A Study on DC Breakdown Strength due to Variation of Specimen Shape of Epoxy/SiO_2 Compound Material Treated with Silane Coupling Agent

김명호, 김재환, 김경환, 박창옥, 손인환, 박재준
(Myung-Ho Kim*, Jae-Hwan Kim**, Kyung-Hwan Kim***, Chang-Ohk Park****, In-Hwan Son**, Jai-Jun, Park**)

Abstract

In order to increase the coupling strength between bisphenol-A type epoxy resin and filler SiO_2, it was treated to filler with silane coupling agent[KBM-603].

To observe how silane coupling agent effects on dielectric breakdown strength of Epoxy/SiO_2 compound material, specimens of eight type were made like following.

(A-1, A-2), (B-1, B-2), (C-1, C-2), (D-1, D-2) (see 2-2. Specimen)

Specimen treated with silane coupling agent had always bigger dielectric breakdown strength than non-treated specimen.

Under the influence of silane coupling agent, increment ratio of dielectric breakdown strength at specimen manufactured by hand drill was very bigger than that of specimen inserted spherical electrode.

Therefore, as the specimen shape was varied, it was studied on effect that silane coupling agent affects on dielectric breakdown strength of Epoxy/SiO_2 compound material.

* : 경원전문대학교 건축설비과
** : 광운대학교 전기공학과
*** : 경원대학교 전기공학과
**** : 상지전문대학교 전기과

1. INTORODUCTION

Polymer materials used to insulation of electrical and electronic apparatus are complexly affected by factors such as state of applied voltage, temperature, humidity and mechanical stress.[1]

Under the influence of these complex factors, it is needed that toughness and dielectric breakdown strength of compound material should be improved for high confidence and long life time of electrical and electronic apparatus.

Therefore in this study as treating silane coupling agent to inorganic filler, dielectric breakdown strength improvement of Epoxy/SiO_2 compound material was contrived through improvement of interface combination between epoxy resin and filler.

Also, from the result as specimen shape was different, it was studied on effect that the silane coupling agent affects on compound material.

2. SPECIMEN AND EXPERIMENT

2-1. Reserve Experiment

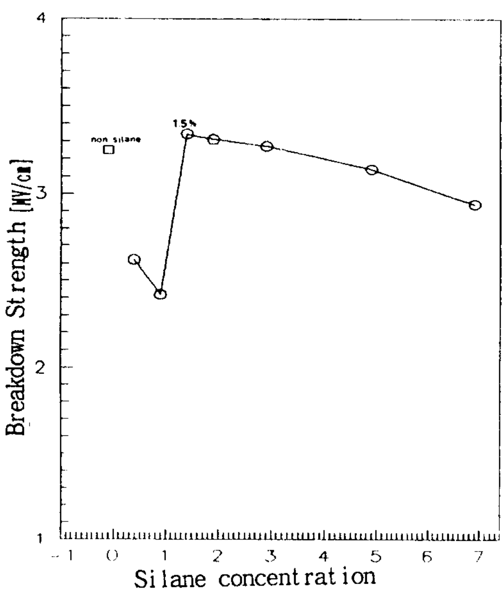


Fig. 2-1. Dielectric breakdown strength due to coupling agent concentration on filler content (DC)

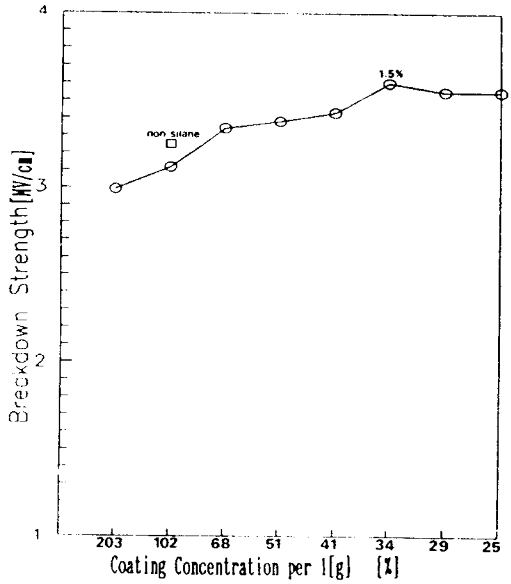


Fig. 2-2. Dielectric breakdown strength due to filler content on coupling agent concentration (1.5%)

Contact badness of filler and epoxy resin existent in filler particle interface between electrode and concentrated stress in the interface is being breakdown by weak point, on behalf of elimination, filler is treated, as in figure 2-1, by providing the variation of concentration of silane coupling agent of the solution at 100.

Therefore treated filler of 7 kinds of concentration is added on epoxy resin at 100 by the ratio of 50[wt%], and dielectric breakdown strength is tried to measure by adding the product as a specimen, the result to figure 2-1 is obtained.

Therefore, as concentration of silane coupling agent is increased by 1.5[wt%], dielectric breakdown strength increases and above that concentration the decreasing tendency of dielectric breakdown strength is showed.

Such phenomena is due to the attachement of monomoleculer layer in silane coupling agent about 1.5[wt%] in the filler surface and above that ranges, it becomes polymoleculer layers and particuler layer is formed due to the action on filler surface of the electrical impurities.

From figure 2-1, it is decided that the silane coupling agent of concentration is most suitable at 1.5[wt%] and the quantity of silane coupling agent being treated filler is changed by controlling particular layer and contact of interface can be made better, by standardizing the compound solution of silane coupling agent concentration 1.5 [wt%] on Toluene 100 and this quantity of filler treated solution is variated from 203 [wt%], 102[wt%], 68[wt%], 51[wt%], 41 [wt%], 34[wt%], 29[wt%], to 25[wt%].

As the known from figure 2-2, the dielectric breakdown strength voltage of treated specimen (under specimen with silane) at 34[wt%] silane coupling agent is increasing by 10.8% than unprocessed specimen(under specimen with non-silane) can be known.

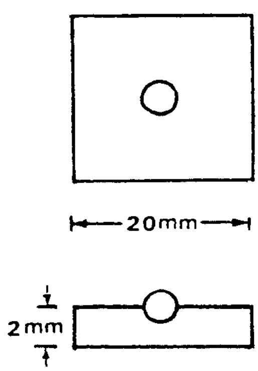
This specimen have made basically for experiment.

2-2. Specimen

Used epoxy resin in this experiment is YD-128(Diglycidly ether bisphenol-A). As curing agent, DDM of aliphatic amine series is employed.

As couping agent one of Aminosilane [chemical name:N-N-(β-Aminoethyl-γ-aminopropyl trimetoxy-silane)] series[2] is employed.

Shape of specimen is shown in figure 2-3.



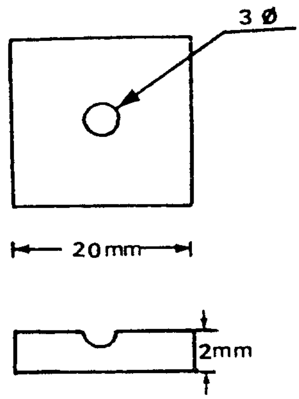
A-1: silane, 5[wt%] of filler content, spherical electrode.

A-2: non-silane, 5[wt%] of filler content, spherical electrode.

B-1: silane, 50[wt%] of filler content, spherical electrode.

B-2: non-silane, 50[wt%] of filler content spherical electrode.

(a)



C-1: silane, 50[wt%] of filler content, electrode by hand drill

C-2: non-silane, 50[wt%] of filler content, electrode by hand drill.

D-1: silane, 100[wt%] of filler content, electrode by hand drill.

D-2: non-silane, 100[wt%] of filler content, electrode by hand drill.

(b)

Fig. 2-3 Specimen shape

Figure 2-3(a) shows specimen inserted spherical electrode before curing of specimen.

Figure 2-3(b) shows specimen manufactured to specified thickness by hand drill of diameter 3[mm] after curing of specimen.

In table 2-1 curing condition and composite ratio of specimen are shown.

Manufacturing process of specimen is illustrated in figure 2-4.

Process of epoxy composites with non-silane an with silane is schematically illustrated in figure 2-5.

2-3. Experimental Method

High voltage experimental device on this

Table 2-1. Composite ratio of epoxy resin

SPECIMEN			A-1 / A-2	B-1 / B-2	C-1 / C-2	D-1 / D-2
COMPOSITE RATIO	MATRIX RESIN	YD-128	100			
	FILLER	SiO_2	5[wt%]	50[wt%]	50[wt%]	100[wt%]
	HARDENER	DDM	27[wt%]			
	ACCELERATOR	DMP-30	0.5[wt%]			
	DILUENT	DBP	0.5[wt%]			
	DILUTED SOLUTION	Toluene	100[wt%] / 0[wt%]			
	SILANE COUPLING AGENT	KBM-603	1.5[wt%] / 0[wt%]			
CURE CONDITION			First cure : 90[℃] X 2[hr] Post cure : 150[℃] X 4[hr]			

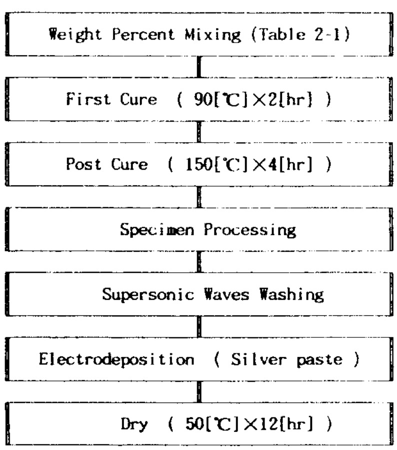


Fig. 2-4. Manufacturing process of specimen

experiment used AC/DC high voltage generater of Pulse Engineering Co., Ltd.

The speed of elevating voltage(i.e DC Voltage) is 1[kV/sec] until specimen will be reached to dielectric breadown point. Breakdown voltage V_{BD} devided by distance

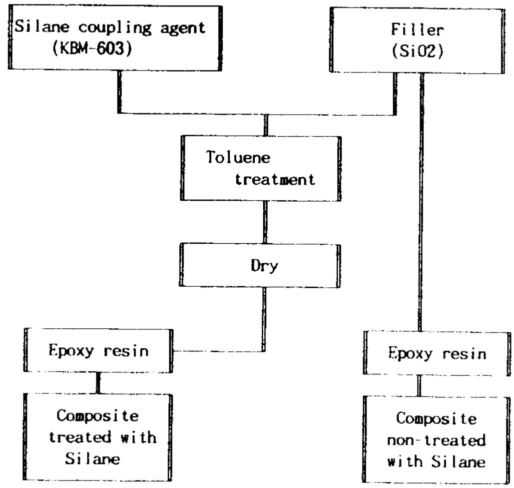


Fig. 2-5. Process of epoxy composites with non-silane and with silane

between electrode D is dielectric breakdown volatage, E_{BD}.

Figure. 2-6 is experimental device.

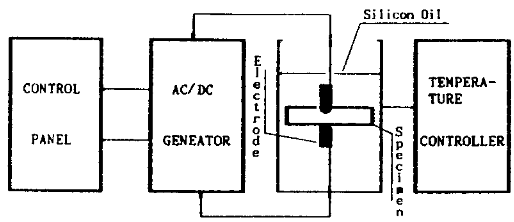


Fig. 2-6. Experimental device

3. RESULTS AND DESCUSSION

3-1. Dielectric Breakdown Strength of Specimen Inserted Spherical Electrode.

Figure 2-7 is the result gained from DC dielectric breakdown experiment due to effect of interface treatment. In the normal temperature, dielectric breakdown strength of A-1 as compared with A-2 was 12.7%, dielectric breakdown strength of B-1 than B-2 was improved about 10.8%.

The reason is due to function of coupling agent like following.

In the figure 2-8 showing structural formula of silane coupling agent, H_2N operating into organic functional group become a reactive part with epoxy resin. By moisture in the air of moisture cling to inorganic material, OC_2H_5 is hydrolysis and then takes form SIOH like figure 2-9.

This SIOH is combined with inorganic silica and coupling strength is increased.(3)

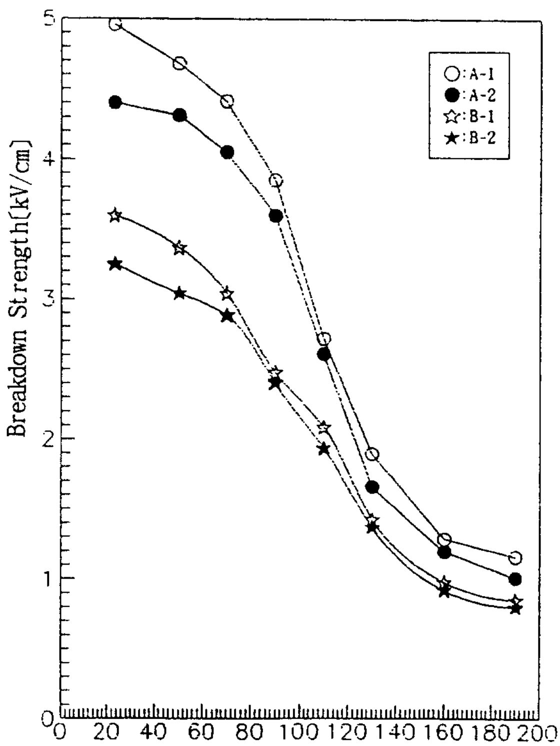


Fig. 2-7. Dielectric breakdown strength of A and B type(DC)

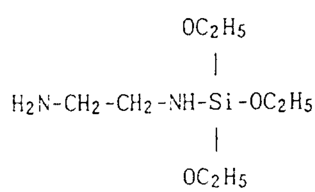


Fig. 2-8. Structural formula

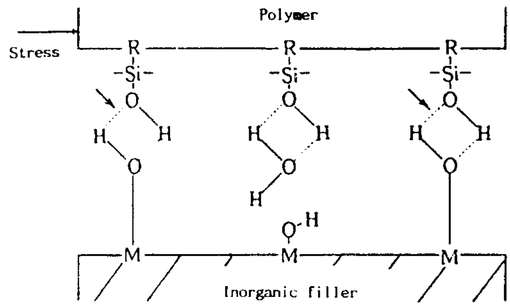


Fig. 2-9. Model of adhesive part

3-2. Dielectric Breakdown Strength of Specimen Manufactured By Hand Drill

Figure 2-10 shows DC dielectric breakdown strength of C and D type.

Dielectric breakdown strength of C-1 than C-2 by comparison is improved about 39.5%, dielectric breakdown strength of D-1 is improved about 24.3%.

As it is able to know in figure 2-7 and 2-10, dielectric breakdown strength of C and D type than that of A and B type was very lowered.

The reason is as follow.

When the specimen is manufactured to specified thickness, deterioration and fine crack of material by occured heat is thought to cause of dielectric breakdown strength's decrease.(4)

From this cause, It is able to suppose that mechanical deterioration was applied to specimen.

As the coupling agent was treated on same condition, it is able to know improvement ratio of Dielectric Breakdown Strength of mechanical deteriorated specimen is larger than that of non-damaged specimen(i.e specimen inserted spherical electrode)

Therefore, As the KBM-603 is treated to epoxy compound material, It is sure that good result can be gained when the electrical stress exists.

Further, it is supposed that even better result can be obtained as the mechanical stress exisits.

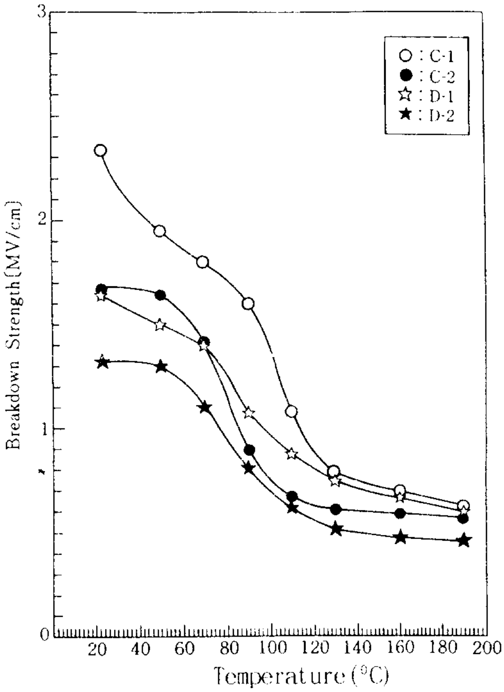


Fig. 2-10

4. CONCLUSION

Conclusion obtained in this investigation experimenting dielectric breakdown property due to interface treatment effect through treatment or non-treatment of silane coupling agent, and dielectric breakdown property due to variation of specimen's shape are as follow.

(1) As the DC voltage was applied, in the specimen inserted spherical electrode and of 5[wt%] of filler content, dielectric breakdown strength of specimen treated with silane coupling agent than that of non-treated specimen was improved about 12.7% in the normal temperature.

Also, in the specimen inserted spherical electrode and of 50[wt%] of filler content, dielectric breakdown strength of specimen treated with silane coupling agent than that of non-treated specimen was improved about 10.8% in the normal temperature.

(2) As the DC voltage was applied, in the specimen manufactured by hand drill and of 50[wt%] of filler content, dielectric breakdown strength of specimen treated with silane coupling agent than that of non-treated specimen was improved about 39.5% in the normal temperature.

Besides, in the specimen manufactured by hand drill and of 100[wt%] of filler content, dielectric breakdown strength of specimen treated with silane coupling agent than that of non-treated specimen was improved about 24.3% in the normal temperature.

As the silane coupling agent(KBM-603) is treated to Epoxy/SiO_2 compound material, it is anticipated that better toughness will be gained in the mechanical stress than the electrical stress.

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(1992년 6월 4일 접수)

김명호

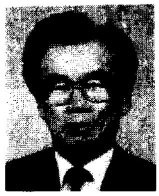
1963년 5월 11일생. 1989년 강원대 공대 전기공학과 졸업. 1991년 광운대 대학원 전기공학과 졸업(석사). 1992년 현재 광운대 대학원 전기공학과 박사과정. 경원전문대 건축설비과 전임강사.

김경환

1960년 11월 25일생. 1982년 한양대 전기공학과 졸업. 1990년 2월 광운대 대학원 전기공학과 졸업(공박). 1992년 현재 경원대 전기공학과 전임강사.

손인환

1968년 1월 13일생. 1991년 광운대 전기공학과 졸업. 1992년 현재 광운대 대학원 전기공학과 재학중



김재환

1934년 9월 10일생. 1958년 서울대 공대 전기공학과 졸업. 1975년 홍익대대학원 전기공학과 졸업(석사) 1983년 동 대학원 전기공학과 졸업(공박). 1959~73년 한국전력(주) 근무. 1964년 불란서 전력공사(EDF) 기술훈련. 1973~75년 홍각공업전문대 전기과 전임강사. 1990~92년 2월 광운대 공대학장. 1992년 현재 광운대 공대 전기공학과 교수.

박창옥

1953년 1월 24일생. 1984년 2월 광운대 전기공학과 졸업. 1986년 2월 광운대 대학원 전기공학과 석사. 1991년 8월 동 대학원 공학박사 학위 취득. 1992년 10월 현재 상지전문대학 전기과 교수.

박재준

1962년 5월 23일생. 1985년 광운대 전기공학과 졸업. 1987년 과운대 대학원 전기공학과(석사). 1987년 동 대학교 대학원 박사과정 1992년 동 대학교 대학원 박사과정 수료.