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ELECTRICAL PERFORMANCE OF ZINC OXIDE VARISTOR USING POWDERS PROCESSED BY DIFFERENT LATEX BINDERS

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ABSTRACT

The critical electrical parameters such as I-V characteristics, watt-loss and energy absorption capability etc. are the determinants for performance evaluation of ZnO varistors. In this regard there are a large number of contributing variables. Selection of proper binder in the processing of electro-ceramic powder is also a crucial factor. It imparts green strength, enhances compressibility and reduces density gradient within the green discs. Grain growth during sintering and subsequent microstructure of the varistor is also highly influenced by the binder system. It is envisaged that a disc with higher mechanical strength could be capable of withstanding more thermal stress due to temperature gradients. The energy absorption capability as well as high current performance can thus be enhanced. It was possible to generate varistor discs from the powder processed by the latex binder with better electrical performance than that of the powder processed with conventional binder of polyvinyl alcohol. Factorial analysis showed that the level of binder and solid concentration in the slurry had great influence on the energy absorption capability of ZnO varistor.

KEY WORDS; Varistor, Binder, Energy absorption capability

INTRODUCTION

A ZnO varistor is a semi-conducting device which possess a non-linear current (I)-voltage (V) characteristics with a symmetrical sharp breakdown [1,2] similar to that of a zener diode. But unlike a diode, a varistor can limit overvoltages equally in both polarities, thus giving rise to I-V characteristics which is analogous to the two back to back diodes. This has enabled it to provide an excellent transient suppression performance. It is the preferred approach to protect the electrical, electronic and power distribution and transmission circuits from destructive voltage levels induced by lightning impulse or switching surges over the past thirty years. There are wide ranges of varistor products which are used for electrical, electronic and power distribution and transmission circuits from destructive voltage levels induced by lightning impulse or switching surges [3].

The critical application parameters for varistor discs are associated with the various region of I-V curve. These parameters are crucial in design operation of surge protector. The product should have a high value of non-linear coefficient, a low value of leakage current, a long varistor life and high energy absorption capability.

ZnO varistor is processed by conventional powder processing route where the additive binder plays a significant rule. Green strength, reduced density gradient within the green discs, grain growth during sintering and subsequent microstructure of the varistor is highly influenced by the binder system. The green and the fired body, homogeneity, grain size, porosity, varistor chemistry are identified to affect the energy absorption capability remarkably [4,5].

The present study was carried out with several latex binder and their blends to evaluate possible alternative binder for processing ZnO varistor. The alternative binder would enhance the energy absorption capability by restricting failure at minimum level of energy and thereby, resulting in an increase in the rating of arrestor blocks. In that case the arrestor could be used for more demanding applications or their volume can be decreased proportionately. The system functional reliability can thus be improved.

EXPERIMENTAL PROCEDURE

Different commercially available binders and their blends were taken. The percent binder and the solid content in the slurry were varied. Under standard spray drying conditions powder was produced from the slurry. Cylindrical green bodies were produced by dry pressing, using Carver Laboratory Press (model M) under 130 MPa and using 17 mm floating die. The compacted discs were sintered in the pot kiln with standard firing profile. The fired bodies were passivated; the flat surfaces were ground and after ultrasonic cleaning and visual inspection of defects such as pinholes and damaged edges, were electroded for performance evaluation. The identification of different binders is presented in Table 1.

Table 1: Identification of different binder systems, depending on the type, the binder level and the solid contents

Binder type	Ltx A	Ltx B	Ltx C	Ltx D	Ltx E	PVA	Ltx C1	Ltx C2	Ltx C3	Ltx C4	Ltx C5
Binder (%)	1.30	1.30	1.30	1.30	1.30	1.30	1.00	1.60	1.00	1.30	1.60
Solid (%)	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	80.00	80.00	80.00

ENERGY ABSORPTION CAPABILITY

The energy absorption capability of the varistors was performed in Haefely (Model no. WO 4435-36) impulse generator with capacity of 50 KV and 45 KJ. The generator produces square waves which consist of LC network of capacitor and reactor coils in between capacitors. The shape of the square wave is given in Fig 1. The energy absorption capability was calculated from the measured peak current and clamp voltage and the time duration by using the following relationship:

$$E = \int_0^t vidt = CVIt \qquad (1)$$

where C is a constant and it depends on the wave shape of testing. The value of V is taken in volt/cm, I in amp/cm^2, and t in seconds to calculate energy in J.cm^{-3}.

The energy absorption capability of varistors was measured by selecting a charging voltage for a fixed charging time. Three repeated shots of 2 ms square wave was applied for each cycle. The charging voltage was selected at a low level so that no failure occurs in the first cycle. The cycle of shot continued until all of the discs of the sample failed. The value of clamp voltage and peak current for each shot was recorded. The cumulative curve of energy absorption was plotted from the calculated energy and the number of discs failed at that energy level.

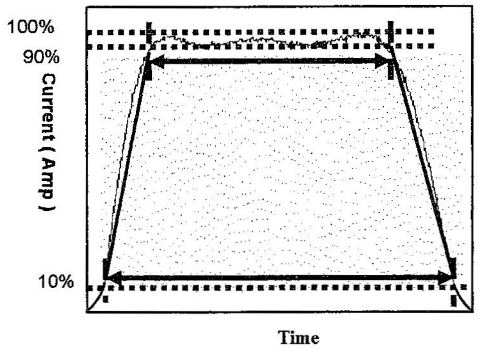


Fig. 1: The shape of the square-wave current applied to evaluate the energy of varistor

NON-LINEAR CO-EFFICIENT

The most critical parameter to characterize for zinc oxide varistor is non-linear coefficient. The co-efficient, α is defined by the following formula:

$$\alpha = \frac{d\ln I}{d\ln V} \qquad (2)$$

The magnitude, therefore, varies with current density. It increases in the pre-breakdown region, attains a maximum value in the non-linear region and diminishes sharply in the upturn region.

FACTORIAL DESIGN

Two level factorial design is a very simple and easy way to identify the main effects and interaction on the response of the process [6]. The analysis was carried out considering the level of binder and the solid concentration as independent variables whereas, energy absorption capability as response. In Table 2 the input parameters with their level and code are given and the corresponding results of investigation are presented in Table 3.

Table 2 Energy absorption capability for Latex binder Ltx C

Test level %		Energy (J.cm^{-3})
Binder	Solid	
(-)1.0	(-)72	265
(+)1.6	(-)72	246
(-)1.0	(+)80	274
(+)1.6	(+)80	267

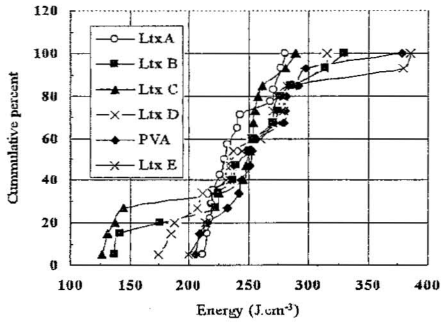
Table 3 Main and interacting effects on energy absorption capability of varistors

Main and interacting effects	Energy ($J.cm^{-3}$)
Binder	-13.0
Solid	15.0
Interaction	6.0

RESULTS AND DISCUSSION

Energy absorption capability of varistors was affected by the powder processing parameters. It is dependent on both the binder and solid levels. The powder processed with lower level of binder and higher solid concentrations can generate varistors of increased energy absorption capability.

Energy absorption capability of varistor made from powder with different binder systems is illustrated in Figure 2. There is no significant difference in the energy absorption capability among the varistors produced from the powder containing latex and the conventional binder, except a poorer performance was observed with binder Ltx C.



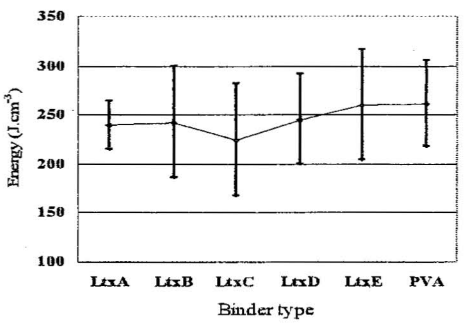


Fig. 2: Energy absorption capability of varistors produced from powders containing different binder systems in the slurry

Ltx C showed enhance performance in terms of the powder characteristics [7] as well as electrical properties like wattloss, clamp ratio, non-linear co-efficient, and nominal voltage etc [8]. The reason of poor performance in terms of energy absorption capability is not clear.

The presence of lower and higher level of Ltx C at lower content of solid in the slurry resulted almost the same energy absorption capability as the conventional one as shown in Figure 3. However, it is much more consistent with Ltx C3 that is, at low level of Ltx C and high solid concentration as given in Figure 4. This consistency can be attributed to the presence of fewer flaws in the fired body as interpreted from Weibull modulus, m, for fired strength [9]. The failure mode is predominantly by electrical puncture for the varistor with all the binder systems

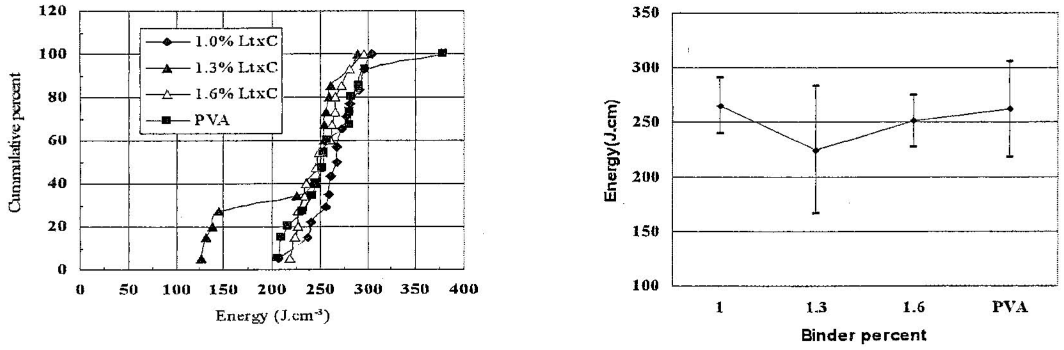


Fig. 3: Energy absorption capability of varistors produced from powders containing different levels of binder at lower solid concentration in the slurry.

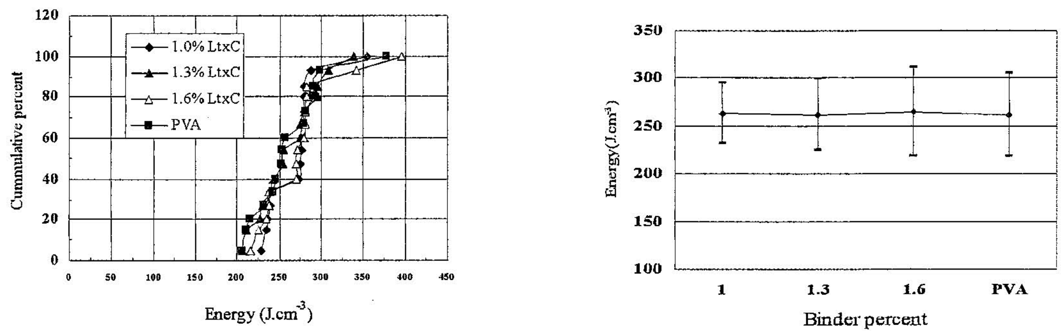


Fig. 4: Energy absorption capability of varistors produced from powders containing different levels of binder at higher solid concentration in the slurry

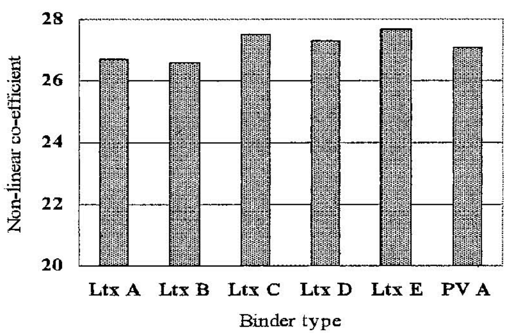


Fig. 5: Non-linear co-efficient of varistor produced from powder with different binder systems

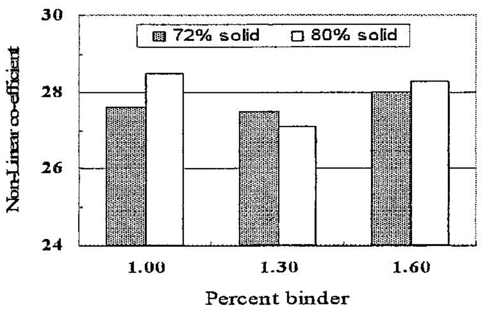


Fig. 6: Non-linear co-efficient of varistor produced from powder containing various levels of binder at different solid concentration

The non-linear co-efficient of varistors produced from powder with different binder systems is shown in Fig. 5. A high exponent is obtained with Ltx C. This is due to sodium incorporated by the binder within the varistor. Sodium acts as a donor and it can decrease grain resistivity at high current density and lower clamp ratio.

The highest exponent was obtained with lower level of binder and higher solid concentration as illustrated in Fig. 6. This may be attributable to larger grain size which can reduce the clamp voltage [10].

CONCLUSIONS

The use of acrylic latex binder in the processing of ZnO varistor has secured better performance in terms of non-linear co-efficient and consistency in energy absorption capability. The use of latex binder has left the scope of reducing the amount of binder and increasing the percent of solid content in the slurry. The powder processed from the slurry containing lower level of binder and higher solid concentration could generate varistor with enhanced non-linear co-efficient and consistent energy absorption capability. It would help to increase the rating of varistor, thereby leaving the scope to improve the system functional reliability.

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