There are a variety of methods for joining plastics, including mechanical, chemical and welding. Each method has its own advantages and disadvantages, depending upon the intended application. Bonds created by welding are the result of intermolecular diffusion at the joint interface. Energy is applied to the materials, softening them at the joint interface and promoting this diffusion.

Welding techniques are categorized into three groups according to the means by which heat is applied: mechanical friction, thermal heating and electromagnetic radiation. Friction welding, including spin and ultrasonic, converts mechanical energy to heat through intermolecular friction. Thermal welding, on the other hand, involves the use of an external heat source, which is transferred to the surfaces through conduction or convection. Typical examples include hot-gas and hot-plate welding. In electromagnetic welding, the energy is converted to heat. In radio frequency (RF) welding, for example, the energy causes dipole vibration, which generates heat. In transmission laser welding, the energy is absorbed and converted into heat.

Transmission laser welding uses a beam of high-density electromagnetic energy that passes through an infrared (IR)-transmissive substrate until it reaches an IR-absorbing substrate. Here the laser light is absorbed and localized heating of the substrates occurs at the joint interface, resulting in an instant weld.

Controlling factors in the process are the power of the laser, the size of the laser beam, welding speed, intimate contact and properties of the material at the interface. Typically carbon black pigment is used as an additive to enhance absorption of the bottom substrate.

First used in the mid-1980s for welding automotive components, laser welding offers a number of distinct advantages compared with other plastics joining techniques. Because it does not involve vibration, it does not impart mechanical damage to a part or generate particulates, making it especially suitable for electronic and medical applications. Moreover, it yields bond strengths that are comparable to other joining techniques, such as hot plate and ultrasonic, without visible markings or weld flash. It accommodates pre-assembly and high weld speeds, permits 3-D contour joint lines and facilitates rapid changeover to different products. In addition, process parameters can be controlled precisely, and low heat input reduces the risk of thermal distortion. The process can be used for both polar and nonpolar materials. The principal disadvantage of laser welding has been the need to use carbon black as an absorbent, posing a limitation in applications where color and appearance are important.

**The Clearweld® Process**

Recently, however, a revolutionary new process has been developed that offers all the advantages of conventional laser welding without the use of opaque materials or the addition of unwanted color. The process can be used to join a wide range of rigid and flexible plastics, both clear and colored, making it ideal for assembling electronic, medical, automotive and consumer products, as well as packaging. Materials can be developed for use with ABS, CA, EVA, HIPS, PA, PC, PCTG, PE, PEEK, PEI, PEN, PET, PETG, PMMA, PP, PPO, PS, PSU, PVC, PVDF, acetal, polyurethane, polyester and other substrates. The welding of dissimilar materials and some thermoplastics is also possible.

The process uses near-infrared-absorbing material systems to convert laser energy into heat. A thin layer of these materials applied at the interface of two pieces of plastic to be
joined absorbs the light, acting as a focal point for the laser. Localized heating of the substrates occurs at the joint interface, producing clean, optically clear joints with no particulates or visible color.

Called Clearweld, the process was invented by TWI, a U.K.-based industrial research and development organization that specializes in materials joining, and has been developed for commercial use by Gentex Corporation, a privately owned technology company. It is patented in Europe and Australia with additional patents pending.

Gentex has developed a series of materials capable of powerful absorption in the near-IR spectrum, while remaining virtually colorless. Clearweld incorporates these absorbents in unique material systems designed for use in a variety of production processes. The effectiveness of these material systems depends upon their compatibility with specific process parameters. These systems are custom-formulated, taking into account substrate materials, part design and process requirements, and are tested and certified for use with specific delivery methods. Initially, these methods are limited to liquid dispensing and industrial ink jet printing, but may be expanded to include other printing methods. The process depends upon accurate and repeatable application of the near-IR absorbent at the localized joint interface.

Another important factor is intimate contact between the surfaces to be joined to ensure sufficient melt flow to produce a strong bond. To obtain intimate contact of the substrates at the weld interface, a certain amount of clamping pressure is required. The amount of pressure depends upon the materials being joined and their surface conditions at the weld interface. Also critical is heat generation. High-power diode lasers provide the electromagnetic energy necessary for generating heat. The typical wavelengths employed range from 940nm to 1000nm. Depending upon specific application requirements, a variety of power levels and configurations may be considered. It is critical, however, that the laser wavelength match the wavelength at which the material system is designed to absorb.

Due to their small size and weight, diode lasers can be used in a number of different ways in the Clearweld process. The choice and configuration of equipment for a given application will depend on a number of factors, including the size and weight of the component being welded, the rigidity of the material, whether it is film-based or molded and the number of components that are required in a given design.

In a fixed laser, moving work-piece configuration, the equipment generally operates as a single-pass process, with the joint heated as the workpiece passes beneath the laser source.

It may be used with a dual-axis flat bed table to weld small-to-medium-sized flexible components with 2-D joint lines or in the form of a continuously moving substrate for welding thin films for packaging applications, for example.

In a moving laser, fixed workpiece configuration, the equipment operates as a single-pass process with the joint heated as the laser beam passes over the workpiece. The laser may be manipulated by a robot for 3-D processing or attached to a moving gantry over a flat bed for 2-D processing. This type of equipment is best suited to large, relatively flexible components.

In a fixed diode array, fixed workpiece scenario, the laser diodes are mounted in a frame designed to match the shape of the component being welded, rather than being put into a single laser source. The process operates with the entire joint being irradiated for a given time. This procedure is suitable for small rigid molded components that may not fit precisely at the joint line. Welding time is set to heat and soften the weld line, which will flow under clamping pressure and close any slight gaps.

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Yet another equipment configuration is a scanning beam and fixed workpiece, whereby mirrors are programmed to move the laser beam around the joint line of the fixed component. The beam moves very quickly scanning the joint many times per second. This effectively heats the entire joint line simultaneously in the same manner as a laser diode array, making it suitable for small, rigid molded components. This equipment has the added advantage of easily altering the weld line profile by simply loading a different program into the scanning unit.

Key to ensuring a successful process implementation are optimization of laser power, weld speed, and absorption of the custom material system. Fine-tuning these parameters can help produce weld strengths in excess of the parent materials and processing speeds equal to or greater than alternative joining techniques.

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