

## Laser Spot-Welding of Plastics

### Introduction

The use of high-power near-infrared diode lasers for joining plastics is growing. More development work is being performed in institutions and in R&D labs, and applications in industry are slowly increasing. Several different approaches are being developed for laser welding of plastics. The main principle now used to laser-weld plastics is known as “transmission welding.” Transmission welding has demonstrated that precise, controllable heating and melting of low melting point thermoplastics can be produced at the interface between a transmissive and an absorptive plastic. The principles of transmission welding were explained in a previous Application Note in this series.

### Welding trials

Although it is often required to produce a welded seam by relative motion between a high-power diode laser beam and the target, there are some situations in which a single spot-weld can suffice. In addition, taking the relative motion out of the welding process can lead to a simpler analysis of that process and can help in comparing the weld performance of different materials. Clear and colored acrylic sheets (often referred to as Perspex<sup>1</sup>) are widely used for signage and other applications where their optical clarity is required. It is also readily available in a wide range of colors. Because of their ready availability and high infra-red transmission, acrylic sheets have been widely used for laser welding experiments. Similarly, polycarbonate (PC), tradename Lexan<sup>2</sup>, has also been used. As this material has better mechanical properties, it is used in more demanding applications, where, for example, toughness is required. Therefore, these materials were used for the first stage of these trials.

A series of experiments was designed to identify the laser parameters required to produce high-strength spot-welds between these two widely used materials.

A large diameter laser spot was used to reduce power density to an appropriate level for laser-welding of plastics. This spot was produced using a Coherent FAP<sup>TM</sup> System, an 800  $\mu\text{m}$  diameter fiber and a 1:1 Optical Imaging Accessory to

provide a collimated beam of approximately 12 mm diameter. These parameters give a power density ranging from 9–35  $\text{W}/\text{cm}^2$ . Results are given in Figures 1 and 2.

The weld damage threshold identifies the point at which thermal damage was first noted in the melt spot. This was usually in the form of bubbles generated in the melt pool. These were noted after the end of the laser pulse, and were not typical of shrinkage porosity. It was concluded that these defects were probably water vapor generated within the material by the laser heating process.

Further important information can be extracted from Figure 3 that compares the polycarbonate and acrylic materials. To achieve a particular weld diameter with the acrylic material requires less energy than to achieve the same weld diameter with the polycarbonate material. This is most likely due to the higher thermal capabilities of the polycarbonate material.

An alternative plot of this data for one material combination, acrylic to acrylic, is given in Figure 4. This plot emphasizes the role of energy input and shows that welding at higher average power and higher average power density is more efficient – less total energy is required to achieve maximum weld-spot size. It should be noted that average power, measured in watts, is simply the rate of input of laser energy, measured in joules. Hence, these results are readily explained by lower conduction losses at shorter welding times. Keeping the pulse duration to a minimum, therefore, reduces heat loss through conduction to the component, which is always a prime objective for a precision welding process such as this.

To expand the scope of these trials, the laser weldability of a completely different type of polymer, polypropylene (PP), was examined. Polypropylene is very widely used in industry because of its very low surface energy. This makes it a very difficult material to bond, either to itself or to other substrates. Polypropylene is also attractive because of its extremely low cost and its recyclability. A standard polypropylene homopolymer was therefore used

Spot Area vs. Weld Time, Acrylic to Acrylic

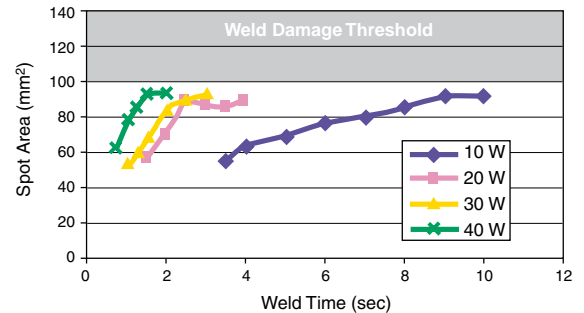


Figure 1. Spot welding data for acrylic

Spot Area vs. Weld Time, PC to PC

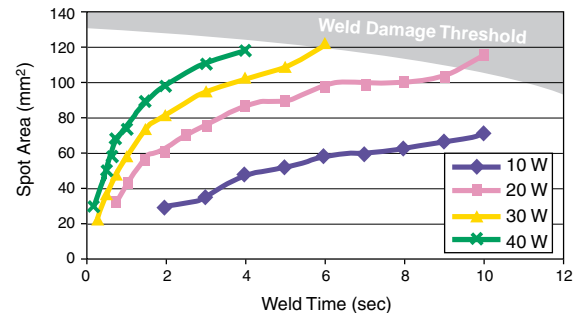


Figure 2. Spot welding data for polycarbonate

Spot Area vs. Weld Time

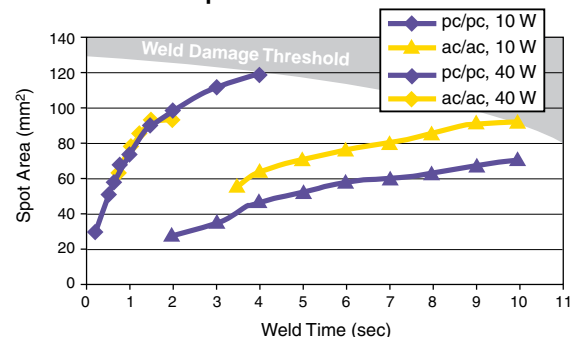


Figure 3. Comparing spot welding of pc and acrylic materials

Effect of Energy Input, Acrylic to Acrylic

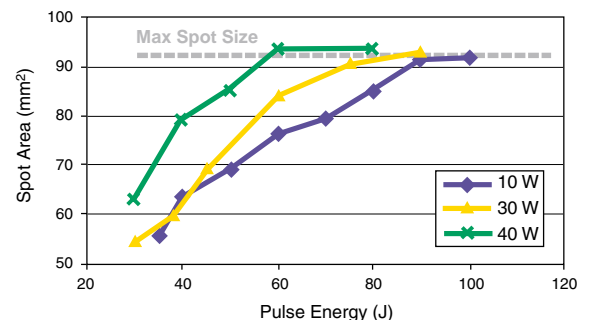


Figure 4. Acrylic to acrylic weld

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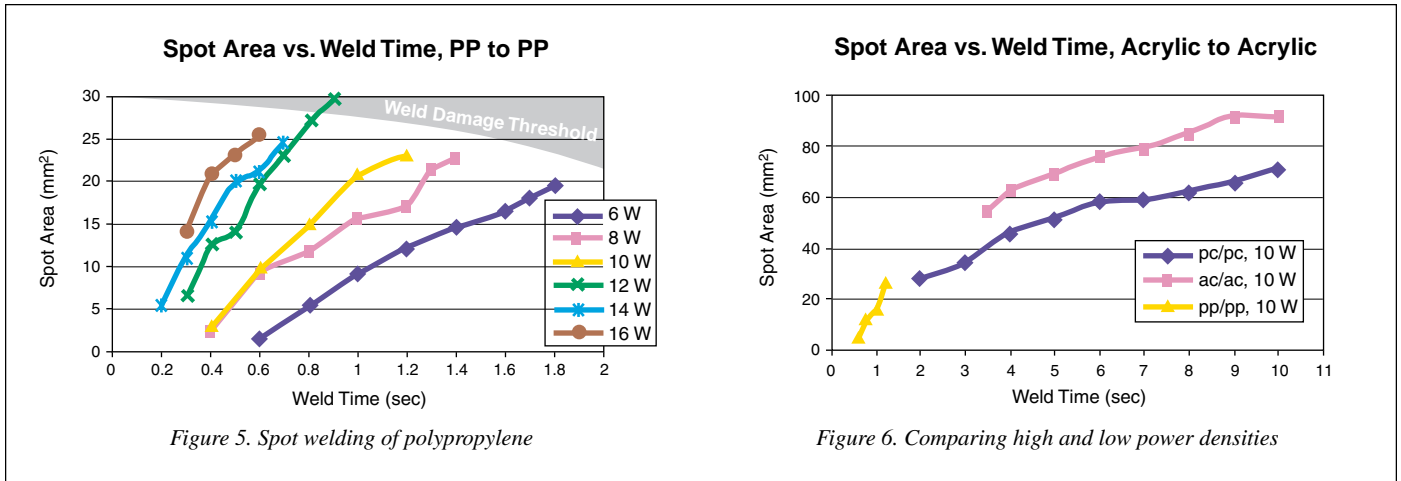


Figure 5. Spot welding of polypropylene

Figure 6. Comparing high and low power densities

for the second part of this work. In this case, because of the higher absorption and scattering of the laser beam by the polypropylene, a higher power density was used. In this case, the actual laser beam diameter was 7 mm; hence, welding times were shorter: Results are given in Figure 5. Please note the different x-axis scale. If equivalent spot sizes and average power had been used on this polypropylene material, weld times would be unrealistically long. These parameters give a range of power density from 16 to 40W/cm<sup>2</sup>. A comparison between the different groups of materials is shown in Figure 6.

In all these results it is clear that higher average power and related higher average power densities, or fluence, produce more rapid melting and welding. It must be remembered that unlike many other laser types, when using direct-diode lasers the actual laser spot size does not vary as the laser power is increased. Hence in these results, the increase in the welded joint area is simply due to a more energetic wetting process that spreads during heating until the wetted area covers the complete area irradiated by the laser beam.

Another important point to note is that in the case of these optimized defect-free joints, joint

strength is always directly proportional to joint area; the bigger the melt spot, the stronger the joint. It was noted that when strength-tested, material failure occurred within the material when the joint area approached a certain size: ~55 mm<sup>2</sup> in the case of polycarbonate material, Figure 7.

In both material types, joint areas were chosen to achieve joint strengths approaching the strength of the parent material.

### Conclusions

- High-quality diode laser spot welding of two major types of plastics materials has been demonstrated using high-power diode lasers.
- These optimized spot welds have been produced at power densities ranging from as low as 10W/cm<sup>2</sup> up to 40W/cm<sup>2</sup>.
- Welding at higher average power and higher power density reduces the pulse energy needed to attain the same size weld at a lower power.
- Material failure can be readily achieved using relatively small melt spots.

Power (watts)	Joint Time (s)	Joint Area (mm <sup>2</sup> )
10	2	46.7
20	0.75	60.8
30	0.3	47.7
40	0.2	67.9

Table 1. Parameters to produce failure in

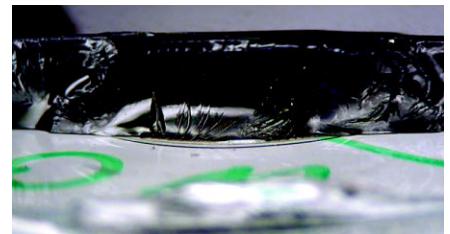


Figure 7. Failure surface of polycarbonate material

1. Perspex is a trademark of Perspex, Ltd., U.K.  
2. Lexan is a registered trademark of General Electric Company

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