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Laser spot welding of copper-aluminum joints using a pulsed dual wavelength laser at 532 and 1064 nm

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Abstract

A modulated pulsed laser source emitting green and infrared laser light is used to join the dissimilar metals copper and aluminum. The resultant dynamic welding process is analyzed using the back reflected laser light and high speed video observations of the interaction zone. Different pulse shapes are applied to influence the melt pool dynamics and thereby the forming grain structure and intermetallic phases.
The results of high-speed images and back-reflections prove that a modulation of the pulse shape is transferred to oscillations of the melt pool at the applied frequency. The outcome of the melt pool oscillation is shown by the metallurgically prepared cross-section, which indicates different solidification lines and grain shapes. An energy-dispersive x-ray analysis shows the mixture and the resultant distribution of the two metals, copper and aluminum, within the spot weld. It can be seen that the mixture is homogenized the observed melt pool oscillations.

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1. Introduction

Laser welding of copper to aluminum is challenging due to several restrictions, which can be derived from the material properties listed in Tab. 1.

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Nomenclature

Al	aluminum
A_{Rip}	amplitude of the modulated power signal in kW
Cu	copper
d_f	focus diameter in µm
EDX	energy-dispersive X-ray spectroscopy
P_{peak}	maximum pulse power in kW
P_1	pulse power in the timeslot t_2 in kW
λ	laser wavelength in nm
λ_{Rip}	wave duration of the modulated power signal in ms
f_{Rip}	frequency of the modulated power signal in Hz
t_1	duration of the peak pulse signal in ms
t_2	duration of the constant or modulated pulse signal in ms
t_3	duration of the decreasing signal in ms

One main challenge is the low absorption of aluminum and especially copper at the laser wavelength of 1 µm. Thus a green laser source in addition to infrared laser light proved to enhance incoupling efficiency and stabilize the welding process [1][2][3][4][5][6][7].

Table 1. Material properties of aluminum and copper [9][10][11].

	Aluminum	Copper (Cu-ETP)
Heat conductivity κ in W/(mK)	235	390
Heat capacity c_p in J/(gK)	0.89	0.386
Density ρ in g/cm^3	2.70	8.93
Absorption at 1 µm in %	6	3

The other challenge is given by the metallurgy of the two mixing materials. Intermetallic phases are likely to form and possess very brittle properties, which are probably resulting in crack formation. Therefore, the mixing behavior of the two metals is of major interest and discussed in several publications [12][13][14][15][16]. As the phase diagram of aluminum and copper, depicted in Fig. 1, reveals, especially between 50 and 80 at.-% of copper intermetallic phases are likely to form.

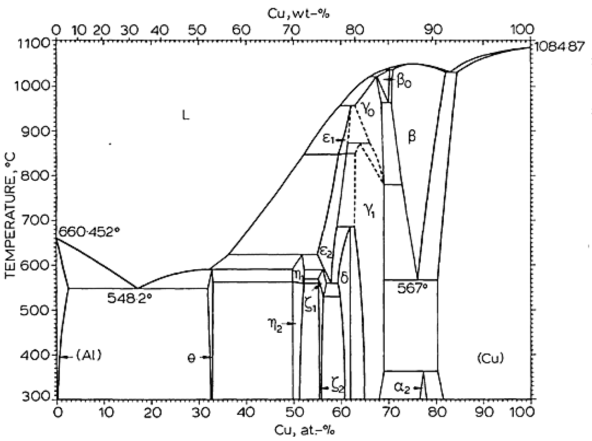

Fig. 1. Phase diagram of aluminum and copper [17].