Cranfield Plasma Solutions

Special Report

Date: 06/06/2022

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Title: 50W Plasma Tact - Surface Energy Modification: Mylar

Executive Summary

The 50W Plasma Tact was deployed for surface energy modification on Mylar thin films, using optimised parameters: 50W forward power, 1W reflected power, 2.48GHz, 10L/min argon, and a 3mm stand-off distance. The surface free energy of the Mylar was increased to a maximum value, which was limited by the local surface melting of the Mylar. The minimum speed achieved, at the optimised plasma parameters, was 1m/min; however, this value resulted in the melting and was unnecessary as a similar surface energy increase was seen when processing at 30m/min. The width of the plasma effect was circa 6mm at 30m/min speed and results in the minimum processing time for the entire surface of a Mylar substrate.

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, 1W reflected power, 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, as a larger distance results in a smaller change in surface energy and a smaller distance sometimes results in plasma shutdown due to plasma jet flow restriction [I].

Single plasma passes were conducted over the surface of Mylar samples to investigate the effect of moving at different speeds. Each sample was processed with three different single passes to ascertain the repeatability of the process. Figure 1 shows the direction of the plasma passes over each sample.

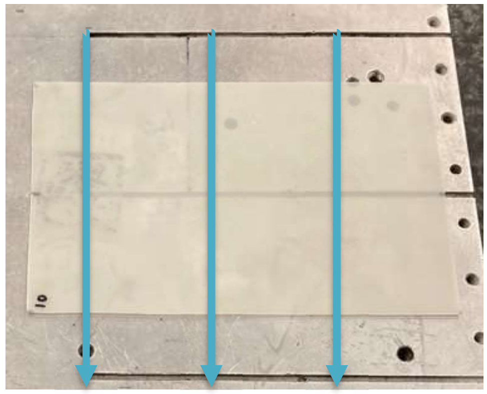

Figure 1

Speeds of between 1m/min and 30m/min were investigated, as these speeds were demonstrated in a previous investigation on glass [I]. Contact angles of deionised water and ethylene glycol were measured, which enabled the surface energy of the Mylar surface to be characterised. The Owens, Wendt, Rabel and Kaelble method for surface energy calculation was deployed, which is a well-established method for polymers [II].

The width of the individual tracks that were created from the experiments in Figure 1, were then used to enable uniform processing of the entire surface of a Mylar sample, at a speed of 30m/min, using a raster pattern as shown in Figure 2.

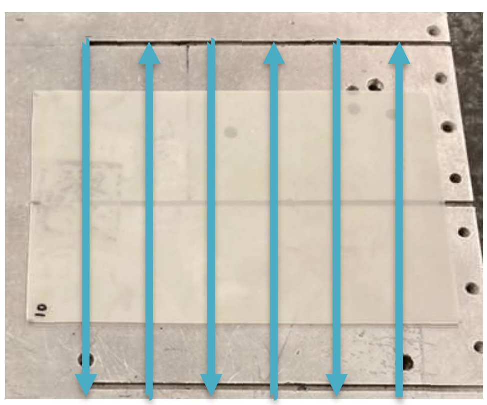

Figure 2

50W Plasma Tact Results

Figure 3 shows the water contact angles on the Mylar surface, which started at a value of (69 ± 2)° and then reduced to circa half the value. Water contact angles of circa 35° appears to be the lowest possible, because at speeds of 1m/min the Mylar surface begins to exhibit melting characteristics.

Figure 4 shows the ethylene glycol contact angles on the Mylar surface, which started at a value of (53 ± 2)° and then reduced to values of less than 20°. Again, this value appears to be the lowest possible, due to melting of the Mylar surface at speeds of 1m/min. The water contact angles appear to gradually increase with respect to speed, which is expected; however, the ethylene glycol contact angles increase and then appear to decrease again, as speed increases; however, this is a misleading artefact due to the scale of the graph and the fact that the measurements were made with a precision of ± 2°.

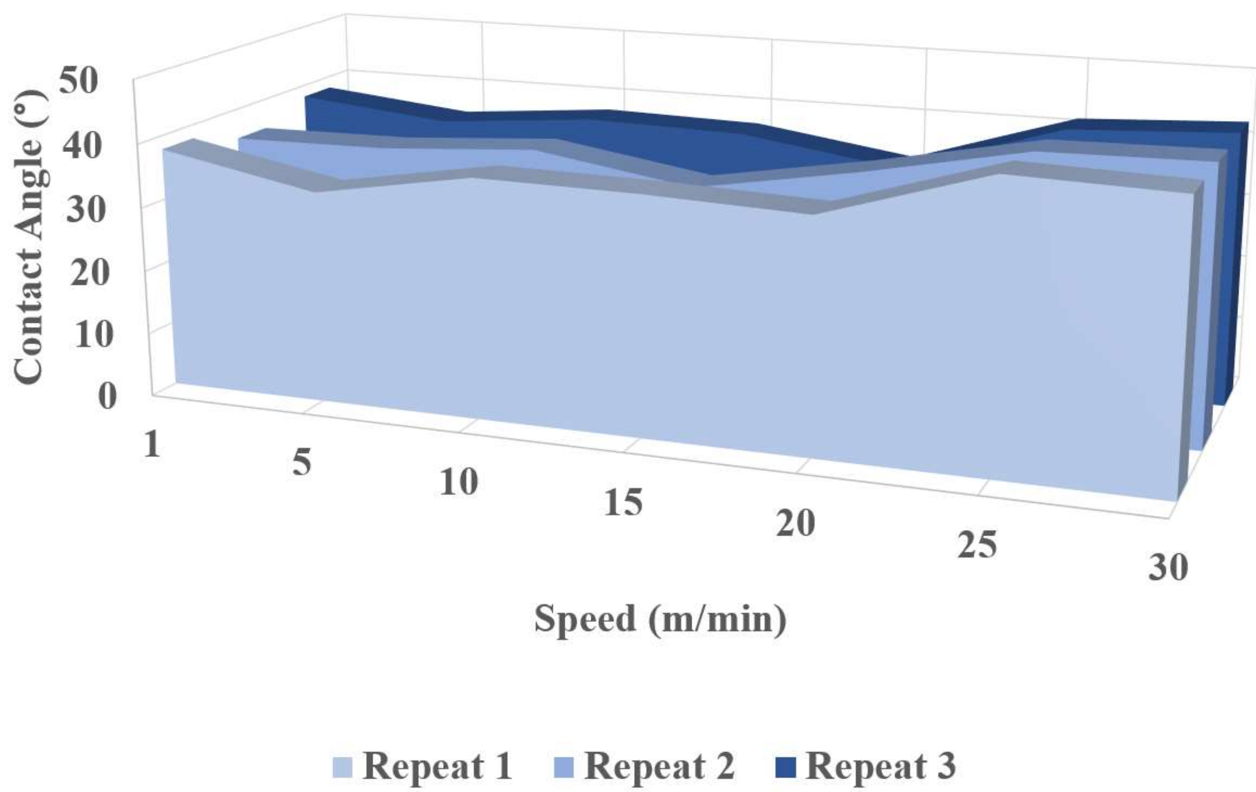

Figure 3
50W Plasma Tact – Mylar – Water Contact Angles
Starting Contact Angle = (69 ± 2)°

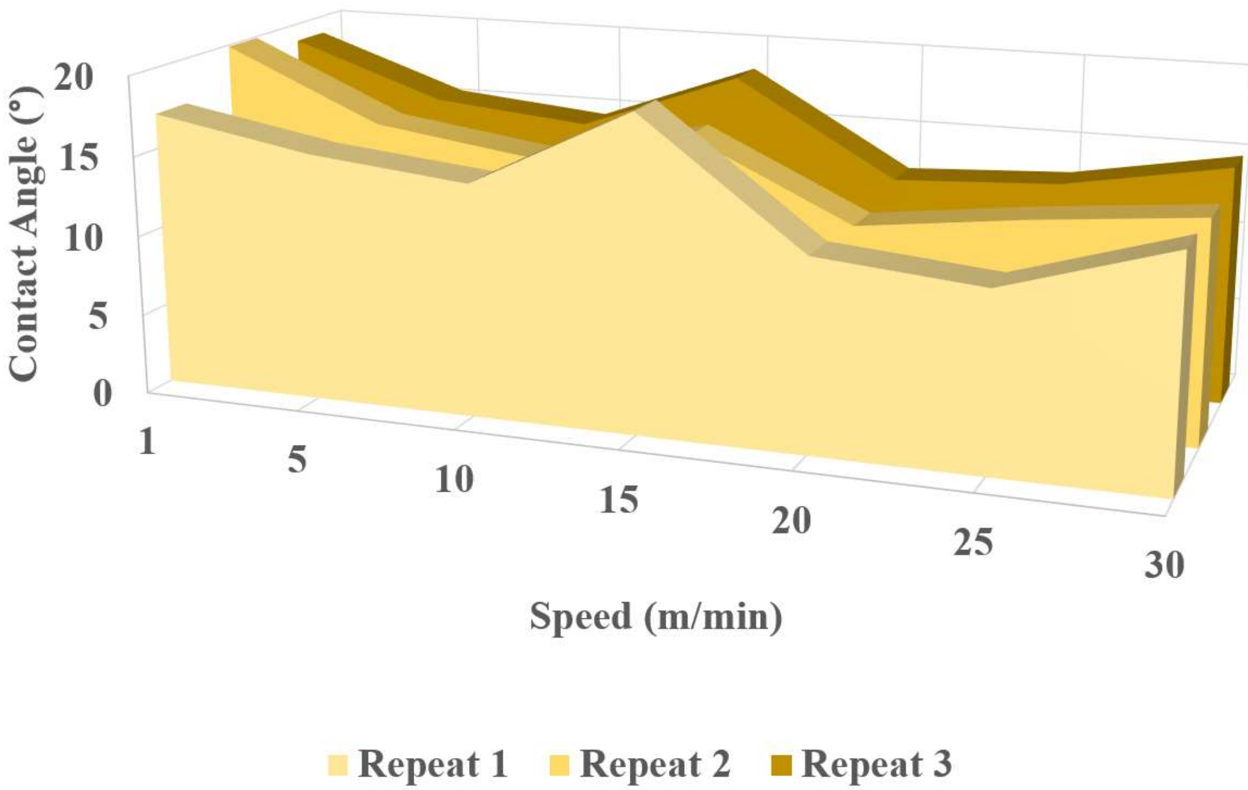

Figure 4
50W Plasma Tact – Mylar – Ethylene Glycol
Starting Contact Angle = (53 ± 2)°

Figure 5 shows the resulting surface free energy on the Mylar surface.

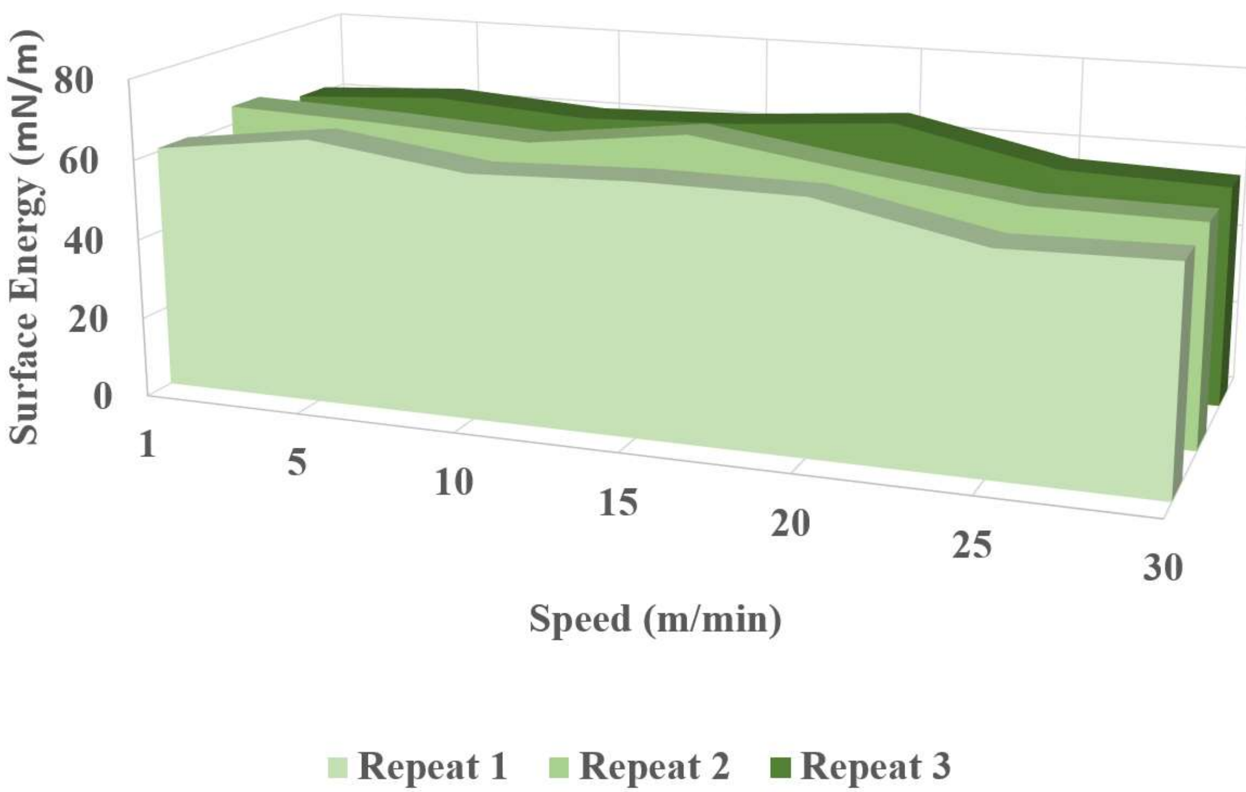

Figure 5
50W Plasma Tact – Mylar – Surface Free Energy

Figure 6 shows how the width of the plasma effect varies with respect to speed. The effect appears to decrease at higher speeds. Processing the Mylar surface at 30m/min reduces the width of the plasma processed track by circa 25%; however, it also allows the processing to be undertaken six times faster, when compared to the results at 5m/min.

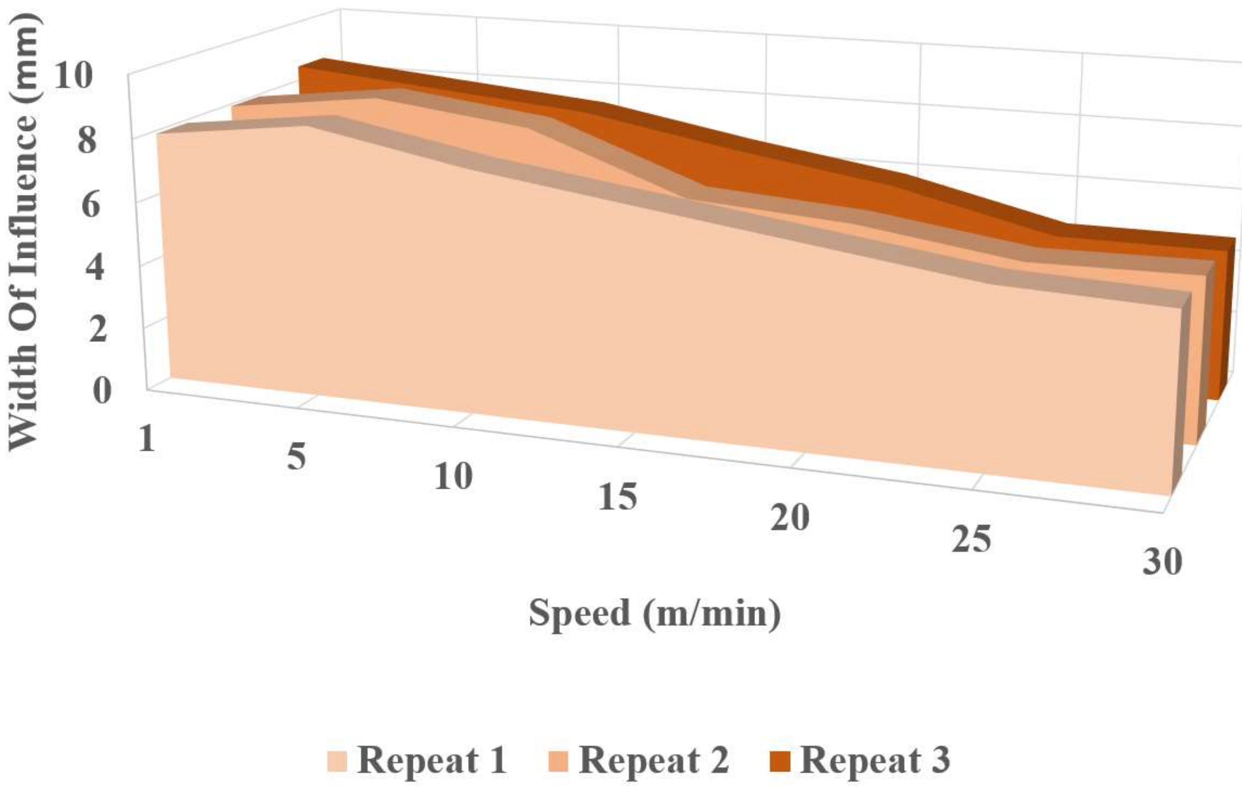

Figure 6
50W Plasma Tact – Mylar – Surface Modification Width

The 50W Plasma Tact was then used to process an entire surface of Mylar, operating at a speed of 30m/min, where the separation between each plasma pass was 5mm. Figure 2 shows the method and Figure 7 shows a photograph of the resulting surface. A video is also attached to this report. Nota bene, that these results are a significant improvement on the work in the Burnt Orange video and are a testament to the optimisation work conducted in this work package.

Figure 7
50W Plasma Tact – Mylar – Surface Energy Modification – 30m/min & 5mm Raster Step

Conclusion

The 50W Plasma Tact has been deployed to increase the hydrophilicity of Mylar. The maximum improvement has been demonstrated, which was limited by the local surface melting of the Mylar. The minimum speed achieved, at the optimised plasma parameters, was 1m/min; however, similar surface energy increases were seen when processing at the maximum speed of 30m/min. The width of the plasma effect reduces to circa 6mm at the speed of 30m/min; however, this high speed enables the minimum time taken to process a surface area of Mylar.

References

I. 50W Plasma Tact - Surface Energy Modification: Glass, Cranfield Plasma Solutions, Special Report, 25/05/2022
II. D. Owens et R. Wendt, 1969, Estimation of the Surface Free Energy of Polymers, Journal of Applied Polymer Science, 13, 1741 - 1747