Laser Welding Guide

Amodel® PPA

Laser welding has become a popular method of joining plastics in a wide variety of applications. This process offers a number of attractive features including:

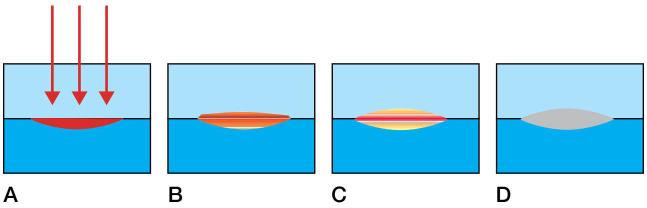
- Speed and efficiency
- Cleanliness, no debris as with vibration or ultrasonic welding
- No consumables, such as adhesives
- No vibration that can damage sensitive components
- High bond strength
- Hermetic seal can be achieved
- Laser equipment can be used for multiple applications

Most Amodel® polyphthalamide (PPA) natural and black grades are suitable for laser welding. Laser transmissive colors are also available as special requests.

Laser Welding Process

Laser welding typically joins two materials that differ in their response to laser radiation. One material is essentially transparent to the laser (the transmissive material) and the other absorbs the energy and melts (the absorbing material). Welding occurs when the laser energy causes the temperature of the absorbing component to increase to its melting point. Heat is transferred to the transmitting component by conduction and when it melts, the laser energy is removed and the material cools forming a strong joint. Figure 1 presents an illustration of the process.

Figure 1: Laser welding process



A: laser energy penetrates the upper layer and is absorbed by the lower material

B: molten material transfers heat to the upper layer

C: a molten pool forms from both layers

D: the pool solidifies when it cools to form a high-strength weld

Types of Lasers

Several types of lasers can be used to weld plastic components. Nd:YAG lasers have the purest light and are typically the most powerful and the most expensive. Diode lasers are more common and less expensive. Since the light from CO_2 lasers is readily absorbed by most plastics, these lasers are not used for transmissive laser welding. CO_2 lasers may only be used for welding very thin films. Table 1 lists the properties of common lasers.

Fiber lasers currently under development offer improvements in energy efficiency, but are relatively high in cost.

Table 1: Laser types and properties

Laser Type	CO_2	Nd:YAG	Diode
Wavelength [nm]	10,600	1,064	800–1,000
Maximum power [W]	60,000	6,000	6,000
Efficiency	10 %	3 %	30 %
Beam transmission	Reflection off mirrors	Fiber optic and mirrors	Fiber optic and mirrors
Minimum spot size [mm]	0.2–0.7 diameter	0.1–0.5 diameter	0.5 × 0.5
Interaction with plastics	Complete absorption at surface in < 0.5 mm	Transmission and bulk heating for 0.1–10 mm	Transmission and bulk heating for 0.1–10 mm

Material Requirements

There are specific requirements for both the absorbing and transmitting materials to be used in a transmissive laser welding application. Ideally, the base polymer comprising each component would be the same, but chemically compatible polymers with similar melt points can also be used. For example, Amodel® AS-1133 HS NT can be welded to Amodel® AS-4133 HS BK324.

Transmissive Material Requirements

The transmissive component allows the laser energy to pass through it to heat the absorbing component below. Therefore, the transmissive component must be relatively transparent to laser energy at the wavelength of the laser being used. The transmissive layer will remain relatively cool while the absorbing component heats. Typically, at least 30 % of the laser energy needs to be transmitted to the absorbing component. The presence of additives, fillers, and pigments can significantly alter the transmissivity of the polymer and proper selection of materials is critical.

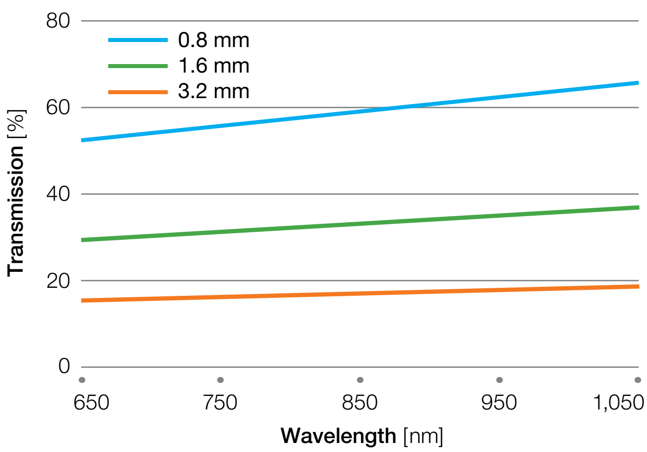
The thickness of the transmissive component is also a factor, since the transmissivity is also thickness dependent. This requires careful design consideration when structural components are to be welded. The typical thickness of transmissive components is 1.6 mm to 0.8 mm (0.06 inches to 0.03 inches). However, this dimension is only required in the area to be welded. Other sections of the part as well as the width of the weld path can be modified to provide for overall part structural requirements. Table 2 lists some common Amodel® PPA grades and the maximum recommended thickness at which the natural color can be used as the transmissive component. The transmissivity of natural-colored Amodel® PPA is shown in Figure 2.

Table 2: Maximum thickness for Amodel® PPA used in a transmissive role

Grade	Maximum Thickness [mm]	Maximum Thickness [Inches]
A-1133 HS NT	1.6	0.063
A-1145 HS NT	1.4	0.055
A-1240 L NT	NR*	NR
AS-1133 HS NT	1.9	0.075
AS-1566 HS NT	0.9	0.035
AS-4133 HS NT	1.1	0.043
AS-4133 L NT	1.4	0.055
AT-1002 HS NT	NR	NR
AT-1116 HS NT	2.1	0.083
AT-1125 HS NT	1.6	0.063
ET-1000 HS NT	1.7	0.066

** Not Recommended*

Figure 2: Typical transmissivity of natural-colored Amodel® PPA resin



Absorber Requirements

The absorbing component is the part which melts and transfers heat to the transmitting part creating the weld. Therefore, the absorbing component contains additives, typically carbon black, that efficiently absorb the laser energy. The amount of the carbon black present is critical; too much or too little can result in inferior performance. When working with Amodel® PPA, most grades with a color code of BK324 or BK543 are suitable for the absorber.

If using a different polymer than the transmitting component, the melting point of the absorber must be equal to or slightly higher than the melting point of the transmitting component. When attempting to weld different polymers, there must be some compatibility between the two resins.

Laser Welding Colors

As noted earlier, most laser welding applications will utilize a natural, or unpigmented polymer as the transmitter and a black polymer as the absorber. Certain application aesthetics may require that both components be the same color. This can create problems, as pigments are typically laser absorbers and would interfere with the transmissivity requirements. Solvay has successfully formulated color systems that are transmissive at the laser light wavelengths yet are absorbers in the visible spectrum, meaning that the parts may be colored as desired. Similarly, there are laser absorbing pigments that can be utilized to impart a color other than black to the absorbing component. Please contact your Solvay representative for a list of masterbatch suppliers who can help you achieve colored laser-weldable Amodel® PPA products.

Conclusion

Laser welding has become a popular and useful method of joining plastic components. Solvay has developed grades of Amodel® PPA specifically for laser welding, both in natural and colors. For more information, contact your Solvay Specialty Polymers representative.

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