Corrosion Resistant Connector Finishes

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As mobile and wearable manufacturers move toward water resistant and water proof devices, the need for corrosion resistance in wet and damp environments becomes more critical. Electronic interconnections frequently employ a combination of electroplated nickel or nickel alloy as a barrier layer to the substrate and electroplated gold as a topcoat. However, under potential bias in wet environments, such as during a charging cycle, these gold on nickel stacks often fail due to corrosion of the connector base substrate.

In order to extend the performance of these electrical connectors, some manufacturers have resorted to using thicker gold topcoats upwards of 1.25µm. While this can marginally increase the performance, the cost to performance gain ratio can be unattractive, especially for cost-sensitive consumer devices.

Xtalic Corporation has custom-engineered an electroplated, nanocrystalline silver alloy stack named LUNA®. It differentiates itself from both traditional electroplated gold and other silver technologies by offering improved corrosion protection for immersion environmental exposures, unmatched by gold even at 1.25µm in thickness.

Voltage-biased immersion tests involving common liquids such as perspiration and saline solutions were conducted on a gold-on-nickel stack as well as two embodiments of the new LUNA® final finish stack:

1. With the LUNA® electroplated onto a nano-crystalline nickel-tungsten alloy, Xtalic product trade name XTRONIC® (or XT for short), as a barrier layer, capped with a 0.05µm proprietary inorganic post treatment
2. With the LUNA® electroplated directly on the substrate with no nickel-based barrier layer, also capped with a 0.05µm proprietary inorganic post treatment.

Both embodiments of the LUNA® stack outperformed a standard gold-on-nickel stack in biased corrosion testing in both electrolytes.

A series of potentiostatic conditions were applied to the various electroplated stacks, including 1 V, 1.5 V, and in some cases 2 V for 30 minutes in artificial perspiration and phosphate buffered saline solution to stress the stacks to failure. It was found that the LUNA®/Xtronic® stack outperformed the gold-on-nickel stack for all conditions and in both electrolytes based on their corrosion currents and qualitative visual results. Figures 1 through 3 show the corrosion currents and optical images of the specimens after testing in artificial perspiration at 1, 1.5, and 2 V respectively.

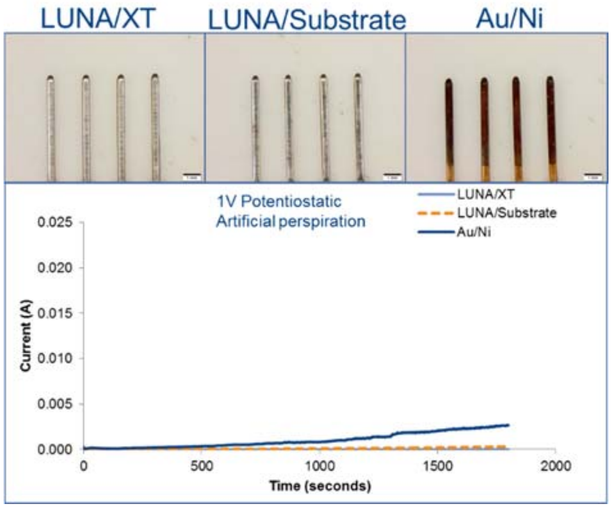

Figure 1. Recorded current over 30 minutes at 1 V showing a gradual increase in current for the Au/Ni stack when immersed in artificial perspiration. Optical images of the samples reinforce the quantitative results, with the LUNA® stacks showing no visible corrosion and the Au/Ni stack showing substantial corrosion.

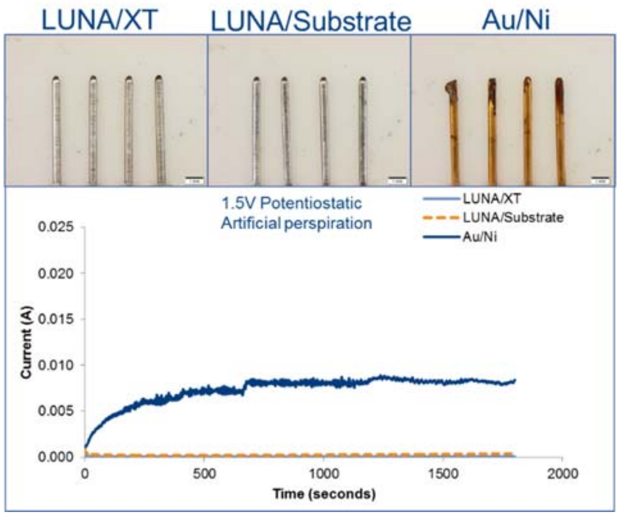

Figure 2. Recorded current over 30 minutes at 1.5 V showing an immediate increase in current for the Au/Ni stack when immersed in artificial perspiration. Optical images of the samples reinforce the quantitative results, with the LUNA® stacks showing no visible corrosion and the Au/Ni stack showing signs of disintegration of the contacts.

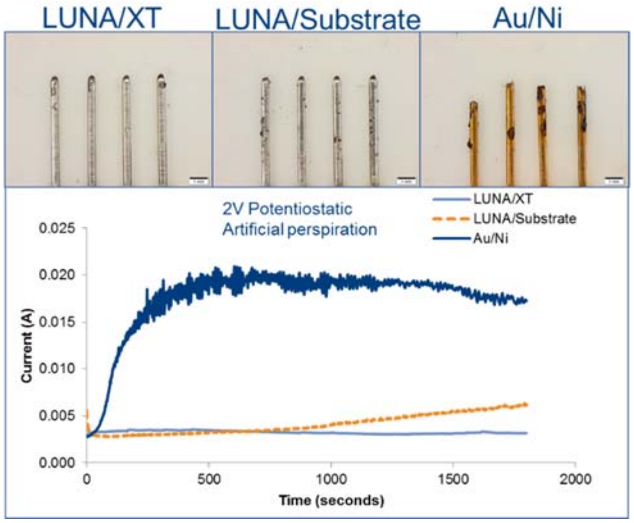

Figure 3. Recorded current over 30 minutes at 2 V showing immediate disintegration of the Au/Ni stack and its substrate when immersed in artificial perspiration. The LUNA® stacks show limited visual surface corrosion after testing, and the LUNA® stack with no barrier layer does exhibit a small gradual increase in current during the test.

In artificial perspiration, LUNA®/XTRONIC® exhibited relatively low corrosion currents in the range of 10^{-6} A for 1 V and 1.5 V and showed no visible corrosion product. A similar trend was observed for the LUNA® without a barrier layer. When pushed further to 2 V, the corrosion current increased to 10^{-3} A for both embodiments of LUNA®. Despite this increase in corrosion current, neither embodiment of LUNA® showed any significant damage to the specimen except for some minor corrosion product visible on the material surface.

The Au/Ni stack exhibited corrosion currents three orders of magnitude higher than those of the LUNA® stacks for 1 V and 1.5 V (in the range of 10^{-3} A), with visible black corrosion product on the surface. When pushed further to 2 V, the integrity of the Au/Ni was fully compromised, subsequently resulting in dissolution of the Cu base substrate.

The performance of all three stacks tested in phosphate buffered saline solution showed a similar trend to those tested in artificial perspiration. At 1V in this solution, the LUNA®/XTRONIC® stack still showed excellent corrosion resistance with a corrosion current on the order of 10^{-6} A. While both the LUNA® directly on the substrate and the Au/Ni stack showed corrosion products on the surface, the corrosion current of LUNA® material was two orders of magnitude lower than that of the Au/Ni after 30 minutes of testing. The Au/Ni stack exhibited a clear break in its corrosion resistance after approximately 500 seconds, when its corrosion current increased from 10^{-4} A to 10^{-3} A, almost crossing into 10^{-2} A. Pushing further, both embodiments of LUNA® showed signs of corrosion at 1.5 V while Au/Ni failed catastrophically at this potential, showing dissolution of the stack as well as the substrate material. The corrosion potentials and optical images for these experiments are shown in Figures 4 and 5.

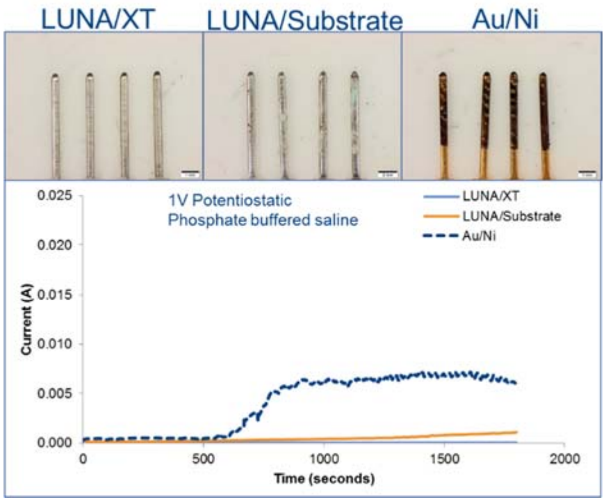

Figure 4. Recorded current over 30 minutes at 1 V showing the failure point of the Au/Ni stack near 500 seconds in phosphate buffered saline solution. The LUNA®/XTRONIC® stack shows no evidence of corrosion, while the LUNA®/substrate sees limited visual corrosion product and a small increase in current over time.

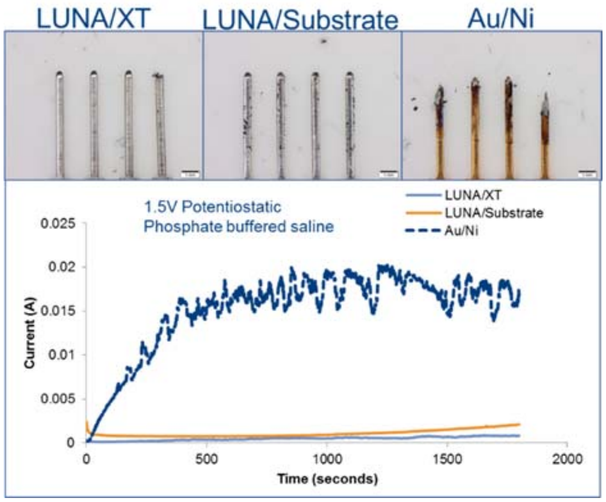

Figure 5. Recorded current over 30 minutes at 1.5 V showing an immediate increase in the Au/Ni current in phosphate buffered saline solution and dissolution of the substrate. The LUNA®/XTRONIC® stack shows a small amount of corrosion, while the LUNA®/substrate stack shows limited corrosion and a small increase in current over time.

The results for immersion corrosion resistance demonstrate that the LUNA® stacks engineered by Xtalic Corporation can provide superior performance over the traditional Au/Ni stack whether or not a Ni-based barrier is implemented. The inclusion of a XTRONIC® stack does provide additional test margin that could be important for some service environments. A thicker LUNA® layer could potentially close some of this performance gap and should be economically competitive when desired.

It is possible that sufficiently improved performance could also be achieved through the use of a thicker gold layer, but based on the results reported herein, the increase in gold thickness would likely need to be significant. Even if proven technically feasible, the cost of employing such a thicker gold layer could also quickly become uneconomical, particularly for mobile device and wearables applications where product pricing can be even more sensitive than in other connector applications. Xtalic Corporation's LUNA® stack, with and without a XTRONIC® barrier layer, can serve as a technically and economically viable option for mobile and wearables applications where corrosion resistance is required in potential-biased wet and damp environments.

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