Laser Welding of Polyamide-6.6 and Aluminium

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Laser welding of polyamide-6.6 and aluminium: effect of preliminary aluminium anodisation treatment

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Abstract

Laser welding is an innovative process when it is applied to hybrid structures like metal-polymer structures. In this study, we focus on the assembly of lightweight structures such as those joining a light metal, aluminium, with an engineering polymer, polyamide. Since the quality and then the weld strength is largely influenced by the surface of the adherends prior to the assembly, the effect of aluminium anodisation is investigated in this work as an adhesion promotion treatment. More precisely, the formation of a barrier layer, and the growth of a porous anodisation layer on top of it, is investigated. The effect of anodisation time and voltage to give different surface characteristics of aluminium, and therefore to provide different strength when welded to polyamide, is evaluated. Anodisation is very beneficial to the strength of the hybrid assembly. However, the link between surface characteristics and joint strength needs further investigations.

Keywords

Aluminium, Anodisation, Surface characterisation, Laser welding, Polyamide, Shear strength

Introduction

Laser welding of metal-polymer assemblies is a fast and innovative process for the development of strong joints in lightweight structures for automotive industries or hybrid structures in biomedical industry. Similar to chemical joining techniques such as adhesive bonding, strength of laser welded assemblies has been shown to be largely influenced by surface chemistry and surface topography of the adherends. This was demonstrated in the case of polymer surface treatment[1] or metal surface treatment for aluminium (Al)[2].

Anodisation of aluminium is a well-known treatment for adhesion promotion purpose. It produces a self-ordered porous oxide layer which is very beneficial to adhesive bonding[3].

In the present study, aluminium anodisation treatments are carried out in order to improve the adhesion of Al-polyamide (PA) assemblies after laser welding. This idea was previously reported in a previous article[4], where anodisation time is changed in order to change the Al surface morphology. In this study, the growth of the porous Al oxide layer is investigated to determine some characteristic anodisation times related to the formation of the barrier layer followed by the growth of the anodic porous layer[5]. The surface morphology and chemistry of Al samples after anodisation is evaluated, as well as their water wettability. Their surface characteristics are then linked with the quality of assembly when treated aluminium is joined to polyamide by laser.

Experimental methods and materials

Materials

AluminiumThe joining partners are 0.5 mm thick EN-AW1050A aluminium (Al) in half-hard state having geometry of 30 mm × 60 mm, and 4 thick mm polyamide 6.6 (purchased from Dutec) with the dimensions of 25 mm × 75 mm.

Prior to the joining process, Al samples were prepared by anodisation. PA samples were wiped with ethanol.

Anodisation

Before anodisation, Al samples are cleaned by immersion in an ultrasonic bath of acetone during 5 min., followed by flushing the sample surface with deionized water and drying in a flow of compressed dry air.

Anodisation is performed in a solution of phosphorous (H_3PO_3) acid in water (10% wt.), in which Al sample is the anode and a platinum grid is the cathode. Then the anodisation process is performed at a constant voltage, see table 1.

After anodisation, Al sample is washed with deionized water and let to dry.

In a first set of preliminary experiments, the voltage is set to 20V and the current is recorded as a function of time during 20 min. It shows that the formation of the anodic barrier layer takes approximately 10s, and is followed by the growth of the anodic porous layer. Two anodisation times at 180s and 600s allow to evaluate the layer properties at two different levels of growth.

Table 1 : Al samples identification following the anodisation parameters

Samples identification			**Anodisation time, s**		
			10	**180**	**600**
Anodisation voltage, V	**10**		10-10	10-180	10-600
	20		20-10	20-180	20-600
	30		30-10	30-180	30-600

Since the pore size and porous layer growth rate increases with anodisation voltage, anodisation experiments are carried out at three constant voltages: 10V, 20V and 30V. Table 1 summarizes these parameters and gives the corresponding sample identification.

Scanning electron microscopy (SEM)

A pressure-controlled FEI Quanta FEG 200 scanning electron microscope from FEI Company is used in secondary electron mode to get information about the samples morphology. The acceleration voltage is generated at 10 kV.

Water wettability

Sessile drop test measurement is performed by a contact angle system OCA 15 from Dataphysics.

Laser welding

Laser welding is performed using a fiber laser (TruFiber 400 from TRUMPF). More information about the process is provided in the article[6].

Strength of the assembly

The joint strength was quantified by means of a single-lap shear test[6].

Results and discussion

SEM pictures at high magnification (80 000x) show that a honeycomb shape porous structure is formed for high anodisation times (Fig. 1).

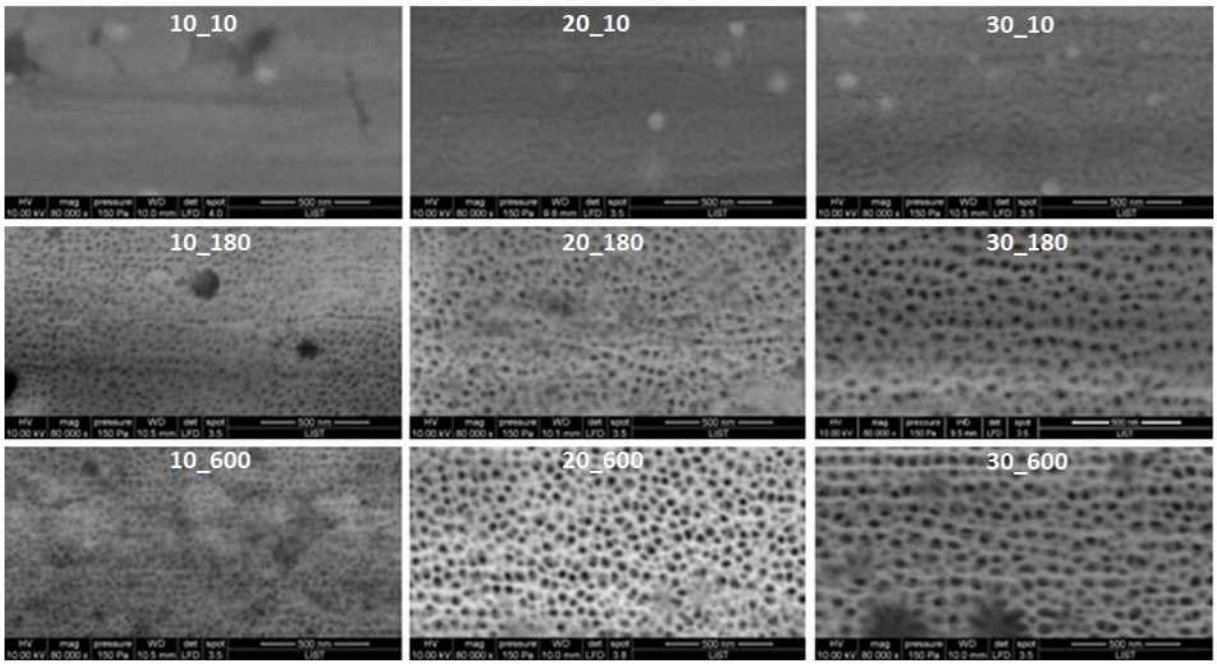

Fig. 1 : SEM pictures obtained for 9 anodisation conditions

Interestingly, the water contact angle data (Fig. 2) are consistent to the SEM pictures, i.e. the angle decreases with the increase of voltage and anodisation time. The only remarkable exception is observed for 30-600 sample, for which the wettability is lower than 20-600 and 30-180. It is assumed that either the lower pore density for 30V compared to 20V and 10V, or the ability of 30-600 sample to trap air in its porosities, is responsible for this result.

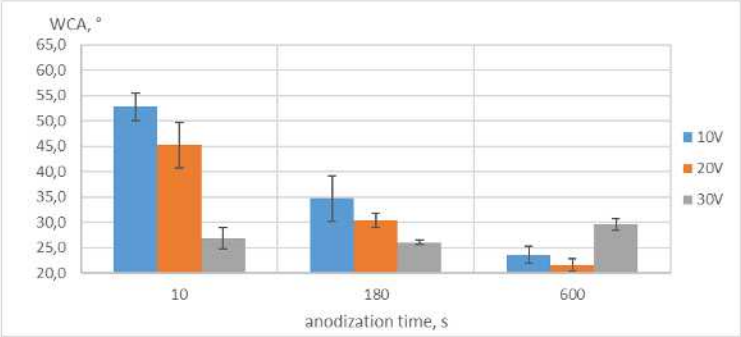

Fig. 2 : water contact angle (WCA) obtained for 9 anodisation conditions.

Seven anodisation conditions out of nine are selected as the most characteristic surface state for further welding and shear strength evaluation (fig. 3).

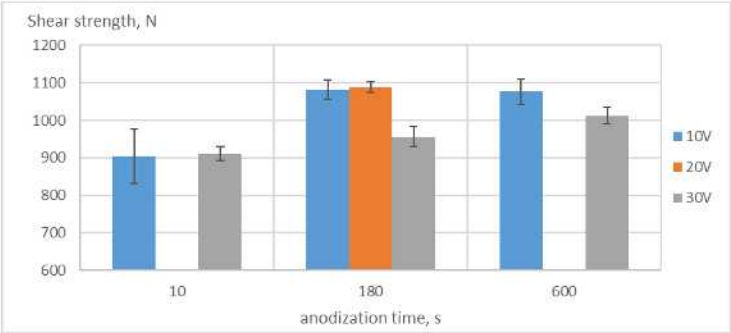

Fig. 3 : shear strength (in N) obtained for 7 anodisation conditions.

For 30V samples, the strength increases with anodisation time, i.e. with porous layer thickness. For 10V samples, this is similar but no further increase is recorded for times greater than 180s.

Comparison of samples performed with an anodisation time of 180s but different voltages show that best results in terms of strength are obtained for 10 and 20V. For information, the strength of reference sample (for Al samples only cleaned by solvents) is close to 700N, meaning that anodisation actually leads to an improvement of the strength, whatever the anodisation conditions.

Conclusion

The effect of both anodization time and voltage on the surface characteristics of treated aluminium is evaluated, as well as its effect on the strength of Al-PA assemblies when PA is laser welded to anodised Al.

Whatever the anodization conditions, it leads to an improvement of the strength of the assembly compared to the untreated sample. And the formation of the porous layer on top of the barrier layer further improve the strength. Still, the link between surface characteristics and strength of the assembly needs further investigation.

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