Performance of Photoimageable Solder Masks – A Study on Thermal Stress Resistance

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Abstract
The continuous temperature resistance of electrically insulating materials can be judged by examining the effect of thermal stress loads on the electrical properties, such as moisture and insulating resistance, tracking resistance, etc.

Which effects on the electrical insulating properties of solder masks are to be expected, in particular under subsequent climatic stress? This paper will present and discuss the results of moisture and insulating resistance tests in different climates as well as further electrical properties from both continuous storage tests at 150°C for 2,000 hours and thermal cycling tests over 1,000 cycles, -40°C/+150°C. The load at the high cycle temperatures shall be compared with those from the continuous temperature storage tests. Furthermore, the theoretical base of this methodology shall be discussed.

In order to consider any potential "pre-damage" caused by the various surface finishes, tests have also been performed with a "preliminary stress load" comparable to that of the printed circuit board and electronic assembly. The influences of processing with various surface finishes such as Nickel/Gold finish (ENIG), chemical tin finish (CSN) and HAL (Hot-Air Levelling) on the thermal cycling resistance have also been examined. The paper shall go on to discuss investigations into the moisture and insulation resistance in different climates as well as the influence of the base material and layout as well as precleaning and solder mask thickness on the thermal cycling resistance.

In addition, comparisons shall be made between aqueous-alkaline and polyalcohol developable materials.

1. Introduction

In material science circles one jokingly refers to the "first law of material sciences":

Everything can be destroyed by force.

Strictly speaking this law naturally does not exist, but is very true! In a serious sense the proclamation that everything can be destroyed by force (= by the exertion of energy), i.e. shifts to a state of greater disorder, can be found in the second law of thermodynamics which specifies that the state of a system strives for its maximum entropy. However, it also defines irreversible processes. In a process with increasing entropy, the reverse process cannot take place.

The force – or, better, stress factor – applied in the processes addressed in this paper is thermal energy, represented by the temperature. The temperature is responsible for changes in materials, whether polymers or metals. If the temperature of a material is increased, the tendency towards a spontaneous increase in the entropy, in other words the tendency towards irreversible modifications, grows. Further corresponding stress factors that influence the reliability are listed in Table 1 [1]:

Table 1 - Stress factors and their failure mechanisms and effects

Stress Factor	Failure Mechanism	Effect	Failure Physics/Model
Temperature	Diffusion/intermetallic phases Decomposition of polymers	Ageing processes	MTTF[1]) ~ $\exp(E_a/kT)$ [2])
Temperature changes / Power cycles	Spontaneous breaking/fatigue	Thermomechanics	$N_f \sim \Delta T^{-1/c}$ [3])
Shock / Vibration	Spontaneous breaking/fatigue	Mechanics	$N_f =\sim \Delta\sigma^{-c}$ [4])
Moisture (Anode) Contamination	Ionic contamination Electromigration (short circuit)	Tracking currents	MTTF ~ $\exp(E_a/kT)$
Noxious gases	Corrosion	Chemical changes	MTTF ~ $\exp(E_a/kT)$
Electric field	Dielectric breakdown	Electrical failure	MTTF ~ $\exp(E_a/kT)$

In particular in the automotive sector the topic of stress factors and resultant failures is becoming increasingly important, especially in view of the fact that more and more electronic assemblies are being built into motor vehicles. These assemblies are also moving closer and closer to the aggregates and thus into increasingly undesirable environments. Automobile manufacturers specify temperature ranges from -40°C [-40°F] to between +80°C [176°F] (in the passenger compartment) and +800°C [1472°F] (exhaust fume sensors). The "conventional" FR4 printed circuit board is certainly not capable of covering this temperature range, but there is talk of a capacity reaching from -40°C [-40°F] to between +120°C [248°F] and +150°C [302°F] [2] [3]. This temperature stress is made up of the "external" temperature and the so-called inherent heat – which increases more and more the closer the components are packed. In engine compartments, for example, temperature increases from 105°C [221°F] to 150°C [302°F] are observed. In particular stress at higher temperatures leads to irreversible changes as defined by the second law. In this context, stress factors that are attributed to higher temperatures are collectively termed "thermal stress loads" [3].

In addition to these for the most part purely thermal processes there are also combined stress determination tests which involve running thermal cycles over a wide temperature range. Besides the thermal stress itself, in particular in the case of material combinations mechanical strain also occurs due to the different coefficients of thermal expansion. Changes in the material properties that originate from the constant fluctuation of minor forces are also known as fatigue. Fatigue can equally become apparent when the stress that occurs remains within the elastic range [4]. These fatigue mechanisms are irreversible processes that are not strongly temperature-related and do not comply with the Arrhenius definition (Table 1). These combined stress factors are referred to as thermal shock loads in the following.

Statements on the cyclability of printed circuit boards and so-called thermal cycling tests (TCTs) on printed circuit boards and assemblies are the subject of discussion in many a workgroup; test cycles are being defined and performed. The primary failures during the high-temperature operation of such assemblies lie in cracking of the plated-through holes and in the clarification of the source of the failures [5] [6]. However, there is still the question of what effects these stress factors have on the ink systems used, in particular on the solder masks. What effects are to be expected on the insulating properties, in particular during later exposure to climatic stress. This paper reveals and discusses the results of long-term storage tests at 150°C [302°F] over 2,000 hours as well as TCTs over 500 cycles and temperatures of -40°C/+150°C [-40°F/302°F] [7].

These tests are performed in order to obtain statements on the probability of potential damage. As a rule, the failure performance of technical products over their life cycle is divided into three categories that characterize the failure mode (Fig. 1):

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[1] MTTF : Mean time to failure with non-repairable systems
E_A : Activation energy for the reaction
k : Boltzmann constant ($k = 1.38 \cdot 10^{-23}$ J/K)
T : Absolute temperature

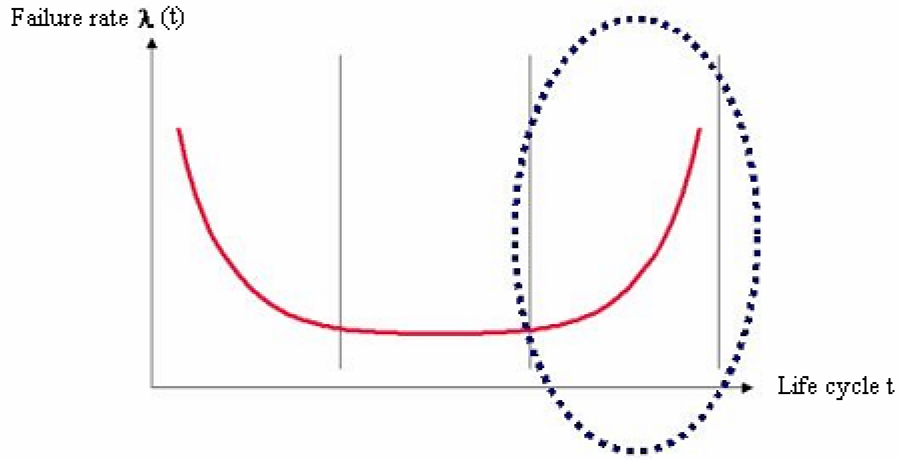
[2] Arrhenius definition

[3] N_f : Number of cycles to failure

[4] σ : Mechanical tension
c : Function of ΔT and frequency

The failure rate as a function of time ("bath tub curve")

Category 1: describes the premature failures mostly distinguished by errors in or during the Figure 1 - manufacturing process. For example, degradation of the solder mask as a result of the soldering process(es) would fall into



this category.

Category 2: is distinguished by the so-called coincidental failures. As a rule, they are caused by errors in operation, maintenance or improper loading.

Category 3: the components have reached the end of their life cycle. The failures are dominated by wear or fatigue. The thermal stress and shock loads on the electronic components and the evaluated solder masks should enable statements on this category.

Category 1	Category 2	Category 3
Premature failures	Coincidental failures	Fatigue failures

2. Thermal stress load

When exposed to a thermal stress load, more or less pronounced, irreversible structural modifications occur in polymers. These structural modifications lead to changes in the mechanical and/or electrical properties.

In particular in the case of electronic assemblies, the thermal stress load should be divided into two categories. The first type of thermal stress load is that resulting from the soldering process(es). Albeit brief, such thermal stress loads lie significantly above the temperature resistance of all components of the assembly. This kind of stress load and its consequences shall not be addressed in this paper as any damage incurred as a result would more appropriately fit into the category 1 pertaining to premature failures due to material or process defects [8].

The thermal stress load during the category 2 life cycle can also be viewed as thermal ageing resistance and differs considerably from the decomposition temperature of a polymer. The thermal ageing process of polymers varies greatly and the ageing mechanisms also vary depending on the operating or stress conditions. Thermal resistance tests to determine the property changes are performed, for example in accordance with DIN EN 60216.

Typical ageing mechanisms – as listed in DIN EN 60216 – are:

- Loss of volatile constituents, such as low-molecular components, that were present from the beginning
- Oxidations; they are often accompanied by an increased cross-linking or embrittlement
- Continuation of the molecular polymerisation which initially often leads to an increase in the electrical and mechanical strength, but later ends in embrittlement
- Hydrolysis of the polymer through ambient moisture; this can be drastically accelerated by the presence of warmth
- Chemical splitting of the low-molecular constituents that form as a result of the ageing process. Such processes can have an autocatalytic effect.

With solder masks two thermal stress loads occur that must be differentiated from one another. On the one hand there is the thermal stress originating from the soldering process and on the other hand there is the actual continuous thermal load from the operation of the electronic assembly. The temperatures in the soldering process are much higher than the continuous operating temperature resistances of the solder masks and can only be withstood for a short period of time. Conformal coatings and casting compounds are normally only subject to the latter thermal stress load.

When examining the temperature resistance, different factors must be considered which can seriously influence the test results. It is of great significance whether a polymer or ink system is exposed to moist or dry heat. Usually, the resistance to moist heat is much lower than to dry heat as with moist heat, in addition to the purely thermal decomposition processes, also hydrolytic decomposition processes take place.

Of further importance is the thermal cycling resistance, i.e. the fact that an ink system which has been cooled and heated several times throughout its thermal treatment may possibly be destroyed earlier than an ink system which was exposed to the same continuous temperature for an identical period of time. The speed at which the temperature is changed can also be of significance. B. Neves [8] has compiled a number of different thermal shock procedures.

If an ink system is exposed to an elevated temperature for a longer space of time, it will mostly become brittle, yellow, lose gloss, and its electrical properties, perhaps even the adhesive properties, will change. The change in the electrical properties is what stands in the foreground of the analyses in this paper.

3. The time-lapse test

In order to be able to make a statement on the failure rate of electronic components in the range of 10^{-10} to 10^{-5} per hour [1] within a reasonable space of time, it is necessary to perform accelerated ageing tests. If the ambient conditions are known – elevated temperatures, mechanical stress, chemical loads – the concentrated exposure to one of the stress factors can make sense for test purposes to shorten the time required to get meaningful results. With the concentrated exposure, e.g. increasing the temperature to shorten the time, it is important that the ageing mechanisms stay the same and that only those ageing processes or failure mechanisms are activated that would occur under normal stress loads.

To determine the "time-lapse" of a particular test the acceleration factor A must be defined: The basis for the calculation of A is the Arrhenius definition according to which the following equation applies for the velocity v of a chemical reaction:

$$v = v_0 \exp(- E_A/kT)$$
$$A = L_0/L_1 = \exp(-E_A/k\,(1/T_0 - 1/T_1))$$

v : Reaction velocity for the higher temperatures
v_0 : Reaction velocity for the start-up temperature
E_A : Activation energy for the reaction
k : Boltzmann constant ($k = 1.38 \cdot 10^{-23}$ J/K)
L_0 : Life span at test temperature T_0
L_1 : Life span at test temperature T_1

The "failure time" is then illustrated in a second graph – time vs. temperature (Fig. 2).

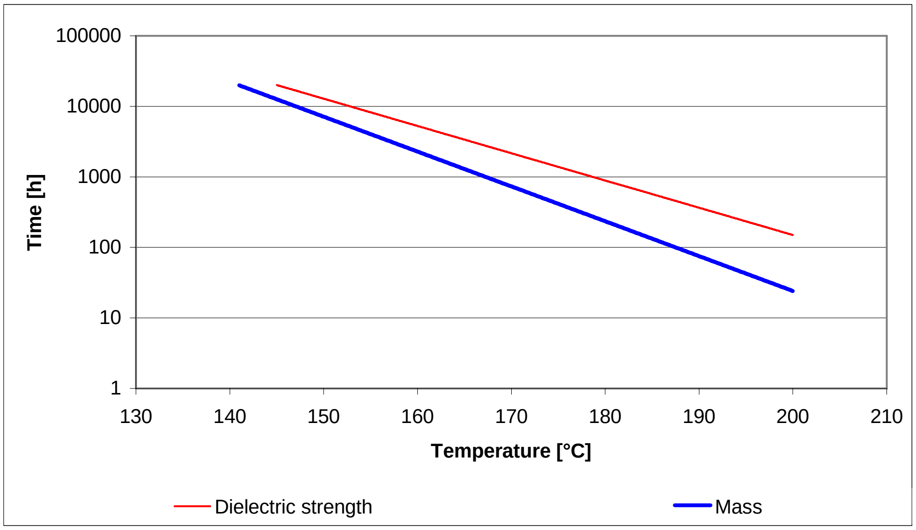


Figure 2 - Graph showing the extrapolation of the failure times determined in appropriate tests over a failure period of 20,000 hours

Simply speaking, this relationship known as the Arrhenius definition describes that an increase in temperature of 10 K reduces the life span by half. A decrease in temperature of 10 K doubles the life span. In electrotechnology, this relationship is also known as the MONTSINGER rule. The time-lapse primarily serves to compare materials and does not usually allow a direct extrapolation to a long-term performance under a correspondingly weaker load [9].

Test programmes such as those described in DIN EN 60216 [10] attempt to simulate the changes in the characteristics of electrical insulating systems when they are exposed to thermal stress. The objective is to determine the so-called temperature index (TI). The temperature index describes the temperature at which one or several properties of a system fall below predefined threshold values, e.g. a mass loss of 25%, a drop in the electrical properties to 75%, etc.

In the following tests, it was chosen to determine the dielectric strength as the electrical property. If one evaluates the measured values based on their unit of dimension KV/mm, the absolute dielectric strength partly increases over the measuring cycle. In comparison, if one evaluates the dielectric strength based on the reference value at a certain original coating thickness, the dielectric strength of the coating will decrease as the thermal storage progresses. In this case, a correlation to a reduction in the coating thickness and thus to a mass loss, for example, is possible and makes sense.

Normally, the temperature index is indicated for 20,000 hours (833 days – long-term behaviour) and 5,000 hours (208 days – short-term behaviour). Since this is impractical for corresponding tests, the storage temperatures are increased significantly, and the failure threshold values are then extrapolated, for example, to 20,000 hours. To this aim, three temperature ranges are selected that are partly well above the expected temperature index. The appropriate properties are then examined in cycles, e.g. 10 cycles of 7 days each, and the resultant values measured depicted in a graph as changes in the properties in relation to the time elapsed. With the help of trend curves, the approximate mathematical functions can be determined. This allows the number of hours to be calculated at each test temperature where the properties fell below the threshold values.

By linking the individual "hours failed", it is possible to extrapolate the mathematical failure temperature for 20,000 hours. The temperature value thus achieved represents the continuous temperature resistance. The extrapolation to 5,000 hours determines the so-called short-term resistance. The exactness of the curves can be established via the regression factor [10].
A number of conformal coatings were tested per this method, whereby the mass loss and dielectric strength were chosen as the properties to be measured. The failure threshold for the long-term storage test described in this paper is defined as a max. 25% drop in the corresponding reference value. The test temperatures were 220°C [428°F], 200°C [392°F], 180°C [356°F] and 160°C [320°F]. At 160°C [320°F] an exposure time of 140 days must still be observed!

After completion of appropriate mathematical calculations, the following values were determined for the conformal coatings (Table 2):

Table 2 - Permanent temperature resistances of various conformal coatings for electronic assemblies (20,000 h = long-term behaviour; 5,000 h = short-term behaviour)

Lacquer	20,000 h	5,000 h
	Temperature [°C]	
Lacquer A (modified polyurethane)	140	160
Lacquer B (modified polyurethane)	140	160
Lacquer C (modified polyacrylic)	130	150
Lacquer D (thermoplastic acrylate)	125	150
Lacquer E (modified epoxy)	150	165
Lacquer F (modified polyacrylic)	130	150
Lacquer G (pure polyurethane)	140	150
Lacquer H (UV acrylate)	130	150

As was to be expected, the conformal coating based on modified epoxy (Lacquer E) exhibits the highest temperature resistance and the thermoplastic acrylate material (Lacquer D) exhibits the lowest temperature resistance of 125°C [257°F]. The temperature resistance then increases from the modified polyacrylic conformal coatings (Lacquer C and Lacquer F) to the modified polyurethane conformal coatings (Lacquer A and Lacquer B) and the pure polyurethane conformal coating (Lacquer G). These results demonstrate that the tested conformal coatings – silicone materials were not considered due to their outstanding temperature resistance – all exhibit a good permanent temperature resistance and can also withstand short-term temperature loads – extrapolation to 5,000 hours – of up to 165°C [329°F]. Permanent temperature loads in the range upwards of 150°C [302°F] require the use of silicone inks.

This problem becomes apparent when conformal coatings or especially solder masks are examined together with their substrate – the printed circuit board. The standard base materials limit the use of this procedure. In the specified temperature range of 200°C [392°F] and more there is massive delamination within the surveyed time period. This violates the condition that only such ageing processes are allowed to occur that also take place at the expected operating temperature.

If time-lapse tests with increased temperatures are not possible or do not make sense because of this condition, it is possible to generate a correlation between the duration of the temperature stress and the desired life span. These figures should be determined from practical requirements. By this method the estimated operating temperatures, for instance, for an electronic control device in an automotive application with a presumed life span of 15 years and 240,000 km mileage – corresponding to an operating time of 6,000 hours – would be as follows [11]:

Operating temperatures:

T_{umin}	=	-40°C	360 h	(6%)
T_u	=	23°C	1,200 h	(20%)
T_{umax} -20°C	=	105°C	3,900 h	(65%)
T_{umax}	=	125°C	540 h	(9%)

For this reason, tests on the continuous temperature resistance of photoimageable solder masks were performed over a period of 500 to 2,000 hours at 140°C [284°F] and 150°C [302°F] respectively. For the tests, specimen boards (IPC-B-25A boards, FR4 base material) were given a complex treatment. In order to consider any potential "pre-damage" in the tests, the boards were subjected to a "preliminary stress load" comparable to that of the electronic assembly. The preparation of the boards comprised the generation of various standard surface finishes such as Nickel/Gold finish (ENIG), chemical tin finish (CSN) and HAL (Hot-Air Levelling). The test boards were then run through a practice-orientated multiple soldering process (2x reflow solder and 1x wave solder) followed by a long-term storage at 140°C/150°C [284°F/302°F] in a fan oven.

One of the key questions is how the electronic assembly should/must look after such an enduring stress load and what the individual components are still capable of performing. For example, the requirements of a solder mask as a dielectric are as follows:

"The reliability of the dielectrics requires that no ionic contaminations from the ambient environment or conducting particles caused by corrosion or electromigration can form conductive paths in combination with moisture, e.g. between traces, pads, etc. on a given conductor plane or between conducting systems on different conductor planes." [12]

For this reason, the insulating properties of the specimens exposed to a continuous thermal stress load of 140°C/150°C [284°F/302°F] were checked by measuring the moisture and insulation resistance based on TM 2.6.3.1 of IPC-TM-650 at 40°C [104°F]/90% r. h. and 85°C [185°F]/85% r. h. with 50 V bias. The determined resistance values of > 500 MOhm are all above the so-called IPC threshold per IPC-SM-840 (Fig. 3). Even the boards exposed to 85°C [185°F]/85% r. h. lie above the minimum requirement of 100 MOhm despite the more severe moisture/temperature load.

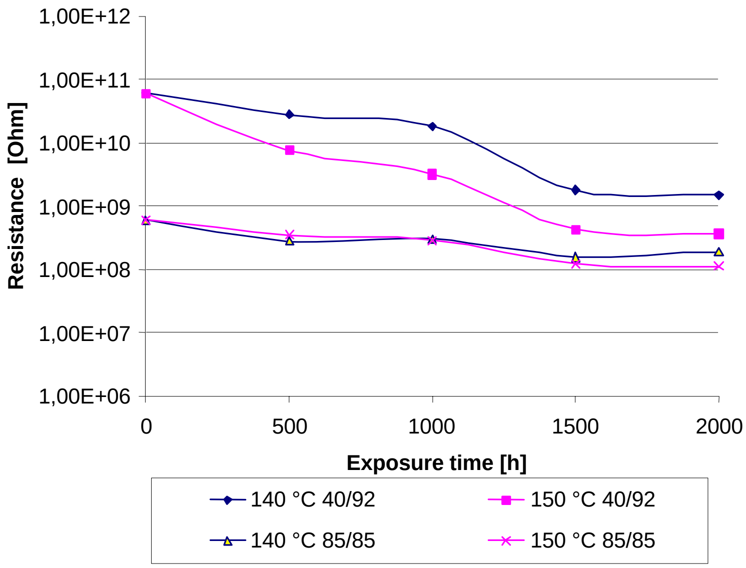


Figure 3 - Insulating resistances of a photoimageable solder mask after long-term thermal storage at 140°C [284°F] and 150°C [302°F]

The decrease in the insulation through the higher temperature load at 40°C [104°F] and 90% relative humidity is obvious, while at the so-called 85/85 conditions the load is already so high that no differences are recorded.

Fig. 4 shows the insulating resistances of a photoimageable solder mask which has been given different surface finish treatments. After generating the various surface finishes, such as Nickel/Gold finish (ENIG), chemical tin finish (CSN) and HAL (Hot-Air Levelling), the test boards were run through a practice-orientated multiple soldering process (2x reflow solder and 1x wave solder) followed by a long-term storage at 150°C [302°F] in a fan oven. All test boards exhibit the same time-related drop in the insulating resistances. No significant difference between the various processes can be detected. However, it seems as though the chemical surface finishes put more strain on the solder masks than Hot-Air Levelling, for example.

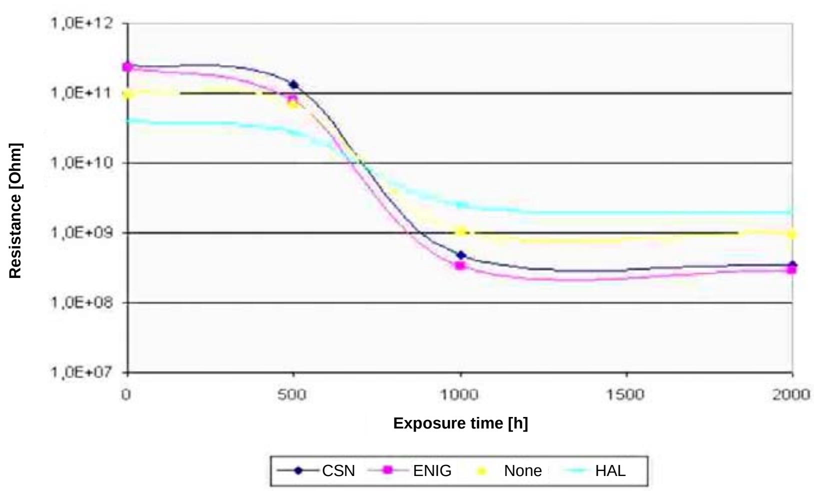


Figure 4 - Insulating resistances of a photoimageable solder mask processed with various surface finishes after long-term thermal storage at 150°C [302°F] (Nickel/Gold finish [ENIG], chemical tin finish [CSN] and Hot-Air Levelling [HAL]; 40°C [104°F]/92% r. h.)

The test boards were exposed to a standard atmosphere, i.e. to oxygen, for the duration of the long-term thermal storage. For this reason, at the prevailing temperatures degradation caused by oxidations cannot be excluded. In order to determine changes specifically to the solder mask surface, an additional electrical property – the tracking resistance (CTI) – was examined.

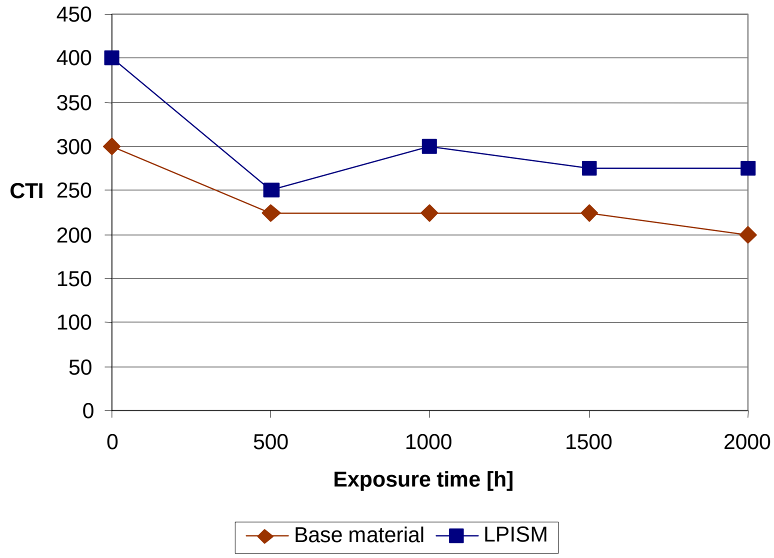


Figure 5 - Tracking resistance (CTI) of a photoimageable solder mask after long-term thermal storage at 150°C [302°F]

This describes the resistance of a dielectric to the formation of tracking currents. The CTI is the highest test current in Volts after drop-application of a test fluid – a defined electrolyte – where no tracking current occurs. The drop-application of the test fluid simulates a contamination.

The test is performed in steps of 25 V up to max. 600 V. There is a noticeable fall in the CTI after just 500 hours' exposure time, however it is still above that of the identically treated FR4 base material measured in the parallel test (Fig. 5). A UV bump after final cure has no effect on the CTI.

At the prevailing temperatures there are certainly changes in the solder mask surface and the base material. However, the reduction of the CTI of the solder mask to values in the range of the base material is still within acceptable limits.

Contrary to the other electrical properties, the dielectric strength tends to rise over the exposure time. The curve values in Fig. 6 were determined without correcting the coating thickness.

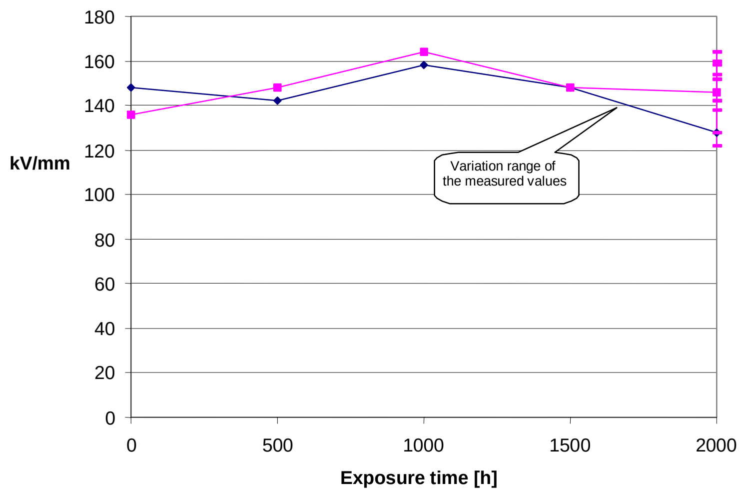


Figure 6 - Tracking resistance (CTI) of a photoimageable solder mask after long-term thermal storage at 150°C [302°F]

4. Thermal shock load

The focal point are the increased requirements on the cyclability of electronic assemblies. The demands of the automotive industry are primarily responsible for pushing the technology forward in this respect. The main cause of failures in the use of electronic assemblies in high-temperature applications leads to the question of how solder masks perform in these test conditions.

Besides the limit temperatures, the temperature switch rate is also of importance in thermal cycling tests (TCT). Accordingly, it is differentiated between so-called "hard" TCTs with a temperature switch rate of < 10 s up to 30 s (also called the thermal shock test) and "soft" or slow cycles with a switch rate of 1 – 3 K/min. To explain the differences between the various "hard" and "soft" thermal cycling tests would go far beyond the scope of this paper.

In accordance with the conclusions and agreements of the ad-hoc workgroup "**Cyclability of printed circuit boards**" of the ZVEI/VdL [5] the analyses to follow comprised the "hard" thermal cycling test. The test conditions were defined as follows:

max. evaluated temperature	T_{max}	=	130 ... 150°C [266 ... 302°F]
min. evaluated temperature	T_{min}	=	-40°C [-40°F]
changeover time			< 10 s
dwell time			30 min
number of cycles			500 (1,000) ... 3,000

The driving force for failures following thermal shock loads is the build-up of thermo-mechanical tension due to the different coefficients of thermal expansion [13]:

$$\sigma \sim E_2 (\alpha_1 - \alpha_2) \Delta T$$

σ = mechanical tension
E = elasticity module
α = coefficient of thermal expansion
ΔT = difference in temperature

Besides the accumulated tensions from the coefficients of thermal expansion – which can already lead to failure – these test procedures also take signs of fatigue of the materials into consideration [4].

All solder masks that comply with IPC-SM-840 must be assessed with respect to their thermal shock resistance. The limit temperatures in this case are -65°C [-85°F] and +125°C [257°F]. 100 cycles with a changeover time of < 2 min and a dwell time at the respective limit temperature of 15 min must be performed. The ensuing evaluation is visual to detect cracks, loss of adhesion, bubbles, etc. The following loads apply:

Test	Specification
100 cycles -45°C [-49°F] (15 min) / +125°C [+257°F] (15 min)	IPC-SM-840 C, TM 650, 2.6.7.1, Class T
100 cycles -65°C [-85°F] (15 min) / +125°C [+257°F] (15 min)	IPC-SM-840 C, TM 650 2.6.7.1, Class H

Class T – Telecommunication – comprises computers, telecommunications equipment and high-end industrial electronics. Solder masks on printed circuit boards of this class are suitable for commercial and high-performance industrial products where a long service life is required, but where an interruption in the performance is not life-threatening. Class H – High Reliability/Military – comprises equipment where a consistent performance is vital. A stoppage or failure cannot be tolerated. Solder masks in this category are suitable for applications where a high level of security is required and continuous operation is paramount, e.g. equipment with a life-preserving function.

In view of the high number of cycles and temperatures targetted not only mechanical stress loads and fatigue make themselves noticeable but also ageing mechanisms as a result of the high-temperature storage and thus they equally become integrated in the overall load.

In accordance with the requirements on dielectrics besides the purely visual inspections per IPC-SM-840 the electrical parameters per the continuous thermal stress load were evaluated. Overall, a thermal cycling test of 1,000 cycles and a dwell time of 30 min still correspond to an exposure time to an elevated temperature of 500 h. For this reason it is not possible simply to transpose the IPC-compliant thermal cycling test to the conditions required in the thermal cycling test here because ageing mechanisms are not recorded after 100 cycles – equivalent to 250 h exposure time.

The visual inspection of the test boards revealed no cracking, delamination, bubbles or other film defects either prior to or after the temperature-moisture cycle.

The moisture and insulation resistance based on TM 2.6.3.1 of IPC-TM-650 at different moisture and temperature conditions was determined in the range of 40°C [104°F] and 90% r. h. up to 85°C [185°F] and 85% r. h. with 50 V BIAS (Fig. 7).

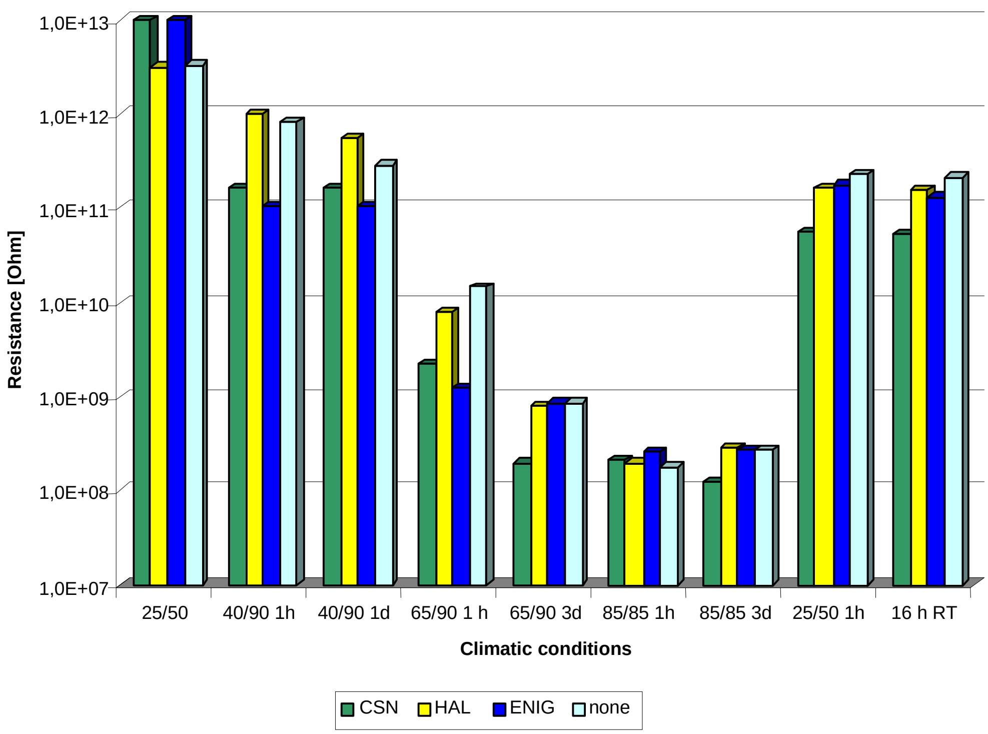


Figure 7 - Insulation resistances of a photoimageable solder mask with different surface finishes after a thermal cycling test (1,000 cycles, -40°C [-40°F] / +150°C [302°F])

All the determined values lie > 500 MOhm and thus above the so-called IPC threshold in the IPC-SM-840. Even the test boards exposed to 85°C [185°F]/85% r. h. lie above the lower limit of 100 MOhm despite the enhanced moisture-temperature load. No significant influence of the various surfaces finishes was detected. Consequently, there was no evidence of pre-damage to the solder mask and/or the adhesive bond between the solder mask and copper conductors. A variation in the pre-treatment of the substrate – not shown here – does not have any marked effect on the insulation values either.

The decrease in the insulation values identified during the thermal cycling test lies within the same range as during the simple continuous thermal storage (Fig. 8) – when only the storage times at the high temperatures are added together. As was to be expected, the thermal cycling test does not have any additional effect on the insulation resistance.

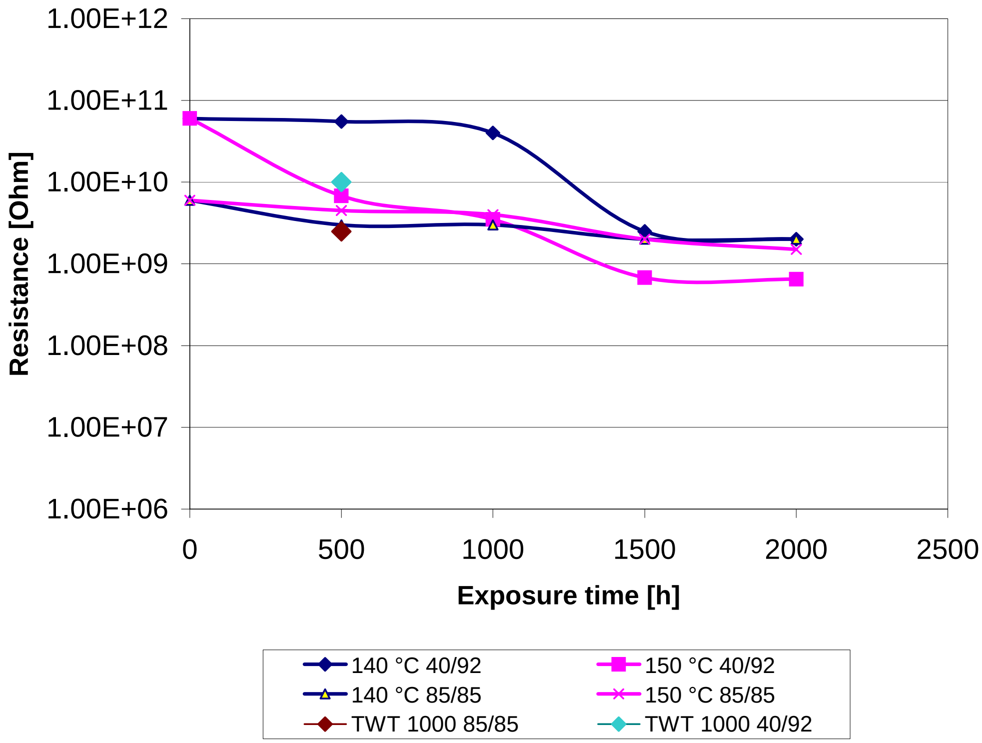


Figure 8 - Correlation of the insulation resistance of a photoimageable solder mask after continuous thermal storage at 140 and 150°C [284 and 302°F] and the corresponding time in the thermal cycling test (-40°C [-40°F]/+150°C [302°F]) (TCT)

5. Summary

Statements on the continuous temperature resistance of both conformal coatings and solder masks are becoming increasingly important. On the one hand, the ambient temperatures in which electronic assemblies are operated are getting higher and on the other hand, the ever tighter population density means the share in the temperature load caused by inherent heat is growing markedly.

The continuous temperature resistance of electrical insulating materials can be judged by performing tests in accordance with DIN EN 60216. Depending on the type of polymer, conformal coatings based on organic polymers can be used up to 150°C [302°F] permanent load or 165°C [329°F] short-term load. Only above these temperatures are silicone inks mandatory.

The tests performed to determine the continuous temperature resistance of solder masks show that their functionality is secured at such a high thermal stress. To determine the functionality after this exposure time in particular the electrical properties were looked at more closely. The moisture and insulation resistance based on TM 2.6.3.1 of IPC-TM-650 showed that no ionic decomposition products form, even under such severe conditions as 85°C [185°F]/85% r. h. at 50 V bias and that values of $> 10^8$ can be maintained. Also the tracking resistance that is important for the insulation could be kept to a satisfactory level.

The thermal cycling resistance of photoimageable solder masks is also very high. Thermal cycles of -40°C/+150°C [-40°F/+302°F] with rapid temperature changes of under 10 seconds can be fulfilled without restriction. The high-temperature thermal stress during the thermal cycling test is comparable to the corresponding long-term thermal storage.

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