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A Study on Copper Welding using Blue Laser

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Abstract: Welding of copper using laser have proven to be very challenging because of high reflectivity, high thermal conductivity and high heat capacity. Many methods have been developed to weld copper, ranging from ultrasonic welding to Infra-Red laser welding. The copper welding methods using ultrasonic welding and Infra-Red laser welding, however have many shortcomings and limitations. But a new developed technique of welding copper using blue laser has proved to eliminate most of these shortcomings and limitations. Here a study is presented to describe the details regarding this newly developed technique of welding copper using blue laser.

Keywords: Blue laser, laser source, visible spectrum, copper.

I. MOTIVATION

The near future in automobiles sector shows a significant change from the standard diesel petrol vehicles prepared to get replaced by electric vehicles. These electric vehicle runs on batteries and lots of assisted electronic components where copper is widely used. In the production of electro mobility components, laser material processing is one of the key technologies for achieving sophisticating goals while ensuring high quality standards for the electrical and mechanical connection. [1] Laser welding of copper is widely performed in these electrical and mechanical components including batteries. The copper welding using method such as ultrasonic welding and Infra-Red welding has many limitations. These limitations are seen within the area of high-performance electronics for the growing electronic vehicle market. A better weld quality with higher speed, compared to these prior techniques, is required to produce high performance batteries and electronics for the growing automotive market.

II. INTRODUCTION

This study relates to laser processing of materials, specifically laser joining of copper materials using laser beams having wavelengths from about 350 nm to about 500 nm, and greater. [6] It describes the method for the application of the laser beam, the beam size, the beam power, the method for holding the parts and the method for introducing the shielding gas to assist in the entire welding process.
Here, a visible light laser system i.e. blue laser is used for welding copper materials together. This is because a blue laser system forms essentially perfect welds for copper-based materials as copper is highly absorbent within the blue wavelength range. [2] Copper absorbs blue light 13 times more than it absorbs Infra-Red. [6] This blue laser system is to be used for welding conductive elements, particularly thin conductive elements, together to be used in energy storage devices like battery packs as well as various electro mobility components.

III. OBJECTIVE

To present a comprehensive study to understand the newly developed method of welding copper using blue laser.

IV. PROBLEMS IN WELDING COPPER WITH OTHER PROCESS

While using an **Infra-Red laser**, the high reflectivity of the copper at 1030 nm wavelength makes it difficult to couple power into the workpiece to heat and weld it. The problem with this method of welding, among others things, is that the vapour formed in the keyhole can lead to a micro-explosion, spraying molten copper all over the work being welded or the micro-explosion can produce a hole completely through the parts being welded.

Laser welding of copper by various other methods like using the Infra-Red laser with a green laser, wobbling the spot in the weld puddle, operating in a vacuum and modulating the laser at a high frequency etc. [5] are not much diversified. While these approaches are presently in use for some copper welding applications, they have narrow processing windows, uncontrolled spatter and an unpredictable variability in the welds produced, and finally have proved to be less than optimal. Another difficulty is faced while welding stacks of copper foil to each other and also to thicker bus bars. Presently, this cannot be done with an Infra-Red laser reliably or in a manner that produces the weld qualities that are required by manufactures. Thus, manufacturers have relied on **ultrasonic welding** methods to bond these copper foils

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together. These ultrasonic methods proved less than optimal and are problematic too. For example, by using ultrasonic welding methods, the sonotrodes (tool used to produce vibration) can wear out during working resulting in defects ranging from incomplete welds to welds with debris left behind. These deficiencies limit the manufacturing yield, the internal resistance of batteries, the energy density of the resulting batteries and in many cases impacts the reliability of the batteries.

V. PROCESS DETAILS (WELDING USING BLUE LASER)

The method includes placing a workpiece in a laser system i.e. the workpiece includes placing a first piece of copper material in contact with a second piece of copper material then directing a blue laser beam at the workpiece resulting in a weld formation between the first piece and the second piece of copper. [6] The obtained weld includes a HAZ and a re-solidification zone; wherein a microstructure of the copper-based material, the HAZ and the re-solidification zone are identical.

The method involved various listed steps to obtain a copper weld:

1. A number of pieces of copper foil positioned in a welding stand (wherein the foil contains at least about 50% cooper).
   Number of pieces: 10 to 50 pieces
   Thickness of copper foil: from about 80µm to 500µm

2. Exerting a force on these pieces of cooper foil to clamp these pieces of foil together in the welding stand.

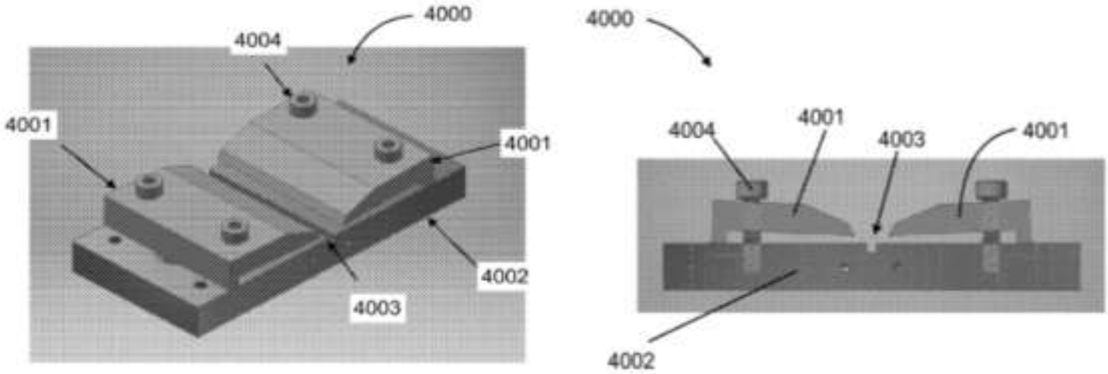

FIG. Schematic view of part holder [6]
4000- Welding fixture
4001- Clamp member or hold downs
4002- Base plate
4003- Support structure or base plate
4004- Bolts

3. Selecting an optical element from the group consisting of a lens, a fibre face, and a window.

4. Using these optical elements, directing a blue laser beam along a defined laser beam path at these pieces of cooper foil [3], wherein the laser beam having properties:
   Wavelength of blue laser beam: about 450 nm
   Beam: CW pulsed beam (1 microsecond and longer)
   Power: at least 500 Watts
   Beam parameter: a beam parameter product of about 44 mm mrad and less
   Spot size: about 400µm and less
   Average intensity: at least of about 400 kW/cm^2
   Peak intensity: at least about 800 kW/cm^2

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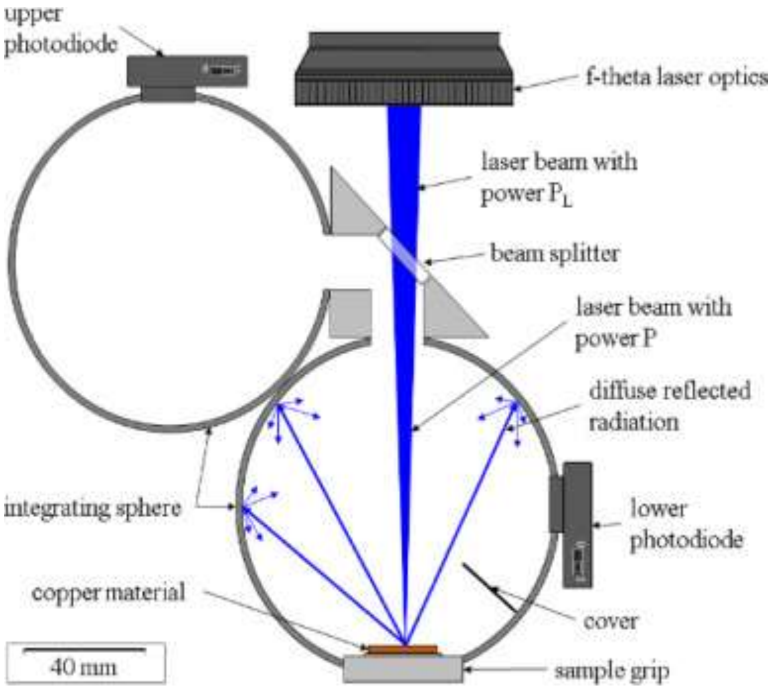

FIG. Process setup [1]

5.Using blue laser beam lap welding the number of pieces of cooper foil together at a welding a speed.
Welding speed: 10 m/min

6.Providing a non-oxidizing clearing gas in a space along the laser beam path (Wherein clearing gas removes plume material from the beam path and prevents oxidation of the number of pieces of cooper foil)
Clearing gas: selected from the group consisting of Argon, Argon-CO_2, Air, Helium and Nitrogen. [1]

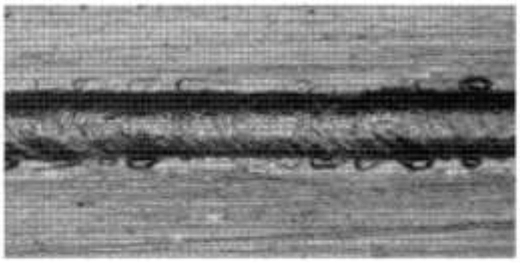

FIG. Weld on copper. [6]

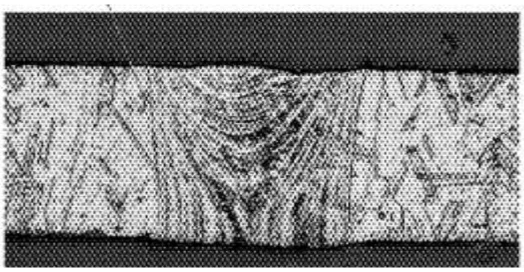

FIG. Bead on plate for weld.[6]

7.The welding speed, clamping force, and a flow rate of the non-oxidizing clearing gas, are pre-determined to provide a lap weld having no visible splatter and no visible porosity.

Results/Features of obtained weld

The systems and methods used here for welding of copper using blue laser has one or more of these following features:

- The identical microstructures show no discernible difference in the weld that would indicate any weakness in the obtained weld.
- The microstructure of the copper-based material, the HAZ and the re-solidification zone are identical.

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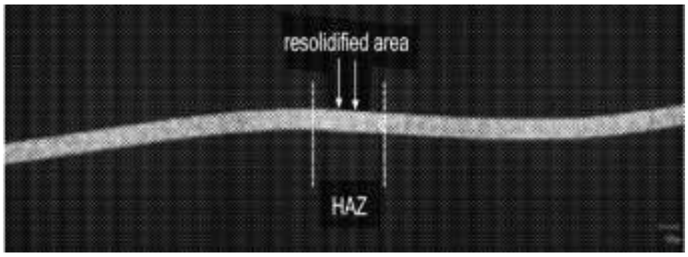

FIG. HAZ and resolidified area in welded copper. [6]

- The identical microstructure includes crystal growth regions of similar size.
- The weld is formed by conduction mode welding (in which there is no vaporization of the weld puddle during the welding process and produces a micro-structure similar to the base metal in the weld bead) and by keyhole mode welding (where very low spatter occurs during the weld and little or no spatter is observed on the surface of the copper after the weld)

FIG. Spatter free weld of copper. [6]

- The range of hardness for the re-solidification zone lies within the range of hardness of the copper-based material.
- The present laser beam systems heat the base material (the material to be welded, e.g. copper) faster than the heat dissipated away from the laser spot during welding.

Advantages

- The present method using a high-power blue laser source (450 nm) solves the problems with previous copper welding techniques. [4]
- This system and method provide stable welding in various welding techniques, including the conduction and keyhole welding modes.
- This system and method minimize, reduces and preferably eliminates, vaporization, spatter, micro explosions, and combinations and variations of these. [5]
- Larger spot sizes are also examined. The spot can be linear, circular, elliptical, square or other patterns. Preferably, the laser beam is continuous beam but here the laser beam can be pulsed, for example from about 1 microsecond and longer.

VI. CONCLUSION

There is a continuing and increasing need for better weld quality, higher speed welds, as well as, greater reproducibility, reliability, higher tolerances and more robustness in the welding of metals and, in particular, the welding of copper metals for electro mobility components including batteries.
Included in these needs, there is the need for an improved method for welding copper to itself and other metals; and, there is a need to address the issues associated with welding stacks of copper foils and these stacks to thicker copper or aluminium parts. The above studied method, among other things, solve these needs by providing the improvements, articles of manufacture, devices and processes. This system using visible spectrum contributes to green technology by reducing human impact on the natural environment.

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REFERENCES

[1] Marc et al. (2020) New approaches on laser micro welding of copper by using a laser beam source with a wavelength of 450 nm-Journal of Advanced Joining Processes. https://doi.org/10.1016/j.jajp.2020.100012

[2] Mark Steven et al. (2018) Blue laser diode (450nm) system for welding copper. Conference- High power diode laser technology XVI, DOI;10.1117/12.2291716.

[3] Feve et al. (2020) Scalable blue laser system architecture. Proc. SPIE 11262, High-Power Diode Laser Technology XVIII, 112620P.

[4] Mathew et al. (2017) Laser welding copper with high power CW blue laser Conference: ICALEO- 2017, 36th International Congress on Applications of Lasers & Electro-Optics, DOI: 10.2351/1.5138176.

[5] S Auwal et al. A review on laser beam welding of copper alloy, The International Journal of Advanced Manufacturing Technology 96(9–12):1-16 DOI:10.1007/s00170-017-1566-5

[6] Finuf et al. United State Patent US 10,940,562 B2