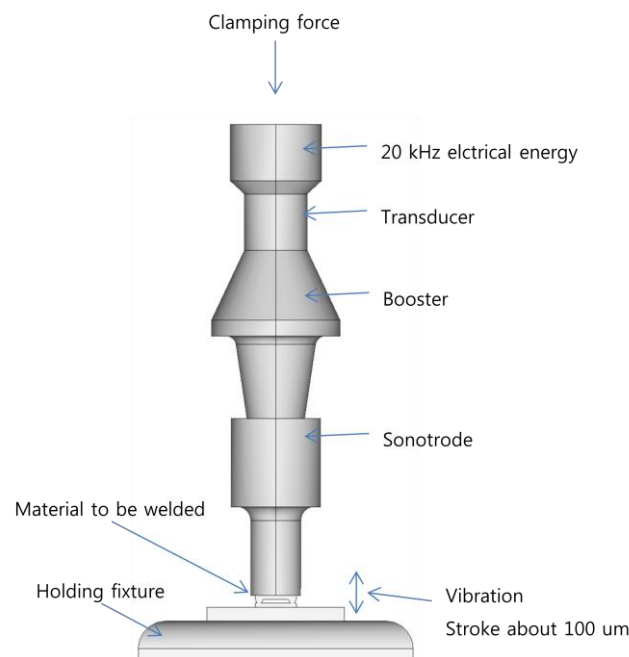


Figure 5. Ultrasonic welding systems

This ultrasonic welding technique has been not only widely used in general plastic welding but also widely applied in various fields because of the advantages that the initial investment is cheaper than other welding equipment. The advantages of this technique are fast processing time and suitability for small products. However, it is very vulnerable in terms of welding strength and water-tightness after welding, moreover as it's vibration welding method uses ultrasonic waves, it faces disadvantages of having a limited welding strength and water-

tightness in relation to the increasing elasticity of the base materials. Further, the ultrasonic waves generated during operation can affect operators' senses of hearing, and thus needs care.

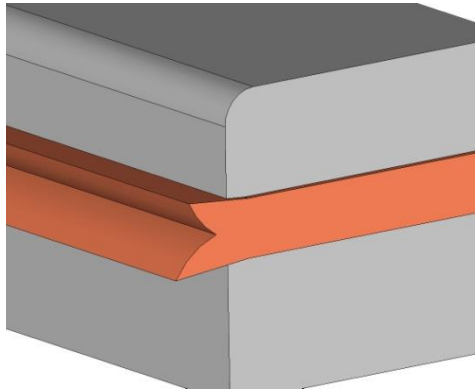


Figure 6. Appearance after ultrasonic welding

2. Plastic welding technology using laser

2.1. Principle

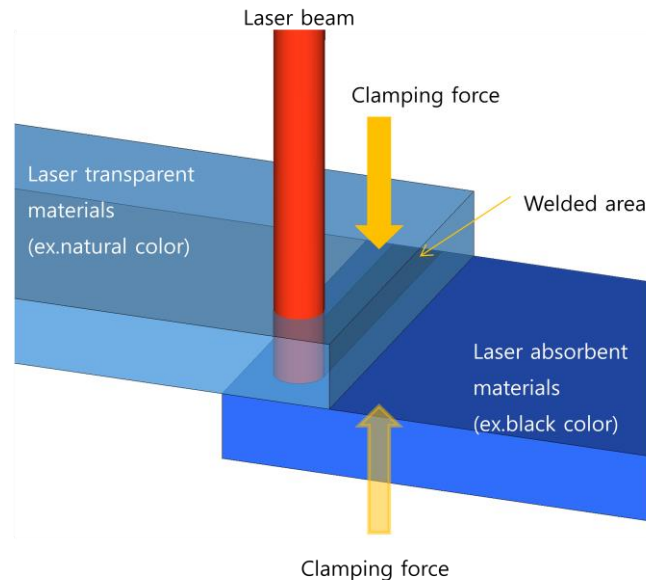


Figure 7. Laser welding principle

Laser plastic welding begins by piling up plastic material which absorbs laser beams (absorbent material ex. black color) with other material that the laser beam passes through (transmitting material ex. natural color). A laser beam scans from the side of the transmitting layer under the state of maintaining a minimum gap between the two layers welded with a clamping jig. Absorbing material is plastic blended with laser beam absorbent materials like carbon black.

The laser beam, after passing through the transmitting material and being absorbed by the carbon black in the absorber, heats via the vibration of molecular ring of absorbent material and that material melts to form a molten pool simultaneously. At this time, the transmission material also melts and is welded by the heat transfer from absorbent materials. Through the cooling process, the welding of two base materials is completed.

2.2. The choice of laser

(1) High-power diode laser (hereinafter HPDL)

HPDL is a kind of semiconductor laser, smaller than other lasers, and highly economical in terms of energy efficiency; reaching as much as 50%. It is advantageous for mass production lines that require a high durability and reliability, such as automotive production lines.

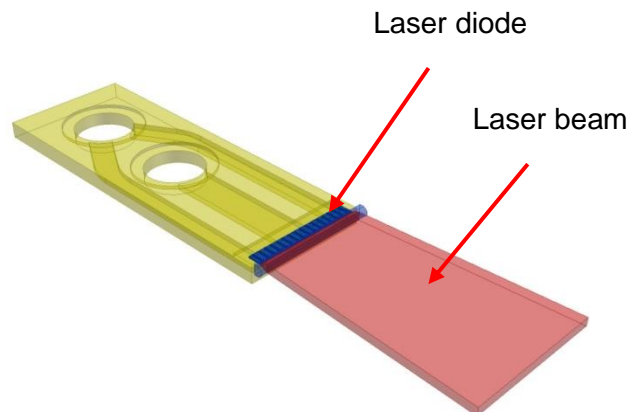


Figure 8. Laser Diode Bar

As with Figure 8, applying high current to the laser diode makes a high output of NIR region wavelength.

The wavelength of the diode laser is generally $\lambda = 800 \sim 1,100$ nm. The diode laser as a kind of semiconductor material made of gallium, indium or aluminum. In order for the laser welding of plastic, in most cases, 100 Watts is sufficient output for melting general thermoplastic resin.

2.3. Energy profile comparison by laser type

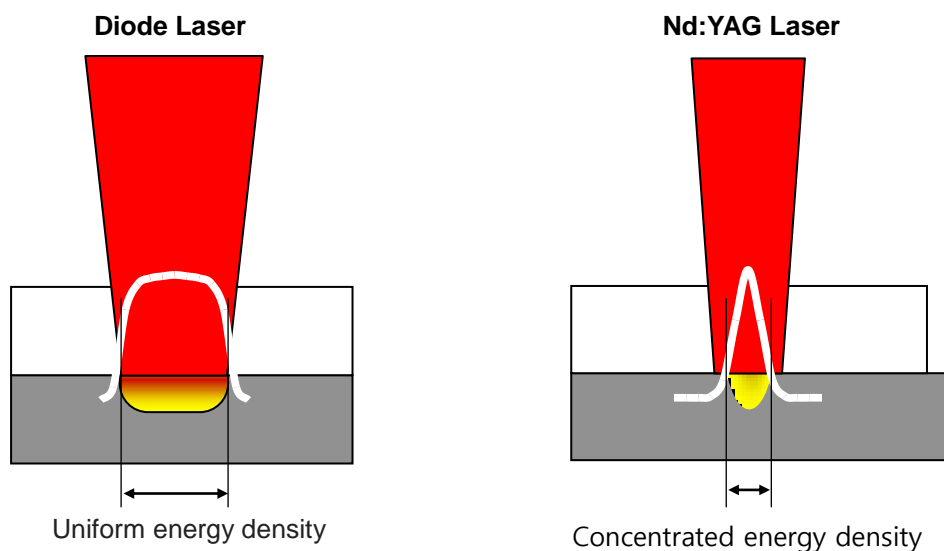


Figure 9. Diode laser & Nd: YAG laser comparison energy profile of laser beam

In general, as shown in Figure 9, the energy profile of the diode laser is shown as top-hat distribution, while the Nd: YAG laser exhibits Gaussian distribution, which has high energy density of the beam center, as such Nd: YAG laser is mainly suitable for miniature products requiring less than 500 μm welding width.

Conversely, if the diode laser beam has a uniform energy distribution at the center of laser

beam, it shows a preferred characteristic for the welding of a relatively large 500 μm or greater products.

2.4. The choice of applicable materials

For laser plastic welding, the resin's properties of the resin are very important. If the laser beam is aimed at the resin, it interacts with the resin; that is, the transmission, reflection, and absorption weaken the laser beam. Transmittance "T" refers to the ratio of the real transmittance amount of specific materials from total irradiated laser output. So the important point is how much transmittance reaches the bottom part being welded. This is closely related to the characteristics of the laser wavelength range and the resin.

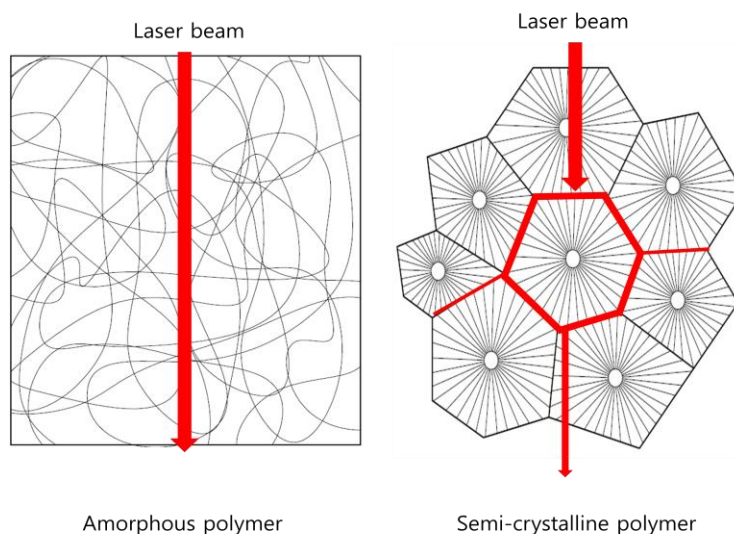


Figure 10. Amorphous structure and partially crystalline structure

If a thermoplastic resin has an amorphous structure such as in Figure 10. Normally transmissivity reaches 85~95 % with a material thickness of 2 mm. However, in the case of a semi-crystalline structured resin (for example, PBT), a reduction of transmissivity occurs due to the refraction of the transmitted beam, usually reduced to 20~40 % at a thickness of 2 mm.

2.5. Laser welding method of plastics

In broad terms, there are four plastic welding methods using lasers, called quasi-simultaneous welding, contour welding, simultaneous welding, and mask welding.

These methods are divided according to the difference of energy transfer method and beam operation. In particular, customers need to consider the shape of the product, investment, the welding pattern, and operation speed among a variety of other elements before choosing a method.

(1) Quasi-Simultaneous Welding

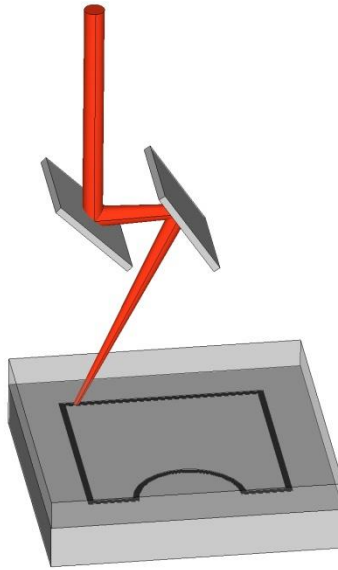


Figure 11. Quasi-Simultaneous Welding

The quasi-simultaneous welding method is performed by using a laser beam a number of times with uniform circumstances using a scanner under a very fast speed (for example, up to 10 m/s) toward welding parts.

At this time, since the welding parts are irradiated over a number of times at a very high speed, it's possible to weld nearly simultaneously. Further, it can overcome gaps at the point of the welding area, and also has significantly high working flexibility compared to the simultaneous welding method.

However, a disadvantage is a fixed scanner location, so that the product position might not always be in an optimal location and also the limited workspace area make it difficult to apply to complex shapes or large products.

(2) Contour Welding

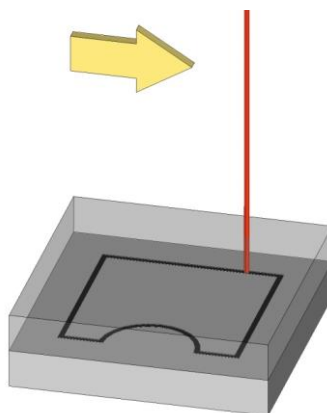


Figure 12. Contour Welding

One of the most often-used processes, contour welding, is a method for delivering a laser beam to the welding area sequentially; it delivers the energy partially so that the melting area is small enough to minimize the flow of melting resin. These advantages can be easily applied to a product having a complicated shape, such as a high flexibility or a three-dimensional shape. This method minimizes gaps through the separate welding projection design. The tolerance range must constantly be controlled from initial product injection.

The output and moving speed of the laser used must take into account be product characteristics; that is, the type of plastic, the amount of additive, transmissivity, absorptivity, and thickness of the product.

(3) Simultaneous Welding

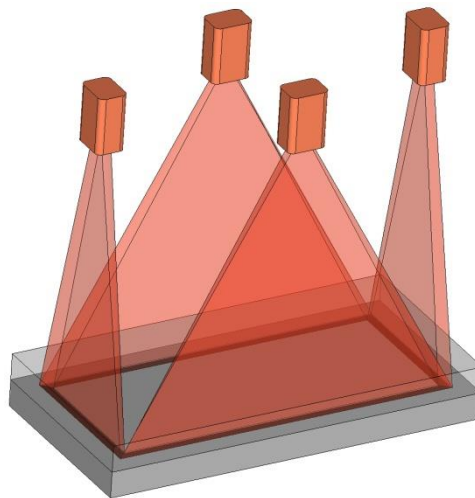


Fig 13. Simultaneous welding method

The simultaneous welding method melts and welds the entire welding area at the same time. It is a method of irradiating simultaneously in alignment with a number of diode lasers the welding area of the product. At this time, the gathered focus of each laser covers the entire welding area, and both the product and laser are all in a fixed state during welding.

The advantages of simultaneous welding method are that the entire welding area is melted at the same time and the gap between the welding force and product is fixed and thus welding quality is easy to manage, however the initial investment cost is high and it is impossible to change the shape of the product. Compared to the contour welding method, though, welding time is very short so it's suitable to apply for many types of production manufactures.

(4) Mask Welding

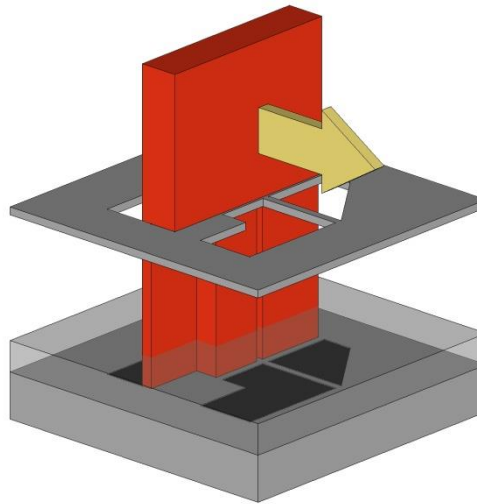


Figure 14. The mask welding method

The mask welding method is the method of irradiating desired portions of products using a mask, which opens only the necessary position to be located between the laser head and product. That is, the position not irradiated by the laser sees no effect as it is blocked by the mask.

In this case, the size and the welding shape of the product depends primarily on the quality of the mask and the laser beam, and the mask can be manufactured to at least approximately 100 μm . In addition, only one movement of the mask can open a variety of complex welding areas.

Mainly it can be applied to very small products requiring precise welding. The mask system in general uses a line beam taking advantage of a diode laser (for example, 20 x 1 mm^2), surely the irradiation of parallel light is a necessary under uniform energy conditions before the laser beam reaches the mask. Production of a mask is used by laser cutting or is made of a chrome-plated glass like the photo-mask method, and the mask by photo-mask method has advantages in regards to shape and flexibility.

2.7. The behavior of laser plastic welding

When plastic material is selected for laser welding and the process parameter is optimized, the preparation of welding is finally ends. Then, the laser beam irradiates following the welding line and set-up speed. One of the most important concepts is to supply sufficient energy to melt the base material in the absorbent layer. This is to increase the kinetic energy of the molecules to ensure complete coupling between the molecular rings of the two base materials.

However, an excessive temperature increase of the base material causes properties to shift, such as color-changes and decomposition, though this is limited.

As shown in Figure 15, the laser beam is absorbed at the first (A) absorption layer, and the layer begins to melt. When melted, the unit volume of base material is increased and the melted absorption layer begins to fill in the small gap between two base materials. As with

the second (B), if the absorbent layer touches the transmission layer, heat transfers to the transmission layer and finally also begins to melt. Through this process, sufficient mechanical and chemical combination is accomplished so that weld strength increases. In particular when a mutual crystallization structure forms between two base materials, the weld strength is further increased.

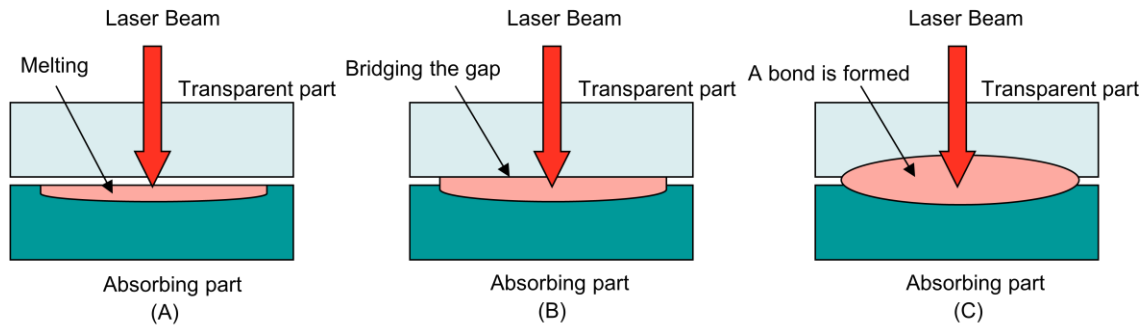


Figure 15. Laser welding behavior

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HQ

Mapo-daero 119 (Gongdeok-dong) Hyeoseong Bldg.
Mapo-gu, Seoul, Korea
Tel 82-2-707-6840 ~ 8, Telefax 82-2-714-9235

KEP Americas

106 North Denton Tap Road Suite 210-202 Coppell,
TX 75019, USA
Tel +1 888 KEPITAL, Telefax +1 888 537-3291

KEP Europe GmbH

Rheingaustrasse 190-196 D-65203 Wiesbaden, Germany
Tel +49 (0)611 962-7381, Telefax +49 (0)611 962-9132

KEP China

A1905, HongQiao Nanfeng Plaza, 100 Zunyi Road,
Shanghai, China
Tel +86 21 6237-1972, Telefax +86 21 6237-1803

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