Moisture in Electronics

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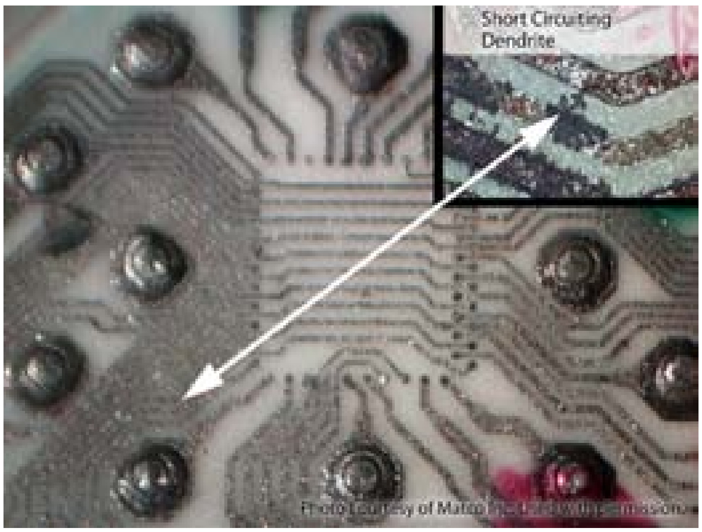
Electronic technology has become not only a means to improve productivity or provide entertainment but in many cases a critical technology that must be protected from failure. Whether it is consumer electronics, avionics, satellites, or defense systems, society has become highly dependent on sensitive electronic technologies. Due to the complexity of the multitude of devices that incorporate electronic components, product failure can result from any number of issues, but a commonly underestimated propagator of product failure is moisture.



The importance of proactive moisture control in electronic products, in many cases, is not realized until premature product failure brings it to the attention of the manufacturer. Product failure brought about by excessive moisture can occur via a number of pathways, the most visually obvious being corrosion. Condensate with dissolved ions from water-soluble acids and salts becomes more conductive than moisture alone, creating the potential for a short circuit. Electrochemical migration from corrosion, often accompanied by the creation of dendrites from dissolved metals (fern-shaped formations that form along an oxidized surface), can result in intermittent performance or a short circuit in electronic assemblies. Numerous modes of electronic component failure share the common denominator: moisture. Controlling moisture is an imperative first step to protecting your product's integrity. The best approach to controlling moisture damage is to incorporate proper material selection as well as an optimized desiccant into the product design phase.

> **"**Contacting a packaging expert experienced in optimized desiccant selection early in the process is a necessity.**"**

Product degradation and failure can result in high warranty costs, lost revenue, brand decay, or worse. Understanding moisture, condensation, and the causes for it in a sealed product will aid the product engineer in choosing the correct solutions to ensure adequate product protection.

Sources of Moisture

Most engineers design their products with certain environmental conditions in mind. When it comes to moisture, enclosing the sensitive portion of an electronic product in a watertight container will not totally solve the problem. Often engineers will mistakenly test moisture-tight containers submerged in water at multiple atmospheres to ensure moisture won't be a problem for their application, only to find themselves faced with moisture related issues later on.

Consideration of the assembly environment and packaging materials are of as equal importance as understanding the effects of moisture on electronic components. There are several reasons for moisture in a sealed electronic housing. One reason is ambient air containing moisture becomes trapped in the device during assembly. A drop in the external temperature during shipping or storage can lead to water vapor condensation within the device. Additionally, water vapor can pervade the plastic housing either through a defect, such as a leak, or via direct permeation through the polymer material.

Common plastics used in enclosures of electronic devices are comprised of flexible polymer chains, which have spaces between the chains, forming what is known as free volume within a plastic. The chains themselves are not fixed to their position but generally maintain some degree of mobility within a polymer. These materials can have fixed and transient pores with pore sizes that that vary greatly depending on the polymer and its processing history, but are usually large enough to allow the passage of water molecules, which are very small - approximately 2.0 Å in diameter.

> **"**Water vapor passes through the polymer by diffusion when there is a greater concentration of water molecules outside the device as compared to inside.**"**

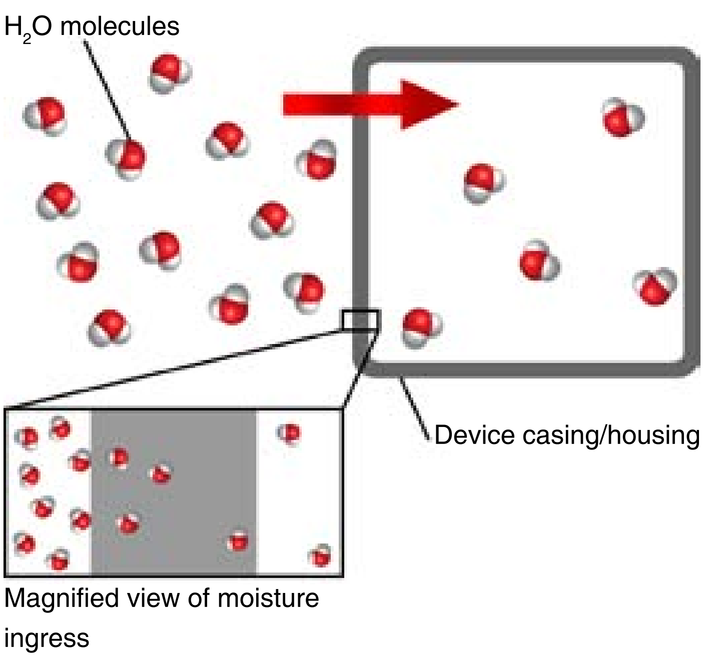
The difference between the external and internal relative humidity (RH) environments of the device is the driving force for water vapor ingress. If the RH is higher on the outside of the housing, water vapor will permeate the material until equilibrium is achieved between the external environment and the internal spaces in the device. The measure of the rate of passage of water vapor through the plastic structure, called the water vapor transmission rate (WVTR), is evaluated at a given temperature and a fixed RH difference between external and internal environments. The individual water vapor permeabilities of the materials used to make a package or housing can be used to predict its overall WVTR.

The lower the WVTR (expressed in grams/100 in2/24 hours at 90% RH and fixed temperature in US standard units), the longer it will take water molecules to pass through it. In addition to the WVTR of the package, the water vapor ingress is controlled by the internal volume of the package and the sorption capacity (moisture absorbing capac ity) of the components within the packaging system. All packaging or internal components (e.g., foam, wadding, felt, plastic, wood) will hold moisture.

Additionally, in most applications, a container is not made of a continuous material; other components (i.e., gaskets and seals) each have their own WVTR. Cracks, holes, and other imperfections present in the enclosure gaskets or seals also contribute to ingress. This is why we can see condensation in an enclosure made of a solid metal, which has a polycrystalline state and exhibits virtually zero WVTR.

Preventing Permeation and Condensation

A first step in preventing or reducing water vapor permeation is to choose packaging materials with the lowest possible WVTR. Polypropylene, for example, has a much lower WVTR than acrylonitrile butadiene styrene copolymer (ABS). Transmission rates are affected by both temperature and humidity (both relative and absolute); therefore, only materials tested under the same conditions should be compared.



Moisture Penetrating Electronic Device

To eliminate moisture trapped in the enclosure, assembly of the device should take place in a temperature and humidity controlled environment. However, the best defense against moisture damage is the use of a desiccant within an enclosure that has a low permeability.

In simplest terms, a desiccant absorbs moisture from the surrounding environment. Absorption can be either physical or chemical in nature. Physical absorption can proceed through dissolution and diffusion in a material or through adsorption (physisorption) at the material surfaces. Adsorption relies on a weak force of attraction (van der Waals force and electrostatic interactions) between the adsorbate (i.e., water vapor) and adsorbent (i.e., desiccant). Because adsorption creates a weak bond, the process can easily be reversed, in the case of a desiccant, by applying heat. Adsorption of molecules can form in either a monolayer or multilayer on the surfaces of the desiccant. Porous desiccants, like silica gel, remove moisture by multilayer adsorption and capillary condensation.

Capillary condensation occurs when water vapor condensates in the capillaries and pores within a desiccant creating a meniscus. The saturation vapor pressure over the meniscus is lower than what it would be of the liquid alone. This means that water vapor above the meniscus will condense to the surface more easily. The smaller the pore diameter, the greater the degree of curvature of the meniscus and the more moisture it can adsorb at low RH.

With chemical adsorption (chemisorption), the molecules of adsorbate form chemical bonds with the molecules of the adsorbent present on the surface. The chemisorption processes tend to be slow and in general are not reversible except under extreme conditions (such as calcining). Calcium oxide is an example of a chemisorbent.

There are many different desiccants, including various grades of silica gel, molecular sieves, calcium oxide, montmorillonite clays, and calcium sulfate – each having their own adsorption characteristics. Care must be exercised when choosing a desiccant to ensure compatibility with your application.

All electronics products are not identical and neither are their desiccant needs. Desiccants are available in many formats, including packets, sheets, tapes, compressed forms, and can even be integrated into a polymer. Compressed form desiccants, which can be formed to fit within a specific space in a device or package, are most widely used with electronic products. They offer greater moisture adsorption in the same dimensional space. This significantly increases the level of functional moisture management per unit volume, protecting the integrity of the electronic components within.

The best time to introduce a desiccant into your product is during the design process. When choosing a desiccant one must consider many factors, including: the amount of moisture that must be removed from the headspace air in the package/product; moisture ingress through the package/product; expected service life; compatibility with the product; space constraints; and expected environmental conditions the product will encounter during shipping, storage, and use. To be certain your desiccant is sized correctly, an application engineer experienced with desiccants should be consulted.

> “The proper desiccant solution can be a useful tool for maintaining product integrity over its entire service life.”

In competitive market, having a reliable product and establishing trust with your end user is essential.

For more information, contact Multisorb Technologies.

-By Daniel J. Casacci and Stanislav E. Solovyov PhD.