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Coating Innovations for Electronics

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# Protective Effect of Conformal Coatings: Water absorption and Water Vapour Permeability

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There are various characteristics impairing the operational reliability of an electronic assembly. One major characteristic responsible for the failure of an electronic assembly is the effect of moisture, for example due to humidity from the air. As a classical means of protection against failure through moisture, conformal coatings are applied. The conformal coatings of electronic assemblies are exposed to moisture on a more or less regular basis.

Again and again, this circumstance gives rise to the user's question whether it is possible to test such conformal coatings as to their performance. From the customer's perspective, a clearly measurable characteristic permitting to draw conclusions on the quality of a conformal coating would be an ideal solution.

Quite often, the customer is keenly interested in knowing or measuring the water vapour permeability or water absorption, in order to evaluate the suitability or non-suitability of a conformal coating in view of protecting the electronics against moisture.

Besides an evaluation of water absorption and water vapour permeability, a large number of test methods such as noxious gas tests or iodine vapour tests are commonly performed to describe the functionality of a conformal coating in terms of moisture.

The studies below are focused on a comparison between the water vapour permeability test and other tests, as well as on the correlation of the results. Conversely, one would also assume that the measuring of a value permits an extensive statement on the conformal coating's functionality.

Coating materials differ both in terms of water absorption and water vapour permeability which may have an effect on:

- mechanical properties,
- adhesion,
- glass transition temperature,
- light and weathering resistance,
- corrosion protection properties,
- electrical insulation properties.

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Moisture and water are among the most harmful factors affecting coating materials. Actually, the water vapour permeability and moisture absorption of polymers, i.e. coating layers, are no absolute criteria as such for excluding them an insulating material. To a certain extent, all polymers are permeable to water vapour; this feature is called permeation. By the same token, all polymers soak up moisture, which is referred to as absorption.

Both characteristics - water absorption and water vapour permeability - can be measured by appropriate methods. In case of water absorption, the result is expressed as a percentage, while for water permeability, the result is indicated as a value of mass per surface area and layer thickness.

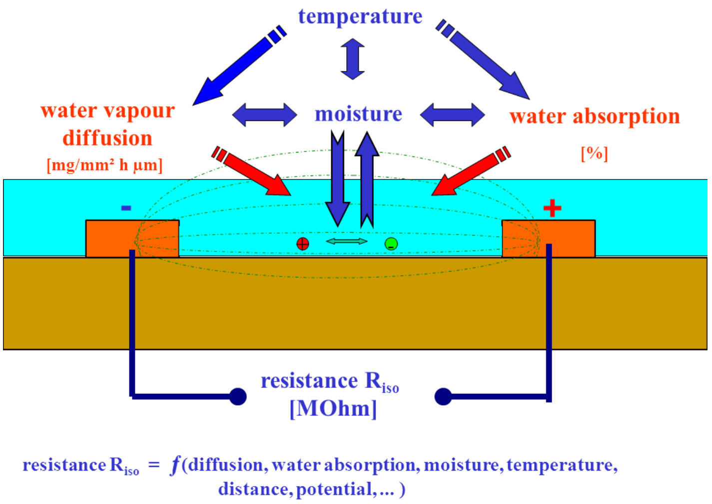



**Fig. 1 Schematic interaction of water vapour diffusion and water absorption under climatic conditions**

None of these two values is an absolute characteristic; they depend for their part on temperature, the prevailing relative humidity (actually on the partial water vapour pressure), or the presence of condensed water on the coating film. The correlation is shown in fig. 1 without considering, however, the influence of any given contamination.

By knowing these characteristic values, one has actually received information on the water balance of a coating material, which however, does not include any details related to the effects of the water balance on electrical insulation properties, meaning the movement of electric charge carriers in the polymer film. Moreover, the values of water vapour permeability and water absorption cannot be regarded as independent of one another. With increasing water absorption, the water vapour diffusion may rise significantly.

Examples of water vapour permeation for various ELPEGUARD® conformal coatings:

| | |
|---|---|
| Twin-Cure® DSL 1600 E-FLZ/75 | 240 g/(m²*d) with 90 µm coating thickness |
| ELPEGUARD® SL 1307 FLZ/232 | 37 g/(m²*d) with 60 µm coating thickness |
| ELPEGUARD® SL 9407 FLZ | 32 g/(m²*d) with 100 µm coating thickness |
| ELPEGUARD® UTC 1507 FLZ | 25 g/(m²*d) with 60 µm coating thickness |
| ELPEGUARD® SL 1301 ECO-BA-FLZ/23 | 102 g/(m²*d) with 60 µm coating thickness |

The characteristic describing this insulation behaviour is the so-called moisture/insulation resistance value (MIR) which is often used as a synonym for SIR = surface insulation resistance. Further below, the electrical insulation resistance under moisture is looked at in detail.

The moisture/insulation resistance used in many different qualification procedures is a combined property of both material and the electrode system. It displays a complex resistance system between two metal electrodes in a comb pattern composed of different dielectrics such as laminate, coating, air and air humidity, as well as of possible leakage currents from ionic contamination, i.e. the moving of charge carriers in this electrode system.

It describes the direct electrical impacts of moisture absorption in this electrode system, which are similar to those found on an electronic circuit carrier. An insulation drop induced by moisture absorption is described as a remaining insulation value. A general characteristic of the operational reliability of electronic assemblies is the so-called surface resistance; its falling below 1 MOhm is generally considered to be critical. In case of a conformal coating, the previously given surface resistance (SIR) between the potentials is replaced by the electrical resistance of the coating film. For this reason, the electrical resistance is often described as SIR value which is not absolutely correct. In various rules and standards, for example, the acceptable drop in insulation under moisture (temperature) load is limited to 100 MOhm.

The comb patterns found on various IPC test boards are typical test structures for measuring the moisture/insulation resistance. In view of describing conformal coatings, test boards of the types IPC-B24 and IPC-B25A are primarily used.

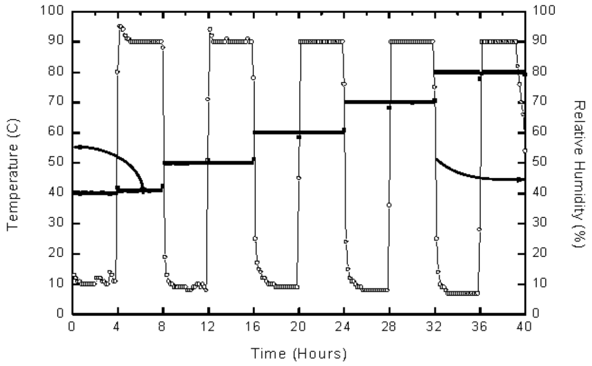
Such a test is employed to instantly detect moisture-induced failures. Similar to the so-called "Highly Accelerated Stress Test" (HAST), it includes different temperature levels and/or different air humidity levels.

Among typical temperature/moisture combinations, one would find, for example, 65 °C/90 % R.H. or 85 °C/85 % R.H. The moisture covers the surface of the measuring arrangement, or it is absorbed by the polymers respectively, and the applied bias (usually between 5 and 100 volts DC) generates an electrolytic cell. Among the typical failure mechanisms, there are electrochemical corrosion processes and/or delaminations.

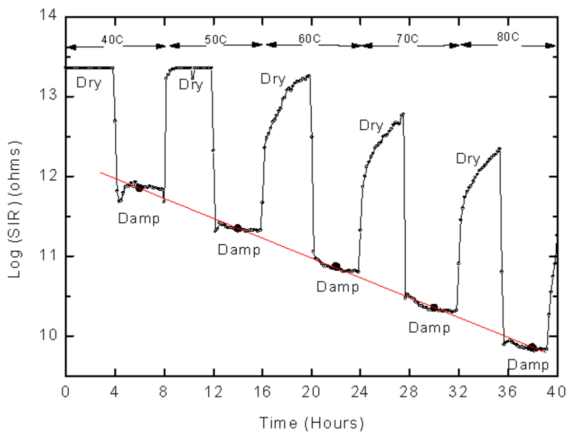
These tests can be performed:

- – as part of a product qualification (solder resist, conformal coating, no-clean flux, etc.),
- – as part of a process qualification (conformal coating, solder processes, cleaning processes, etc.),
- – for comparing different materials,
- – for comparing different processes.

In this context, the moisture and insulation resistance can be regarded as a composite parameter, as a qualifying feature describing the results of different physical characteristics by reducing them to one single characterising feature.




**2.a**
**Temperature-moisture profile**




**2.b**
**Moisture and insulation measurings**

Fig. 2: The dependence of a conformal coating's moisture and insulation resistance on temperature and air humidity in a cyclical moisture-temperature test [Tomlin NPL-Report CMMT(A) 2000]

Typical dependencies of the moisture/temperature behaviour of conformal coatings (fig. 2.a) and their description via the moisture/insulation resistance are depicted in the Tomlins curves (fig. 2.b).

These diagrams also display the typical transient effects of the resistance value, for example in the drying phase (fig. 2.b). These transient curves are typical diffusion-related dependencies. A typical transient of moisture absorption can be taken from the detailed section of a gradient (fig. 3).

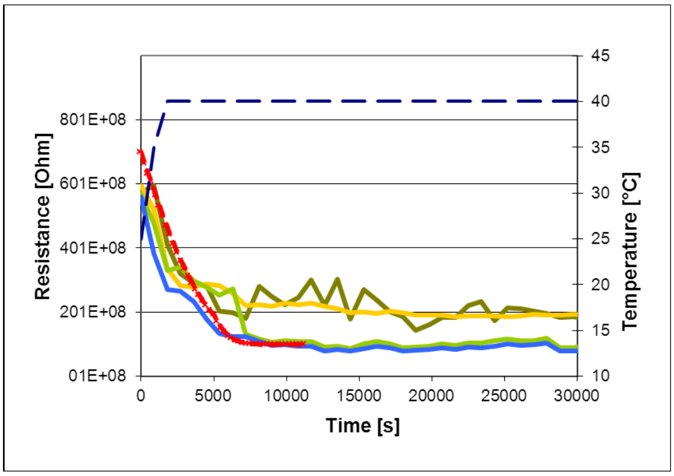



**Fig. 3: Transient effects of the moisture/insulation resistance with beginning condensation (40°C/100% R.H.)**

Fig. 3 displays the transient effects of the moisture/insulation resistance for a coating film measured in the initial phase of a condensation water test 40°C / 100% R.H./ 100 V. This diagram covers several conformal coating films (coloured lines) and also includes the error function (dotted line = erf(x)) which describes the typical mathematical solution of the unidimensional diffusion equation. This means that the transient effects can be described mathematically through a diffusion process, or respectively, diffusion processes underlying water vapour permeability can be determined through a drop in moisture/insulation resistance. Here the usual detectable diffusion values expressed in g/cm² µm d have been obtained as electrical resistance values. The same applies to water absorption values usually given in % which can be obtained as electrical resistance values directly through moisture/insulation resistance.

The table below shows the results of various tests conducted with six ELPEGUARD® conformal coatings which, however, do not allow to draw a correlation based on the results indicated.

| | **DSL 1600 E-FLZ/75** | **SL1307 FLZ/232** | **SL 9407 FLZ** | **UTC 1507 FLZ** | **SL 1301 ECO-BA - FLZ** | **SL 1800 FLZ** |
|---|---|---|---|---|---|---|
| Noxious gas test | GX | GX | GX | GX | GX | GX |
| Water vapour permeability [g/(m²*d)] | 240 | 37 | 32 | 25 | 102 | 37 |
| SIR;1000 h, 85 °C/85 % R. H. [log Ohm] | 7,9 | 9,4 | 8,1 | 10,1 | 8,2 | 9,6 |
| Iodine vapour test Impedance shift | none | none | large | slight | slight | none |

The diagram below displays various test results related to the acrylate-based conformal coating ELPEGUARD® SL 1800 FLZ which allow to establish a correlation through direct comparison:

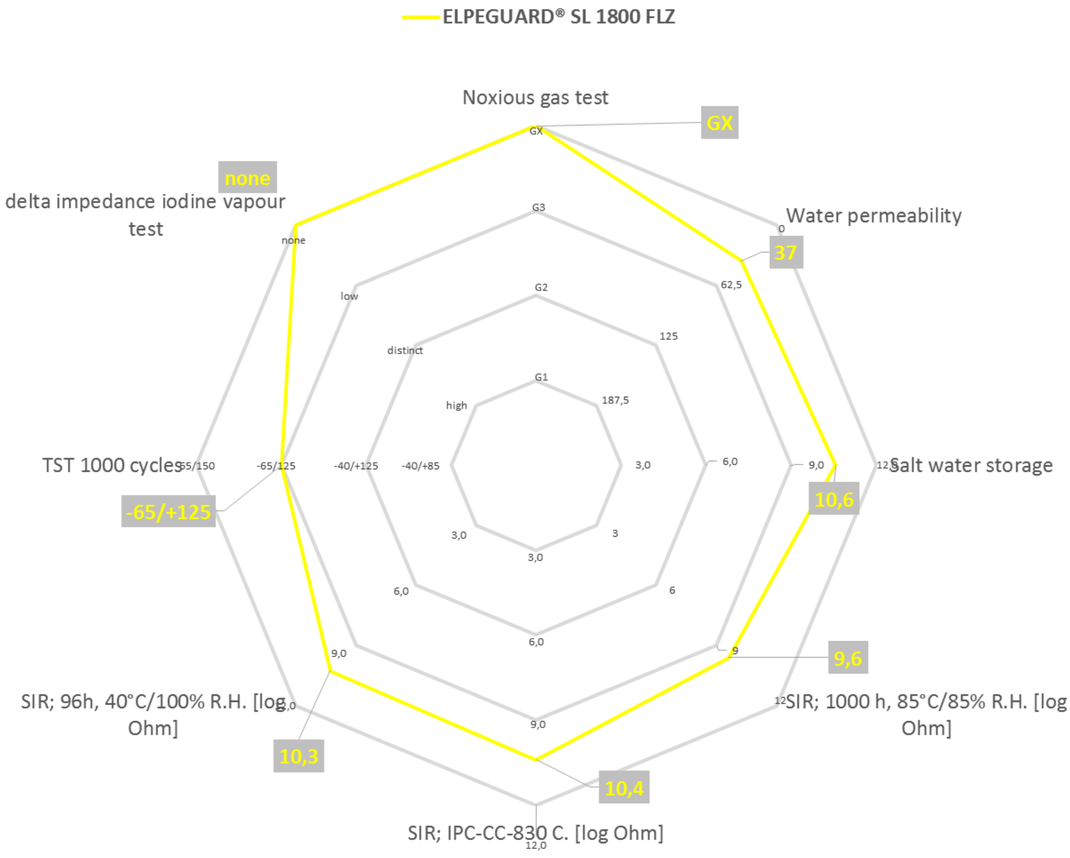



**Fig. 4: Different test results with ELPEGUARD® SL 1800 FLZ**

This approach clearly shows that water absorption and water vapour permeability are important characteristics for looking at the protective effect, although every value alone is not significant enough to allow a general statement on the quality of a conformal coating in terms of resistance against environmental loads and above all, against moisture loads.

Measurings of moisture and insulation resistances (so-called SIR or MSIR values Moisture Surface Insulation Resistance) can be measured and directly utilized as electrical resistance value.

If such electrical resistance values are determined in sequential test series (measuring of SIR values under condensation K08, temperature cycle test K05, noxious gas test K18 etc.) in the frame of validation studies, the addition of these values most easily allows to evaluate the quality of the conformal coating applied. Performed on assembled validation boards, this does not only permit to evaluate the material employed, but also to qualify the complete conformal coating process and the upstream solder process of the electronics.

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