Cranfield Plasma Solutions

Special Report

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Title: 50W Plasma Tact - Surface Energy Modification: 6082 Aluminium

Executive Summary

The 50W Plasma Tact was deployed for surface energy modification on an Aluminium 6082 sheet from RS Components, using optimised parameters: 50W forward power, 0W reflected power, 2.48GHz, 10L/min argon, and a 3mm stand-off distance. The surface free energy of the aluminium alloy sheet was increased at a speed of 30m/min, which was a speed previously demonstrated on Mylar to show maximum surface energy modification at a speed that will be acceptable to industry. The water contact angles and surface energy along the path of the plasma torch were characterised, as this sample from RS Components was a real world example of a sheet of aluminium that will be processed in industry and not a virgin substrate that is typically used in university laboratory experiments. Water contact angles were between 80° to 125° before processing and this range reduced to between 10° to 15° after plasma processing. The significantly high pre-processing contact angles on the alloy surface, were due to significant surface contamination in the form of finger prints and other oils, which are typical in industrial settings, but rarely shown in published literature.

Method

The 50W Plasma Tact was installed into the RAP machine. The plasma torch parameters were set so that the optimal plasma was discharged for surface energy modification using pure argon gas: 50W forward power, 0W reflected power (0W was achieved rather than 1W due to the environmental conditions), 2.48GHz frequency, 10L/min gas flow rate, and a 3mm stand-off distance. The stand-off distance of 3mm was found to be optimal, in previous work packages, on both glass and Mylar, which is a polymer used in the EV sector [I,II].

A single plasma pass was conducted, using a complex path, over the surface of the 6082 Aluminium sheet. The complex path was undertaken for two reasons: firstly, to demonstrate that only the plasma processed path would have the increased surface energy; and secondly, so that multiple points along the processed path could be measured and compared. The latter point was important to analyse, because the aluminium alloy sheet was a typical example from a supplier, which unlike most examples in literature had significantly different initial surface energies across its surface due to surface scratches and contamination such as finger prints. Literature shows that typical water contact angles for unprocessed 6082 Aluminium alloy sheets will be circa 70° [III]. In fact, when measuring the water contact angles on the RS Components sheet, water contact angles of between 80° and 125° were observed. The higher water contact angles were concluded to be due to finger prints and other surface contamination. Note well, that no surface roughness characterisation was performed; and, even though the surface roughness should not have changed due to the plasma process, the scratches on the surface of the sample will change the absolute surface free energies calculated; however, this does not affect the relative change in surface energy created by the plasma. RS Components generally use a plastic protective film, on their sheet samples; however, this sample was sent with no such protective layer; hence, the scratches on the sample's surface and the contamination, which is representative of real world manufacturing workshops.

The video titled '6082Al' shows the aluminium sheet being processed at 30m/min set speed; however, note well that the torch only reached the maximum speed on the long passes, whereas on the short passes slower speeds were achieved due to the limit of the acceleration curves on the motion stage. Figure 1 shows how water preferentially sticks to the plasma processed areas on the surface of the sheet.

Figure 1

Contact angles of deionised water and ethylene glycol were measured, at various stages on the path of the plasma, which enabled the surface energy along the path to be characterised. The Owens, Wendt, Rabel and Kaelble method for surface energy calculation was deployed, which is a well-established method for flat, smooth surfaces that naturally exhibit relatively low to high surface free energy [IV].

50W Plasma Tact Results

Figure 2 shows the water contact angles on the aluminium alloy surface. The water contact angles before plasma processing varied significantly between 80° and 125°, which corresponds to different levels of surface contamination across the surface of the sample.

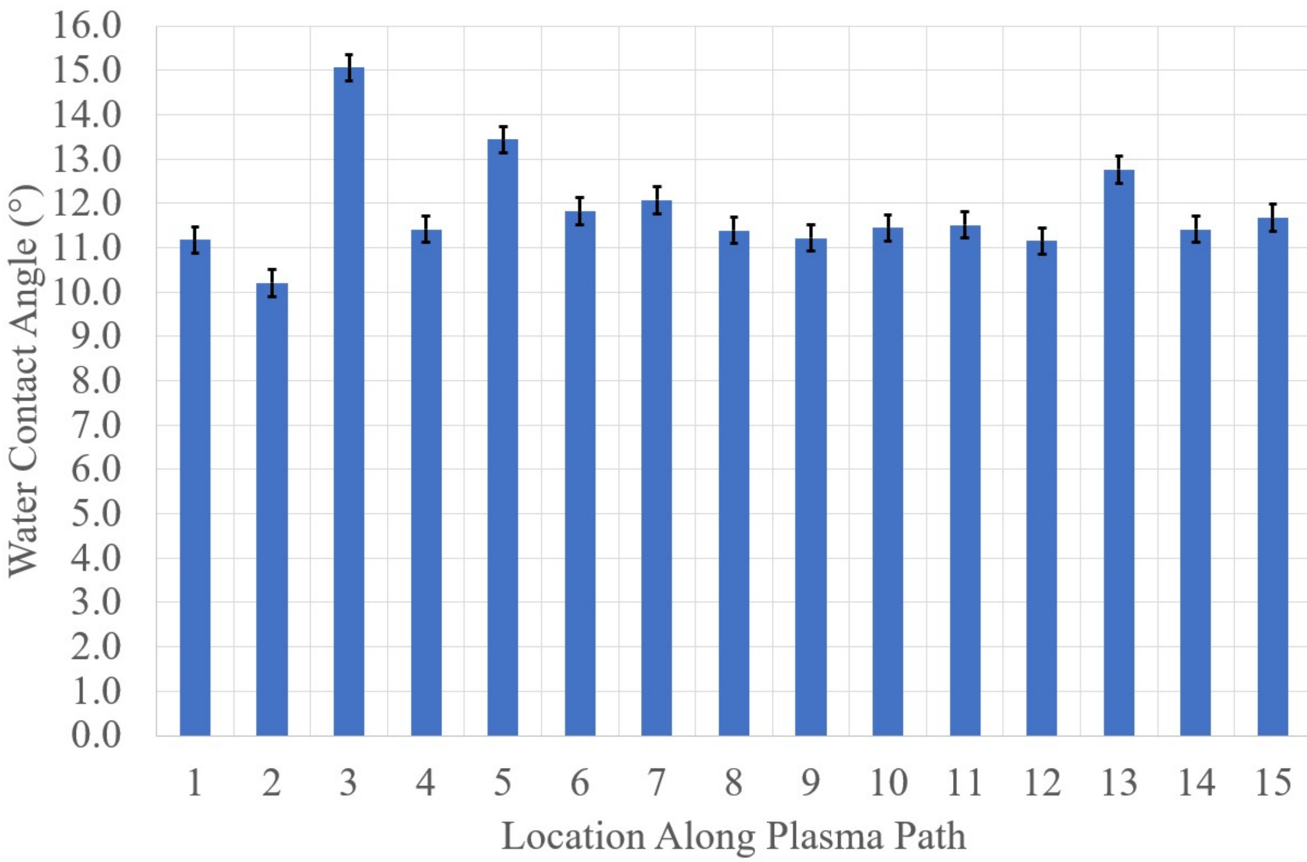

Figure 2
50W Plasma Tact – Aluminium 6082 – Water Contact Angles After Plasma Process
(Starting Contact Angles = 80° to 125°)

The post plasma processing contact angles all fall within a relatively narrow range of circa 10° to 15°, which shows that the plasma processing has made a significant improvement to the wettability of the aluminium alloy surface, irrespective of the level of pre-existing surface contamination.

Figure 3 shows the surface energy on the aluminium alloy, after plasma processing the surface. The surface energy along the plasma path falls within the range of circa 92mN/m to 95mN/m, which may indeed appear high when compared to glass and polymers but compared to pure aluminium is in fact relatively low. Pure aluminium has been measured to have a surface energy of 840mN/m [V]; however, in the presence of air, an oxide layer will form on the aluminium surface, which will reduce this value and alloys are known to exhibit relatively lower surface energies. Notwithstanding, the resultant surface energy of circa 92mN/m to 95mN/m is due to the water contact angles being circa 10° to 15°, which in turn is due to the pre-existing surface conditions.

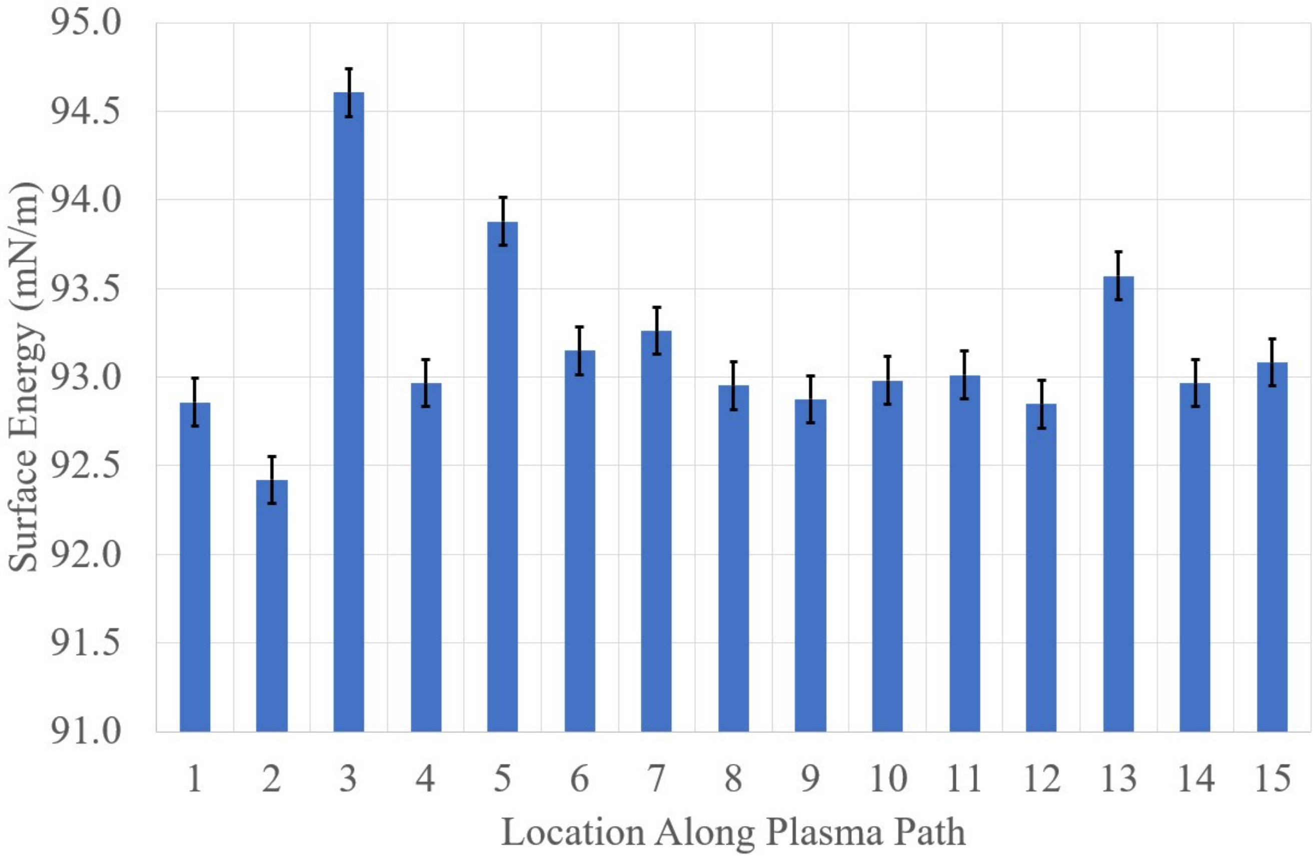

Figure 3
50W Plasma Tact – Aluminium 6082 – Surface Free Energy After Plasma Process

The increase in surface energy corresponds to the increased wettability of the aluminium alloy surface, which is shown in Figure 1. This result shows that plasma adds value to manufacturing chains, by increasing the wettability and hence the bonding of the surface to other materials and coatings. Further cleaning of the surface could be performed, but would require processing at slower speeds, which would not be acceptable to industry as plasma technology must add value to manufacturing processes without increasing manufacturing timeframes.

Conclusion

The 50W Plasma Tact has been deployed to increase the hydrophilicity of 6082 aluminium. The wettability was achieved with optimised plasma parameters at a processing speed of 30m/min, which was the speed shown on Mylar to have maximum plasma benefit, whilst processing fast enough to add value to manufacturing chains. Water contact angles were reduced from between 80° to 125° down to between 10° to 15°, which is a significant result considering the pre-existing surface contamination.

References

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