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**Title: Intercept Technology, a New Frontier in Packaging**

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## Abstract:

Telecommunication products, and electronic assemblies, are being deployed in increasingly aggressive corrosive atmospheres as equipment is moved out of the central offices and closer to the customer. The European RoHS directive mandates the elimination of hexavalent chromium from plated metals, and Lead (Pb) from solder. These issues leave the products significantly more susceptible to corrosion. Lucent Technologies Bell Laboratories has developed a material (Trade name Intercept Technology™) that combines contamination free long-term corrosion protection with permanent ESD protection. Intercept Technology™ consists of a blend of polymers (e.g. polyethylene, polypropylene, and styrene) co-valently bonded with corrosive gas neutralizing proprietary catalyzed additives. The resulting permanently anti-static material imparts an unequalled ability to neutralize corrosive gases for extended periods of time, creating clean microenvironments within the Intercept environment. This material is also non-outgassing and clean of ionic species. It can be manufactured into bags, tubing, sheets, foam, plastic corrugate, paperboard boxes, etc. Protection from atmospheric corrosion by H<sub>2</sub>S, COS, and HCl for such things as electronic components, pre/post plated cabinets, housings, electronic assemblies, and export shipping of metallic systems is provided. This paper will review various tests and case studies (including solderability testing) compared to traditional packaging systems.

## Keywords

Static, Solderability, Corrosion, Silver, Electronics

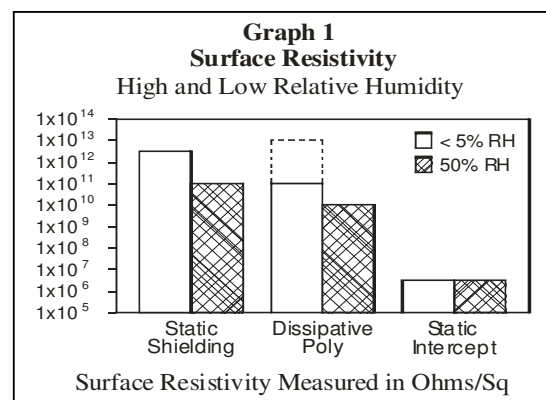
## ESD Considerations

ESD can have a devastating effect on the quality and reliability of manufactured electronics. ESD is caused by improper material usage and or corrosion of surfaces causing Electrical Overstresses (EOS). Consequently ESD (and corrosion) 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. 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 the importance of ESD control will increase.

The principle measure of an ESD dissipative material is a surface resistance. A range of 10<sup>5</sup> to 10<sup>9</sup> ohms/square is used as a standard by major corporations. Various methods have been used to obtain materials in this range, but present materials are known to suffer from a number of disadvantages.

Carbon-loaded polymers are often used as static dissipative materials. Certain carbon blacks are highly conductive, so dispersing them in a polymer at a high enough concentration can provide conductivity in the appropriate range. Unfortunately, this conduction mechanism is characterized by a percolation threshold (1,2,3,4). At concentrations below this threshold there are no continuous conducting paths through the material. For concentrations above this threshold, there are many random conducting paths and the resistivity drops to very low values. Manufacture of carbon-loaded polymeric materials with resistivity in the ESD range is difficult because the resistivity is a function of the carbon black concentration and of the processing conditions as well. An additional disadvantage of carbon-loaded polymers is that carbon particles tend to shed. Thus carbon-loaded polymers are normally unacceptable for use in clean rooms.

A common approach to ESD dissipative materials is to coat an organic chemical on a plastic part. These organics are usually amines or amides, and when atmospheric water is adsorbed, the surface becomes conductive in the ESD range. When added to or coated on polyethylene, the resulting product is known as "pink poly" or "antistatic or dissipative poly". This approach to ESD control has 3 major drawbacks. One is that the organic compounds are volatile, so after a period of several months to several years, much of the coating evaporates and the material becomes insulating (5). Unfortunately,



there is no visible indication that ESD protection has been lost. A related problem is that the volatilized organic may deposit on the part being protected, thus coating it with an organic film which may be corrosive and insulating. The third drawback is that these materials do not function in low humidity, since they rely on adsorbed water. Thus in dry climates, and certainly in dry packages, where the relative humidity can drop below 30%, they become insulating, (Figure 1)

## Atmospheric Pollution

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 (6). Thus parts in storage or in shipment are particularly vulnerable. This problem is most severe for copper and silver which react with hydrogen sulfide (H<sub>2</sub>S), carbonyl sulfide (COS), sulfur dioxide (SO<sub>2</sub>), and hydrogen chloride (HCl). These trace gases are widespread (7). Consider hydrogen sulfide: the ambient concentrations (Fig. 2) are generally in the range of

0.1 part per billion (ppb) to 10 ppb in NAR (North American Region), but this normal ambient level increases dramatically in Asia, due to a deterioration of air quality conditions caused by an increase in fossil fuel consumption and less rigorous pollution controls. Laboratory measurements<sup>8</sup> of H<sub>2</sub>S corrosion of copper, silver, and bronze, have shown that corrosion product film thickness is proportional to the H<sub>2</sub>S concentration up to 4 PPM, times the duration of exposure. One year of exposure of copper to background concentration of 1 ppb of H<sub>2</sub>S can grow a sulfide film about 50 nm thick. The higher level of atmospheric corrosive gases in Asia becomes of particular concern.

A common method of protecting electronic components from corrosion (other than gold plating) involves depositing a protective coating called a volatile corrosion inhibitor (VCI). A volatile organic is soaked into a piece of paper and then sealed in a container with the part to be protected. The resulting thin insulating film which forms on the part excludes water from the surface. Two limitations of this method, as for pink poly, are that the organic material can evaporate without warning over a period of time, and that it coats the part with an insulating film, a film that could potentially attract dust or could interfere with Solderability.

Lucent Technologies Bell Labs reviewed this issue of needing clean, permanent ESD protection, coupled with long term, non-contaminating corrosion protection. The resulting new material has found increasingly wide acceptance as replacement for foil packaging (the dry method of protection), as well as replacement for traditional ESD materials (shield bags, pink poly, etc.) as well as traditional anti-corrosion products, such as VCI materials, emitters, oils and most desiccants.

The new RoHS measures will impact the ability to protect metals from corrosion. Electronics face the exclusion of lead, used for PWB's and PCB's. Lead is used due to its ability to flow easily and provide for an effective solder joint. Lead free systems are susceptible to contamination and to corrosion, as shown later in this paper. The exclusion of Hexavalent

**H2S Levels – China**  
**Figure 2**  
**(Testing Courtesy Lucent Technologies Bell Labs)**

- Average H2S level in NAR and Europe • 7 ppb
- Average Level of H2S outdoor (Shanghai) • 800 ppb
- H2S found inside electronic manufacturing plants - Souzhou • 1500 ppb
- H2S is studied more because it is over 10x times more reactive than SO<sub>2</sub>.
- SO<sub>2</sub> is more of a problem when soot or dirt is in the air - it does cause concern in Asia due to high level of coal used

**US Army TACOM (Tank Command) Evaluation Of Intercept Barrier Materials for Military Packaging**  
**Figure 3**

Coupon	SALT-FOG Test Data Comparison		
	<< Days of protection against corrosion >>		
	Intercept Poly <u>4-mil</u>	VCI Poly <u>4-mil</u>	MIL-PRF-131Metal Foil / Poly <u>5-mil</u>
Steel	102	28	62
<b>Aluminum</b>	<b>130</b>	<b>59</b>	<b>91</b>
Brass	130	28	91
<b>Zinc</b>	<b>97</b>	<b>59</b>	<b>77</b>

Chromium for protective coatings on metal, such as frames and cabinets has an impact on the aesthetic as well as the functional performance of these metal parts, assemblies and/or systems. Testing performed by the US Army at Picatinny Arsenal in the NJ shows the effectiveness of Intercept versus the other traditional materials, see Figure 3.

### Intercept Technology

The material described in this paper provides both 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  $10^{10}$   $\Omega$ /square. It performs independently of the humidity. 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 particles as additives to react with and neutralize corrosive atmospheric gases thus

preventing their penetration through the polymer. An additional additive, acting in synergy with the reactive particles, provides excellent ESD properties. The material is called reactive polymer because of the reactivity of copper particles with corrosive atmospheric gases. Variations of conventional polymer processing techniques have been used to successfully produce reactive polymer in various forms.

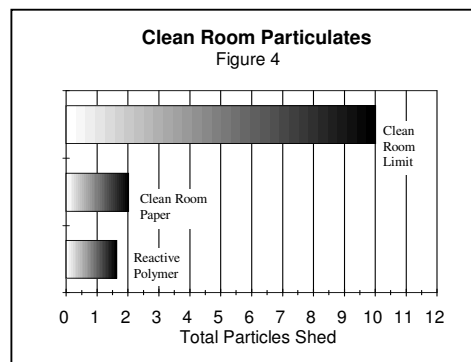
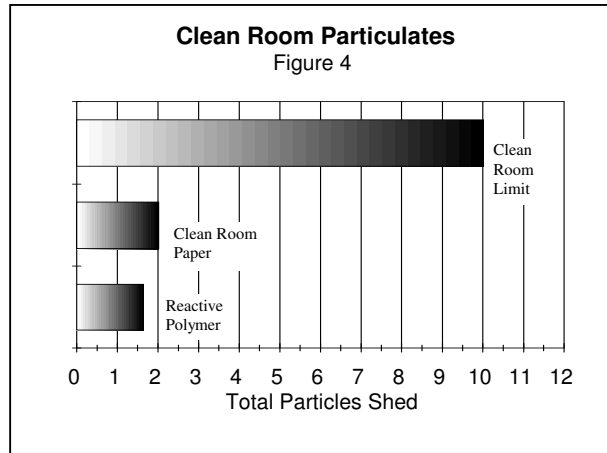
AT&T Bell Labs ESD Group, Murray Hill, NJ, E.I. DuPont Nemours ESD Group, Wilmington, DE, and Baxter Healthcare Industrial Div. ESD Group, Valencia, CA, have performed the following measurements in agreement with each other.

Tests of surface resistivity as a function of relative humidity have been made at RH of 50%, 12.5, and 5%. The instrumentation and method were the same as above. Results show no measurable change from 50 to 12.5% RH. When the samples were taken down to 5% RH a decrease of 0.3% was statistically calculated. We believe this phenomena 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.

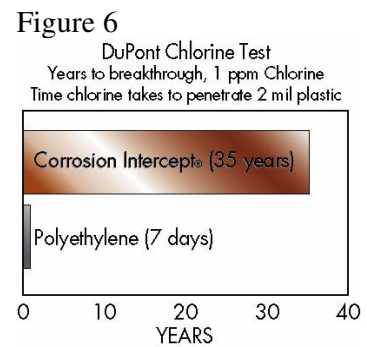
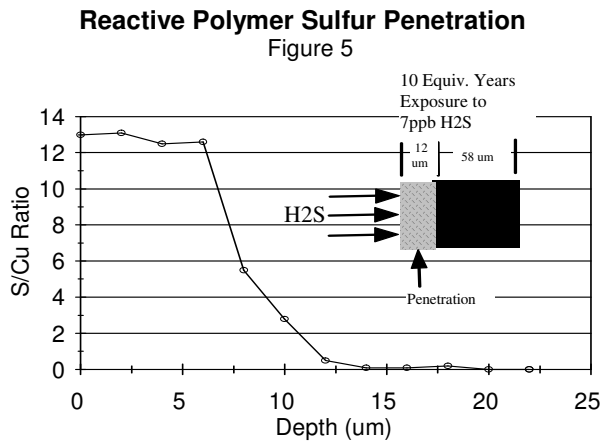
Samples were subjected to Mil Spec B81705C Elevated Temperature Test (160° F for 12 days), and 24 hour water wash test as per Federal Test Method 101-4046. None of the samples were affected by these tests.

Static decay time was measured according to Mil Spec B81705 C using an ETS 406C analyzer. Since static decay is maximized at low humidities all samples were tested at 5% RH. All samples tested had static decay times less than the detectable time of the test instrumentation, that is <0.01 seconds with a 20 KV charge. The maximum time allowed is 2 seconds

Reactive Polymer particle shedding was measured using a Helmke Tumble Tester. The total measured were 1.6 particles per cubic foot (Fig. 4) The AT&T specification for class 10 approval is a of 10 particles/ ft.<sup>3</sup>. As a reference cleanroom approved paper shed 2 particles/ft.<sup>3</sup>



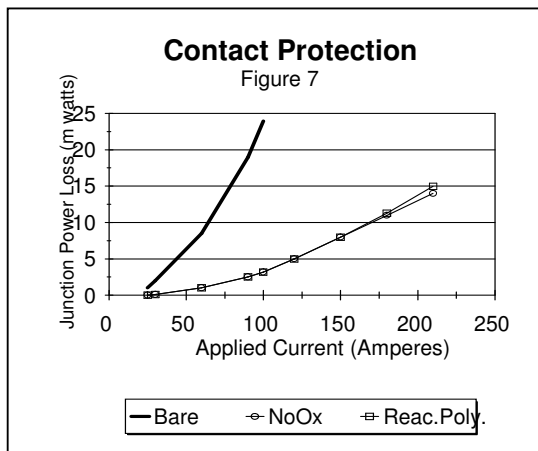
Corrosion protection from the sulfur- and Chlorine-containing gases H<sub>2</sub>S, COS, and HCl results as their diffusion through the reactive polymer is stopped by reaction with additives to form stable compounds. The effectiveness of the reactive polymer for corrosion has been tested by sealing test coupons of copper inside a bag of reactive polymer and placing it inside a chamber filled with a measured concentration of H<sub>2</sub>S. After completion of exposure, some bags have been cut in cross section and examined with a scanning electron microscope with energy dispersive x-ray analysis to determine the location of sulfur. The result (Fig. 5) shows that H<sub>2</sub>S has penetrated only part of the way through the polymer. Controls run with polyethylene without the additives show H<sub>2</sub>S beginning to penetrate 1000 times sooner. Additional tests were performed using "Clam Shell" film holders, much like the ASTM cup device for measuring water weight loss. With 100% of HCL corrosive gas applied to one side of the film the concentration of permeating gas was measured on the reverse side with a Mast Oxidant Monitor. Time delay for the application of gas to the reverse side detection was the measurement criteria. Typical polyethylene time delays of 16 to 18 minutes were measured. The same resin containing the Reactive Polymer Additives time delays were 173 to 473 hours – see Figure 6. Data was normalized to 1 ppm HCl - ambient for NAR.



Corrosion protection is an important part of Electrical Overstress Protection (EOS). EOS can be caused by the high power dissipated when current flows through a high resistance junction. The following describes an experiment designed to demonstrate the relationship between corrosion and EOS.

Forty Eight copper bus bars (3 x 20 x 75 mm) were manufactured and acid dip cleaned. At the AT&T factory 12 bars were buffed clean with hand held power buffer than coated with No-Ox7 (commercial anti oxidant grease). All of the individual bars were paired, bolted, and torqued to form mated electrical junctions. 6 junction assemblies were placed in 0.075 mm thick Reactive Polymer bags. All of the assemblies were stored for 4 weeks in air containing approximately 4 PPM of hydrogen sulfide. The junction resistance 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  $R=E/I$  and dissipated power by  $W= I \times E$ .

Figure 7 shows the results. The unprotected bars formed poor junctions. The bars protected by the Reactive Polymer, however, provided junctions as good as the labor intensive buffed and No-Ox coated junctions.



## Solderability

The move towards lead free in electronics makes corrosion protection even more critical. Lead free options require surfaces free of contamination as well as corrosion (tarnish). One leading technology is Immersion Silver for PCB's. Immersion Silver does not clog small via openings nor does it breach small gaps between prints or traces on circuit boards as does HASL (Hot Air Solder Leveling). As electronics move to higher density and/or frequencies the necessary spacing becomes critical, so in order to conform to the fine line spacing and in conjunction with RoHS the necessary move to Immersion Silver to replace HASL is necessary. Utilizing this knowledge Solderability tests on plated silver substrates was performed at the American Competitiveness Institute (ACI – an independent laboratory in Philadelphia, PA). The coupons were cleaned and normalized. Control samples were placed in a Nitrogen cabinet, while other samples were placed and sealed in standard 100 micron ESD packaging as well as a 75 micron Static Intercept Bags. The samples were then placed into ASTM Salt Fog testing for seven (7) days, removed and soldered. See Figure 8 below. It is readily apparent that acceptable Solderability was not obtained for the coupons placed within standard ESD bags, but that full Solderability was maintained for the coupons within the Intercept bags.



Samples sealed in Brand X bags



Figure 43 Coupon #16.



Figure 44 Coupon #17.



Figure 45 Coupon #18.



Figure 46 Coupon #19.

Samples sealed in Intercept® bags

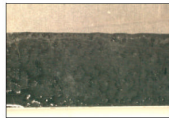


Figure 33 Coupon #1.



Figure 34 Coupon #2.

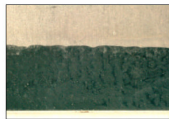


Figure 35 Coupon #3.



Figure 36 Coupon #4.

## Applications

The desirable properties of the reactive polymer (Intercept) and the absence of undesirable properties 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 have been embracing the use of Intercept for export shipping, resulting in better protection with reduced costs over other commercial products. Similarly, companies such as Lucent Technologies are looking at Intercept as a way of increasing the reliability of their electronic and telecommunication products, particularly under the RoHS restrictions.

For ESD control in the electronics industry, thin polyethylene reactive polymer can be used for packaging in the form of bags, sheet, bubble wrap, and pallet wrap. These materials can replace traditional ESD materials adding corrosion protection, which minimizes the impact of the environmental pollution in Asia versus NAR.

Corrosion protection of copper and silver is needed by many industries. In electronics, connectors and bare printed wiring boards are subject to corrosion, as are all silver plated components. It has been shown that reduced corrosion will reduce 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. Among consumer products, silver and copper jewelry, household silverware, and brass musical instruments could all benefit from corrosion protection. Many items in museum collections are in storage at any time, and bronze artifacts and silver objects would benefit from protection by protection with the Intercept Technology.

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