Development of Laser Welding Applications With Blue-IR Hybrid-Laser

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ABSTRACT With the trend of promoting carbon neutrality in the world, the vehicle electrification has begun to progress. When electrified, it is expected that the number of copper containing components will increase and the number of joining portion will increase. On the other hand, in copper welding with Infra-Red (hereinafter IR) fiber laser is said to be difficult to achieve a welding quality which has no welding defects, due to frequent occurrences of spatters and blowholes. We believe that Furukawa Electric's hybrid laser based on its characteristics could achieve the targeted welding quality without causing any defects during welding, and we are moving forward in the development of the applications. In this paper, the development results especially on the applications to in-vehicle batteries and motors are reported.

1. INTRODUCTION

Currently, in the world, the efforts to control the greenhouse gas emission are proceeding in order to prevent global warming. Japan, as is the case, has begun to work on various measures towards the achievement of the carbon neutrality in 2050. Among them, the efficient use of electrical energy is thought to play a major role. Especially, the vehicle electrification is focused on the issue and some manufacturers are even considering to use Electrified Vehicles (xEV) for all models sold at that time.

When vehicles are electrified, the amount of coppers used in batteries, motors and other components and their joining portions are expected to increase. The joining is carried out by various methods such as Tungsten Inert Gas (TIG) welding, ultrasonic welding and laser welding, but in recent years, the laser welding technologies has been attracting attention from the viewpoint of reduction in joining time and improvement in the degree of freedom on the joining shape. We have proposed a welding technology using IR fiber lasers. In particular, the IR fiber laser and the beam mode control technology proposed by Furukawa Electric have been well received by various customers due to its impact in the spatter suppression and the welding defect suppression.

On the other hand, copper has a problem that the light absorption rate is very low about 5%, because the wavelength of the laser light is longer than that of the IR fiber laser. Furthermore, when the beam mode control is not used, with a difficulty in a molten pool control, spatters occur frequently and under this influence blowholes occur frequently too, resulting in impossibility to obtain the required welding quality for the components. To solve this problem, there is a tendency to increase the absorption rate of the laser light by shortening the wavelength of the laser for welding. Visible light lasers such as blue and green, which have a higher absorption rate than IR, but the output of these lasers are still low. In consideration of the required welding time and the quality for each component, sufficient output is not guaranteed, in the current situation.

Here, it was considered that these problems could be solved by using an oscillator combined with a 450 nm band blue semiconductor laser and an IR fiber laser by utilizing the molten pool control know-how through beam mode control developed at Furukawa Electric. Currently, the above new laser and a new process using it are being proposed.

In this paper, as typical examples of the application of these newly proposed processes, the applications of the laser welding to batteries and motors, which are major components for xEV mentioned at the beginning, will be described.

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2. APPLICATION OF THE HYBRID LASER TO BATTERY COMPONENTS

The lithium-ion battery is manufactured through processes such as “coating”, “electrode cutting”, “current collector welding”, “sealing” and “modularization” as shown in Figure 1. Above all, for the lithium-ion battery whose battery capacity is determined by the surface area of the laminated electrodes in the current collector, a multilayering technology for the current collector is required. Furthermore, in advancing the multi-layering of the electrode foils, suppressing the copper powder generation during the joining process is also a technical issue. If copper powder is generated in the joining process, metal precipitation is induced in the active material of the battery cells. Then the precipitates break through the separator which is situated to prevent contact between the positive electrode and the negative electrode, resulting in a short circuit. This can cause the battery overheat, and in the worst case, leads to an accident such as ignition.

In order to solve these problems, it is necessary to develop and to apply a laser welding technology that does not generate the spatter in the current collector welding process. So, it is expected and bringing attention on the achievement of a multi-layer electrode foil welding technology that leads to improvement in the battery performance and its safety. However, when the current collector welding is performed using a general fiber laser, as described above, because of the low laser light absorption rate in the solid state copper, the molten portion is not stable due to the rapid local heat input. And the foil in the surface layer is torn as shown in Figure 2, or the spatter is generated as shown in Figure 3, which both raises issues.

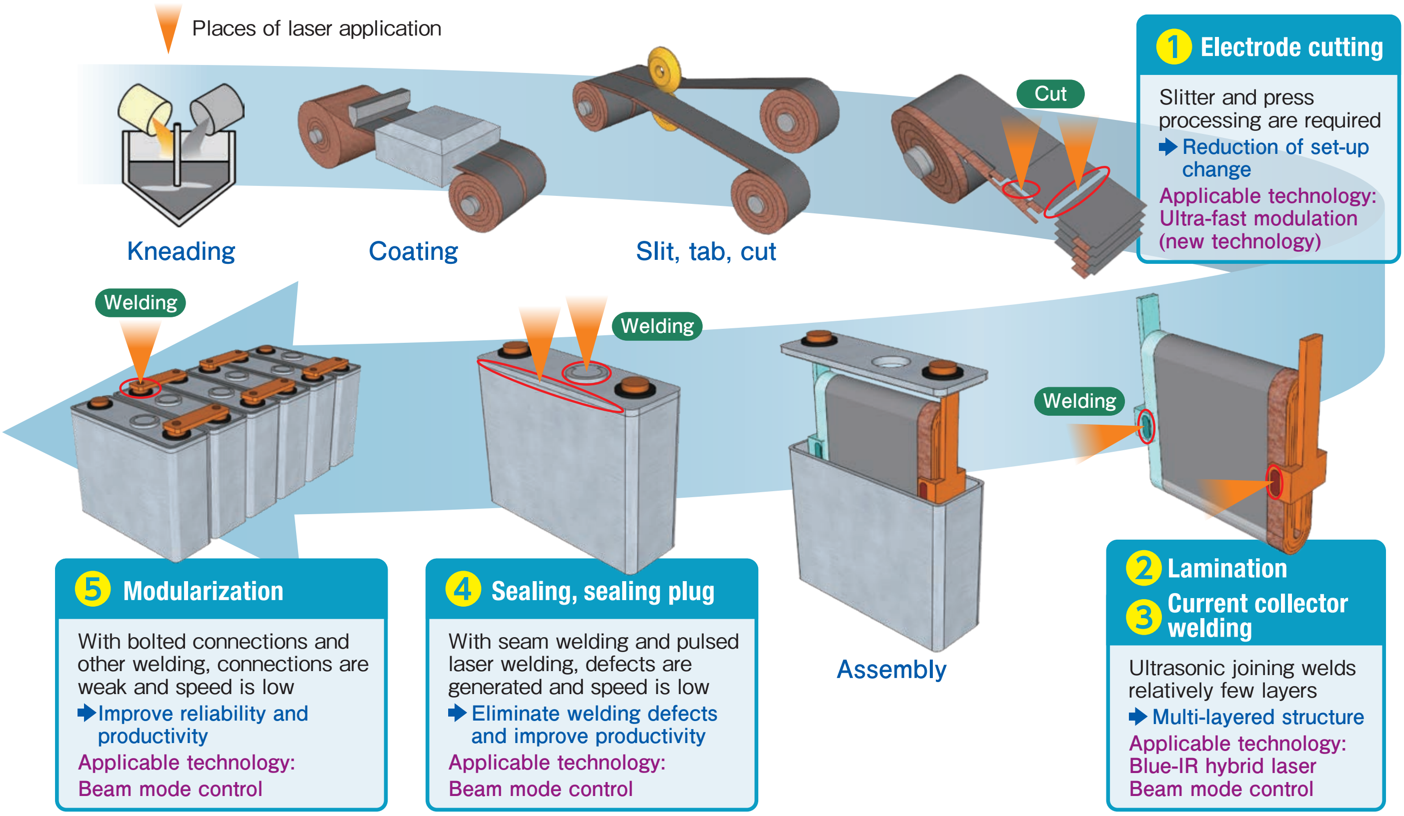

Figure 1 Example of manufacturing process for lithium ion battery.

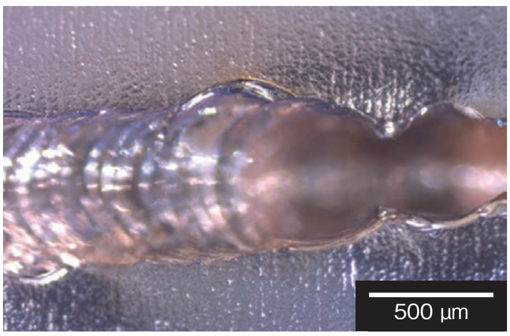

Figure 2 Surface of current collector welding with a general fiber laser.

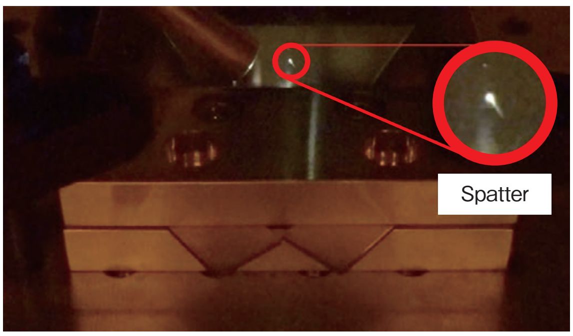

Figure 3 Status of processing with a general fiber laser.

BRACE is a Blue-IR hybrid laser using two types of lasers, and makes possible to flexibly control the input heat distribution by appropriately adjusting the respective laser conditions. Then the defects shown in Figure 2 can be prevented by forming a stable molten pool even for processed products like a metal foil. With this stable molten pool forming, deep penetration processing can be achieved by suppressing the spatter generation, which is a serious problem in the current collector welding process. Regarding the principle, see the separate paper "Features of Blue-IR Hybrid Laser and Copper Processing Technique" included in this special issue.

Figure 4 shows a welding result, using BRACE, for a laminate consisting of 50 copper foils and a copper plate simulating a current collector. As can be seen from the surface and the cross-sectional photographs, it is demonstrated that a high-quality welding is achieved while ensuring a sufficient welding width and suppressing the occurrence of welding defects such as spatters and blow holes. Figure 5 shows the welding result of a structure in which a copper foil is placed between two copper plates. As described, welding is possible even for the structure consisting of copper plates and a copper foil that have different shapes.

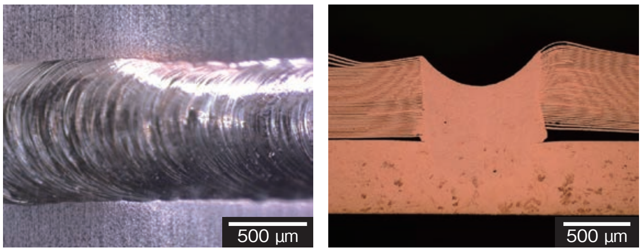

Figure 4 Current collector welding example 1 with BRACE.

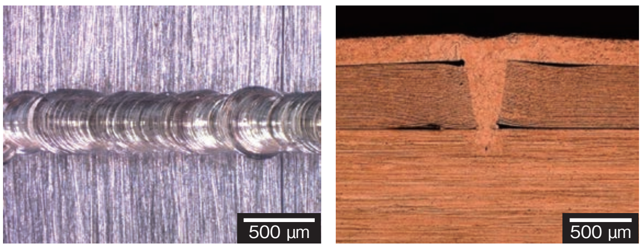

Figure 5 Current collector welding example 2 with BRACE.

3. APPLICATION OF THE HYBRID LASER TO MOTOR JOINING POINTS

As mentioned at the beginning, as the electrification progresses, demands and types of motors will be increasing. So, it is considered that demands for productivity improvement will increase also complicated motor shapes differed from the conventional ones will appear. Therefore, considering the contribution to these from the viewpoint of the welding, the shortening of the welding time and the welding corresponding to various joining shapes are required. The laser welding is available by irradiating the laser light to arbitrary points. In view of this, the welding with the shape shown in Figure 6, which is different from the conventional overlapping shape welding, can be easily available. Even if the shape of the motor becomes complicated, its welding will be available.

On the other hand, in the conventional fiber laser welding which focuses on a laser beam with a high energy density at one point, spatters and blowholes occur in the same manner as the welding process for battery. Considering that the motor is an electric device, it is easy to imagine that the spatter occurrence not only causes a decrease in the strength of the welded portion, but also adhere to the inside of the circuit and induces an unintended short circuit which leads to an equipment failure.

Figure 7 shows a condition when hairpin welding is performed with using of BRACE. From this figure, it can be seen that the welding is performed with a considerable suppressing of the spatter. Currently, the hairpin welding with BRACE takes more than 0.3 seconds. Considering the improvement of motor productivity in the future, it is necessary to shorten this welding time, and for the purpose of reducing the welding time to 0.1 seconds or less, currently the output of oscillators is being increased and the development of the process technology is proceeding. We believe that we will be able to provide a shorter time and a high-quality welding, in the future.

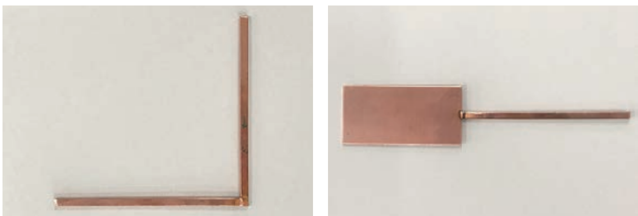

Figure 6 Free-form welding results using a laser welding.

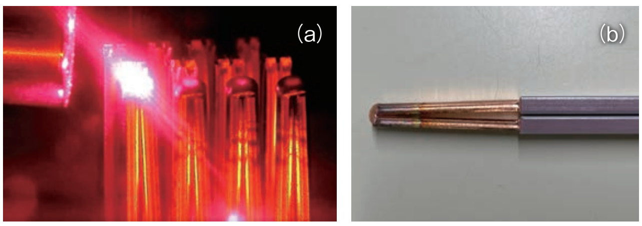

Figure 7 Welding of rectangular wire with BRACE.
(a) State of welding (b) Welded sample

Furthermore, in collaboration with NITTOKU Co., Ltd., we are currently developing a welding machine equipped with a laser and a Galvano Scanner as shown in Figure 8. The laser can be selected for the IR-multimode lasers, as well as for the hybrid lasers. We would also like to make it possible to propose not only as oscillators but also as a processing equipment to customers who are considering the application of the laser welding in motor manufacturing processes.

Figure 8 Winding welder equipped with BRACE (prototype).

4. CONCLUSION

As mentioned in this paper, BRACE is a product that takes advantages of the knowledge gained in the beam mode control technology and the copper welding technology developed by Furukawa Electric, and currently its adaptation to batteries and motors is being promoted. Regarding proposals in this field, and in addition to the oscillator and the joining process technology, we are working with our partner in order to make also possible proposals for a processing equipment.

In addition, it is also possible to bring in customer’s samples to our Chiba Works and try them for process examination using BRACE. Furthermore, in June 2021, a Co-application laboratory was opened at YOKOHAMA RESEARCH CENTER in NICHIA CORPORATION, and it is possible to try it there. (Figure 9)

We will proceed with the development of the welding technology, aiming to be able to make proposals towards a society where electrification and even carbon neutrality can be achieved.

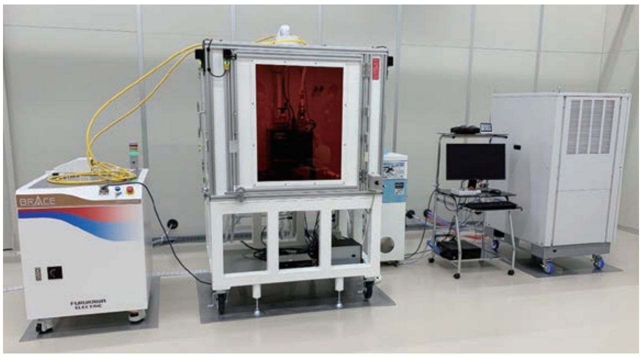

Figure 9 Co-application laboratory (YOKOHAMA RESEACH CENTER, NICHIA CORPORATION).