Technical Innovations at AMADA WELD TECH:

Advances in Laser Welding Systems and Technology for Medical Device Manufacturing

The challenges of many medical device manufacturing applications are pushing the need for more sophisticated metals-joining technologies. In response to these demands, laser welding has become an important enabling technology, as single-use medical devices become smaller and smaller and as demand grows and reliability requirements tighten for implantable cardiac health management device. The use of laser welding is also making practical a wider range of applications as a newly available laser light wavelength opens the door to reliable laser welding of copper and gold alloys. This article highlights motion and laser control techniques beneficial to hermetic laser seam welding of implantable devices, and new metals joining production methods made possible by the availability of “green light” (532nm) pulsed welding lasers.

SMOOTHING OUT “BUMPS” IN THE ROAD FOR LASER WELDING IMPLANTABLE DEVICES

Seam-welding implantable medical devices such as heart rhythm management devices require unique motion system control solutions, in addition to precise control over the delivered laser energy. The principle task in this case is to seam-weld the two halves of the device together, achieving a reliable hermetic seal. Equipment built for this purpose usually consists of a rotary stage holding the implantable device while applying pressure to clamp the two halves together and a XYZ robot that aims the laser beam at the edge seam, maintaining orthogonality to the seam as well as tight control of the focus offset distance. Operation of the coordinated four-axis motion control system is deceptively simple: just turn the rotary stage and keep the laser beam pointed at the seam. But a number of practical concerns need to be addressed.

For one, the contour of the seam to be welded is most often not a simple circular path as the sample parts depicted in **figure 1** illustrate. By studying the kinematics of the motion system needed to follow a typical welding contour at constant speed, one finds that there are points in the motion of some of the stages that require theoretically infinite deceleration / acceleration. These stages must instantaneously reverse

Figure 1 – Implantable medical device showing typical contours.

direction without decreasing speed. See the polar acceleration plot in **figure 2** as an example. Unless managed properly, this motion results in a large reactive force transmitted through the machine structure that is felt as a strong impulse force (“bump”) in the otherwise smooth operation of the servos. The impulse causes the holding fixture to flex or vibrate and can cause irregularities in the spot to spot spacing in the seam, often resulting in a hermeticity failure.

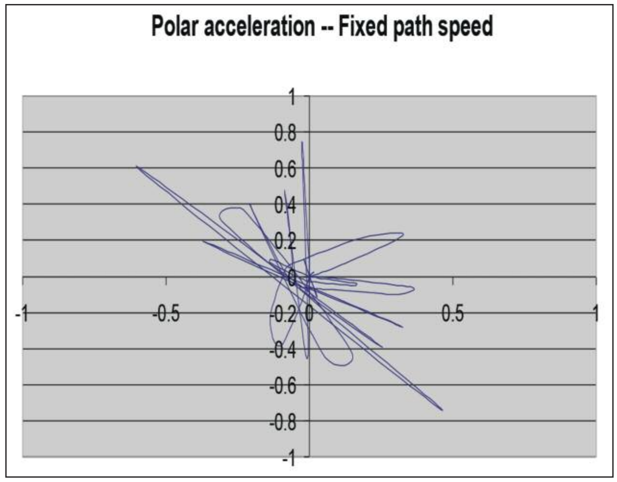

Figure 2 – Polar acceleration plot showing rapid changes in acceleration in X and Y axes of focus head positioner while executing a contour seam weld.

In the past, a typical solution has been to slow down the whole operation so the force impulse is low enough to not affect the performance of the weld, but this means a lower production rate and higher product cost.

A better approach is to use variable speed contour welding with “position-based firing.”

The motion system is set up to minimize the magnitude of the sharp changes in acceleration by slowing down as needed at these inflection points and then speeding up along the benign segments of the contour. Using special software to achieve “position-based firing” along the contour, it becomes a simple matter to fire the laser not at a constant repetition rate, but rather in response to its actual position along the contour at any point in time. The good news is that the special software works with ANY contour, so there is no reprogramming or parameter “tweaking” needed to accommodate any implantable device now or in the future. And a programming tool that allows the operator to import a *.DXF file of the contour and set up the entire process in a graphical environment makes this a practical process, allowing for fast changeovers between part types and fast introduction of new part types into production.

An effective laser welding production process for implantable medical devices clearly requires good coordination between the laser power supply and motion control system, and provision for setting up and managing the special challenges posed by the unique contour shapes involved.

GREEN LASER LIGHT ALLOWS AUTOGENOUS WELDING OF COPPER.

Interaction between laser light and materials is very dependent on the wavelength of the laser light and on the type of materials, as shown in **figure 3**. For example, near infrared (1064 nm) solid state lasers interact well with non-copper metals (iron, cold-rolled steel, nickel-plating, some aluminums, etc.), but fail to work consistently well with so-called “red metals” such as copper or gold alloys.

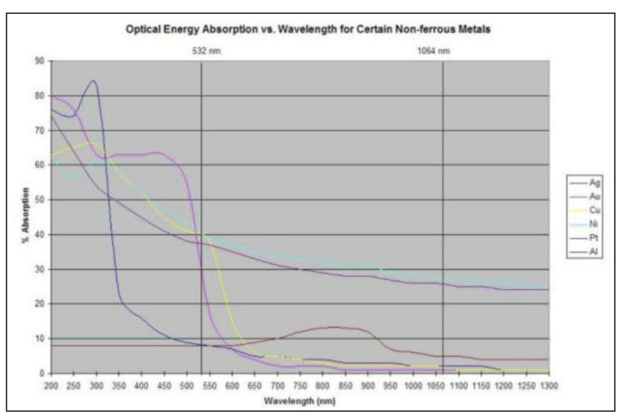

Figure 3 – Copper absorbs laser light with a wavelength of 532 nm substantially better than at a wavelength of 1064 nm.

The availability of a reliable green light (532 nm) laser welder has opened the door for a number of key medical device applications where traditional laser welding simply could not be utilized. Some of the inherent advantages of green laser welding include:

o Precision welding of copper and gold alloys

o A true metallurgical weld as an alternative to conventional soldering

o Consistent high-reliability electrical connections with no long term resistance drift

o Non-contact process that completely eliminates risks of ESD or physical damage to the parts being joined

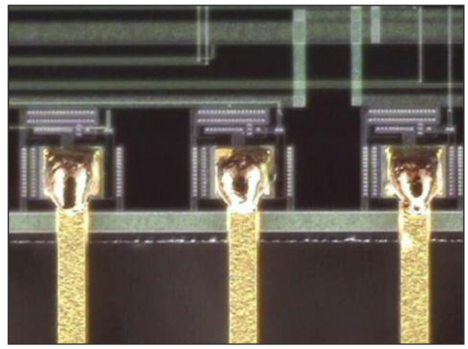

Figure 4 – Autogenously welded gold-plated copper leads onto semiconductor connection pads using 532 nm pulsed Nd:YAG laser welder

Because it is a true autogenous weld, in which the materials are melted and joined without the requirement for a third material (solder, brazing compound, or welding wire), a laser welded connection is inherently more reliable than any soldered connection. Green laser welding can easily address critical electronics interconnect applications within active implantable medical devices, from eliminating soldering at the component and PCB level to overcoming the limitations of existing bonding methods at the semiconductor packaging level. The use of green laser welding to attach leadframe connections as shown in **figure 4** can provide a very effective alternative to ultrasonic bonding. In addition, because it is a non-contact process, green laser welding completely eliminates the risks of electrostatic discharge (ESD) or physical damage, which can result in expensive scrap or latent defects in the components.

SUMMARY

The application of lasers to difficult medical device manufacturing problems is ever expanding. New advances in precision laser beam delivery are making possible smaller and smaller devices, promising the availability of newer and more effective therapies for a wider range of conditions. Combining close coordination between motion systems and lasers can improve the reliability and reduce production costs of active implantable devices. And new production-grade green lasers now offer the promise of extending the reach of reliable laser welding to critical electrical and electronic connections. Far from being just another method for joining metals, laser welding can help bring the next generation of medical devices into existence.