

# ◆ Static Intercept\* Technology: A New Packaging Platform for Corrosion and ESD Protection

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Telecommunications providers expect products to perform reliably during operation in the field. Achieving the expected hardware reliability is due to an amalgamation of multiple factors. A significant contribution to reliable performance results from the incorporation of specific materials, which are very corrosion resistant and electrostatic discharge (ESD) safe during the design and manufacturing phases of the equipment life cycle. Environmental protection must be given to products to ensure that the products retain designed reliability during global storage and transport. There will be cases of material corrosion with as-received or stored products and there are many instances of “less than ideal” storage conditions for our products (e.g., customer warehouses without air-conditioning or environmental controls). We have developed a strategy to mitigate these problems by the use of a Static Intercept\* packaging platform. This technology simultaneously protects equipment and components from corrosion, moisture, and ESD in a single packaging material for seven years or longer. The technical merits of Static

Intercept, which currently provides the longest available protection against corrosion and ESD degradation, will be discussed in terms of addressing *these storage issues*. © 2006 Lucent Technologies Inc.

## **Introduction: Static Intercept\* Technology**

The material described in this paper provides both electrostatic discharge (ESD) and corrosion protection, and has properties which surpass those of the available alternatives. It has been manufactured with stable, controllable surface resistance in the range  $10^5$  to  $10^{10}$  /square that is independent of the humidity and compliant with NEBS\* GR-1421-CORE ESD requirements 4.8.1.5.1.72. It does not contain volatile additives, so it does not contaminate the parts it is used to protect. It consists of a polymer matrix such as

polyethylene, polypropylene, or styrene containing reactive compounds which react with and neutralize corrosive atmospheric gases so as to prevent their penetration through the polymer. Another unique property of the material is that it cleanses the environment inside the bag by neutralizing corrosive species trapped within the bag during packaging. An additional material, acting in synergy with the reactive compounds, provides permanent ESD properties. The material is called reactive polymer because of the

reactivity of the compounds with corrosive atmospheric gases. Variations of conventional polymer processing techniques have been used to successfully produce reactive polymers in various forms.

Lucent Technologies Bell Labs, as well as E.I. DuPont Nemours' Electrostatic Discharge (ESD) Group in Wilmington, Delaware, and the Baxter Healthcare Industrial Division ESD Group, in Valencia, California, have performed the following experiments and measurements that support and confirm the technologies' superior performance.

### ESD Considerations

ESD can have a devastating effect on the quality and reliability of manufactured electronics. ESD can be caused by improper material usage and/or by the corrosion of surfaces resulting in electrical overstresses (EOS) [2]. Consequently, ESD is a major issue throughout the electronics industry. Electronic devices often include circuitry designed to minimize their sensitivity to ESD, but such protection is usually not sufficient during periods of storage and transport. The standard practice, therefore, is to be sure that during manufacture, shipment, and storage, sensitive components and assemblies contact only static dissipative materials. As device dimensions continue to shrink, materials' protective surfaces become more susceptible to corrosion of the engineered conductive grounds. Consequently, the hardware will experience increases in ESD damage as the hardware plated surfaces become less conductive and cause the ESD shielding protection of the hardware to diminish [2]. The principal measure an ESD dissipative material is surface resistance (SR). The industry standard set by the ESD Association [1] specifies materials' SR must be within a range of  $10^5$  to  $10^{10}$  ohms/square. Various methods have been used to obtain materials in this range, but commonly used materials are known to suffer from a number of disadvantages. A common approach to ESD dissipative materials is to saturate organic chemicals on plastic surfaces. These organics are hygroscopic in nature. When atmospheric water is adsorbed, the surface becomes conductive in the required ESD range. When colorant is added to the organic coated polyethylene, the product is known, for example, as "pink poly" or "blue poly" or, without added colorant,

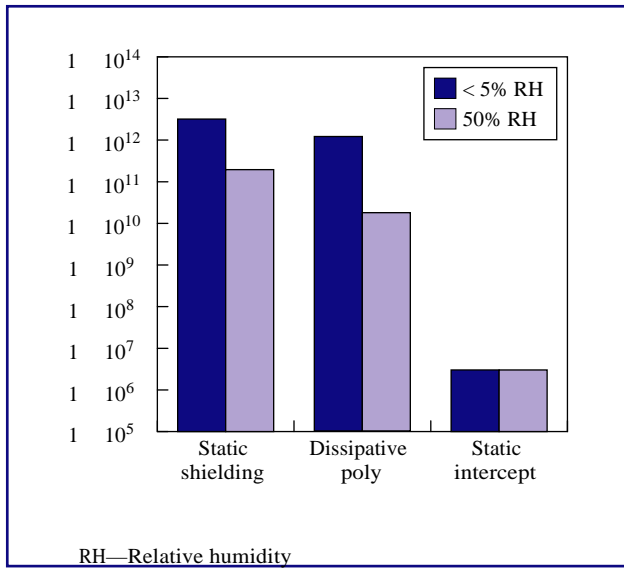
**Panel 1. Abbreviations, Acronyms, and Terms** ACI—American Competitiveness Institute ASTM—American Society of Testing and Materials CMOS—Copper metal oxide semiconductor EOS—Electrical overstresses ESD—Electrostatic discharge HASL—Hot air solder leveling IPC—Institute for Printed Circuits NAR—North America region NEBS\*—Network Equipment Building System PWB—Printed wiring board RH—Relative humidity SMT—Surface mount technology SR—Surface resistance VCI—Volatile corrosion inhibitor

as "antistatic or dissipative poly." Static shielding bags also use an inner layer of this organic loaded material in order to provide a static dissipative surface on the bag interior surfaces. This approach to ESD control has three major drawbacks:

1. The organic compounds are volatile, so after a period of several months in hot conditions to several years under cooler conditions, much of the coating evaporates and the material becomes insulating [5]. Unfortunately, there is no visible indication that ESD protection has been lost.
2. Since they rely on adsorbed water, these materials do not function in low humidity, and thus in dry climates, and certainly in dry packages, where the relative humidity can drop below 30%, they become insulating. This is shown in **Figure 1**.
3. The volatile organics can degrade performance of optical components from deposition of the organics on their lenses and fiber mating faces.

### Atmospheric Pollution

Telecommunication products and electronic assemblies are being shipped, stored, and deployed in increasingly aggressive corrosive atmospheres as an evolution of globalization takes place in the manufacturing, supply chain and customer deployment phases of equipment life cycles. At the same time, these products are moving outside of controlled



**Figure 1.**  
*Surface resistance measured in ohms/sq at high and low relative humidity.*

central office environments to remote sites closer to the customers. These remote locations are subject to more substantial environmental stresses than are experienced in controlled central office environments. Concurrently, commonly used corrosion inhibitors such as hexavalent chromium from plated metals and lead from printed wiring boards (PWB) and component solder finishes are being eliminated.

Static Intercept consists of a blend of polymers covalently bonded with copper metal oxide semiconductor (CMOS) and corrosive gas neutralizing proprietary additives and catalyzing agents. The resulting permanently anti-static material imparts an unequalled ability to neutralize corrosive gases for extended periods of time up to 20 years with a 3 mil (76 micron) thick bag in the North America region (NAR), shorter times in more aggressive environments. This material is also non-outgassing (a requirement for optical components), and free of ionic species (a requirement for high reliability electronic products as in telecommunications). Static Intercept also provides protection from corrosion by atmospheric gases such as hydrogen sulfide (H<sub>2</sub>S), carbonyl sulfide (COS), and hydrogen chloride (HCl). This is important for electronic components, pre/post plated cabinets, housings, electronic assemblies, and export shipping of metallic systems. Static Intercept bags provide

necessary protection from product degradation without additional product handling or materials. Corrosion of critical conductor surfaces by trace atmospheric gases is another reliability concern. Although the rate of corrosion may be slow, the effect is cumulative [3]. Parts in storage or in shipment are particularly vulnerable. This problem is most severe for copper and silver, which react with H<sub>2</sub>S, COS, sulfur dioxide

(SO<sub>2</sub>) and HCl. These trace gases are widespread [10].

Consider hydrogen sulfide: the ambient concentrations are generally in the range of 0.1 part per billion (ppb) to 10 ppb in NAR, but the ambient level is dramatically higher in Asia at 30 to 200 ppb due to an increase in fossil fuel consumption and less rigorous pollution controls. Laboratory measurements [4] of the H<sub>2</sub>S corrosion of copper, silver, and their alloys have shown that corrosion product film thickness is proportional to the H<sub>2</sub>S concentration up to 4 ppm, and up to 1,000 ppm-hour's concentration-exposure length. Exposure of copper to a background concentration of 1 ppb of H<sub>2</sub>S for one year can grow a sulfide film about 50 nm thick. The higher level of atmospheric corrosive gases in Asia becomes of particular concern.

One method of protecting electronic components from corrosion involves depositing a protective coating with volatile corrosion inhibitor (VCI) oils which are coated or absorbed onto paper or plastic materials which are subsequently sealed or formed in a container (bag or box) with the part to be protected. The VCI species evaporates from the VCI material and condenses on the product. The VCI places a thin contaminating film on the product, which excludes water and corrosive gases from the surfaces being protected. Limitations of this method are that the organic material protection is only sufficient for short term protection ( 30 days in air), evaporation occurs without warning over a period of time, which leaves the part without protection and in many cases with an insulating film, a film that may interfere with solderability, and, over long periods of time, the remaining film can absorb atmospheric water and concentrate corrosive gases within that film, ultimately causing more degradation on the surfaces than if no corrosion inhibition was used. The deposited organic compounds can also interfere with optical device transmission,

which prohibits the use of these materials with optical components.

### ESD Testing

We recognized the issue of needing non-contaminating, permanent ESD protection, coupled with long term, non-contaminating corrosion protection. As a consequence of research, Static Intercept, a new reactive polymer material, was invented. Static Intercept has been proven and specified to be a replacement for foil packaging (the dry method of protection). It also outperforms traditional ESD materials (e.g., shield bags, or pink poly), and volatile corrosion protecting products.

Tests of surface resistivity of Static Intercept as a function of relative humidity (RH) have been made at RH of 50%, 12.5%, and 5%. Results show no measurable change from 50% to 12.5% RH. When the sample's test environment was dried to 5% RH, a decrease of only 0.3% in the sample's SR was observed. We believe this phenomenon is due to the resistivity of the molecular water on the polymer surface which evaporates at 5% RH. The decrease can be attributed to the contribution of the conductivity of the surface water to the inherent resistance of the polymer, verifying that the polymer matrix does not rely on the content of atmospheric water for electrical conductivity.

Static Intercept samples were subjected to the Mil Spec B81705C Elevated Temperature Test (70° C for 12 days), and 24-hour water wash test as per Federal Test Method 101-4046. None of the samples' ESD characteristics were affected by these tests.

Static decay time of the Static Intercept samples was measured according to Mil Spec B81705 C using an ETS 406C analyzer. Since static decay is inversely related to humidity, all samples were tested at 5% RH so the samples would be stressed at the least favorable conditions. All Static Intercept samples tested had static decay times less than the detectable time of the test instrumentation, 0.01 seconds, with a 20 KV charge (a shorter time is better). The maximum time allowed is 2 seconds (typical new pink poly bags exceed the 2 second requirement in the 5% RH test).

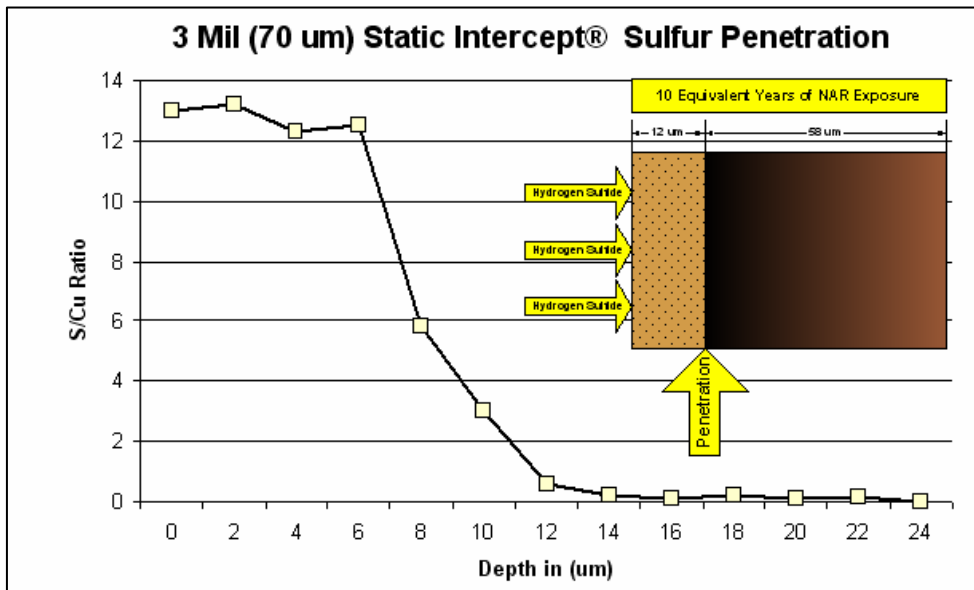
### Corrosion Testing

Corrosion protection from the sulfur- and chlorine-containing gases H<sub>2</sub>S, COS, and HCl occurs as they are neutralized, while diffusing through the reactive polymer, by reactions with covalently bonded getter materials which convert the corrosive gases to stable non-volatile compounds. The effectiveness of the re-active polymer for corrosion protection was measured by sealing test coupons of copper inside a bag of re-active polymer and placing it inside a chamber filled with a calibrated concentration of H<sub>2</sub>S. After completion of exposure, samples were cross sectioned and examined with a scanning electron microscope and energy dispersive x-ray analysis to determine the rate of diffusion of sulfur through the film. The result, shown in **Figure 2** demonstrates that H<sub>2</sub>S penetrated only 17% of the way through a 70 mm (2.7mil) polymer in a 10 year equivalent NAR test. Controls run with polyethylene without the additives illustrates that H<sub>2</sub>S penetrates standard polyethylene materials 1000 times faster (1 week of protection) than Static Intercept.

Additional tests were performed using "clam shell" film holders, similar to the ASTM cup device for measuring water weight loss. With 100% of chlorine gas applied to one side of the film, the onset of permeating gas was measured on the reverse side with a chlorine detector with a sensitivity of 10 parts per billion. Time delay for the onset using a trigger of 50 ppb was 16 to 18 minutes for a typical polyethylene resin, and 173 to 473 hours for the reactive polymer processed resin. **Figure 3** details the time it will take 1 ppm of chlorine to penetrate 0.002-inch film. The time of onset data was converted and normalized to 1 ppm HCl ambient for 35 years in NAR and effective protection times should be reduced by 3 to 5 times for locations outside of NAR. The results of this experiment prove the importance of the reactive nature of the Static Intercept packaging system and the magnitude of improvement in protection of Static Intercept over standard non-reactive packaging.

### Copper Contact Resistance

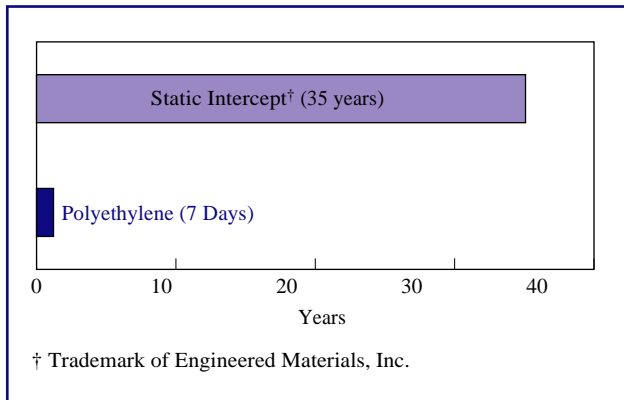
In 1988, forty-eight copper bus bars (3 x 20 x 75 mm) were manufactured and acid dip cleaned.



† Trademark of Engineered Materials, Inc.

NAR—North America region

**Figure 2.**  
3 mil (70 um) Static Intercept<sup>†</sup> sulfur penetration.



† Trademark of Engineered Materials, Inc.

**Figure 3.**  
DuPont chlorine test.

Twelve bars were buffed clean with a hand held power buffer then coated with No-Ox7, a commercial anti oxidant grease. All of the individual bars were paired, bolted, and tightened to form mated electrical junctions. Six junction assemblies were placed in 3 mil (76 micron) thick Reactive Polymer (SI) bags. The assemblies were stored for four weeks in air containing approximately 4 ppm of hydrogen sulfide. This stressed exposure is the equivalent to 10 years in NAR and 2

to 3 years outside of NAR. The junction resistances of the bars were tested following this corrosive air exposure. Testing utilized a model #398R universal systems 200-ampere DC power supply to supply current across the junctions. The junction voltage drop was measured with a Fluke\* #8840 digital multi meter. Junction resistance was calculated by  $R = \frac{V}{I}$  and dissipated power by  $W = I^2 R$ . **Figure 4** shows the results. The unprotected bars had degraded (increased) in junction resistance. In contrast, the bars protected only by the reactive polymer provided junctions as good as the labor-intensive buffed and No-Ox coated junctions.

### Copper Solderability

Copper is the predominant metal used in telecommunications equipment. Copper and its alloys have the most desirable cost/benefit ratio of all conductors. These metals, however, are very susceptible to atmospheric corrosion. Many engineering solutions are used to protect copper and its alloys from atmospheric degradation. However there is a certain percentage of equipment surface area that has exposed copper

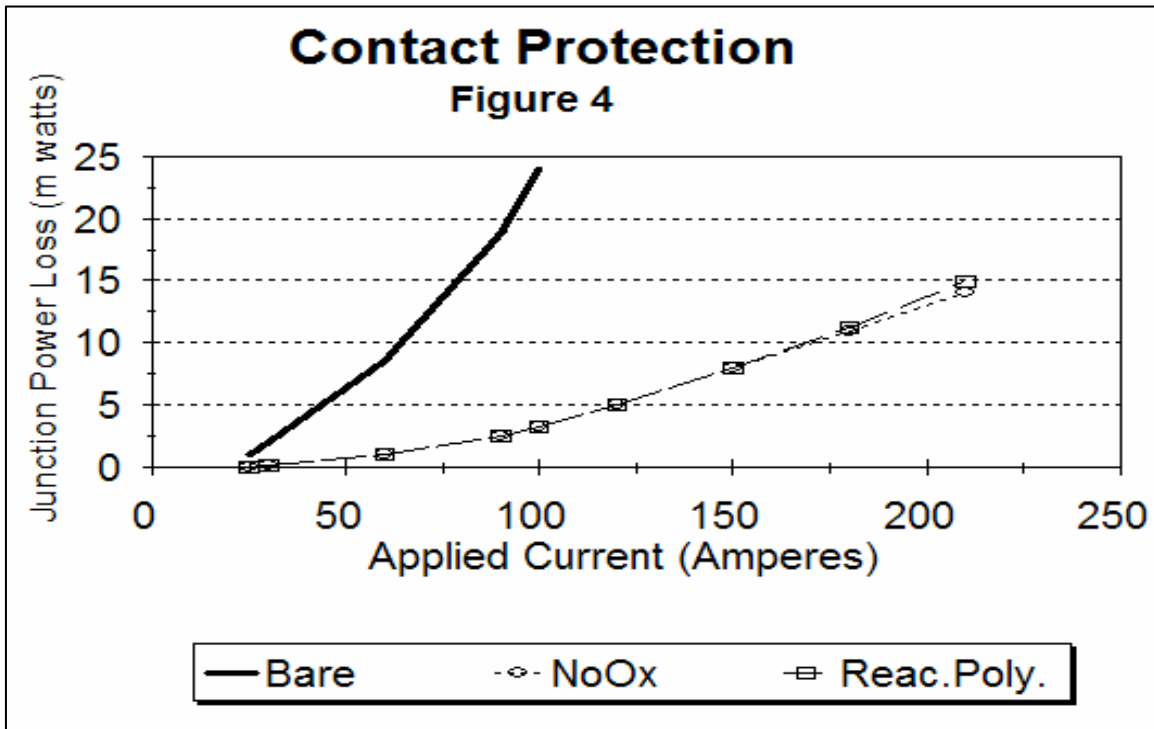


Figure 4.  
Contact protection.

(e.g., press fit thru-hole connector pins, unplated PWB vias and traces, cut ends of SMT leads). Since these metal surfaces degrade during shipping and storage more than others we had Maverick Technologies (an independent laboratory in Oklahoma City, Oklahoma) perform a standard test measurement of the ability of Static Intercept to protect against the slight surface degradation that affects solderability as a very sensitive evaluation of the surface's condition. The testing was performed in 2005 with cleaned and packaged copper samples that were not previously evaluated from the 1988 experiment described in the previous section. These samples were stored for 17 years in an uncontrolled indoor NAR environment representing 17 years of actual (non-accelerated) environmental exposure.

#### Copper Storage, the 17 Year Exposure Test

Copper samples 1 through 7 stored in Static Intercept had similar appearances in oxidation levels. Slight deviations occurred from sample to sample, but in magnitude all had comparable levels of oxidation. Samples 1 through 4 were all in unopened heat-sealed Static Intercept technology 3 mil bags. Sample 5 was in a Static Intercept bag that had been torn at some point

previous to inspection. Samples 6 and 7 were in Static Intercept bags that were opened some 4 years previous, in the circa 2001 time period. Sample 8 was a larger bus plate that was in a standard clear polymer bag since 1988. Heavy oxidation was noted and observed on this sample. Sample 6 was etched with a light acid (acetic) to remove any light oxidations that existed. This sample served as the baseline control for comparing the levels of solderability of the remaining samples.

The objective of the tests was to compare the solderability of each bar based on a variety of different packaging and storing conditions that each was subjected to. Static Intercept packaging was the primary packaging used.

The IPC/EIA/JEDEC J-STD-002B Test A, the Solder Bath/Dip and Look Test method, was followed during the test. This is the industry standard for measuring the solderability of leaded devices. The following conditions and materials were used:

- Flux Type: ROL 1 type
- Solder Type: Sn60/Pb40
- Flux Time: 7 sec
- Flux Dry Time: 20 sec
- Solder Dip Time: 5 sec

## Results

Based on the above tests on the bus bars with a variety of packaging conditions, the following conclusions are made:

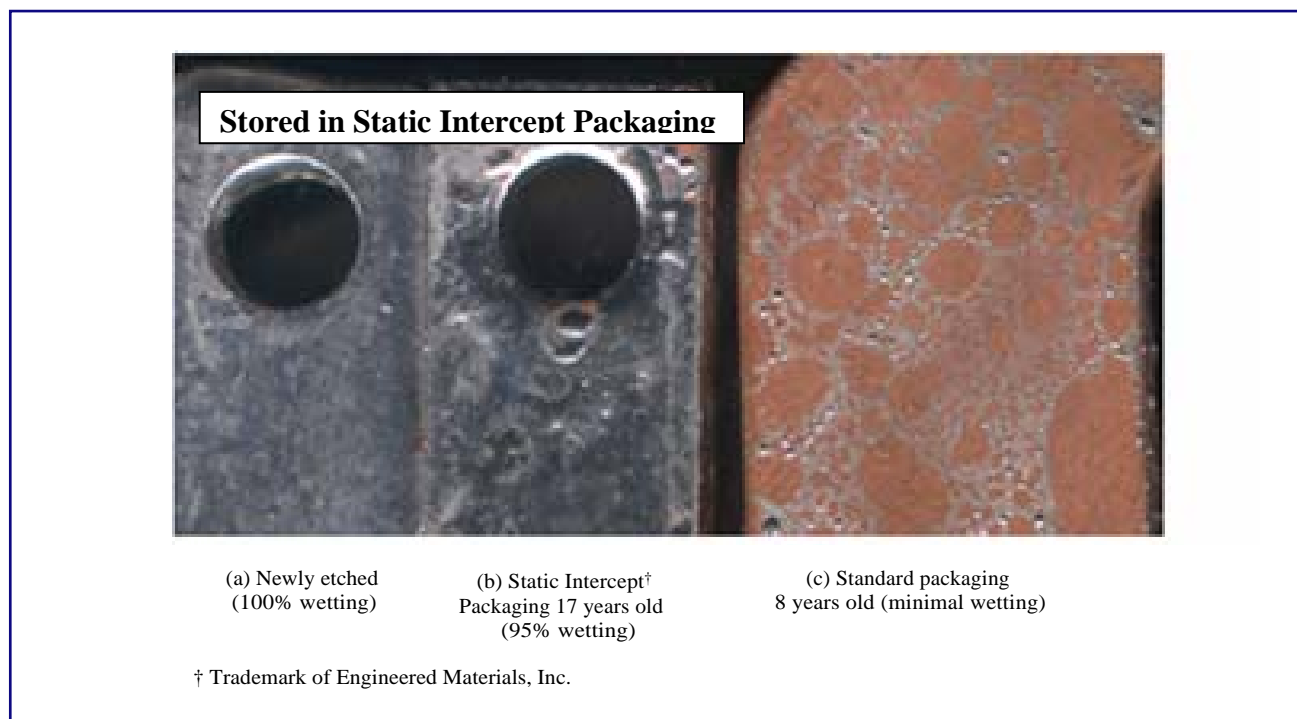
- A freshly cleaned control (sample 6) had 100% solder coverage.
- Samples 1, 2, 3, 4, 5, and 7, which were Static Intercept protected, had 95% solder coverage.
- Sample 8, which was standard polyethylene bag protected, had 0% solder coverage.

The bus bars that were packaged in the Static Intercept packaging and stored for 17 years passed all solderability tests, exhibiting only slight surface solderability decay over the time since packaging as shown in **Figure 5**. This is a 5–10% reduction in solderability as compared to a known good just-cleaned 100% solderable sample. This reduction in solderability passes all IPC requirements for solderable surfaces. The unsealed plastic bag packaged bus bar (sample 8) exhibited 0% wetting, and even with a light acid etching exhibited poor solderability.

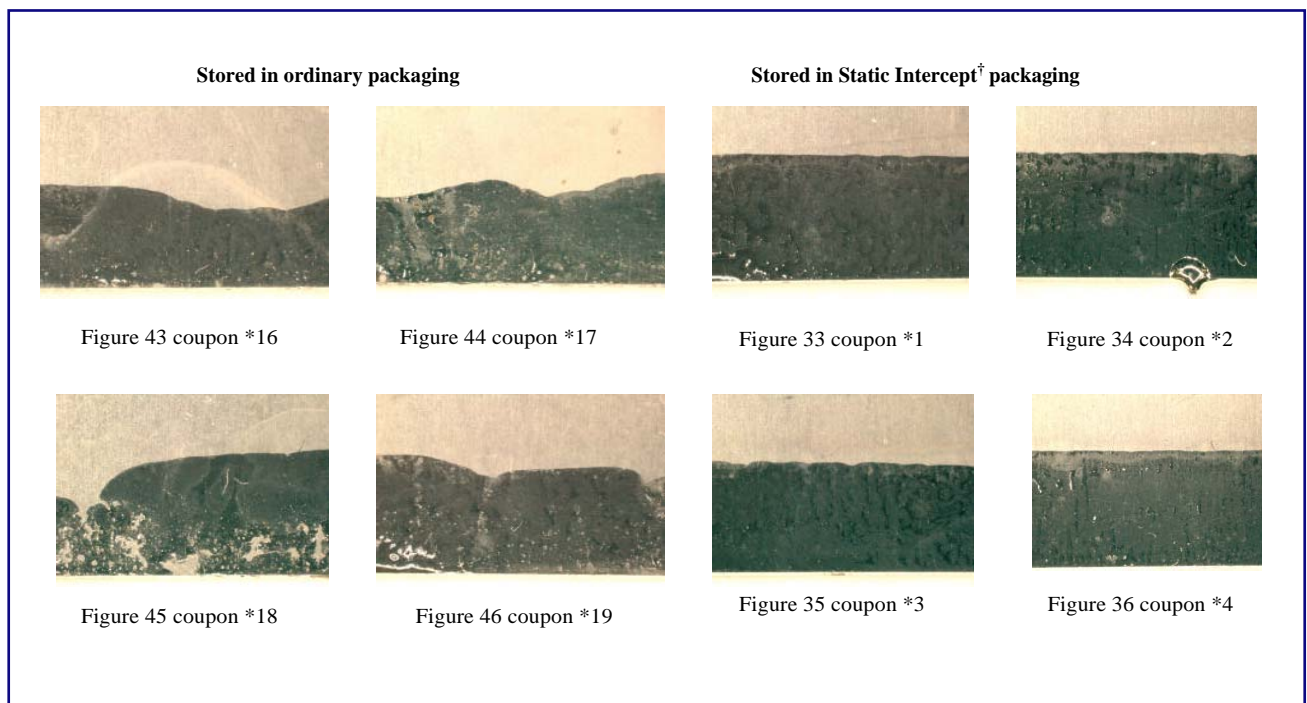
The Static Intercept packaged samples had a significant level of protection against copper corrosion over time, including the bars that had tears in the bags. Static Intercept performs gas neutralization through preferential gettering of the corrosive gases. This functionality provides efficient proximity neutralization of corrosive gases so as to significantly lower the corrosive gas concentration in the vicinity of the torn opening of the bag. This correlates to the substantial improvement in solderability over a similar bar in a standard polymer ESD bag packaging environment.

## Silver

The move towards lead-free materials in electronics manufacturing makes corrosion protection even more challenging. Lead-free materials options require surfaces free of contamination as well as corrosion (tarnish). One leading board finish used today is immersion silver (ImAg). Immersion silver maintains surface planarity and does not clog small via openings or breach small gaps between features on



**Figure 5.**  
*Copper bars following the solder dip tests.*



<sup>†</sup> Trademark of Engineered Materials, Inc. ASTM—  
American Society of Testing and Materials

**Figure 6.**  
*Immersion silver plated copper surfaces following ASTM B117 standard salt fog testing.*

circuit boards as hot air solder leveling (HASL) does. As electronics move to higher density and/or frequency, spacing between conductor dimensions is reduced. This reduction in conductor spacing and features creates additional challenges for HASL finishes. The combination of benefits of ImAg and its ability to replace lead containing finishes provides significant advantages over HASL as a PWB finish, though ImAg is more sensitive to shipping- and storage-related corrosion than HASL. Static Intercept packaging is designed to eliminate this concern. In order to evaluate the effectiveness of Static Intercept packaging on ImAg, solderability tests on ImAg plated substrates were performed at the American Competitiveness Institute (ACI), an independent laboratory in Philadelphia, Pennsylvania. Control samples were placed in a nitrogen cabinet, while other samples were packaged and sealed in either standard 4 mil (102 micron) ESD packaging or 3 mil (76 micron) Static Intercept bags. The samples were placed into an ASTM salt fog testing apparatus for seven days, removed, and solder-tested using IPC/EIA/JEDEC J-STD-002B component solderability Test A. Results are shown in

**Figure 6.** Note that the roughness of the black ImAg surface indicates greater corrosion, a consequence of less protection. Acceptable solderability was not retained for the coupons placed within standard ESD bags, but full solderability was preserved for the coupons within the Static Intercept bags.

### Applications

The properties of the reactive polymer (Static Intercept) make it attractive for use in a wide variety of applications. These fall in the general categories of industrial ESD control, commercial corrosion prevention, and consumer product corrosion prevention. Companies are using Static Intercept for export shipping and storage, resulting in better protection with reduced costs over other commercial products. For ESD control in the electronics industry, Static Intercept can be used for packaging in the form of bags, sheet film, bubble wrap, and pallet wrap. These materials enhance the packaging performance of traditional ESD materials by adding corrosion protection, which minimizes the impact of environmental degradation in global manufacturing and deployment.

Corrosion protection of copper and silver is needed by many industries. In electronics, copper- and silver-based connectors and printed wiring boards are subject to corrosion, as are all silver containing surfaces. Reduced corrosion will decrease the number of connector-related circuit failures and enhance solderability. Other industries dependent on clean copper are the electric power industry, which uses massive copper conductors, and the electroplating industry, which needs to protect finished parts during shipment. This technology has been used in a broad spectrum of applications such as: consumer products, silver and copper jewelry, household silverware, musical instruments, museum collections (especially paintings containing metallic inks), and other metallic artifacts. See **Panel 2** for a sampling of companies and institutions outside of the telecommunication market that incorporate this packaging technology into their products.

### Cost-Effective Solution

Presently, there are no industry standards that define requirements for long-term storage and corrosive gasses for equipment or components. Storage conditions could be 100 times worse than the intended use conditions, consuming some of the product's life prior to deployment. These problems can be exacerbated with the future introduction of materials that may be more susceptible to storage-related corrosion. A cost-effective solution is to provide protection at the component/product level. This is accomplished by placing each unit into a Static Intercept package. The package essentially creates a mini controlled environment that follows the component/product throughout the supply chain, closing the gap between manufacturing and storage facilities.

The cost of the Static Intercept versus a standard ESD bag is comparable and, for the most part, there is no change in process to implement it. Simply, wherever an ESD bag is used today, it can be directly re-placed with the Static Intercept version. In addition to the ESD protection, the Static Intercept bag will prevent a reduction in the product's reliability and life during deployment. If, for example, a circuit pack failed and needed to be returned, the process would

### Panel 2. Commercial Users of Static Intercept\* Technology Platform Packing

Avon Gear  
Baldor Motors\  
Boeing and Aero Jet  
Diebold  
Fine Arts Express  
General Dynamics  
German Military  
Getty Museum  
Guggenheim Museum  
Honeywell/Germany  
Japan Museums (Katotech)  
Kew Gardens (U.K.)  
Lemforder (BMW)  
Lockheed/NASA  
Messier Dowty  
Minneapolis Museum of Art  
Nichols Aircraft  
Raytheon  
Royal Danish Mint  
Royal Mint of U.K.  
SAIC  
Singapore Air Force  
TRW  
Tate Gallery  
U.S. Mint  
U.S. Coastguard  
U.S. Merchant Marine  
U.S. TACOM (Tank)

include shipping, analyzing, obtaining replacement parts, repair, retest, and reshipping. This does not include the cost and frustration for customers. Static Intercept can prevent this from happening. **Conclusion**

We have developed the capability to address atmospheric corrosion and ESD issues during product storage and shipment through a packaging strategy that uses Static Intercept packaging materials. Static Intercept Technology packaging is an available, cost effective solution. Static Intercept is a unique pack-aging system that provides unparalleled permanent dual protection from atmospheric corrosion and ESD damage. This material protects products from degradation and latent defects due to the common negative

environmental factors seen during shipping and storage. We have also demonstrated that this packaging strategy will also provide lower overall product costs for equipment and service providers by improving reliability, extending product shelf life, and reducing product failures

#### Acknowledgements

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#### \*Trademarks

Fluke is a trademark of Fluke Corporation.

NEBS is a trademark of Telcordia Technologies, Inc.

Static Intercept is a trademark of Engineered Materials, Inc.

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