Nickel-free Metal Finishes

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The Center for Disease Control estimates that 10-20% of the population has a nickel sensitivity that can cause allergic reactions. As mobile devices and wearables become increasingly popular, the need to eliminate Ni from these devices comes to the forefront. Most devices on the market employ a male to female connector for charging and file transfers. The traditional final finish stack used in these mobile connectors employs an electroplated gold top coat for wear durability and corrosion protection and a nickel barrier layer to prevent intermetallic diffusion between the gold and the base substrate (typically a copper alloy). While a gold top coat is excellent for wear durability and corrosion protection in some cases, the inherent porosity in electroplated gold allows the nickel from the barrier layer to leach out under damp conditions, causing allergic reactions in individuals with nickel sensitivity, especially in the wearables space.

Current options for the removal of the nickel barrier layer from the system involve the use of multiple precious metals that can become costly. For example, a common stack used for nickel removal involves using a relatively thick palladium layer as an intermetallic diffusion barrier layer between the copper alloy substrate and the gold top coat. Palladium and gold, being precious metals, can fluctuate based on market conditions and can affect the bottom line in production for cost-sensitive devices.

Xtalic Corporation has successfully developed a novel nanocrystalline silver alloy stack named LUNA® which can effectively replace the gold top coat as well as allow for the removal of the nickel intermetallic diffusion barrier layer. Not only does the LUNA® stack offer a nickel-free option to the traditional gold on nickel stack, the cost of the LUNA® stack is a fraction of the cost of other nickel-free options on the market.

Laboratory testing shows that the LUNA® stack, without the use of a nickel layer, can provide equivalent or better durability and corrosion resistance when compared to an industry standard gold on nickel stack, while also acting as a diffusion barrier for copper thus preserving its electrical performance as a final finish. In contrast with traditional silver coatings, the LUNA® stack is thermally stable, maintaining its nanocrystalline grain structure and durability performance.

To evaluate the thermal stability of the LUNA® stack, both LUNA® and a representative traditional electroplated silver were heated to 150ºC and 225ºC for extended time. As calculated by the Ag (111) peak broadening (Fig. 1) in X-ray Diffraction, which can also be visualized in the FIB images shown below (Fig. 2), almost no grain coarsening was observed in the LUNA® layer at 150ºC or 225ºC after 500 hours. In contrast, the traditional silver layer grain sizes increased substantially after the aforementioned annealing conditions. After 500 hours at 225°C, catastrophic failure of the traditional silver coating was observed with extensive copper migration through the coating and onto the contact surface, causing large scale voiding (Fig. 2).

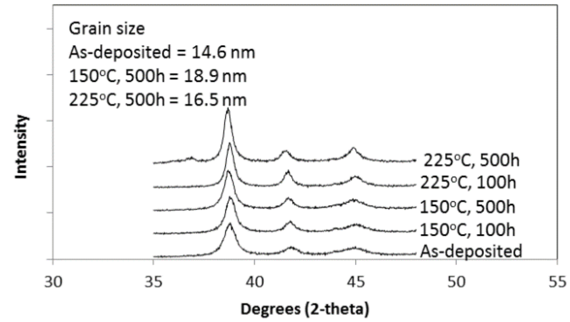


Figure 1. *X-ray Diffraction of LUNA® shows no peak broadening at Ag (111), even after 500 hours at 225℃*

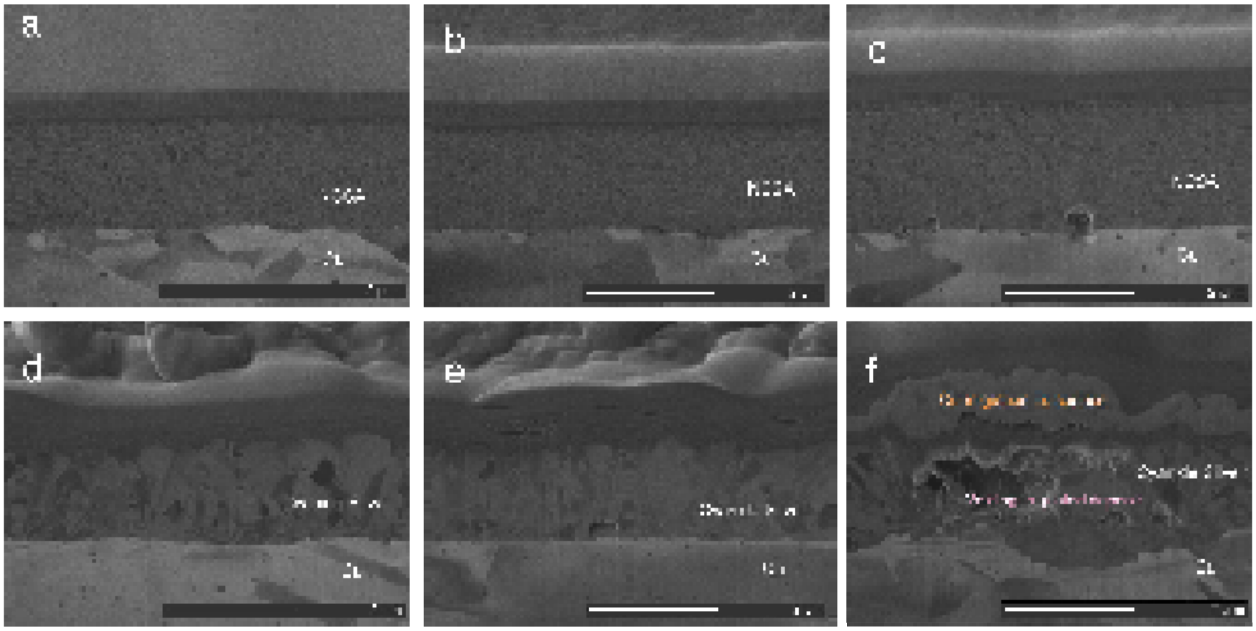


Figure 2. *R Focused ion beam image of LUNA®.*
(a) As-deposited, (b) 150ºC, 500 hours, (c) 225ºC, 500 hours, and traditional silver: d) as deposited, (e) 150ºC 500 h, and (f) 225ºC 500h. The top layer in the images are Pt, which was deposited before FIB cutting to protect the surface of the samples.
(e) 150ºC 500 h, and (f) 225ºC 500h. The top layer in the images are Pt, which was deposited before FIB cutting to protect the surface of the samples.

The intermetallic thermal stability at the LUNA® copper alloy substrate interface showed minimal intermetallic diffusion taking place. Fig. 3 shows Auger line scans of LUNA® on copper after 150ºC and 225ºC after 500 hours of annealing.

The intermetallic zone increased by less than 0.2µm, demonstrating that the LUNA® stack does not require a barrier layer between the copper substrate and the top coat. This option allows for complete removal of nickel from the connector system as well as eliminating the need for a costly palladium intermetallic diffusion barrier layer.

The wear durability of the LUNA® stack was benchmarked against a traditional gold on nickel stack to prove equivalence performance. Testing was carried out on a 1mm radius dimple worn against a flat coupon under a 50g load to simulate the Hertzian stress experienced by typical mobile connectors. After 10,000 mate/unmate cycles simulation, the LUNA® stack showed equivalent performance to a process of record 0.75µm of gold on nickel stack. Fig. 4 shows EDS maps of the different layers after durability testing.

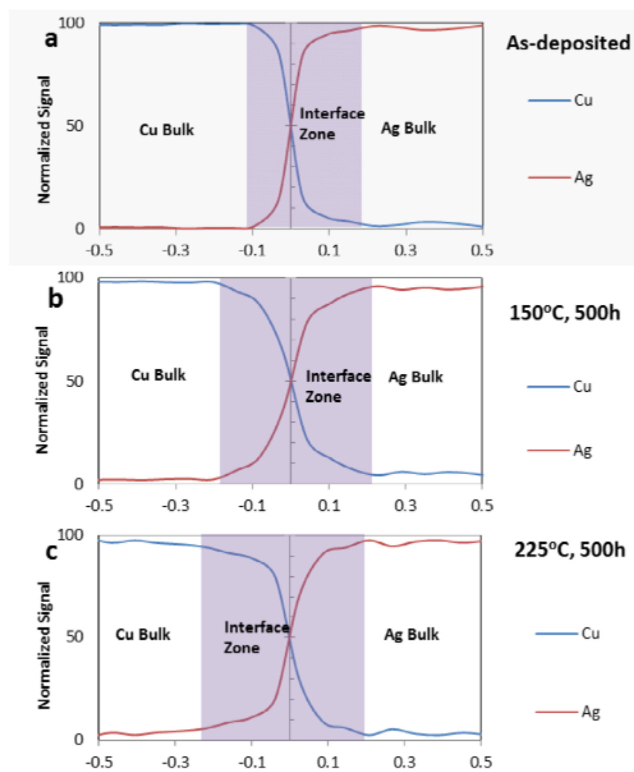


Figure 3. *Auger scanning across LUNA®/copper interface: (a) As-deposited, (b) 150ºC, 500 hours (c) 225ºC, 500 hours*

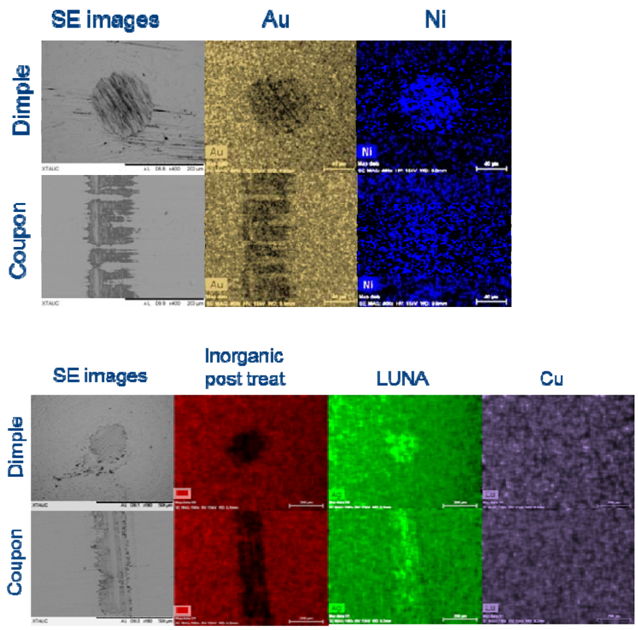


Figure 4. *Wear durability of LUNA® electroplated directly on top of copper substrate after 10,000 wear cycles under a 50 g load. Breakthrough of the thin inorganic post treat (used as a color stabilizer for the LUNA®) resulted in an increased LUNA® signal in the wear track. Both dimple and coupon showed no sign of thinning to the base substrate.*

Industry standard corrosion tests such as neutral salt spray and mixed flowing gas (MFG), as well as biased immersion corrosion in artificial perspiration, were carried out on the LUNA® stack in parallel with a typical 0.75µm gold on nickel stack. The LUNA® stack showed no corrosion of the base substrate after 24 hours of neutral salt spray and 5 days of class IIa MFG testing. While the gold on nickel stack failed catastrophically in artificial perspiration biased immersion corrosion testing. While the gold on nickel contacts started to dissolve, the LUNA® showed minimal corrosion up to 30 minutes of testing. The LUNA® showed equivalent performance to the gold on nickel stack in neutral salt spray and MFG testing but outperformed in the biased immersion corrosion testing as shown in Fig. 5 and Fig. 6, respectively.

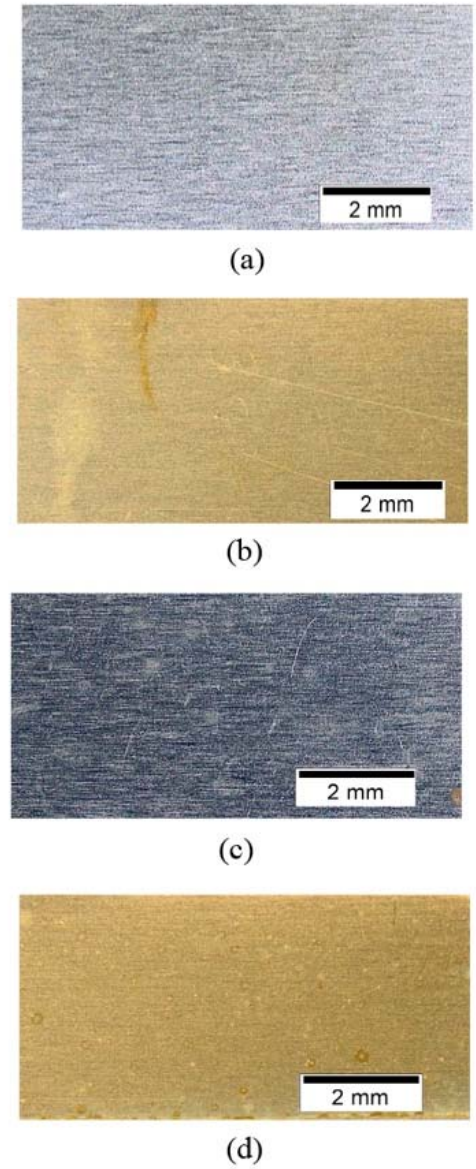
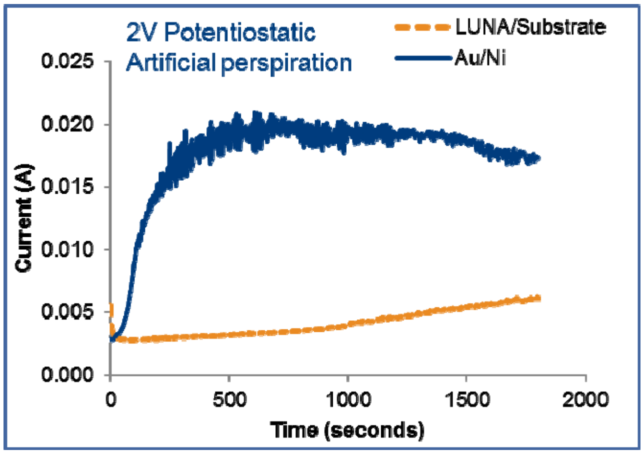


Figure 5. *Industry standard corrosion tests:*
(a) LUNA® stack after 24 hours of neutral salt spray, (b) gold on nickel stack after 24 hours of neutral salt spray (c) LUNA® stack after 5 days of class IIa MFG exposure, (d) gold on nickel stack after 5 days of class IIA MFG exposure



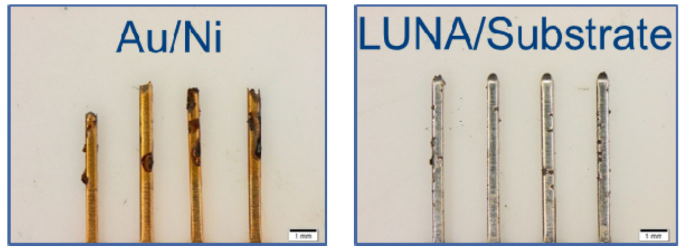


Figure 6. *Biased immersion corrosion testing in an artificial perspiration solution at 2V showed the gold on nickel stack failing in less than 10 minutes of testing while the LUNA® stack can withstand up to 30 minutes of testing under the same testing condition with minimal corrosion.*

The combination of thermal stability, interface stability, wear durability and corrosion resistance makes the LUNA® stack a viable option for use as both the barrier layer and the contact finish. The LUNA® stack allows for the complete removal of nickel from mobile and wearables electrical contact finishes from a performance standpoint. It also offers a more economical option to other nickel-free electroplated stacks on the market. With the superior technical performance and attractive economic considerations, Xtalic Corporation's LUNA® stack can be a viable solution for the costly nickel sensitivity problem amongst mobile and wearables applications.

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