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INTRODUCTION OF A NEW PCB SURFACE FINISH FOR THE ELECTRONICS INDUSTRY

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ABSTRACT

A new PCB surface finish has been developed that offers outstanding performance and excellent environmental protection. This finish has the potential to replace more common finishes such as ENIG, ImAg, ImSn, ENEPIG, or OSP with a chemically resistant plasma deposited coating. The substitution of the wet processes with this dry plasma process offers significant advantages e.g. lower quantities of chemicals used, environmental benefits and improved operator safety.

The surface finish is applied to the whole board offering unique chemical protection before and after the soldering operation. A substantial test program has been undertaken investigating a wide range of performance characteristics of the PCBs including solder performance, corrosion resistance, electrical performance, RF performance and many other PCB performance characteristics.

Key words: surface finish, PCB, plasma deposited

INTRODUCTION

The electronics industry has evolved dramatically in recent decades with increasing demands on technology to make products smaller, faster and/or cheaper. In recent years there has been an increased awareness of damage to the environment, resulting in a plethora of legislation and guidelines that impact electronic products and their manufacturing process. Electronic products are also being used in increasingly aggressive environments. The market for electronic goods has been shifting with growing markets in the Far East where the combination of high humidity, high temperatures and high pollution levels are resulting in significant premature failure rates.

A range of surface finish are currently available, however, the transition to Pb-free and the higher processing temperatures has reduced the effectiveness of these surface finishes. For example, organic solderability protectant (OSP) and immersion tin (ImSn) suffer reduced solderability after two surface mount cycles. This makes subsequent wave solder hole-fill very difficult, especially in the case of high aspect ratio holes on thick PCBs. Electroless nickel immersion gold (ENIG) has enjoyed popularity for higher end applications. However, this finish performs poorly with Pb-free SAC305 solder under high strain rate conditions. There have been many drop test studies performed that show the stiff SAC305 solder combined with the brittle Sn-Ni intermetallic layer results in early failures.[1] [2]

For these reasons, many OEMs changed the surface finish on Pb-free products to immersion silver (ImAg). Unfortunately, since that transition there have been many reports of field failures from creep corrosion and several papers published on the topic.[3] [4] [5] When such products are used in environments high in sulfur, copper suflide corrosion product will form and can bridge circuit spacings resulting in fairly rapid failure. Even high value server products in data centers have been significantly impacted by such failures.[6]

Companies invest a great deal of time and effort in the search for the appropriate surface finish for their Pb-free products. In some cases companies have turned to Pb-free HASL.[7] SnCuNi alloy has proven effective as a HASL finish, however process control can be difficult and its effectiveness with fine pitch components remains to be seen.

The ideal surface finish would enable a tin-copper bond for good reliability. It would would have good shelf life and hold up to multiple Pb-free reflow cycles to enable good hole fill soldering. It would remain as a corrosion protection layer on areas not soldered. Finally, it would enable probe testing through it for high first pass yields during in-circuit test. A surface finish with all these attributes has not been available in the market.

The surface finish being reviewed in this paper shows great promise in meeting all the requirements listed above. Furthermore, it can achieve such results with a much simpler and environmentally friendly process. All the common surface finish processes offered today involve a number of wet chemical process steps. For example, they begin with a water wash and acid etch step. This is followed by various metal plating processes (immersion, electroless, or electrolytic). In the case of OSP, the polymer is deposited in a fluid bath. The last step is typically a water rinse. The advantage is high product throughput but the chemical and waste water output is also high. The surface finish being proposed in this paper is deposited with a plasma process. This Semblant Plasma Finish (SPF) is uniform in thickness, is able to coat the walls of high aspect ratio vias, and is environmentally friendly.

BACKGROUND

After years of experience in diagnosing and solving problems associated with surface finishes on PCB's, a team of consultants in the Technology Division of the PA Consulting Group were formed to develop a new surface finish that would address all of the problems that had been encountered. A number of concepts were evaluated and ultimately the most promising was developed. Initial feasibility trials were conducted using a wide range of soldering processes with very favorable results. An extensive test program was then undertaken to:

- characterise the materials and electrical properties of the new finish
- provide comparison test data against established technology
- develop and optimise all aspects of the process to achieve a high performance surface finish suitable for high volume applications

Upon completion of the feasibility phase for this new surface finish, the project moved into scale-up and commercialization. An independent company was established and given responsibility for completing the development and optimization of the technology and qualification of the finish.

PROCESS DESCRIPTION

The Semblant Plasma Finish (SPF) consists of a nano-coating of fluorinated polymeric material.

It's applied using a plasma chamber such as that shown in Figure 1. The SPF is currently applied in a two step batch process, however progress is being made in converting this to an in-line high throughput manufacturing process.

Figure 1. Typical plasma chamber

Lightly oxidized PCBs can be plasma cleaned in the chamber prior to film deposition. If PCBs were to become heavily oxidized and tarnished, they may require being run through the standard wet acid etch and clean line. Therefore, under well managed board handling procedures, the need for wet chemicals can be eliminated from the surface finish deposition process. Being a vapour deposition process it does not suffer the surface tension limitations of wet chemistries. It has good throwing power and will deposit onto high aspect ratio via walls (such as that shown in Figure 2) and small geometries such as microvias.

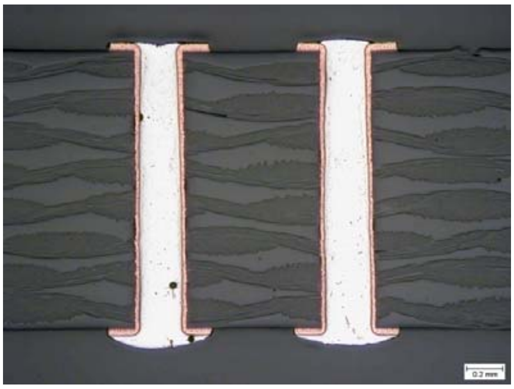


Figure 2. Vias with 8;1 aspect ratio

The SPF is applied across the whole of the PCB and is removed by the soldering process only in the areas where flux and solder are applied in a similar way to OSP. However, unlike OSP this finish will not break down at the temperatures used in Pb-free processing. Where the surface finish is not removed, the PCB is left with a protective layer that is highly resistant to environmental corrosion. This property has the added benefit of eliminating the need for a solder mask where appropriate. Effectively using the surface finish as the solder mask could be a cost savings paradigm shift in PCB production (as well as the additional elimination of wet processes used in solder mask application). This approach may not be appropriate for products where flux spray is used (e.g. wave solder) but could be beneficial for products that only utilize surface mount assembly with solder paste. More investigation is required to fully leverage this promising cost savings.

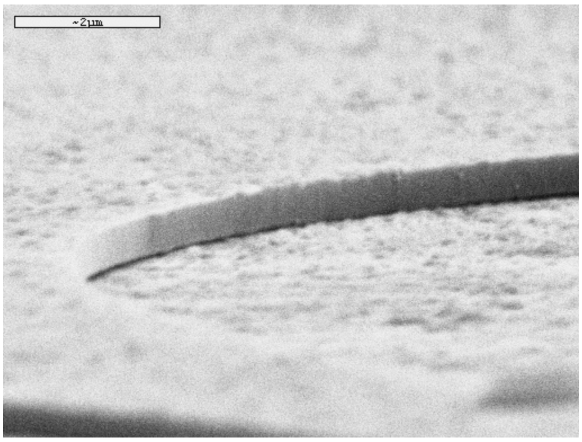


Figure 3. The Semblant Plasma Finish after etching with flux.

As of the writing of this paper, the following processes have been fully optimized:

- PCB preparation
- Plasma deposition process
- Soldering process

Through optimization of the parameters associated with each step in the total process, the SPF has been proven to be suitable for high volume manufacturing.

ENVIRONMENTAL BENEFITS

The plasma process replaces the wet chemical processes currently used, which has a number of benefits including:

- Elimination of water useage
- Effluent handling virtually eliminated
- Eliminates useage of precious and semi-precious metals including nickel
- Is a much safer process for operators with the elimination of dangerous chemical such as cyanide and thiourea

SOLDER PERFORMANCE

A test PCB was developed to facilitate soldering trials for fine pitch and BGA devices and also for wettability testing.

The SPF is removed during the soldering process by the flux when it reaches its activation temperature. Good solder joints can be achieved with several proprietary pastes that were previously designed for OSP.

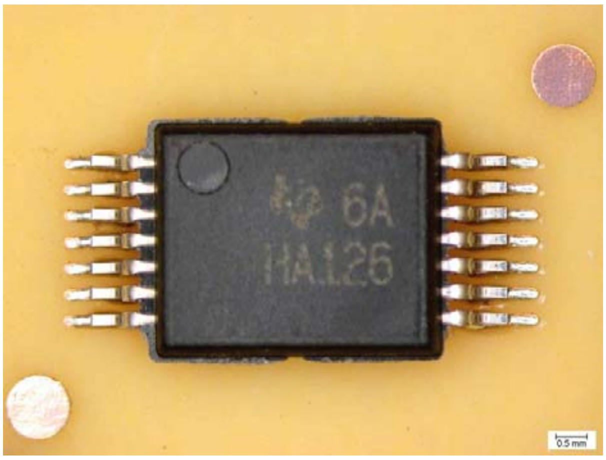


Figure 4. Surface mount component mounted on a PCB with SPF. Pitch: 0.015 inch

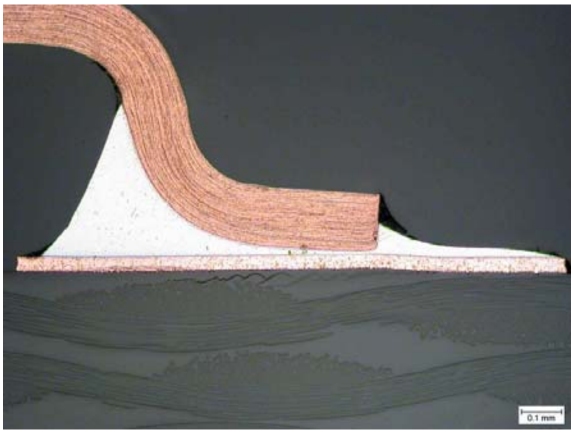


Figure 5. Fine pitch cross section

The joint is made directly to copper and consequently has very strong intermetallics with no unnecessary intermediate intermetallics (see Figure 5 & 6).

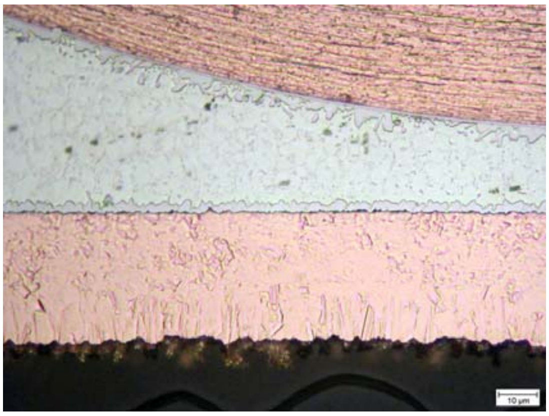


Figure 6. Joint cross section showing SnCu intermetallics

Figure 7 shows the result of screen printing solder paste onto BGA pads that were previously treated with SPF. A BGA pattern on a PCB without solder mask was also evaluated. No-clean paste was deposited onto the pads and reflowed. Wetting readily took place to the pads, but the solder did not flow outside of where it was originally printed (figure 8).

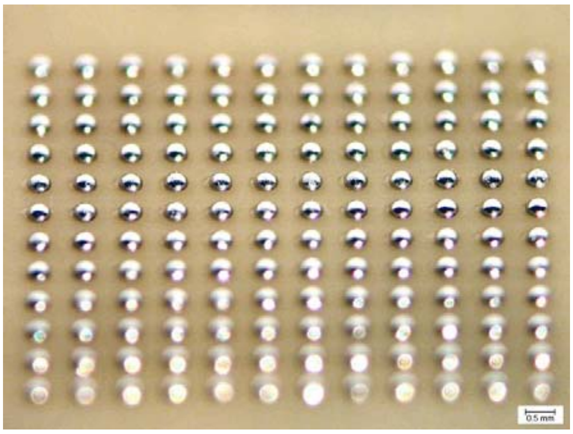


Figure 7. Solder paste stencilled onto 0.8mm BGA pads and reflowed.

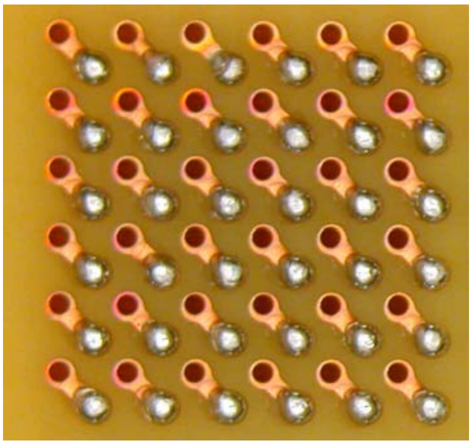
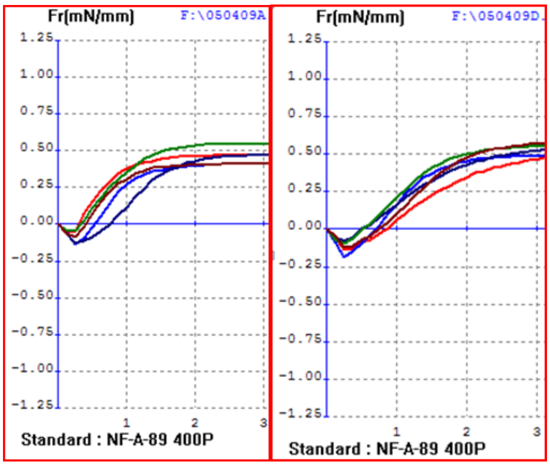


Figure 8. Solder paste printed onto dog bone pattern BGA pads with ACF but no solder mask. The solder stays where it is printed.

Independent solder shear tests have been carried out which have shown the joint strength to be equal to or greater than ENIG and OSP. Preliminary aging tests have also indicated that the degradation in joint strength is less than for ENIG over a ten year period.

WETTING BALANCE TESTS

Wetting balance trials were carried out on samples as supplied and after conditioning by storing for eight hours at 72C/85% R.H. Results are shown in Figure 9.



As supplied Post Conditioning

Figure 9. Wetting balance results for samples with SPF.

ELECTRICAL PROPERTIES

Surface insulation resistance testing was carried out using the IPC-B-24 test coupon and the resulting SIR measurements were above the industry minimum level of 100 megohms. These tests are being repeated using the IPC-B-25 test coupon.

To illustrate the high frequency performance of the plasma coated finish, three striplines were designed into the test board, to resonate at 600MHz, 1GHz and 2GHz. The SPF was applied to two test boards at different thicknesses. The 1/4wave for each track was measured where the short circuit at the end of the track is effectively transformed to an open circuit at the SMA connector. This impedance and frequency was used to draw conclusions on the effects of the coating materials. Measurements were also carried out on ENIG, ENEPIG and OSP reference boards. Figure 10 shows plots of the real components of the impedances at the three different frequencies.

ENVIRONMENTAL PROTECTION

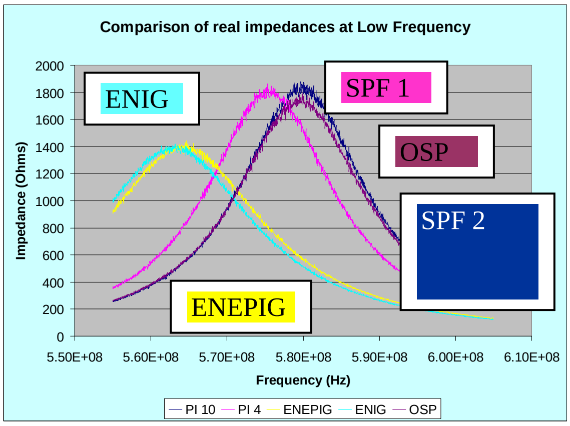
Various environmental tests were performed to evaluate the robustness of the SPF. The results were then compared to standard finished widely used today

Corrosion Performance

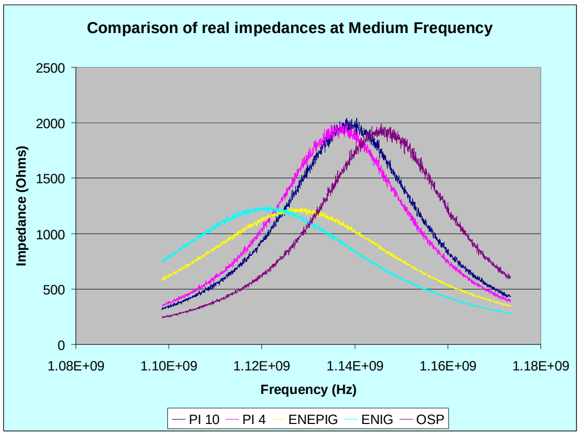
Creep corrosion failure has become a growing problem with ImAg and even OSP surface finishes when used in highly polluted environments. The effectiveness of the SPF was evaluated using mixed flowing gas testing. .

An ENEPIG reference board and a SPF treated board were subjected to a static buffered Na_2SO_3, environment for 24 hours, with RH~80% at 41.5^{o}C. The results of this test are shown in Figure 11.

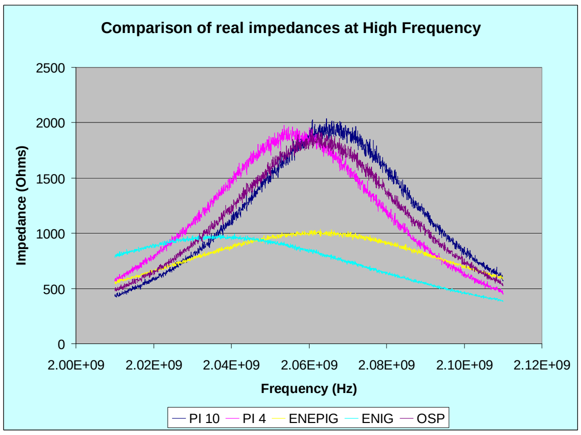
PCB's with the SPF were subjected to a Class III mixed flowing gas test by the University of Limerick. After 20 days exposure these PCB's showed no visible evidence of corrosion, in comparison to Pb-free alternative finishes. The MFG exposure was performed at a constant temperature and relative humidity of 30°C and 70% RH respectively. The corrosive gases used in the chamber were 100ppb of H_2S, 200ppb of SO_2, 200ppb of NO_2 and 20ppb of Cl_2. Photos of each surface finish are shown in Figure 12 after 20 days in the MFG chamber.



600MHz

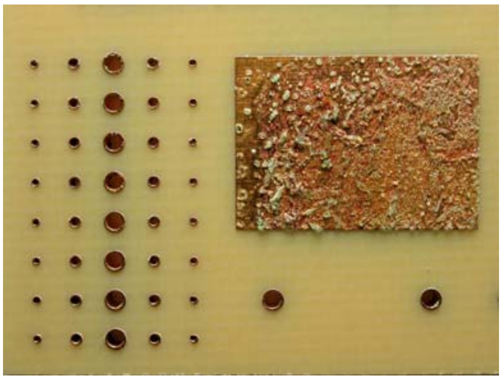


1GHz

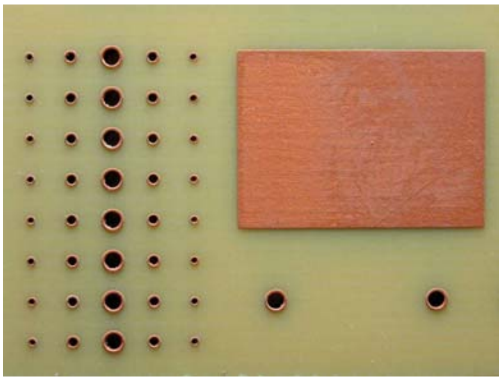


2GHz

Figure 10. Impedance and frequency results for various surface finishes.



ENEPIG



SPF

Figure 11. MFG test results for NiPdG finish and Semblant Plasma Finish.

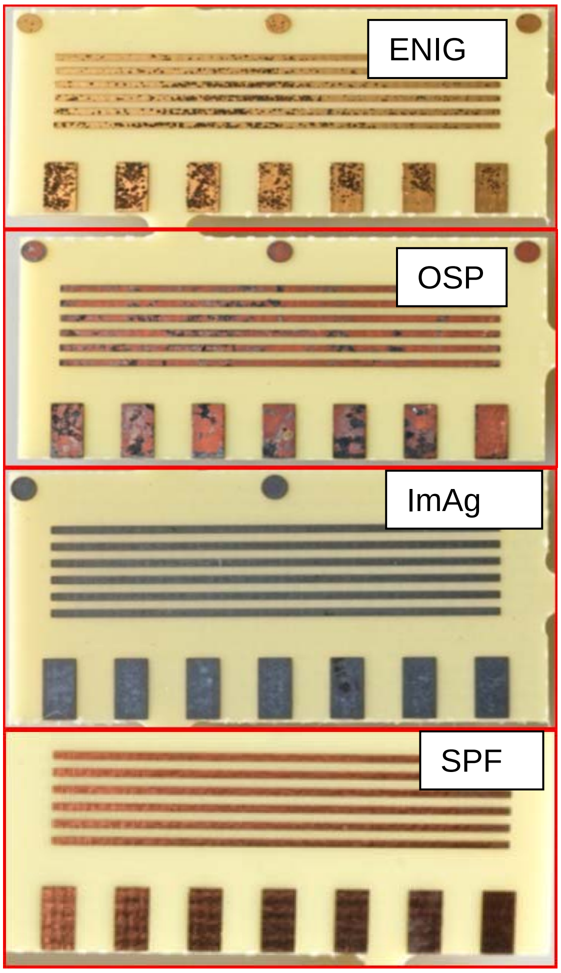


Figure 12. Surface finish appearance after 20 days in the MFG chamber.

Salt Mist Tests

PCB's with the SPF were subjected to a salt mist spray along with ENIG, ENEPIG, OSP and Immersion Silver references. Results are shown in Figure 13.

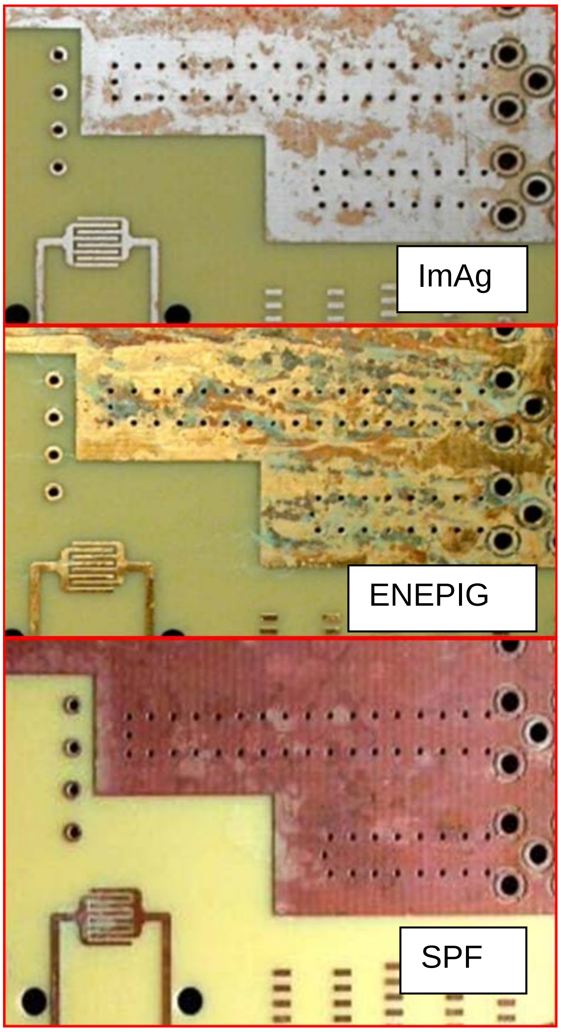


Figure 13. Surface finishes after severe salt spray testing.

MANUFACTURING

As previously mentioned, the plasma deposition process developed to date is a batch process. This type of machine was used to optimize the process and prove feasibility of the surface finish. Various levels of automation are currently available to enhance the throughput and make the process cost effective for a greater number of applications. Should a board require rework and removal of the SPF, this can be accomplished through plasma etching in the same process chamber. The film is opaque in appearance, however there are several methods being developed to detect the film and measure its thickness (to enhance inspection and process control).

In today's manufacturing environment, floor space is at a premium. The elimination of long wet processing lines for depositing surface finishes would have a favourable impact on cost and material control.

FURTHER WORK

One attribute that makes this Semblant Plasma Finish superior to OSP is its ability to conduct in the z-direction.

This feature is currently being characterised Once this capability is optimized it will be extremely useful for in-circuit testing and for use with pressure connectors.
Another area of investigation is with direct wire bonding through the finish. Preliminary work has been carried out demonstrating the ability to form strong wedge bonds using gold and aluminium wire. Development work in this area is continuing.

CONCLUSIONS

The results achieved to date clearly demonstrate that this Semblant Plasma Finish holds great promise with many attractive capabilities. It's been said that selecting the best surface finish for the application is the most complex and yet the most important decision one can make when developing a new Pb-free electronic assembly. The SPF introduced in this paper could make that decision much easier. The stability of the Semblant Plasma Finish may also enable elimination of solder mask in some applications. As electronic manufacturers are pressured to become more green, this dry process for depositing a finish becomes even more attractive. Once the in-line plasma process completes development, this surface finish will be ready for higher volume applications.

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