Application Tech Note

COHERENT® SEMICONDUCTOR DIVISION

Micro-Welding Plastic Tubes Using High-Power Diode Lasers

Introduction

Welding plastics with high-power diode lasers is currently the subject of a great deal of interest in industry and in research institutions. The technique of transmission welding has now been demonstrated using high-power diode lasers. This produces controllable local heating and melting of a low-melting-point thermoplastic at the interface between transmitting and absorbing layers of thermoplastic materials. Diodes offer a number of advantages for this type of process over conventional solid-state or CO_2 lasers—namely controllability (temporal and spatial), reliability and ease of automation.

Using the full-feature, microprocessor-based F-Package System, the Applications Laboratory has developed a technique for welding small-diameter, thin-wall plastic tubes. The advantages of the F-Package System are its small size, low capital cost, electrical efficiency and ease of use. Various laser powers are available from these systems, from 500 milliwatts to 2.5 watts depending on the delivery fiber diameter and selected diode laser engine. This is important as the power required depends on the dimensions of the joint and the welding speed.

As with many laser processes, the main objective is to achieve the desired result with minimum heat input to the part. This note gives guidance on processing parameters for thin-wall tube joints on specific problem materials. It details how the minimum heat input was achieved. This practical approach to tube joining is applicable to many different joints and material combinations.

Experimental Details

Process development trials were initiated to evaluate high-temperature plastics tube joining. A standard overlap joint configuration was chosen to demonstrate this novel approach to producing joints with minimum heat input. Two materials, PTFE and FEP (both grades of Teflon, fluoropolymers) were chosen as they are generally considered difficult to join. This difficulty is due to their excellent high temperature properties and chemical stability. These materials were also chosen because if these materials could be joined, then most other lower temperature thermoplastic materials could also be joined. This has indeed been proven—a range of chemically similar materials has been joined to each other, i.e. polypropylene to polypropylene, nylon to nylon, polyurethane to polyurethane. Newer thermoplastic materials such as Pebax, can also be joined if the joint configuration permits transmission welding. Other materials will shortly be added to this list.

Samples were produced using a 1.7 watt, 980 nm F Package System (*Figure 1*). The energy was delivered through a 200 µm diameter optical fiber (NA <0.16). The tube welding set up is shown in *Figure 2*.

Figure 1: F-Package System

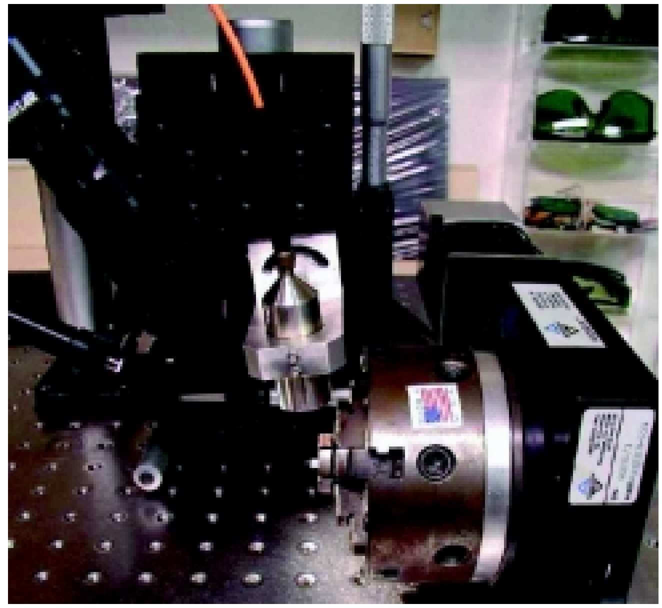

Figure 2: Tube welding set up

A standard 1:1 Optical Imaging Accessory (OIA) was used. The theoretical minimum joint width was ~200 µm (.008"); the working distance was 33 mm (1.3"). The tubes were held in a rotary chuck as shown in *Figure 2*. The inner tube has been expanded to fit tightly into the outer tube (*Figure 3*). This fit up is essential for controlled wetting and joining to occur. Tube assemblies were rotated beneath the OIA using a CNC-controlled rotary axis at 11 rpm, giving a welding time of 5.4 seconds. Such trials using a range of different average power levels at a constant rotational speed are an effective technique to identify the minimum heat input for a particular joint configuration. In the case of this FEP to FEP joint, optimized results were obtained using 750-mW average power and these parameters produced a .012" (300 µm) wide circumferential joint (*Figure 3*). A small increase in power was required to achieve the higher temperatures required to join PTFE to FEP. Although speed may be increased as average power increases, this makes process development and closed-loop control less straightforward.

Figure 3: 0.012” wide circumferential weld on 0.005” wall FEP/FEP tubing

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The joint shown above is comprised of a FEP inner tube (.041" internal diameter, .005" wall thickness) and a FEP outer tube (1/8" OD, 1/16" ID with a .030" wall thickness). Pull tests on these joints have shown that material failure occurs before joint failure and that a hermetic seal was created between the tubes. This confirms that the estimation of the required joint size was correct—the shear strength of this joint exceeds the tensile strength of the material. No associated thermal damage is observed. Clearly the objective of this process, to minimize heat input to the material and yet still achieve a sound, strong, hermetic joint, has been achieved.

Additional Details

A range of laser wavelengths has been used for plastics welding. In this instance a 980-nm laser was used. No significant absorption in either the PTFE or FEP outer tubes was observed. No thermal damage was observed other than the very limited wetting shown in *Figure* * ARABIC *4.* The position of the laser focus with respect to the joint is clearly important as this controls the power density at the work piece. Because of the long working distance of the OIA, significant deviations from focus (~+/- 0.5mm) can occur before differences in the process are noted. This leads to a large working distance and a reliable process.

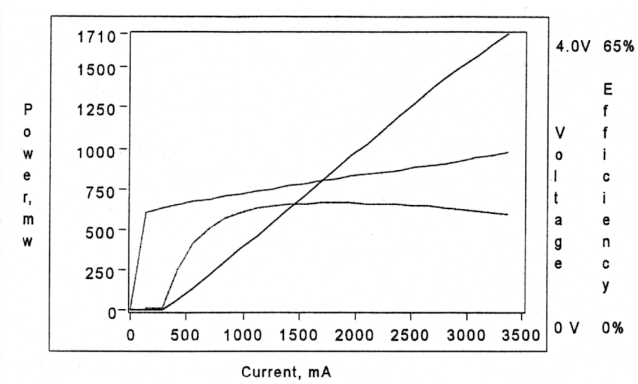

Figure 5: Showing the output F-Package System used

Advantages of Diode Laser Tube Welding

Because of the controllability of diode laser welding—its ability to place the precise quantity of heat just where and when it is required—the following advantages are claimed:

- special high-temperature materials such as PTFE, FEP can be welded

- thermally-sensitive, high-value components can be welded

- excellent mechanical properties can be achieved

- fiber delivery allows greater manufacturing flexibility

- process is non contact and sterile

Cut/Weld Processing

It has also been demonstrated that by using different processing parameters, it is possible to cut the inner tube at similar speeds to the joining process (*Figure 5*). This raises the possibility of a cut and weld process, both performed on the inner tube.

Figure 6: In Situ Tube Cutting

Conclusions

The F -Package System has shown good welding performance on a range of small-diameter plastic tubes that are currently considered difficult to join. All of these laser-welded joints appear to be superior to those produced by other techniques in that total heat input is minimized.

By using any one of a number of different lasers within the F-Package System, the appropriate power and wavelength may be chosen for a particular welding application.

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