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# Evolution of laser welding to dissimilar materials joining<sup>†</sup>

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**KEY WORDS:** (Laser Welding) (Dissimilar materials joining) (Steel) (Aluminum alloy) (Plastic) (TEM image)

## 1. Introduction

Metals and plastics have been used in several industrial applications such as automobiles, electronic devices and aircrafts. The features of metals include high strength, high toughness, high heat conductivity and high heat resistance. For example, low carbon steel is typical for automobile parts, for its easiness of press working in addition to the above properties. Moreover, aluminium alloy has a good resistance to corrosion and is lightweight, so it would be utilized more and more for weight saving of transport machines. On the other hand, plastics are characterized by lightweight, high corrosion resistance and excellent formability. Polyethylene terephthalate (PET) is known as a typical engineering plastic and commercially available bottles.

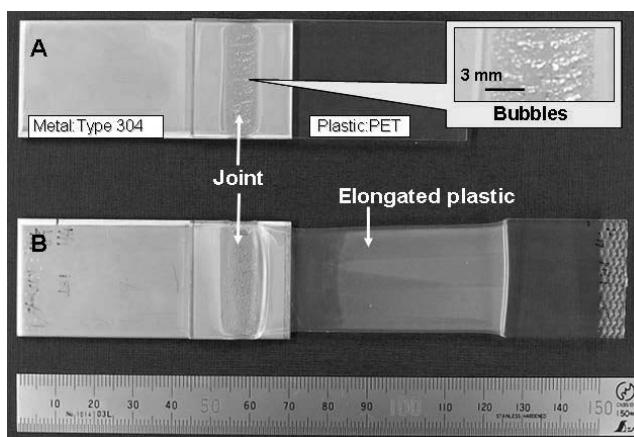
Recently it has been reported that the LAMP joining between metals and engineering plastics could produce sufficiently strong joints, which possessed tensile shear loads of more than 3000 N with samples of 30 mm width as shown in **Fig. 1** [1]. The LAMP joining is characterized by the formation of small bubbles in the plastic just near the interface, and it was interpreted that the bubbles enabled the melted plastic to join to the metal surface by the generation of their high pressures. Plastics and metals were tightly bonded in nanometer sizes, which suggested the strong physical bonding and a possibility of chemical bonding.

In this research, LAMP joining method was applied to

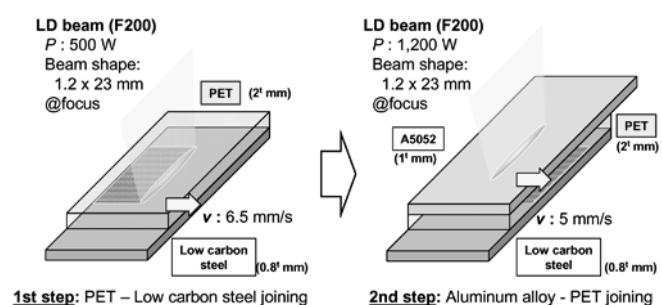
produce a strong dissimilar metal joint. The LAMP joining was created by optimization of diode laser (LD) joining parameters such as laser power or welding speed depending on each kind of material. The metallic materials used were low carbon steel and aluminium alloy because this combination was expected to be utilized more extensively in transportation means. PET was used as plastic material because it could produce strong joints with various metallic materials and some joint parts could resist heat cycle tests according to the previous research [2]. Thus it was thought that PET was one of the best plastics suited to dissimilar metal joining. The strengths of LAMP joints were measured by tensile shear testing. The best welding conditions were obtained for PET and low carbon steel as well as PET and aluminium-alloy, and dissimilar metals joining was implemented separately under these conditions to evaluate the joint strengths.

## 2. Experimental Results and Discussion

Dissimilar metal welding was exploited with the procedures as illustrated in **Fig. 2**. The first step of dissimilar welding was the LAMP joining between PET and low carbon steel by plastic side irradiation, and the second step of joining was performed between A5052 and PET by metal side irradiation, under the respective desirable welding conditions. The dissimilar metal joint through a plastic plate could be fabricated. The tensile shear load achieved 5000 N. This was because the stress on the plastic was compressive in the tensile shear test, so the joint strength was improved in comparison with the base plastic elongation of 3000 N. In addition, the joint part had no



**Fig. 1** LAMP joints before and after tensile shear test.



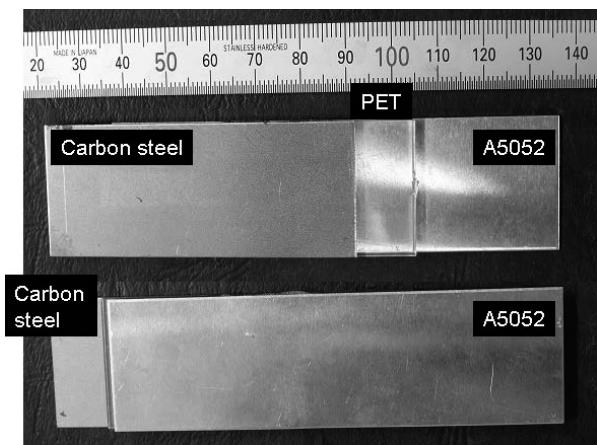
**Fig. 2** Schematic experimental set-up of LAMP joining for dissimilar metal welding.

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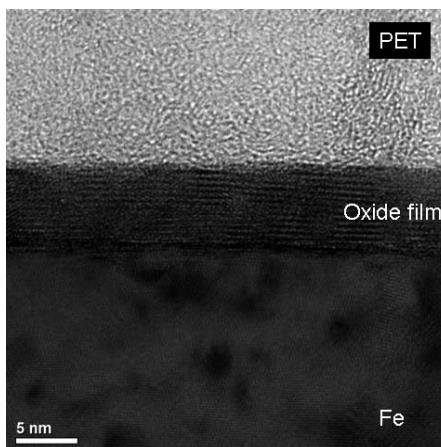
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weld bead on both surfaces of A5052 and low carbon steel, and showed good appearances as shown in **Fig. 3**.

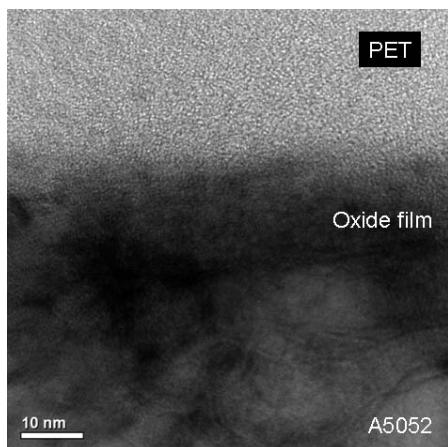


**Fig. 3** Surface appearances of dissimilar metal welds produced by LAMP joining with both-side irradiations.

Concerning the boundary between carbon steel and PET in the obtained joint, the observation image is shown in **Fig. 4**. The bright upper part is PET polymer and the dark lower area is Fe. The TEM image demonstrates



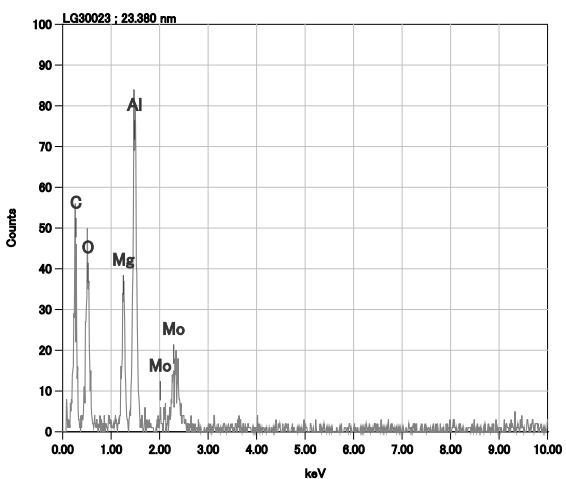
**Fig. 4** TEM image of boundary between carbon steel and PET in dissimilar metal weld.



**Fig. 5** TEM image of boundary between aluminum alloy and PET in dissimilar metal weld.

that the carbon steel and the plastic are tightly bonded at the atomic or molecular size level.

On the other hand, as for the boundary between A5052 and PET in the obtained joint, the observation image is shown in **Fig. 5**. The bright upper part is PET and the dark lower area is A5052 aluminum alloy. The TEM image also demonstrates that the aluminum alloy and the plastic are tightly bonded at the atomic or molecular size level, which was similar to the above-mentioned LAMP joints. Moreover, it was found that the oxide film was composed mostly of aluminum and magnesium by energy dispersive X-ray spectroscopy (EDS) analysis as indicated in **Fig. 6**. A carbon peak was measured in the EDS analysis, which means that the oxide film of A5052 and the polymer molecule of PET are close on the atomic or molecular size level.



**Fig. 6** EDS analysis of dissimilar metal weld with LAMP joint.

### 3. Conclusions

LAMP joining made dissimilar metals joining possible without formation of brittle intermetallic compounds between them and without dissimilar metal corrosion or bimetal corrosion by sandwiching a plastic plate. The dissimilar metals joint with a plastic plate could be fabricated and the joint shear load reached to 5000N, which was high. Then both A5052 sheet and low carbon steel sheet were deformed and elongated due to the formation of strong joints.

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