EVALUATING THE EFFECTS OF PLASMA TREATMENT PRIOR TO CONFORMAL COATING ON ELECTRONIC ASSEMBLIES TO ENHANCE CONFORMITY OF COVERAGE

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ABSTRACT

The corrosion of Nickel-Palladium-Gold (Ni-Pd-Au) finish terminals in humid environments is known to be reduced with the application of a conformal coating such as acrylic. Corrosion has a higher rate of occurrence around the terminal ‘knee’ of a surface mount component, which may be reduced with the application of conformal coatings. Although radio frequency (RF) plasma processing is generally known to enhance conformity of conformal coating to surfaces through ionic bombardment, the effect on the functionality of assembled printed circuit boards (PCB) is not as well known. The purpose of this study is to assess whether RF plasma processing can enhance the adhesive and coverage qualities of an acrylic conformal coating on PCBs, specifically on Ni-Pd-Au terminals with a knee, and if plasma processing has an effect on the electrical functionality of components and fully assembled PCB. Optical metrology was used to quantify and photograph the enhanced knee surface after boards were plasma processed and conformally coated with acrylic; electrical testing of printed circuit boards was used to determine electrical functionality. Results show that plasma processing can enhance the quality of the conformal coating as well as increase thickness of the coating around the knee of a terminal. Settings of RF power, process gas, process pressure, and plasma process time were used to come to this result.

Key Words: Conformal coating, Plasma process, Conformity enhancement, Printed circuit boards, Optical metrology

INTRODUCTION

Terminals finished with Nickel-Palladium-Gold (Ni-Pd-Au), a common terminal plating finish, are known to be susceptible to corrosion - notably in outdoor environment applications. [1,2] Conformal coatings are well known to mitigate this corrosion by means of parylene[3], urethane, epoxy, and acrylic. [4] Most noted in these studies, however, was a consideration for the conformity of coverage of the conformal coating to the underlying printed circuit board. Reactive ion bombardment using an argon RF plasma process is one known method to increase surface adhesion by means of the kinetic transfer of atomic energy incident to the surface under bombardment which creates dangling bonds. [5] Oxygen was also considered for simultaneous use with argon because of its capability to remove fluxes and organic compounds found in solder reflow based processes that may not be removed with conventional aqueous wash.

Based on these advantages, plasma processing before application of an acrylic-based conformal coating was chosen to be studied, with focus on conformity of coverage around the Ni-Pd-Au terminals and the knee of the terminal solder connection of a PCB with multiple components. Although there is an advantage of plasma processing in these regards, the possibility that plasma process would affect functionality of components used on the PCB assembly was a concern. The variety of components on the PCB includes discrete components, active components, and programmable microcontrollers. A study was coordinated between Nordson ASYMTEK, Nordson MARCH, AirBorn Electronics, and the Desich SMART Center (DSC) to investigate the viability of the RF plasma process.

OBJECTIVE

The objective of this experiment is to evaluate the effects of RF plasma processing on the conformity of coverage of conformal coating of the knee of individual Ni-Pd-Au leads on electronic assemblies using Humiseal® 1B31 Acrylic and to determine if any change in electrical functionality occurs. The specific area of interest is the coverage of the coating on the Ni-Pd-Au knee (Figure 1) of a surface mount SOIC20 microcontroller - a programmable microcontroller - on each assembly.

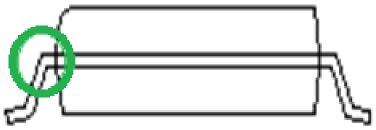

Figure 1: Side profile of SOIC20 microcontroller with knee highlighted in green

The evaluation is accomplished in three stages, with objectives for each below:

- Stage 1: test the effect of argon RF plasma process parameters on discrete components in order to mitigate concern of the effect of vacuum pressure and plasma power on electric functionality.
- Stage 2: evaluate the effect of plasma power and process gasses on semi-populated PCB using optical metrology and electrical testing on the SOIC20 microcontroller.
- Stage 3: evaluate the effect of plasma time and process gas pressure on both semi-populated and fully-populated and functional PCB using electrical testing and optical metrology.

METHODOLOGY

In Stage 1 discrete components were tested to evaluate the effects of plasma process parameters on the same type of electrolytic capacitors used on the fully populated boards. Each capacitor was measured for capacitance, and impedance, as well as being connected to an oscillator circuit that produced a capacitive based frequency before and after initial pressure and plasma testing. Samples were subjected to 10 mTorr vacuum pressure and run through baseline argon RF plasma processes to establish minimal change in tested electric functionality.

Four sets of boards were used for Stages 2 and 3 of the experiment. Set A consisted of six semi-populated boards. Each board in Set A (Figure 2) had microcontroller and SMT components that could be used to power the microcontroller and turn on an LED. Set B consisted of six boards populated with only a microcontroller, to be used for optical measurements only (Figure 3). Set C consisted of six fully populated and functional boards (Figure 4) with discrete components, SMT components, and surface mount components. Set D consisted of a single fully populated board (Figure 4) to be used as a control, with no RF plasma processing.

In Stage 2, thicknesses of conformal coated coupons were measured to obtain baseline film thickness data, and to ascertain the feasibility of optical measurements through the Humiseal® 1B31 acrylic on a flat surface. Preliminary photographs of boards were taken to determine the best angle at which to measure pins of the microcontroller. Stands were built to hold the boards at fixed reference angles in order to measure these pins. Stage 2 consisted of making optical measurements at DSC of the microcontroller pins and testing each board in Set A at AirBorn for electric functionality before and after plasma processing and conformal coating. Each board was processed while varying plasma power and the argon/oxygen gas mixture during plasma process. Plasma processing occurred at DSC in an ISO (class 1000) cleanroom; the conformal coating occurred at the Nordson facility. These logistics required plasma-processed boards to be transported in vacuum sealed N_2 purged static shield bags prior to conformal coating. The resulting best coverage around the knee of the microcontroller pins was used for controls in Stage 3.

Stage 3 consisted of optically measuring each board in Set B at DSC and electrically testing each board in Set C at AirBorn. Boards in Set C were not optically measured due to limitations in optical focus and size of the components on the fully populated board. A board from Set B was run with a board from Set C with the same plasma settings. Each board pair was processed with varying plasma time and backfill gas pressure during the plasma process. Boards in Set C were electrically tested after conformal coating. Boards in Set B were optically measured after conformal coating.

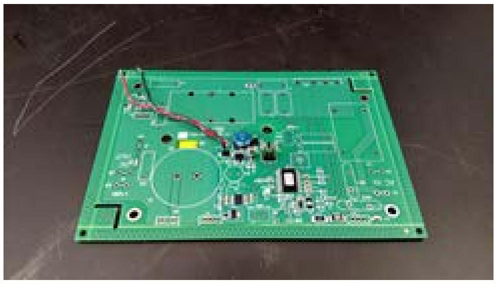

Figure 2: Example of Board in Set A

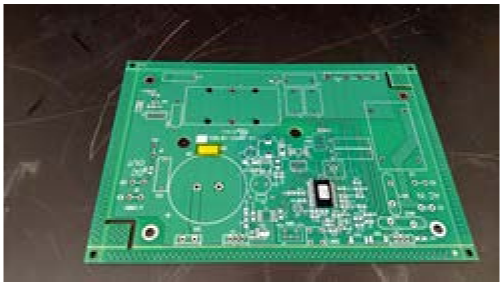

Figure 3: Example of Board in Set B

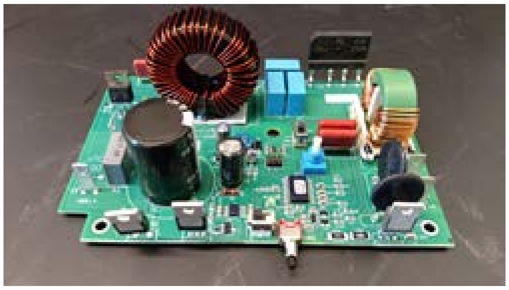

Figure 4: Example of Board in Sets C and D shown with permission of AirBorn Electronics

EXPERIMENTAL SETUP

Stage 1 setup was accomplished by measuring each discrete component with an Agilent E9490A LCR meter. Each component was measured at a fixed 1 kHz frequency and values of capacitance and impedance. Components were also tested using an Agilent DSO-X 2024A Oscilloscope and a squarewave oscillator circuit in which capacitance controls frequency. Additional electric values measured were rising overshoot percentage and peak-to-peak voltage.

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.

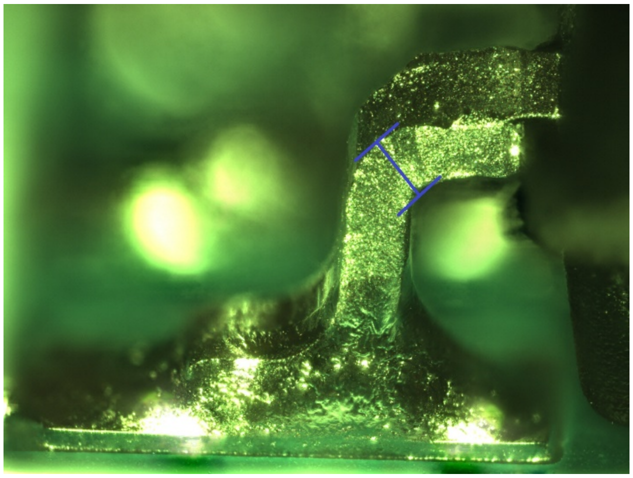

Figure 5: Example of focused image of Pin 10 of uncoated microcontroller pin with measurement reference indicated

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
Watts	*mTorr*	*sccm*	*seconds*
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	
Watts			*sccm*	
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% O_2

Process Pressure		Process Time		
mTorr		*seconds*		
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 µm - 60 µm of 1B31 acrylic coated on the pins of boards of Set A. The uncoated microcontroller Ni-Pd-Au terminals measured a knee thickness ranging from220 µm – 230 µm 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/O_2 was used there was an increase in thickness of 275 µm – 285 µm 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 O_2 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/O_2 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 O_2 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.

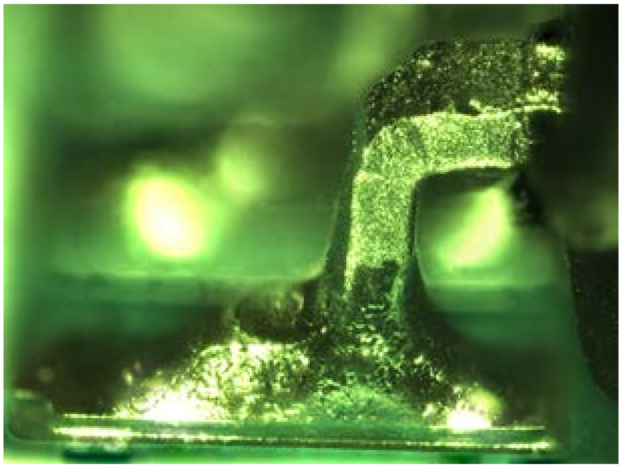

Figure 6: Board Set A before processed in Ar/O_2 mixed plasma

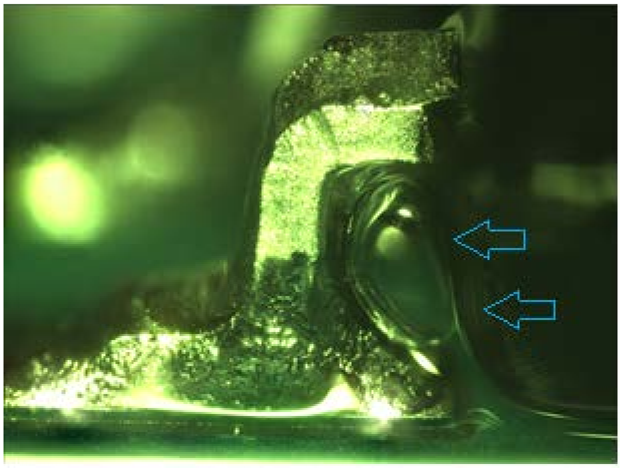

Figure 7: Board Set B after processed in Ar/O_2 mixed plasma

Optical metrology for Stage 3 showed a total of 40 µm - 60 µm of 1B31 acrylic coated on the boards of Set B. When the Ar/O_2 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 µm and 260 µm.

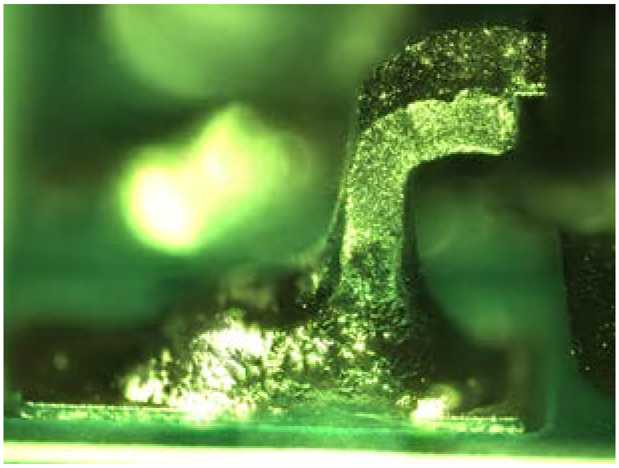

Figure 8: Board Set B before processed in Ar plasma

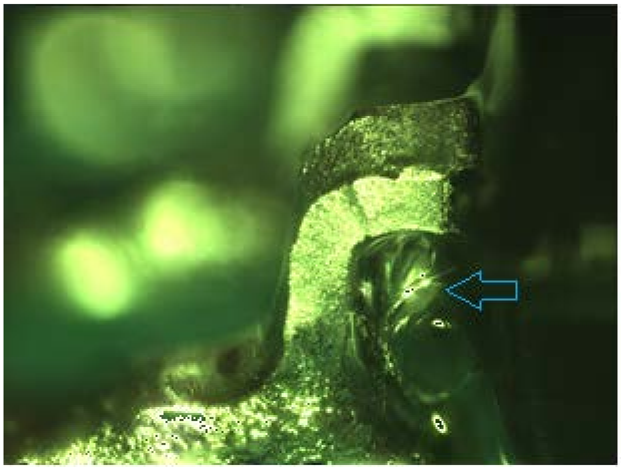

Figure 9: Board Set B after processed in Ar plasma

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.

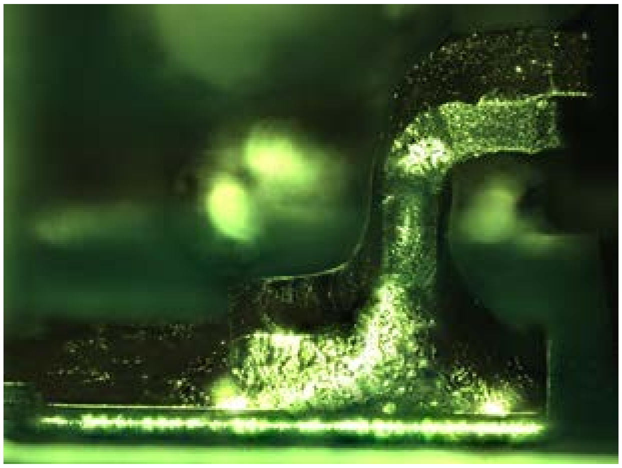

Figure 10: Before board processed in 500 mTorr process pressure

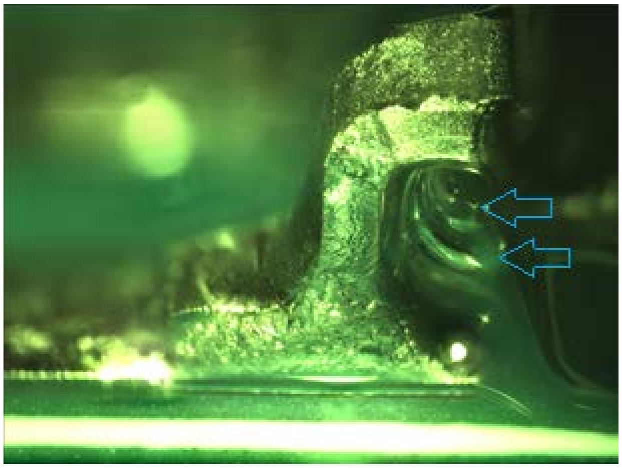

Figure 11: After board processed in 500 mTorr process pressure

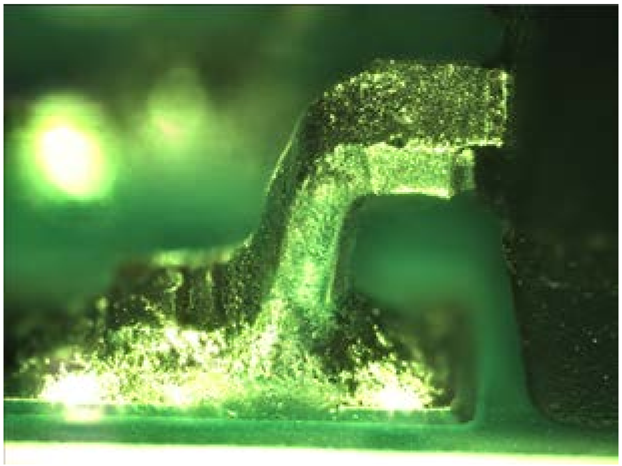

Figure 12: Before board processed in optimal settings

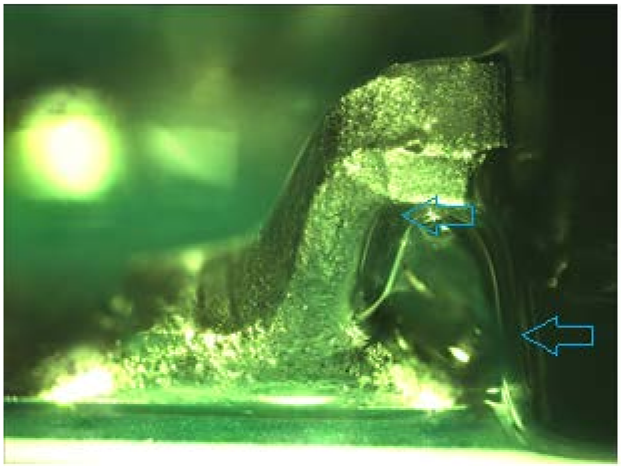

Figure 13: After board processed in optimal settings

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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