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# Combined Accelerated Climatic Tests of Electrically Conductive Adhesives

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**Abstract**:
Electrically Conductive Adhesives (ECAs) are one of the relatively new and quickly expanding replacements for the use of classic lead-based solders in the electronics industry. However this expansion comes at a cost – and one of the most important aspects of this cost is the spreading of ECAs into less than favorable operating environments. While in the past ECAs were used mostly on static LCD screens, nowadays their use did spread already into the realm of portable devices and car electronics. This of course means, that such devices are subjected to much harsher climatic and mechanical stresses than table-mounted flat screens. However, there is a lack of a long-term experience with such applications and thus it is hard to assess the reliability of electronic devices using ECAs. To expand our knowledge about their reliability in such conditions, a series of experiments was undertaken and will be presented in this article.

## INTRODUCTION

Electrically Conductive Adhesives (ECAs) have already been used in the electronics industry for 30 years. In recent years, ECAs play more and more important roles in industry. The main reasons for their use are low curing temperature and environmental concerns. Thus it is one of the alternatives better suited for the next generation lead-free packaging technologies. Their applications vary, but mostly include various heat-sensitive devices or devices with fine lead pitch, such as LCD and LED screens. With increased use of ECAs these devices are being used even in harsh environment, such as laptop computers or various displays used in the automotive industry (multifunction displays on dashboards, GPS navigation…).
In these conditions, the industry faces many serious challenges concerning long-term stability and reliability of electronic devices. One of the most serious problems is that there is a lack of long-term reliability data. To amend this, a series of tests was undertaken. This paper presents the results of combined climatic tests including constant dry heat and temperature cycles on electrically conductive adhesive joints. This resulted in a series of climatic shocks, intended to accelerate the creation and progress of possible defects.

## EXPERIMENT

### Samples

Long-term stability and reliability of ECAs was studied on test PCB using 1206 SMD resistors 0R0 and two types of ECAs. The adhesives used in this study were two-component (AX 12 LVT) and one-component (AX 20) commercial electrically conductive adhesives produced by Polish producer Amepox. The adhesives used in this study used silver flakes as filler. The curing was performed in a hot air oven by manufacturer's specifications, i.e. 10 minutes at 120°C for AX 12 LVT and 8 minutes at 180°C for AX 20. The highest of the prescribed curing temperatures was chosen in both cases, based on previous experiments which showed worse curing at lower temperatures. These experiments will be described in a separate publication.

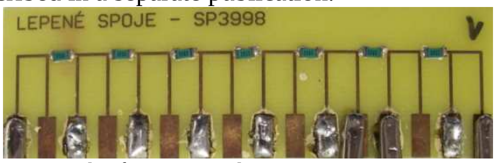


Fig. 1: Example of experimental PCB

### Climatic Tests

Test temperature profiles were selected in order to cover a relatively wide range of temperature conditions to emulate real-world experience. Climatic tests included constant dry heat and temperature cycles. Parameters of climatic test are:

- Constant heat at three temperature levels: 75 °C, 100 °C and 125 °C.
- Duration of the test at each temperatures level: 1000 hours.
- After each 165 hours 6 temperature cycles (75/-15, 100/-25 or 125/-45 °C).

Thus long periods of constant thermal stress were followed by a series of significant temperature shocks, resulting in mechanical stress on the ECA joints caused by different thermal expansion coefficients of used materials.

### Failure Criteria

Test plan for all tests was chosen in the format [1]:

[n,U,t]

So the test plan consists of n (42) resistors, with no replacement U during the time t (1000 hours). The time t is dependent on the type of test and it is based on experience from previous experiments.

Every week, the resistance of samples was measured using the Kelvin four—probe method. This measurement took place both before and after the series of climatic shocks. The percentage change of measured electrical resistance was used as a failure criterion. For the purpose of this evaluation, the changes were transformed to relative values so that both sets of specimens can be directly compared. The minimal value was taken as basic reference point for calculating the resistance change.

It may seem odd to use the minimal and not the initial value for such comparison, but our main aim upon starting the experiment was not to investigate the initial resistance drop, but the following increase of the resistance caused by the climatic test. Using the minimal value as a reference point allows much easier comparison of the rates of change of electrical resistance.

Failure analysis was performed on the chosen specimens after the end of the experiment. Results of this analysis would exceed the scope of this article and will be published separately.

## RESULTS

Following boxplots are used to present the measured values of electrical resistance. The showed characteristics are: Median, Upper Quartile, Lower Quartile and outlying values.

Figures 2 and 3 show measured data for test level 75 °C, Figures 4 and 5 show measured data for test level 100 °C and Figures 6 and 7 show measured data for test level 125 °C.

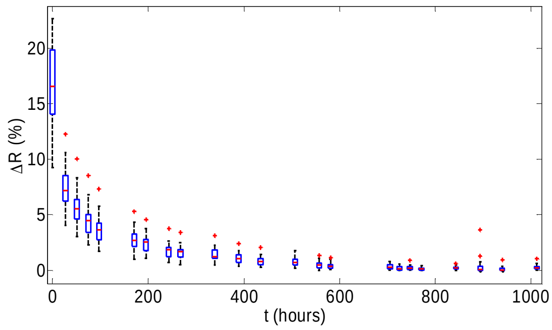


Fig. 2: Measured data for two-component adhsive AX 12 LVT at the temperature 75 °C

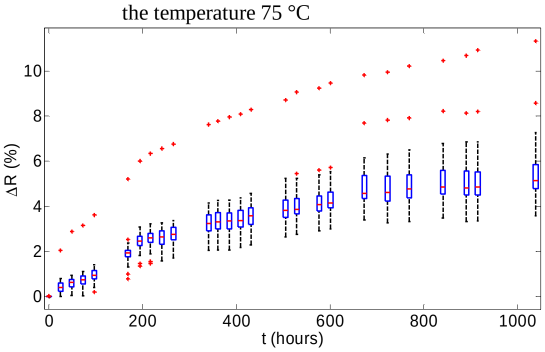


Fig. 3: Measured data for one-component adhsive AX 20 at the temperature 75 °C

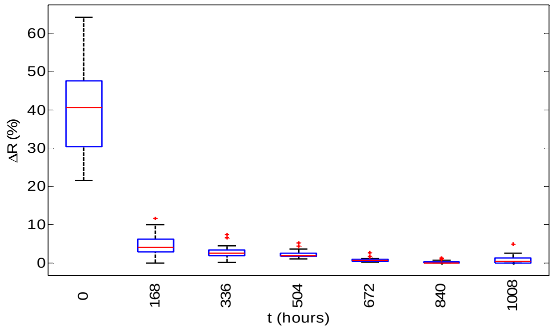


Fig. 4: Measured data for two-component adhsive AX 12 LVT at the temperature 100 °C

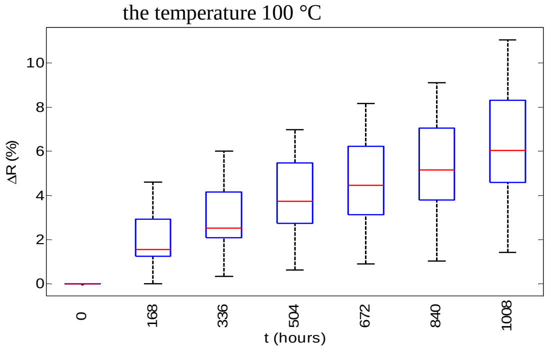


Fig. 5: Measured data for one-component adhsive AX 20 at the temperature 100 °C

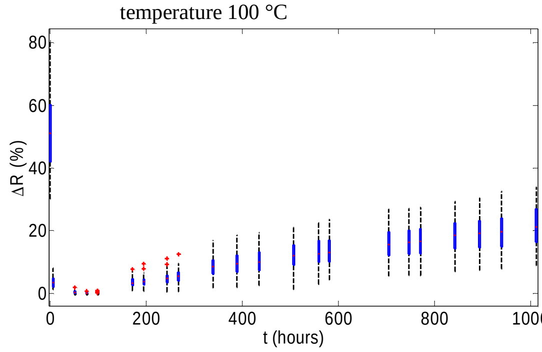


Fig. 6: Measured data for two-component adhsive AX 12 LVT at the temperature 125 °C

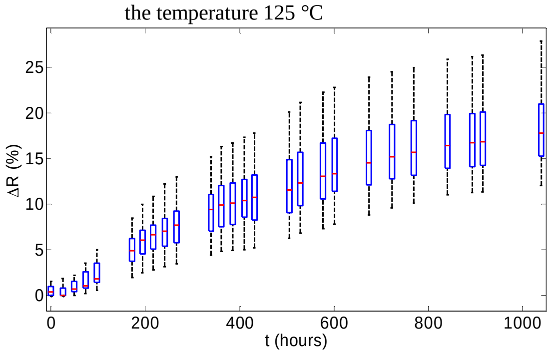


Fig. 7: Measured data for one-component adhsive AX 20 at the temperature 125 °

## CONCLUSIONS

Reliability tests of electrically conductive adhesive joints using combine climatic test have been carried out on the test printed circuit boards. Two types of electrically conductive adhesives were tested. In order to allow mutual comparison of these two types of adhesives, both samples of conductive adhesives came from the same manufacturer.

According to our measurement, ECAs are generally more sensitive to harsh environment than solders. These phenomenons came out:

- In all experiments better reliability of two-component adhesive was observed.
- The higher the temperature during the test, the higher increase in electrical resistance of both adhesives.
- Two-component adhesive AX 12 LVT has in all tests a drop down at the beginning of climatic load. The drop down indicates that the adhesive is not fully cured. The higher the temperature during the test, the higher decrease in electrical resistance. This phenomenon will be studied in further experiments combining all recommended curing profiles for the adhesives with various temperature levels for thermal aging.

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During climatic tests no relevant changes in structure of joints were optically observed. Complex failure analysis will be conducted using the electron microscopy and cross-sections of ECA joints.

Comparison of median percentage changes in electrical resistance of the samples are shown in Figure 8 and 9. The initial drop recorded on AX 12 LVT samples is clear, as well as following growth of resistance on the 125°C temperature level, however at lower temperatures we didn't manage to reach the minimum itself in the time frame of our experiment.

If we compare this with the recorded resistance growth for AX 20, the differences are obvious – there is no initial drop, and while the increase for 125°C is similar in both cases, aging on lower temperatures shows almost 5% increase of resistance of AX 20, while there is no significant change recorded for AX 12 LVT.

Results of this comparison show two major points:

- A two-component adhesive (AX 12 LVT) witnessed a rapid change of resistance in a short period after its manufacture. This observation leads to a conclusion that the recommended curing temperature profiles are not optimal and that the time for curing should be probably longer than prescribed.
- At the highest temperature, both ECAs showed a similar increase of electrical resistance, however at the lower temperature levels, the single-compound adhesive showed remarkably larger increase.

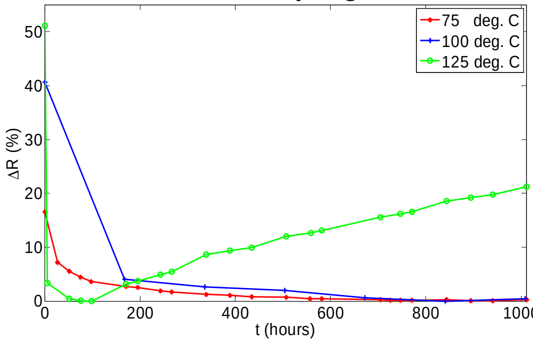


Fig. 8: Median of measure data for two-component adhsive AX 12 LVT at all temperatures

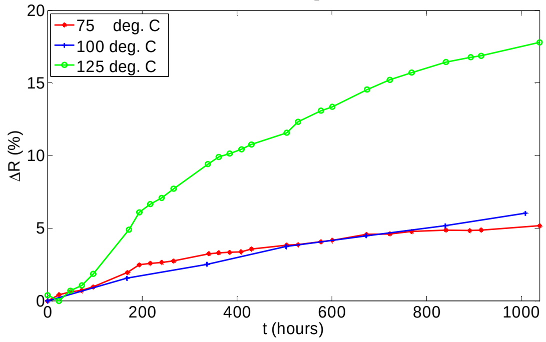


Fig. 9: Median of measure data for one-component adhsive AX 20 at all temperatures

## ACKNOWLEDGMENTS

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