NanoSHIELD-AU™ TECHNOLOGY

An Electro-Spec Plating Innovation

Introduction

Electro-Spec specializes in electroplating, passivation and heat-treating services for the medical, automotive, aerospace, military, nuclear and RF/microwave industries. With a vision to innovate, Electro-Spec's core value is to make the impossible, possible. We work with customers and suppliers in a collaborative manner to add value through technology, quality and services. One of our more recent technological developments has been the introduction and adaptation of NanoSHIELD-AU™ to enhance corrosion and contact resistance and lubricity, while reducing the necessary plating thicknesses of precious metals. With Electro-Spec's NanoSHIELD-AU™ technology, we offer "Future Technology, Today."

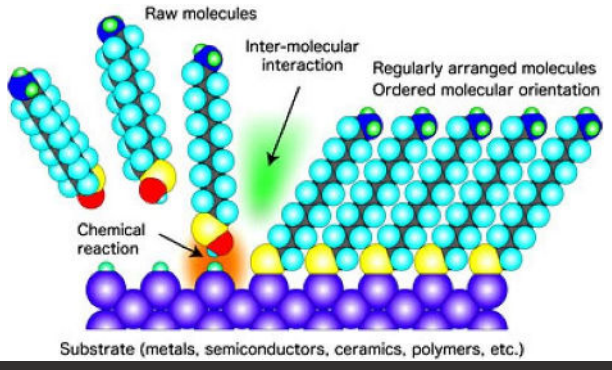
The formation of a layer of NanoSHIELD-AU™ technology is done by molecular self-assembly. This self-assembly is a reversible chemical process, by which a homogeneous, but randomly applied, material solution adopts a pre-defined arrangement. This is done without any direction or management from an exterior source. The primary property of the self-assembled system is that it spontaneously forms at the local level. As more molecules attach themselves to a surface, they continually arrange and rearrange themselves to form a more efficient and complete layer. The structure builds itself, eventually filling the entire surface of the plated component.

The use of NanoSHIELD-AU™ is an emergent technology of chemical synthesis processing. This process has been adopted in many cutting-edge micro and nano-technologies, including, polymer sciences, and materials engineering. Molecular self-assembly systems lie at the technological interface between chemistry, molecular biology, polymer and materials science. Many self-assembling systems have been developed; NanoSHIELD-AU™ represents a significant advance in the molecular engineering with simple molecular building blocks. This technology has shown itself to be useful for a wide range of commercial and metallurgical applications. The acceptances and use of this technology is growing at an accelerating pace. One major commercial application of self-assembling molecules is to actually reduce the thickness of gold on components by incorporating a layer of NanoSHIELD-AU™ as a post treatment process.

Although this technology is more commonly associated with biosciences and chemical engineering, with its use as a post-process to electroplating, Electro-Spec is showing that NanoSHIELD-AU™ has a promising future in manufacturing and metal forming technologies. Electro-Spec first adapted this process to finishing plated surfaces several years ago. The process employs bi-directional or multi-functional molecules that offer two or more termination groups with different functionality. Typically, one end is attached to a specific surface while the other end provides a specific functionality. These molecules can be attached to metals (alloys), glass, ceramic, plastics, etc. In this manner, it is possible to impart or enhance the intended performance of a surface or enable completely different properties and applications over a plated surface. This NanoSHIELD-AU™ technology is unique in the plating market and to Electro-Spec, as no other metal finishing company in the world can incorporate this type of post treatment to reduce gold thicknesses, while enhancing wear and corrosion resistance at the same time. This is all accomplished without altering the hardness or purity of the gold.

NanoSHIELD-AU™, which is a post-plating process, forms a protective layer on gold plated surfaces. The plated part is immersed in a pre-mixed blend of proprietary chemical polymers. The bath is heated to a specific temperature where the molecules begin to be pulled from the solution, attaching to the plated component. Within the bath, the 'head' of the polymers attach themselves to the sulfur in the gold deposit while their 'tails' attach to each other eventually forming a continuous, impervious layer. This continuous layer is the defining characteristic of NanoSHIELD-AU™. The immersion process only takes about three minutes and there is little post processing to complete the finishing.

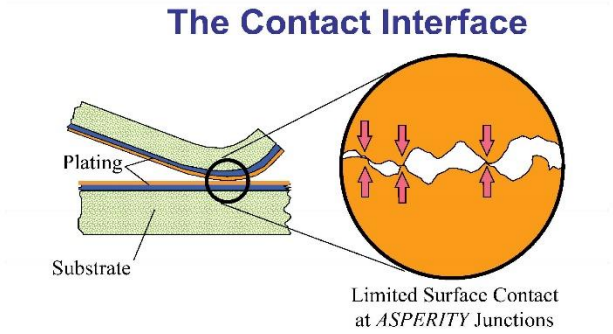
There are both qualitative and quantitative benefits to the implementation of the NanoSHIELD-AU™ technology. Precious metal thickness can be drastically reduced, leading to significant cost savings through life cycle extension by enhanced corrosion, diffusion and wear resistance for electronic applications. One customer was able to reduce the gold thickness on their parts from 50 µ" to 10 µ". The additional cost of applying NanoSHIELD-AU™ is minor compared to the considerable material savings, especially with respect to precious metals. Other benefits are of a qualitative nature by providing enhanced contact resistance, diffusion resistance, corrosion and wear resistances which do not bring direct cost savings to a company, but they do add significant value to their products in terms of performance and longevity.



Contact Resistance

A plated surface has increased resistivity due to the unevenness of the surface. This creates limited surface contact at asperity junctions. This limited surface contact constricts the flow of current through these asperities, rather than across the entire contact area. This has a detrimental effect on the electrical properties of the system.

Electrical resistance is the property of a conductor due to which it opposes the flow of current through it. A material, or conductor, with a uniform cross section has a resistance proportional to its resistivity (rho) and length (L) and inversely proportional to its cross-sectional area (A). A material with a higher resistance allows less current to flow through it when compared to a similar lower resistance material with the same cross-section.



Standard Resistance equation:

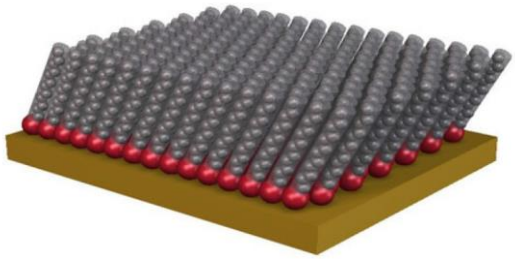
$R = rho * L/A$

Resistance equation with a non-optimal contact resistance:

$R = rho * L/A + R(contact)$

The addition of any contact resistance decreases the efficiency of the electrical system and creates areas of localized heating, reducing its effectiveness at carrying current. By coating a plated surface with NanoSHIELD-AU™, the voids in an uneven surface are filled and the surface becomes smoother. The effects of the remaining asperity junctions are greatly minimized. This shifts the contact resistance equation closer to the ideal resistance equation.

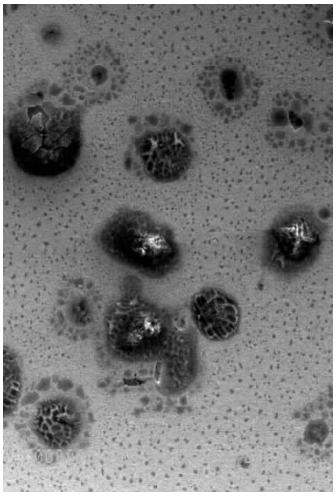
Corrosion Resistance

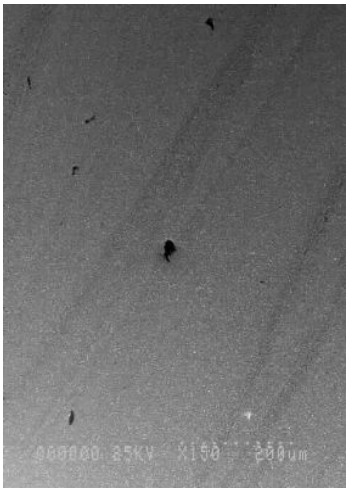


Corrosion resistance begins with reducing the porosity of the surface of a material. Porosity is the void fraction of a material and is a measure of the voids in a material with respect to the volume of the material. The porosity of a material is influenced by the surface impurities, the condition from machining, extruding or forming, the grain structure of the plating, and the thickness of the plating. With respect to plating, porosity is directly impacted by the thickness
of the plating. In general terms, with respect to precious and semi-precious metal plating, the level of porosity can be reduced by increasing the thickness (and expense) of the plating. The introduction of NanoSHIELD-AU™ forms an impermeable layer of molecules independent of surface roughness or topology. They create a nearly complete barrier, with localized zones of zero porosity, prohibiting the introduction of corrosives into the material. This technology affords a drastic reduction in plating thickness (with respect to porosity) while resulting in increased resistance to corrosion. Three common tests to determine the corrosion resistance of a plated material are the Nitric Vapor test, the Sulfurous Acid test and the Potassium Hydroxide test. Each of these tests measures how the surface resists corrosion in different environments and over time.

Nitric Vapor (ASTM B 488) Gold and Nickel

This specification establishes the requirements for electro-deposited gold coatings for engineering applications, employed specifically for their corrosion and tarnish resistance, bondability, low and stable contact resistance, solderability, and infrared reflectivity. Coatings are classified into types, which characterize minimum purity, and codes. Coatings shall be sampled, tested and conform to specified requirements as to purity, hardness, appearance, thickness, mass per unit area, ductility, adhesion and integrity.



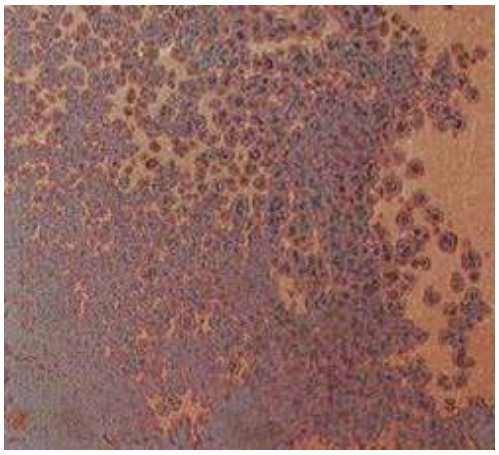


Sulfurous Acid and Gold (mixed flow gas test)

This is a rapid test to determine the porosity of a gold surface and its resistance to oxide corrosion. When exposed to sulfurous acid, the anodic oxidation rate of gold is five times faster than that without sulfurous acid. The passivity of the gold electrodes is attributed to the accumulation of elemental sulfur on the surface of gold. The sulfurous acid reacts with this oxidation product, decreasing the decomposition and improves its stability.

Potassium Hydroxide (85%) in solution

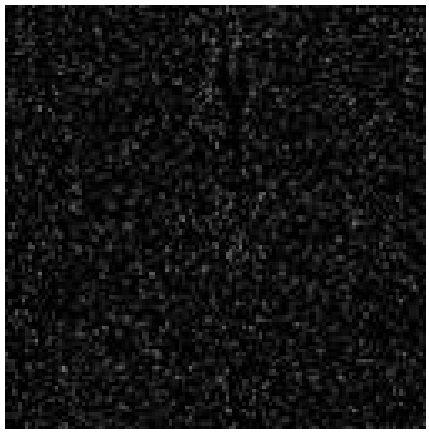
Potassium Hydroxide (KOH) is a highly corrosive chemical as it introduces large amounts of highly basic hydroxide ions (OH+) into a solution. These hydroxides rapidly attack the surface of metals, stripping them of any positive ions. This is such an aggressive solution that it will even strip normally inert gold ions from a surface to form unstable hydroxides. These unstable hydroxides quickly separate back into solution, but the damage had already been done. This reaction occurs more frequently near rough interfaces.



Wear Resistance

The use of NanoSHIELD-AU™ results in a dramatic increase in lubricity and wear characteristics when compared to normal finished surfaces. Lubricity is a measure of the reduction in friction that a lubricant adds to a system. In this case, the lubricant is the layer of NanoSHIELD-AU™. This study of lubrication and mechanism wear is called Tribology. As it is difficult to measure the lubricity of a surface directly, tests are performed that quantify a lubricant's performance with respect to a base surface. This is done by determining the wear caused to a surface by an object in a given amount of time or over a certain number of repetitions. Other factors such as surface size, temperature, and pressure are also specified. Lubricity is deemed worse as more wear-scars are witnessed on the surface of the test piece. For this reason, lubricity is also termed a substance's anti-wear property.

Electro-Spec, in conjunction with its in-house metallurgical lab and customer partnerships, has performed tests of the NanoSHIELD-AU™ surface with a universal micro-tribometer. This device uses a 100-gram load with a 12.5mm motion at 30 hertz to create a controlled load and sliding motion on a surface. This device can monitor the contact resistance and the friction force. A test of over 1000 cycles was executed on a gold plated (50 micro-inches) with underplates of nickel (50 micro-inches) and copper (10 micro-inches) both with and without NanoSHIELD-AU™. The surface without NanoSHIELD-AU™ showed that the repetitive process wore through the gold plating, damaging even the nickel and copper underplate layers. Whereas the wear on the NanoSHIELD-AU™ treated surface showed little to no wear. Analyzed data showed the coefficient of friction was 20-25% less on the NanoSHIELD-AU™ surface when compared to the non-treated surface.



Customer Testing and Integration

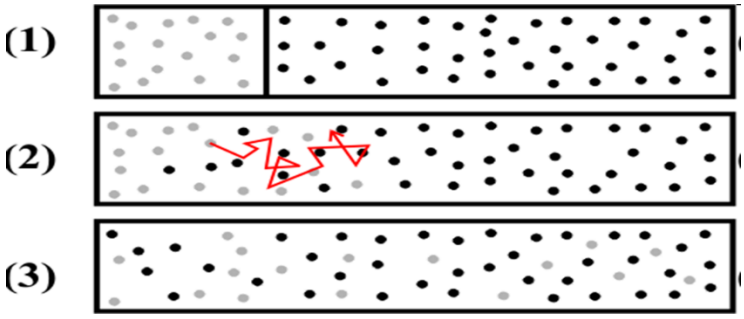
Major companies that find this product to be advantageous are the RF/microwave industry, the medical industry, and any industry that uses extensive gold plating, like coaxial cable and battery technologies. This technology is so new that it is just beginning to catch the attention of the military and government procurement offices. However, as of now, there are no military or governmental specifications for this process, so it is not currently used for any military products. As more customers begin to use and adapt the technology, surface, corrosion, and wear specifications are being compiled. Currently there is no governing body over NanoSHIELD-AU™ in manufacturing as there is for plating and other manufacturing processes.

Electro-Spec is working with several major American RF/microwave companies that have adopted this technology. Proof of concept testing employed all of the following extensive tests:

Test Type	Protocol or Chemical Agent
Salt Spray Test	MIL-STD-202 Method 101
Industrial Corrosion Test	Potassium Sulfide Vapors
Nitric Acid Test	Nitric Acid Vapors
Solderability Test	MIL-STD-202 Method 208 with steam
Voltage Standing Wave Ratio (VSWR)	MIL-PRF-39012
Insertion Loss Test	MIL-PRF-39012
Contact Resistance	MIL-PRF-39012
Dielectric Withstanding Voltage (DWV) Test	MIL-STD-202 Method 301
Insulation Resistance Test	MIL-STD-202 Method 302
Corona Test	MIL-PRF-39012

Many companies have realized cost savings with Electro-Spec's NanoSHIELD-AU™ technology. One major Original Equipment Manufacturer (OEM) is looking into incorporating NanoSHIELD-AU™ into all of their worldwide supply of components to help prevent premature degradation of their product's life cycle. While another RF connector supplier has incorporated NanoSHIELD-AU™ on all parts that get gold plated, specifically bodies that get soldered to drastically reduce plating costs.

Electro-Spec's NanoSHIELD-AU™ offers enhanced corrosion and contact resistance, delivering 35% to 75% reduction in precious metal cost while providing equal or superior performance. However, cost savings are only one part of the benefits of this cutting edge plating process. NanoSHIELD-AU™ imparts stable contact resistance at the interface of inert surface materials (oxidation resistance). It also provides a diffusion barrier to intra-granular and trans-granular metallic contamination and modification (such as Cu migration), increased corrosion resistance via low porosity, and enhanced resistance to contact wear due to its increased lubricity. In addition, NanoSHIELD-AU™ also delivers higher surface conductivity and higher solderability.



Electro-Spec Inc. is continually recognized as one of the leading specialty plating facilities in the United States, with a customer base from North America to Asia and Europe. We are synonymous with high quality and high reliability surface finishing, with a commitment to excellence, quality, and service that is unsurpassed in the industry. To learn more about advanced plating processes and how Electro-Spec can remove costs from your manufacturing processes, please contact us for support and professional consultation.

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