Physical Properties of Elastic Epoxies for High Voltage

Kwan-Woo Lee*, Yong-Sung Choi* and Dae-Hee Park*

Abstract - In this paper, the thermal and mechanical properties of elastic epoxy for the application of high voltage products were investigated. Glass transition temperature (Tg) of elastic epoxies cannot be found from room temperature to 200°C by DSC (Differential Scanning Calorimetry). Weight reduction occurred at 285°C and 451°C according to a thermogravimeter. The first temperature was affected by addictives and the second by epoxies characteristic. Maximum tensile strain showed 28.3 kgf/cm^2 at 20% of mechanical stress in addictives 35 [phr]. The SEM (Scanning electron microscope) micrograph of the fracture surface observed void and tearing of elastic epoxy at addictives 35 [phr]. On the other side, the SEM micrograph of the rigid epoxy showed a broken trace.

Keywords: DSC, Elastic epoxy, Glass transition temperature, Maximum tensile, Void

1. Introduction

Electrical demand has gradually increased according to industrial development, instigating a higher demand for various electric related materials. Electric materials can be classified as conductors, semiconductors, and insulators. If the same material demonstrates different properties, industrial demand will be great and cost of the material will be at prime. The solid insulation material used for high voltage is largely elastic or another substance that is very strong.

Epoxy consists of excellent mechanical and electrical properties making it popular for use in high voltage fields [1, 2]. However, the epoxy, even though it has elasticity, has still not been used for high voltage material. Adding addictive to the epoxy gives it an elastic quality that can be in great demand as an insulated material. The one reason as the same manufacture condition is because the compact manufacture can be. The other demand is manufactured that the epoxy mixes the main and the hardener.

When epoxy is mixed, exothermic reaction occurs and if thermal expansion coefficient differs, internal stress occurs between metal and epoxy [3]. This stress exists in the epoxy's structure even when it hardens. A crack can easily occur during heat cycle testing. This crack is rapidly dropped the electric efficiency of the high voltage product [4, 5].

The elastic property is measured by the ratio of elasticity that it can get from the stress and the strain. If the elasticity is generally high, its stress curve is laid down on the right side. Alternatively, if plasticity is high, its curve is on the left side. The causes that the elastic epoxy has on elastic property are 10 branches, but the microvoid, bridge and share band have confirmed. SEM analysis is applied as elementary data that analyze these properties [6, 7].

Thus, the paper compares as the basic data for researches a ratio of elasticity measurement and micro properties evaluated by SEM analysis with rigid epoxy.

2. Experiments

The epoxy sample was made of a key compound in the form that adds a modifier in the epoxy of the bisphenol A type. Ratio of modifier at the rate of 0 [phr], 35 [phr] and 70 [phr], upon sufficient reaction with modifier and epoxy, removed a void after adding hardner and filler at about 30 minutes in 0.05 [torr]. Because it is a poured mix-liquid, it can remove a cell in a preheated slice of mold, and vacuously remove a cell again taking away the void left by that cell. Furthermore, it enforces the first hardening and the second hardening.

The second hardening is necessary because the reaction of the epoxy does not occur perfectly at the first hardening and the remainder of epoxy reacts again when hardening occurs, altering the temperature once again. Such being the case, additional study is needed on the first and second reaction time and reaction condition by temperature. This condition is omitted at a slice manufacture; a slice is manufactured at a decided condition of the first hardening during 3 hours at 130°C, and the second hardening during 12 hours at 120°C.

The experiments were evaluated by order of DSC, TGA (thermogravimeter analysis), elasticity rate and SEM to investigate microscopic thermal property of epoxy having elasticity.

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3. Results and Discussion

DSC was measured to investigate the transition temperature of epoxy and calorification·endothermic reaction. Temperature range extended from room temperature to 200°C and the temperature rise speed was 10°C/min. Appliances used DSC Q100, with a calorification reaction that decreased. Fig. 1 shows DSC of modifier 35 [phr]. Although general epoxy appears as glass at the transition point of 60~90°C, elastic epoxy does not appear as glass at a transition temperature of this range. This confirms that glass transition temperature according to hardening temperature and time may not appear [8].

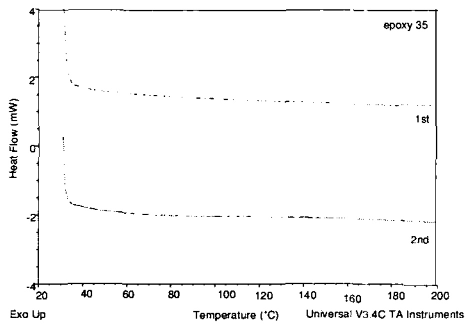

Fig. 1 DSC analysis result in case admixture is 35 [phr].

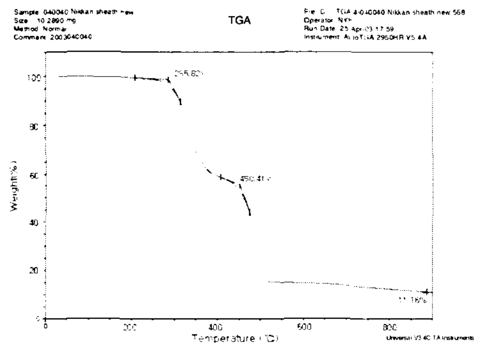

Fig. 2 TGA analysis result in case admixture is 35 [phr].

In case use exceeding thermal transition temperatures of the material leads to a decline of electrical and mechanical properties, it should be used in lower temperature conditions than heat transformation temperatures according to the working conditions of the product. In the meantime, the instantaneously usable heatproof property is dependant on thermal transformation temperatures. For the measurement of thermal transformation temperatures, a TGA instrument was used and the temperature rise speed was 5°C/min. In case of unused modifier, weight decreases occurred at 450°C. However, the first weight decrease occurred as shown in Fig. 2 at 285°C in the use modifier and the second weight decrease occurred at 450°C. This shows that the molecular bond of modifier is segregated at 285°C. The dissociation of epoxy's molecular bond is expected at 450°C, which takes place at the point of the second weight decrease.

A stress/strain graph was composed to study elasticity property at normal temperatures. This graph is a ratio of strain and stress expressing the elasticity property of elasticity style epoxy. If the elasticity is strong, strong elastic hysteresis curved line is shown as in Fig. 3 such as the B-H hysteresis curve of electricity. Further research is required to make a hysteresis curve, and to compare the existent epoxy and elasticity property of epoxy of the elasticity in this paper. Tensile strength of epoxy for high voltage is 60~100 kgf/cm^2 and the elongation rate is about 1%. This means that the ratio of mechanical strength is high but the ratio for stress is low. Usually, if mechanical strength is high, it is influenced greatly on stress that takes place in the interior. Interior stress is divided into thermal stresses and by stress hardening contractions. Hardening stress of epoxy resin occurs by hardening contraction. When cool at hardening temperature, tensile stress occurs as compressive stress by heating. On the other hand, thermal stress takes place when the heat coefficient of expansions of epoxy resin and the thermal expansion coefficients of inserted material are different. The relation is expressed by equation (1),

$$\sigma = K \int_{T_R}^{T} \alpha_R(T) - \alpha_S(T) E_R(T) dT \qquad (1)$$

where, σ is thermal stress and K is the constant which is decided by a form. T is temperature. $\alpha_R(T)$ is thermal expansion coefficient of epoxy resin. $\alpha_S(T)$ is thermal expansion coefficient of metal outside other material and $E_R(T)$ is the elasticity rate of the resin. Namely, thermal stress occurs to a great extent, while general epoxy has high mechanical strength and decreased interior stress to regulate filler, etc. to set the thermal expansion coefficient of epoxy resin in other material resin with metal to decrease this stress. Elastic epoxy absorbs the stress of epoxy using a modifier. Exterior and interior stress can both be absorbed.

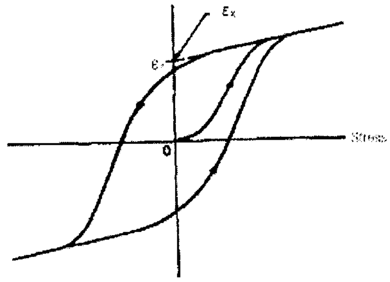

Fig. 3 Strong elasticity hysteresis curve by exterior stress.

Fig. 4 shows tensile strength in a stress graph in case the ratio modifier is 35 [phr]. The target level of tensile strength is 85 kgf/cm^2, but appeared to be 26 kgf/cm^2. When the mechanical property is stronger, tensile strength appears high, but the modifier ratio must be properly regulated because otherwise the property of elongation rate appears in a poor light. Tough property does not appear greatly even if using a modifier.

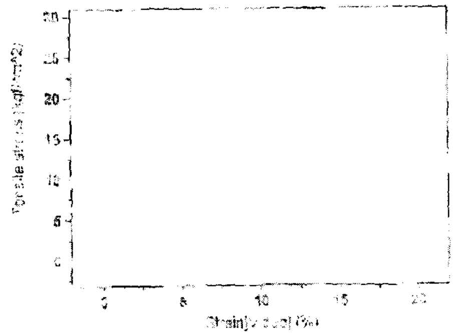

Fig. 4 Elasticity rate graph of epoxy to which modifier 35 [phr] is added.

The following experiment is a SEM analysis for microscopic inspection to look for elasticity characteristics. The SEM equipment used is Hitachi's S-2500C. Cause that elastic epoxy has elasticity is known as greatly 3: one, (1) according as crack of particle that has elastic property is progressed, elastic particle between cracks tears and the stress happens; (2) when generate many halls around particle that receive elasticity of region that receive stress in void's modification; and (3) when this particle scatters stress because particle that receive stress in mattress form straggles in element. Fig. 5 shows the SEM photograph analyzing the section of epoxy for high voltage. As we can see from Fig. 5, this epoxy lacks elasticity and the hardness level is high with broken property appearing throughout this section.

Fig. 6 shows the SEM micrograph of the case that added modifier 35 [phr] to the elastic epoxy. Traces that tear in the micro void and element are partially showing. The center portion displays the well-torn phenomenon of the case in which stress is applied. This torn phenomenon plays an important role in improving the elastic property of epoxy. The upper part of the void is massed and is contracted in compression while the elastic property of the void is deformed to tensile. Also, the upper portion of the void performs the role of scattering stress partially throughout the matrix. Therefore, the void and modifier take charge of the role on constituents that heighten elasticity, improving elastic property in cases where the void mixes evenly.

Fig. 7 shows the SEM micrograph of epoxy to which *modifier 70 [phr] is added*. It displays from the surface roughness that in the case of the addition of epoxy modifier 35 [phr], elasticity could be greatly decreased.

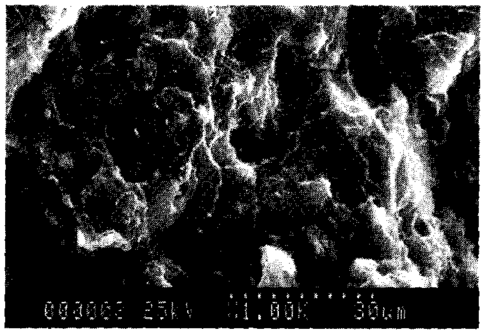

Fig. 5 SEM analysis of epoxy for high tension.

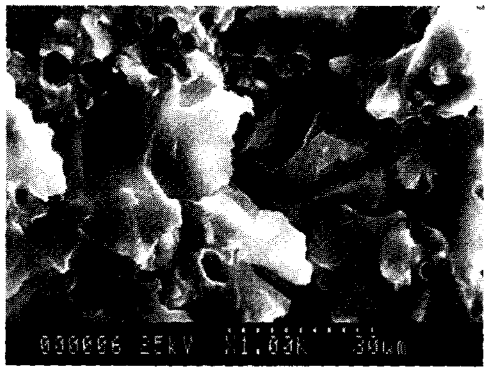

Fig. 6 SEM analysis of elasticity style epoxy to which modifier 35 [phr] is added.

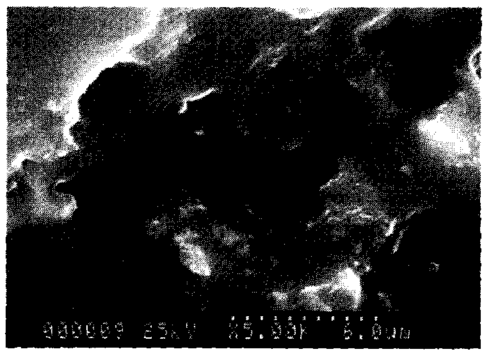

Fig. 7 SEM picture of elasticity style epoxy to which modifier 70 [phr] is added.

From the analysis result of these SEM micrographs, the elastic property of epoxy could experience change according to the content of the modifier, and displays a nature that can change according to working conditions. To use elastic epoxy by dielectric parts for high voltage, surface resistance and dielectric breakdown properties are very important, and the result of dielectric properties currently acquired is thought to be very important as basic data. Beside these properties, environmental effect and moisture need additional research to determine their effect on elasticity property and deterioration mechanism. Specially, it is necessary to compare elastic property with existent epoxy, and conduct further examination concerning mechanical characteristics and relation to elasticity, etc.

4. Conclusions

From our experimental results concerning the thermal and mechanical characteristics of elastic epoxies, we determined that modifier affects the thermal characteristic and elasticity characteristic. Furthermore, the following conclusions were obtained.

(1) Glass transition temperature of epoxy did not show from room temperature to 200°C in DSC analysis.

(2) Degradation temperature at 285°C due to effect of modifier in TGA analysis.

(3) The elastic property from the elasticity property rate of epoxy showed an increase in elastic property rather than a decrease in mechanical strength.

(4) Propensity for elasticity according to the addition of modifier from SEM analysis appears strongly. In particular, we could confirm that influences in elasticity in the modifier's addition amount 35 [phr] appear strongly.

Acknowledgements

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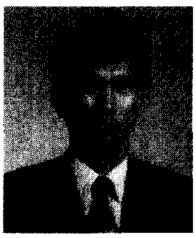

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