

All discrete components were subjected to two process parameter tests in a Nordson March AP-300 Plasma System. In the first test, components were subjected to vacuum of 10 mTorr for 5 minutes. The same parts were then subjected to a 2 minute Argon plasma treatment at 225 watts with a process pressure of 170 mTorr. A base pressure of 80 mTorr and a pressure range of 40 mTorr remained constant for all plasma processes of components and boards throughout the experiment. A solid power shelf was placed in slot 6 and a solid ground shelf was placed in slot 3, leaving a 2.75" space between shelves. Parts were tested both before and after each of these tests. A reference capacitor was tested in all stages in order to identify possible variations associated with the test equipment or cleanroom environment.

For Stage 2, boards in Set A were first tested for electrical functionality at AirBorn. The boards were brought to DSC in static shield bags, cleaned according to cleanroom protocols, and optically measured using a Nikon Measurescope MM-400 and a Lumenera Infinity 1 camera. Photographs of pins 10, 11, 13, 15, and 17 of the microcontroller were taken on the z-axis. With NIS-Elements D software, the focused sections of individual photographs for a single pin were combined to create one image of the completely focused pin, which was used for metrology, as shown in Figure 5 for Pin 10.

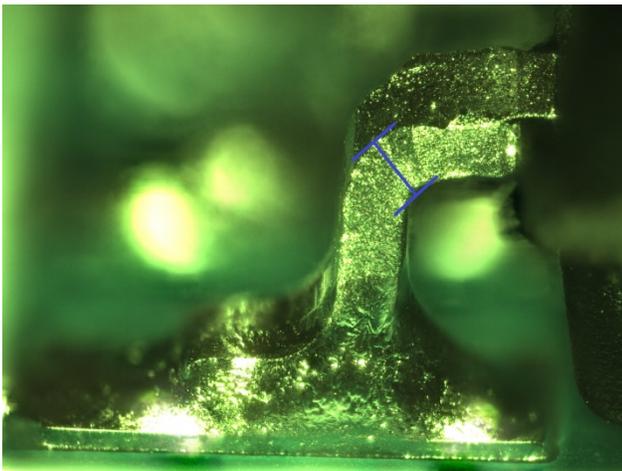


Figure 5: Example of focused image of Pin 10 of uncoated microcontroller pin with measurement reference indicated

The Nordson MARCH AP-300 plasma system was programmed to vary plasma power and process gas ratio between recipes, while keeping process time and process pressure constant as shown in Tables 1, 2, and 3.

Table 1: Nordson March 300 settings for discrete components tested in Stage 1 - gray areas held constant

RF POWER	Process Pressure	Process Gasses	Process Time
<i>Watts</i>	<i>mTorr</i>	<i>sccm</i>	<i>seconds</i>
0	10	0	300
225	170	100% Ar	120

Table 2: Nordson MARCH AP-300 settings for boards from Set A tested in Stage 2 – process pressure remained constant at 150 mTorr, process time remained constant at 120 seconds

RF POWER			Process Gasses	
<i>Watts</i>			<i>sccm</i>	
150	225	300	100% Ar	80% Ar/20% O ₂

Table 3: Nordson MARCH AP-300 settings for boards from Sets B and C tested in Stage 3 – RF POWER remained constant at 225 Watts, process gasses remained constant at 80% Ar/20% O₂

Process Pressure		Process Time		
<i>mTorr</i>		<i>seconds</i>		
150	500	60	120	180

Boards in Set A were individually placed in the plasma system, run at the designated recipe, purged and sealed in an antistatic bag, and transported to Nordson facilities. Each board was conformally coated on a specific section within one hour of plasma treatment. Coating was done using an SL-940E with a Viscosity Control System to dispense Humiseal® 1B31 Acrylic blended with a 2:1 Xylene to Acrylic mixture and dispensed with an SC-280C circulating design dispensing head. Boards were then run through a TCM-2200 curing oven for five minutes, with settings of 75 percent infrared and 25 percent convection heat, followed by a room temperature cure of twenty-four hours.

Subsequent to the completed cure of the conformal coating of boards in Set A, boards were electrically tested for microcontroller functionality using methods determined by Airborn and optically measured using the Nikon measurescope at DSC. Measurements focused specifically around the knee of the pins on the microcontroller were taken pre- and post-plasma and coating processes. They were compared to determine the plasma process parameters for Stage 3.

Stage 3 setup required measuring the pins of the microcontroller on boards in Set B and determining the plasma process parameters for boards in Sets B and C. Boards in Set B were cleaned according to cleanroom protocols, and optically inspected and measured executing the aforementioned procedure using the measurescope. The plasma system was programmed to vary process time and process pressure between recipes, while keeping plasma power and process gas ratio constant as shown in Table 1. One recipe from the set A group was repeated as a verification. A board from Set B and a board from Set C were placed in the plasma system in pairs, processed at the same time with a designated recipe, purged and sealed in individual antistatic bags using an Accu-Seal Model 35-23G vacu-purge sealer, and transported to Nordson facilities. Each board was conformally coated within 1 hour of plasma treatment with the same equipment and parameters used for

boards in Set A. The Set D control board was transported and coated with boards in Sets B and C.

Subsequent the complete cure of the conformal coating of boards in Sets B, C, and D, full functionality testing using methods determined by Airborn was performed on boards in sets C and D, and optical measurements using the Nikon measurescope were performed on boards in set B at DSC. Measurements of the pins pre- and post-plasma and coating processes were compared to determine the optimal plasma system parameters for conformal coating.

RESULTS

Testing in Stage 1 showed less than 2% change in the electrical behavior of all electrolytic capacitors before and after vacuum processing and plasma processing, which was within acceptable levels.

Optical metrology for Stage 2 showed a total of $40\ \mu\text{m}$ - $60\ \mu\text{m}$ of 1B31 acrylic coated on the pins of boards of Set A. The uncoated microcontroller Ni-Pd-Au terminals measured a knee thickness ranging from $220\ \mu\text{m}$ - $230\ \mu\text{m}$ at measurement point referenced in Figure 5. The optical measurements of pre- and post-coating indicated an increase thickness of attached acrylic using an RF plasma power level of 225 watts, with an 80 percent-20 percent mixture of argon to oxygen gas, respectively. When Ar/O₂ was used there was an increase in thickness of $275\ \mu\text{m}$ - $285\ \mu\text{m}$ measured at the knee. This thickness increase was 15% greater than parts plasma processed in just Ar plasma. Visual observations indicated that the acrylic coating had better coverage, specifically underneath the pin and on the lower portion of the microcontroller as shown in Figures 6 and 7. When O₂ was left out of the plasma, 'stringers' and bubbles often formed between the pin and the SOIC20 package which can be seen in Figures 8 and 9. The coating thickness on the pins after using the Ar/O₂ mix was the same between the 225 watt and 300 watt plasma. Both thicknesses were 5% thicker than the 150 watt plasma; therefore, 225 watt plasma was selected with an 80 percent-20 percent mixture of Ar to O₂ gas. Boards that were electrically tested in stage 2 were found to be functional. Each microcontroller received power, output the programmed oscillation, and could accept new code.

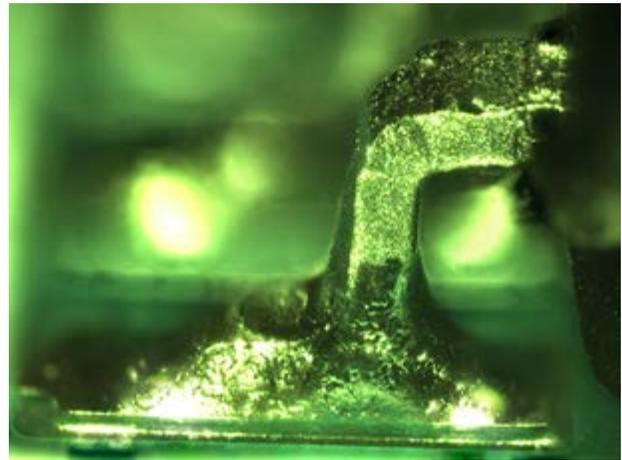


Figure 6: Board Set A before processed in Ar/O₂ mixed plasma

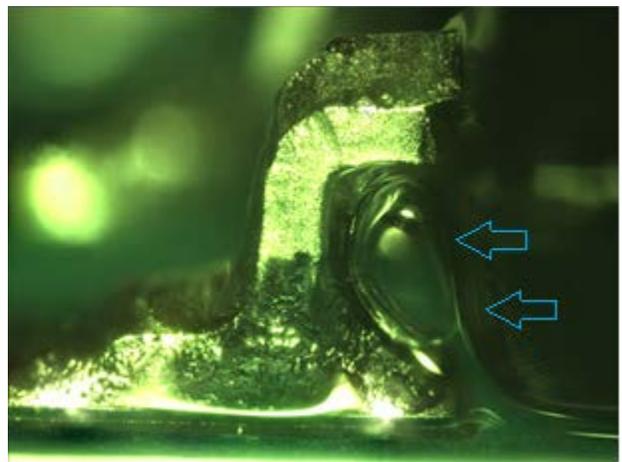


Figure 7: Board Set B after processed in Ar/O₂ mixed plasma

Optical metrology for Stage 3 showed a total of $40\ \mu\text{m}$ - $60\ \mu\text{m}$ of 1B31 acrylic coated on the boards of Set B. When the Ar/O₂ process pressure was increased from 150 mTorr to 500 mTorr, the knee on the pin remains well coated; additional stringers and bubbles, however, are visible under the pin and around the base of the microcontroller as shown in Figures 10 and 11. The bubbles that occurred after processing in 500 mTorr pressure caused difficulty in making a direct measurement of thickness at the knee; however, it's estimated to be between $240\ \mu\text{m}$ and $260\ \mu\text{m}$.

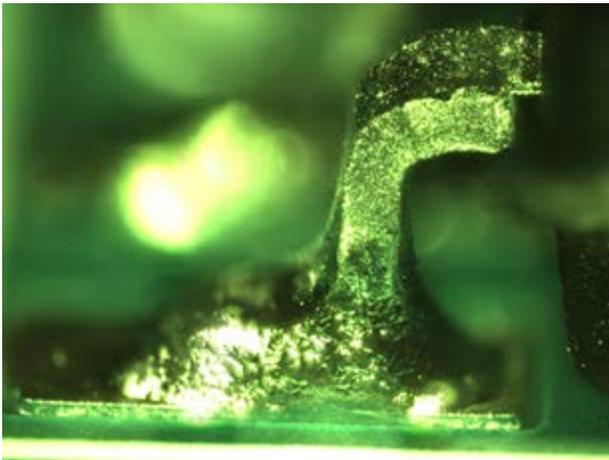


Figure 8: Board Set B before processed in Ar plasma

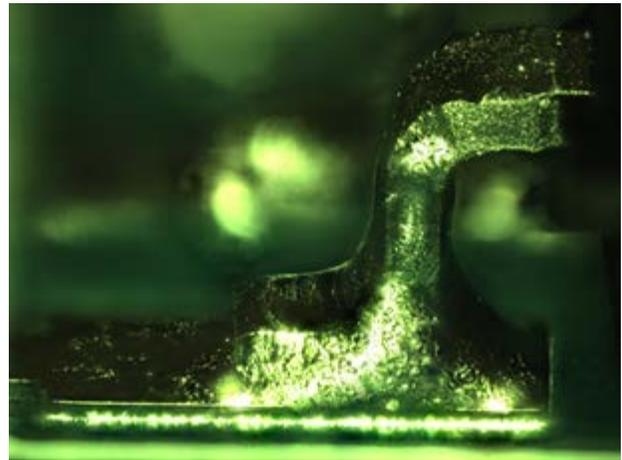


Figure 10: Before board processed in 500 mTorr process pressure

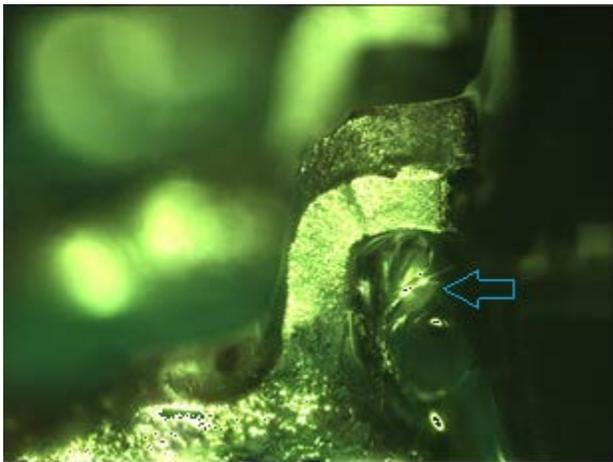


Figure 9: Board Set B after processed in Ar plasma

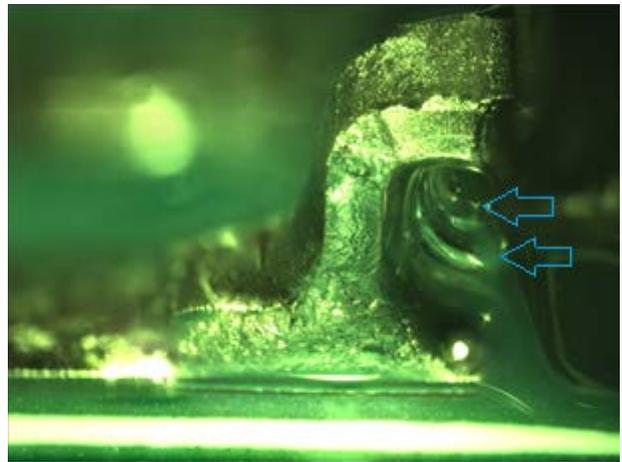


Figure 11: After board processed in 500 mTorr process pressure

One board was processed with the same process parameters in stage 2, and repeated in the thickness range of 275 μm – 285 μm around the knee. Increasing process time had a positive effect increasing the thickness of material from the resulting settings in stage 2 by 3%, especially around the knee as can be seen in Figures 12 and 13. The optimal settings for this result are shown in Table 4 which include a base pressure of 80 mTorr, range of 40 mTorr, a powered solid RF shelf setting with one slot space (2.75" clearance) between shelves.

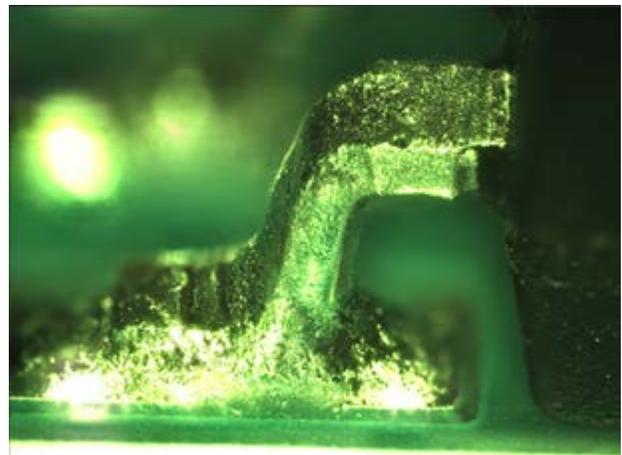


Figure 12: Before board processed in optimal settings

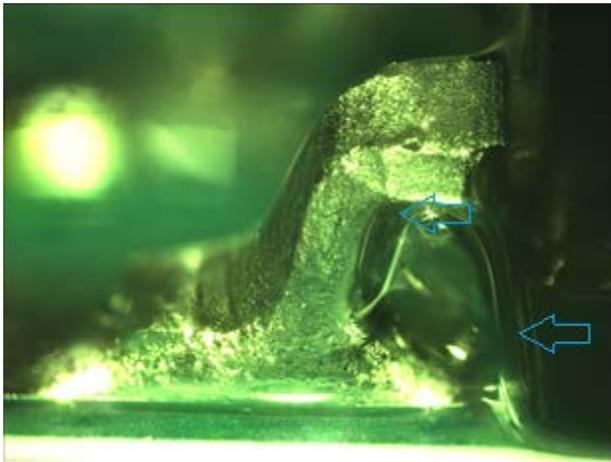


Figure 13: After board processed in optimal settings

Table 4: Optimal plasma process settings for Humiseal® 1B31 Acrylic on PCB boards and components using the Nordson March 300 Plasma System prior to coating

RF Power	Process Pressure	Process Gasses	Process Time
225 Watts	150 mTorr	80% Ar/20% O ₂	180 sec

CONCLUSION

Processing PCBs in the Nordson MARCH AP-300 plasma system increased the conformity of coverage of the Humiseal® 1B31 acrylic to the components on the board and did not affect electrical functionality. It was shown in stage 2 that 225 watts of RF plasma power had as much effect as 300 watts of RF plasma power in regards to improvement of conformal coating. The lower of the two plasma power settings was selected as the optimal setting based on the concept that lower power lessens possible risk of damage to active components on a board and still provides advantages to conformal coating. The lower process pressure of 150 mTorr was selecting as the optimal setting because the higher process pressure is believed to limit the argon plasma capability. With a higher process pressure the mean free path of the charged particles is reduced by the increase of additional gas, which reduces the kinetic effect of bombardment and thus decrease the surface tension at the coating interface. An argon and oxygen blend of 80 percent-20 percent, respectively, was selected as the optimal setting over a solely argon process. Overall the experiment was shown to be successful.

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