의료용 전기 접점부의 마이크로 레이저 용접

LASER MICROWELDING FOR ELECTRICAL INTERCONNECTION IN BIOMEDICAL TECHNOLOGY

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ABSTRACT Over the past few decades, there has been increasing research and commercial activity in invasive and non-invasive biomedical technology. One important challenge to developing these devices involves the increasing density of electrical interconnects. Resistance spot welding is limited in the density of interconnect based on either the size of welding head or the positional precision with which a weld can be made. Development of an automated laser microwelding system would permit the continued advancement of these important biomedical technologies.

The objective of this work is to demonstrate the application of pseudo-pulse Nd:YAG laser technology as an alternative to resistance spot welding in performing electrical interconnection within biomedical products. To date, some experiments have been conducted by using a pseudo-pulse 1064 nm Nd:YAG laser, a successful weld of a 25 ㎛ diameter Pt/Ir wire to a 316 stainless steel shim can be made. Another application involves welding clips, which may be used for external interconnection, to electrodeposited nickel domes that make particular interconnections to specific insulated wires within a cable. These results show a great deal of promise for developing such a process.

1. Introduction

Over the past few decades, there has been increasing research and commercial activity in invasive and non-invasive biomedical technology. One important challenge to developing these devices involves the increasing density of electrical interconnects. With the number of wires coming from these devices in excess of 100, the spatial challenges of electrical interconnects are clear. [1-2] Resistance spot welding is limited in the density of interconnect based on either the size of welding head or the positional precision with which a weld can be made. Spot welding of wire diameters below 50 ㎛ is difficult. Materials of interest include platinum, gold, copper and nitinol. Development of an automated laser microwelding system would permit the continued advancement of these important biomedical technologies.

Recently, OSU performed a nation-wide survey of companies involved in providing laser welding services. When asked if they could weld a 25 ㎛ dia. stainless steel wire to a nominally 300 ㎛ stainless steel pad, the following summary of responses was obtained :

- Nine definitely could not
- Six were uncertain
- Two thought they could
- One said they have done it successfully although it is a proprietary process and, therefore, it is unknown if this can be done at high-volume.

The objective of this work is to demonstrate the application of pseudo-pulse Nd:YAG laser technology as an alternative to resistance spot welding in performing electrical interconnection within biomedical products.

2. Preliminary results

To date, some experiments have been conducted at OSU which have shown that by using a pseudo-pulse 1064 nm Nd:YAG laser, a successful weld of a 25 ㎛ diameter Pt/Ir wire to a 316 stainless steel(SS) shim (Figure 1) can be made. This weld was produced with a peak power density on the order of 105 or 106 W/cm2.

A tensile force normal to the surface of the shim was placed on the wire and resulted in a fracture along the interface between the weld and the wire which indicates good adhesion of the weld to the SS substrate. Specific conditions for the weld have been found difficult to reproduce in part because the preliminary welding power supply that produced the weld is unreliable.

A typical pulse from the laser is shown in Figure 2. Key parameters of a quasi-pulse laser include the overshoot(height of the transient), pulse current(height of the plateau), and pulse width(duration). Other variables initially investigated in the process included the pulse frequency and number of pulses per weld.

These results show a great deal of promise for developing such a process. It is believed that when the size of the wire gets to a particular maximum diameter(probably within the size of focus of the optics), laser micro-spot welding becomes achievable. By micro-spot welding, it is meant that laser energy is delivered on top of the wire. When dimensions get so small, this greatly simplifies the design of the weld joint.

Complications arise from figuring out how to fixture such a setup for a high-speed laser micro-spot welding setup.

3. Laser spot welding application

In an effort to pursue a more robust laser platform as well as to simplify fixturing, μ-Helix laboratories developed a laser spot welding application and pursued laser implementation with the assistance of GSI Lumonics. GSI Lumonics is known to have pseudo-pulse lasers with some level of pulse shaping. The details of this welding application are given below.

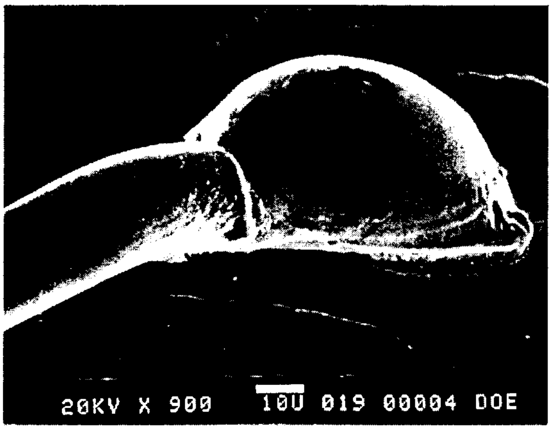

Fig. 1 The welding of a 25 ㎛ dia. Pt/Ir wire to a SS substrate Nd:YAG pseudo-pulse laser.

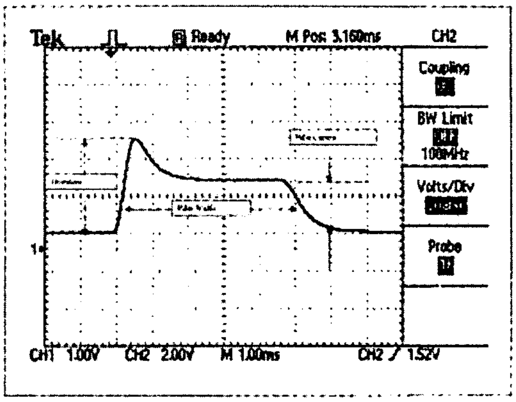

Fig. 2 Key parameters associated with a pseudo-pulse laser.

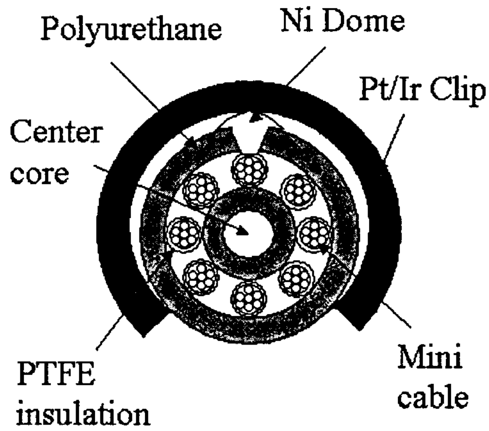

Fig. 3 Cross-sectional schematic of typical weld

3-1 Weld sample and fabrication process description

(1) Weld parts

The application involves welding clips, which may be used for external interconnection, to electrodeposited nickel domes that make particular interconnections to specific insulated wires within a cable. A cross-section of the cable welding application is shown in Figure 3. Overall, the cable consists of 8 mini-cables wrapped around a central core. The outer insulation of the cable is a 0.002 to 0.003 inch thick layer of polyurethane. Each mini-cable that the nickel is electroplated on consists of six strands of wire wrapped around a center wire. Each of the seven strands is 0.0012 inches in diameter. Each of the mini-cable is insulated with PTFE insulation about 0.001 inch thick. The wire in the cable is 316 stainless steel. To simplify fixturing, the clip is clamped around the outer insulation of the cable in an effort to contact the Ni dome. The clips consist of platinum/iridium(80/20). As mentioned, the nickel domes are made by electrodepositing Ni into laser micromachined holes through the outer insulation of the mini-cables. The nickel was plated to fill the hole made with the laser to make a nickel dome above the height of the outer insulation.

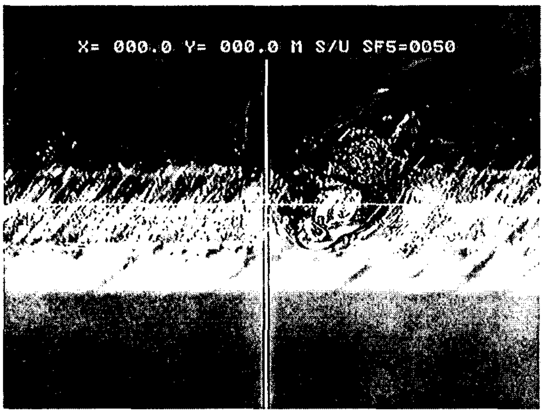

Fig. 4 Cable without clip (weld #8)

(2) Laser welding

The weld parts were welded using a LuxStar ®100 pulsed Nd:YAG laser at GSI Lumonics. The beam was delivered with a fiber optic beam delivery. There are 8 welds along the axis of the wire. Welding conditions are shown in Table 1. All welds used a single pulse of laser and a soft flow of argon as a cover gas(Ar).

For the #8 weld, there was incomplete fusion so the clip could slide back and forth. After sliding out the clip, the appearance of nickel dome can be seen as shown in Fig. 4. Figures 5 shows the typical appearance of welds on the outer surface of Pt/Ir clip

3-2 Weld section pictures

A series of cross-section perpendicular to the axis of the cable were taken for three of the welds.(Figures 6 to 8) Welds #3, #4, and #7 were chosen among the 8 welds to investigate the weld with crater, good bead and high energy as indicated in Table 1. A weld sample was cut as a proper length to mold with epoxy resin, and the sample was supported by a stainless steel clip.

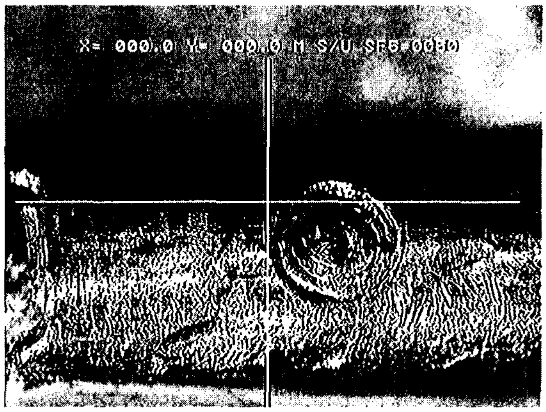

Fig. 5 Weld #4 clip surface (good)

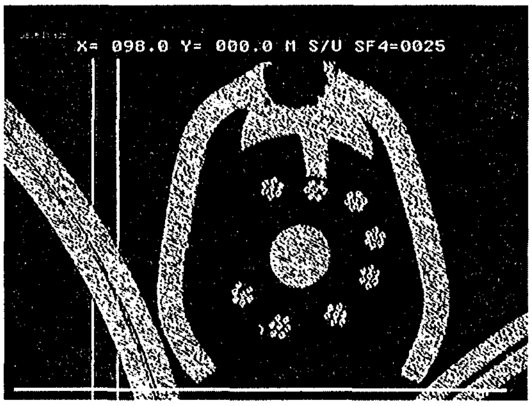

Fig. 6 Cross-section of weld #3 (crater)

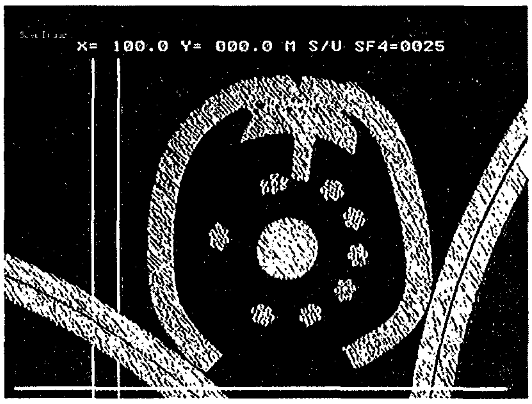

Fig. 7 Cross-section of weld #4 (good)

Table 1 Welding conditions and size of weld

Weld (clip) No.	1	2	3	4	5	6	7	8
Laser energy, J	7.2	7.2	7.2	7.2	7.2	7.2	7.6	4.2
Estimation by GSI	-	-	Crater	Good	-	-		
Eye inspection at OSU	Crater	Crater	Crater	Good	Crater	Crater	Crater	Not joined
Weld nugget size (axial/transverse dia), μm	511/608	725/776	591/608	549/612	617/636	523/632	660/764	452/540

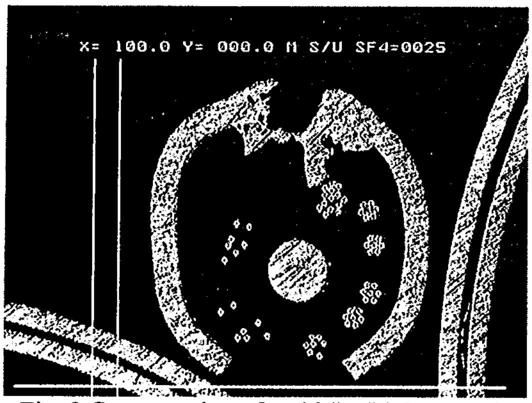

Fig. 8 Cross-section of weld #7 (high energy)

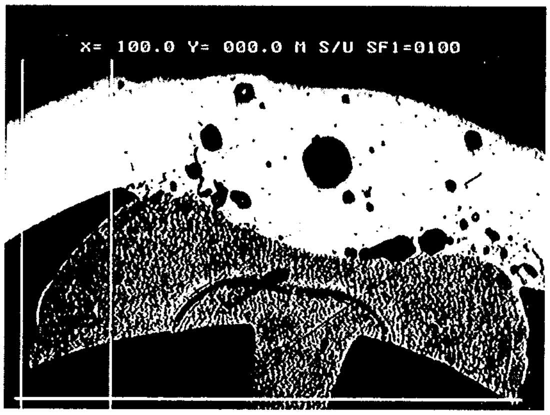

Fig. 9 Magnified micrograph of weld #4 in Fig. 7 after polishing and etching (4×)

4. Discussion

From the electric continuity test, there were several shorts between mini-cables. Reasons for this could be the placement accuracy of the holes drilled in the insulation of the wires. Further, two clips (#7 and #8) were not connected to any wires and two clips (#3 and #5) were connected to the same wire. It is expected that this also may be due to inaccurate hole placement in the insulation (see Figures 7 and 8). From visual inspection, clip #8 was not welded to the Ni dome. At the same time, all three Figures 6 to 8 show some coalescence of the Pt/Ir and Ni plating. This indicates that while the laser spot welding looks feasible, the drilling and plating process will require more development to ensure contact between the mini-cable and Ni plating.

Five of the first 6 welds had a crater in the weld nugget. Weld #4 is promising. Perhaps this is because the energy density was less for weld #4 (out of focus) though the weld nugget size does not support this conclusion. Perhaps also the surface conditions of the Pt/Ir were different for weld #4. Since all 6 welds were at the same laser energy (7.2 J), it is expected that this may be on the edge of too much energy per pulse.

For weld #3 (Figure 6), a deep hole was formed on the surface of the Pt/Ir clip at the weld center. Consequently, the amount of welded metal is small, decreasing the mechanical strength of the weld joint. However the weld still has good electric contact. For the good weld nugget (#4), there is no crater like weld #3, so the weld joint is much larger than that of weld #3 But several voids/pores are apparent in the weld (Figure 9). For the weld with the highest laser energy input (#7) there can be seen a big and irregular shaped crater in the weld (Figure 8). However, the weld still provides electric continuity. From the comparison of weld #7 with weld #3, i.e., there is a larger crater in weld #7 than weld #3 as expected.

The weld boundary between the Pt/Ir clip and Ni-plating can be seen in Figure 11. It shows that sufficient coalescence of the Pt/Ir and Ni dome. Since 5 of the 6 welds at a laser energy of 7.2 J developed a crater in the weld nugget, it is expected that less laser energy is needed. More experimentation is needed to seek an optimal laser energy for welding. Further, weld #4 gives us some indication of perhaps how the crater was formed. Since Pt/Ir has a higher melting temperature than Ni, it is possible that the voids are entrapped Ni vapor. Perhaps evaporation and rapid expansion of the Ni below the Pt/Ir clip led to expulsion of liquid layers of Pt/Ir during processing.

5. Concluding remark

The results of this investigation based on the inspection of several prototypical welds can be summarized as follows:

(1) The drilling and plating processes before welding are important to ensure electrical contact between the mini-cable and the Ni-plating.
(2) A promising laser spot weld was made between the Ni-plating and Pt/Ir clip. More effort is needed to define the optimal welding conditions. This suggests that a suitable spot weld is possible with one pseudo pulse.
(3) Some insight into the mechanism of crater formation has been provided which should be helpful in preventing or minimizing crater/void/pore formation.

References

[1] G.A. Knorovsky and D.O. MacCollum, The Effect of Laser Welding on LIGA Materials, ICALEO 2001

[2] A. Olowinsky, T. Kramer, N. Dumount, H. Hanebuth, New Applcations of Laser Beam Micro Welding, ICALEO 2001