

Printable Epoxy Paste for Varistor Applications

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Abstract

Varistors are passive, two-terminal solid state semiconductor devices that are used to provide over-voltage or over-current protection to electrical and electronic circuits. Metal-oxide varistors (MOVs) are typically made up of a durable ceramic material, which protects them against sudden surges of high current or energy. However, there are some drawbacks of MOVs, such as having a short life span and a large dynamic resistance.

NAMICS has developed a solvent-less epoxy paste that has shown non-linear properties and sustained reliability, very similar to that of an MOV. With NAMICS's proprietary blend of epoxy and other additives, we were able to achieve low-voltage varistor values (< 16 V) with minimal leakage current, comparable to commercially available MOVs being sold today. Printed varistor epoxies have a chance to revolutionize the semiconductor industry by offering miniaturization of components and a solder-less, one-step curing process, all while maintaining the same properties that are offered by MOVs.

Key Words

Epoxy, Low-Voltage, Miniaturization, Solder-less, Varistor

I. Introduction

Electrical surges, such as overvoltage charges, electrostatic discharges, or lightning strikes, can lead to permanent damage in electronic systems. These systems require overvoltage protection from these types of surges [1], [2]. Varistor products can help protect electronic systems from damage, due to their unique ability to decrease resistance as voltage increases (“*variable resistor*”) [2]. The most common type of varistors are metal oxide varistors, also known as MOVs. These varistors are very reliable, providing consistent and reliable overvoltage

protection for a wide range of voltages. However, MOVs have some drawbacks, such as their size, bulkiness, need to be soldered, fire hazards, and limited lifespan [3].

The authors aimed to develop a low-voltage (< 16 V), solder-less, epoxy-based varistor paste that functions as well as market-standard varistor components. In doing so, this could lead to a change in the packaging of electronic systems, allowing for the use of miniaturized components and for overvoltage protection across the entire circuit board.

II. Materials and Methods

The materials that comprise the epoxy mixture used in this study consist of a combination of epoxy, dispersing agents, coupling agents, and a proprietary powder blend developed by NAMICS-Diemat, Inc. and eM-TECH, Inc. The mixture was blended together using a 3-roll mill and a Speed Mixer. The epoxy mixture was then dispensed onto a polyamide film, containing six different electrodes that vary in size. The epoxy mixture was heat-cured.

The cured epoxy samples were subjected to IEEE tests 5.2 (varistor voltage test), 5.3 (leakage current test), 5.4 (capacitance test), as well as an IV curve test, by using the following electrical testing equipment: Power Supply Teledyne LeCroy T3PS16081P, DMM Teledyne LeCroy T3DMM4-5, DMM B&K Precision 5493C, and Keithley SourceMeter 2600 Series. The test methods can be found in [4, pg. 13-15].

III. Results and Discussion

The goal of these experiments is to compare the experimental epoxy mixture to market standard MOVs, to prove that this epoxy can be used as a substitution for these products. In some graphs below, the market standard MOVs will be shown on the left side of each graph, listed as “Market Standard ___V.” (The numbers listed next to the name of the Market Standard samples are the voltages that each product is rated to protect against. For example, Market Standard 13.5V is rated to protect from surges exceeding 13.5V.)

IV Curve Test

The relationship between the current (I) through and the voltage (V) across the terminals, is typically described by:

$$I = k \cdot V^\alpha \quad (1)$$

The term α describes the degree of non-linearity [2]. A high- α varistor would have a graph similar to the one shown below, in Fig. 1.

Typical IV-Curve for Varistor Component

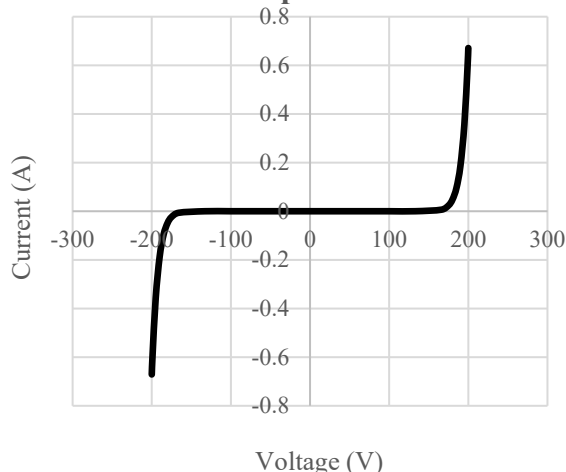


Figure 1: Example of an IV-Curve for a Varistor Component [2]

The following graph is an IV-curve example of a standard MOV varistor, shown below in Fig. 2.

IV-Curve of 5.35V MOV Varistor

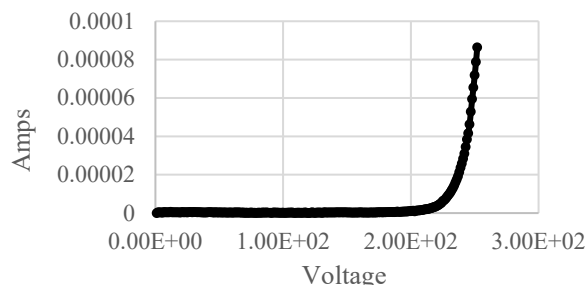


Figure 2: IV-Curve of Market Standard MOV

The following graphs are a result of the authors' epoxy mixture.

IV Curve of Printable Epoxy R&D Sample

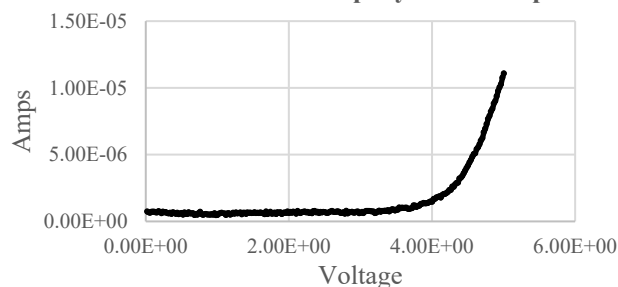


Figure 3: IV-Curve of Printable Epoxy Sample

As shown, the epoxy mixture showed similar traits of non-linearity, compared to the MOV varistor.

IEEE Test 5.2 – Varistor Voltage Test

The following graph shows that our epoxy mixture directly compares and performs similar to the MOVs.

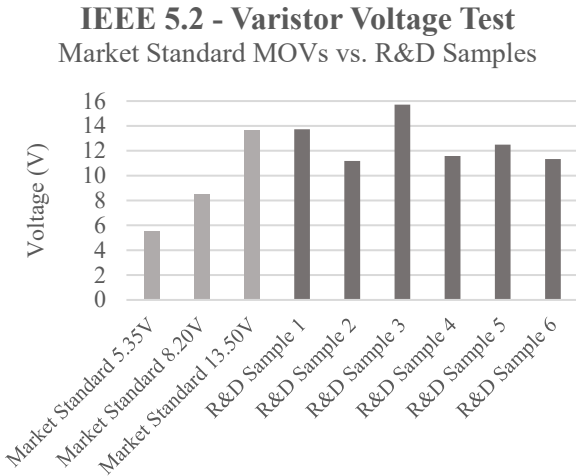


Figure 4: Varistor Voltage – Comparing MOVs to R&D Epoxy Mixtures

IEEE 5.3 – Leakage Test

The following graph shows that our epoxy mixture has a slightly higher leakage current compared to the MOVs.

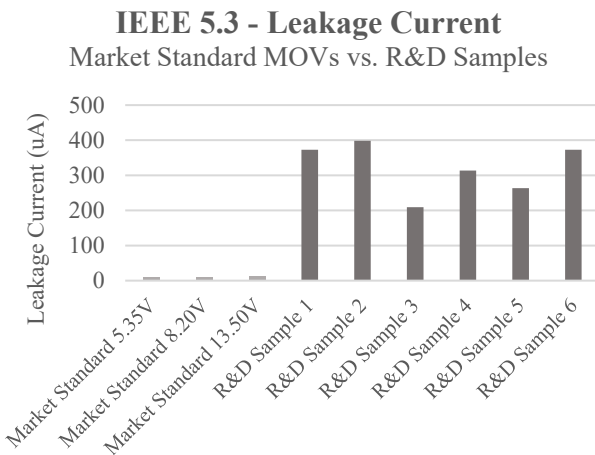


Figure 5: Leakage Current – Comparing MOVs to R&D Epoxy Mixtures

IEEE 5.4 – Capacitance Test

The following graph shows that our epoxy mixture has comparable capacitance to the MOVs.

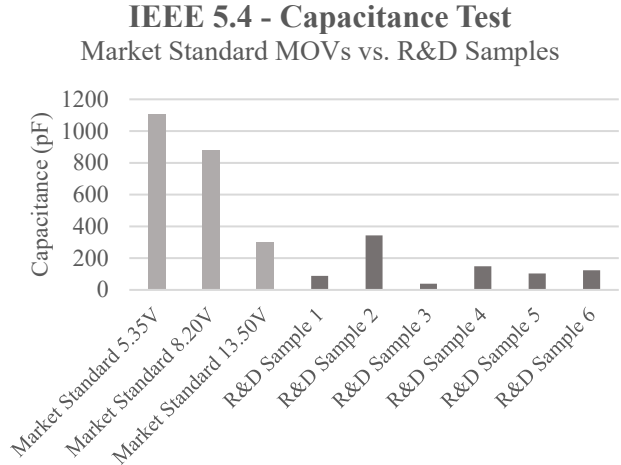


Figure 6: Capacitance Test – Comparing MOVs to R&D Epoxy Mixtures

The developed epoxy mixture is very comparable to MOVs available on the market today. IV-curve testing shows that the alpha values of the non-linear curves for the epoxy matrixes are very similar to the MOVs'. Varistor voltages of the epoxy matrix are very comparable to low-voltage (< 16V) MOVs. Leakage currents, while higher than the MOVs, could be improved by testing on an alternative substrate. At this time, the epoxy samples have only been tested on polyamide film. The authors believe that testing on a PCB board substrate, like the one the MOVs were mounted to for this test, will help lower leakage current. Lastly, the capacitance testing shows that our epoxy mixtures are also similar to the MOVs, if not lower, which opens up another type of product that this epoxy paste could be used in.

This new product offers characteristics to varistor products that are not often seen in sintered ceramic MOVs. Being able to operate at low voltages with low capacitances allows for this epoxy paste to be used in a variety of low voltage applications, such as motor-driven systems, noise dampening systems, and many more.

IV. Conclusion

As shown, NAMICS-Diemat, Inc. and eM-TECH, Inc. have developed a printable epoxy product that can act as a varistor in low-voltage electronic applications. The use of this varistor epoxy can lead to a complete redesign of electronic circuit boards, allowing for miniaturization or flexibility. Also, studies have not concluded yet, but NAMICS-

Diemat, Inc. and eM-TECH, Inc. believe that they are able to alter this epoxy formulation to achieve resistor properties. This ability to easily change the formulation to achieve entirely different results is something that could make finding the best product very easy for the end-user. Lastly, in the future, this printable epoxy could be used in other ways to improve the performance of the circuit boards.

References

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