Development of Environmentally Friendly Electrical Insulation Tape Composed of a PE/EPDM Blend

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ABSTRACT: A PE/EPDM environment friendly blend was processed via a critical method to an elastic film backing imitating conventional PVC electrical insulation tape. The film backing was surface treated, coated with a pressure sensitive adhesive, dried, and unwound in sequence to become an electrical insulation tape for evaluation. The evaluation procedure was according to authoritative electrical insulation tape standard UL-510. The general physical properties and the unique characteristics of samples, composed of different materials, were tested. PE/EPDM was qualified to meet most of the requirements for UL-510 except exposure to heat. Among other characteristics, exposure to cold test, breakdown voltage, and flame resistance of PE/EPDM were significant. Therefore, an environment friendly PE/EPDM electrical insulation tape is well suited to low temperature and room temperature environments.

KEY WORDS: PE/EPDM blend, electrical insulation tape, UL-510 standard.

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INTRODUCTION

ELECTRICAL INSULATION TAPE is commonly made with polyvinyl chloride (PVC) film backing due to its low cost, easy fabrication, and good physical properties. The quantity of electrical insulation tape produced and its uses are enormous. In the last decade, however, environment friendly, or eco-materials, have been extensively developed to protect the environment. The European Union has legislated that new electrical and electronic equipment put on the market should not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB), or polybrominated diphenyl ethers (PBDE) from 1 July 2006 [1]. Waste from Electrical and Electronic Equipment (WEEE) Directive even proposes to ban halogenated flame retardants after 2008. Taiwan tape industry will face a serious challenge due to these legislations because Taiwan is one of the top PVC electrical insulation tape exporting countries.

The electrical insulation tape was invented in 1975 [2]. The tape can be wound upon itself in a roll form and thereafter easily dispensed without the use of a barrier such as a liner. Film backing materials of electrical insulation tape have already been developed to replace PVC, but it is an EVA/EPDM blend cross-linked for reinforcement to emulate the elastomeric characteristics of PVC film backing [3,4]. This, however, is disadvantageous to recycling and reuse. An environment friendly material is urgently needed to replace PVC film backing in electrical insulation tape. This study, intends to develop an eco-material that is completely evaluated as film backing electrical insulation tape.

The evaluation procedure is in accordance with UL-510 electrical insulation tape standard [5] that is recognized by the tape industry world over. The film backings and insulation tapes of different materials are tested, and Reference [3] shows the stress–strain curves. The analysis focuses solely on the curve depicting the stretching of the tape, and the physical properties (for example, tensile strength) during the recovery of the tape is not suggested. However, in our evaluation, by analyzing the variation of the curve depicting both the stretching and the recovery of the tape, the differences between non-PVC film backing and PVC film backing are significant. An electrical insulation tape of eco-materials as competent as PVC can be produced. A new method of manufacturing has been developed and it has been proved that eco-material can be used in making the environment friendly electrical insulation tape.

EXPERIMENTAL

Film and Tape Preparation

The method of preparing an electrical insulation tape film backing is described as follows. First, a mixture of polyethylene and EPDM rubber, and optional additives was prepared. The mixture was mixed using an extruder. After mixing, the mixture may be made into pellets through a twin-screw extruder at about 160–240°C for the convenience of mechanical operation. Next, the mixture or pellets were melted and formed into a film at 140–180°C. The film may be formed via a blown film molding process. The film thickness was about 0.10–0.15 mm.

Next, the film was drawn at a stretch ratio of 1 : 3 in the longitudinal or machine direction (MD) and at a stretch ratio of 1 : 3 in the transverse or crosswise direction (CD). This is a critical and novel step of the preparing method of PE/EPDM film [6]. In this step, the electrical insulation tape film backing shows physical properties similar to those of PVC (Formosa Plastics S-70 grade) film backings.

Finally, the film obtained was subjected to a surface treatment. The surface treatment can improve the adhesion strength of the film surface to the adhesive. The method of surface treatment was corona treatment with 1000–5000 V/cm^2. The film backing subjected to a surface treatment was uniformly coated with a layer of polymeric pressure sensitive adhesive, such as acrylic adhesive or rubber adhesive, with a thickness of 0.02 mm, forming an electrical insulation tape for evaluation (see Figure 1).

Testing Equipment and Procedures

All mechanical tests were measured at 23°C and 50% relative humidity. The tensile strength and elongation at break were monitored with an Instron 4467 universal testing machine using a crosshead speed of 200 mm/min. The deformation set was determined on the test specimen after 10 min of conditioning, which was relieved from the stress–strain test using a stretch-recovery speed of 200 mm/min with a maximum elongation of 100%.

The flame test was contacted by keeping a burner flame (125 mm outer cone and 38 mm inner cone) vertically under the test specimen so that the tip of the blue inner cone touched the center of the specimen. The flame was allowed to remain in contact with the specimen for 15 s. After 15 s, the burner was turned off and the cease time recorded for each test.

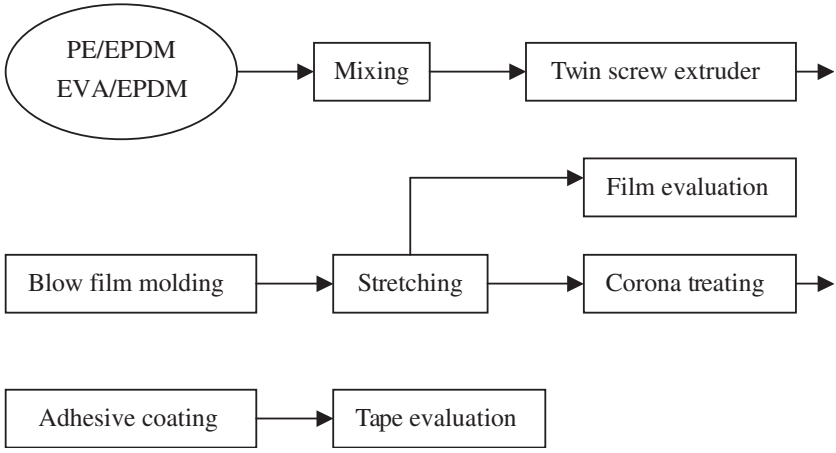

FIGURE 1. Method of preparation.

The breakdown voltage was tested with a Hipotronics 750-2/D149 testing machine. Heat shrinkage was determined on the specimen (100 mm in length and 100 mm in width) after a 100°C heat conditioning for 1 h. The heated specimen was measured to compare heat shrinkage. Heat shrinkage was calculated as shown in the equation below.

$$\text{Heat shrinkage } \% = \frac{100\,\text{mm} - \text{measure data (mm)}}{100\,\text{mm}} \times 100\%$$

Exposure to heat test, exposure to cold test, deformation test, and adhesive strength test of electrical insulation tape required by UL-510 Standard were employed in conducting the evaluation.

RESULTS AND DISCUSSION

The tensile strength, elongation at break, breakdown voltage, and deformation set of a conventional PVC electrical insulation tape film backing, the unmodified PE film, PE/EPDM 1/1 (a composition comprising 50 parts by weight of PE and 50 parts by weight of EPDM), and EVA/EPDM 3/1 (a composition comprising 75 parts by weight of EVA and 25 parts by weight of EPDM) films obtained from the method described in Figure 1 were tested, respectively, according to UL-510 test standard. The results are given in Table 1.

Table 1. Film evaluation.

	Tensile strength (kgf/mm^2)	Elongation at break (%)	Deformation set (%)*	Heat shrinkage (%)**	
UL-510 qualified standard	PVC > 1.41, PE > 1.05	PVC > 100, PE > 60		CD	MD
PVC	2.30	270	11–14	0.84	3.44
PE	1.50	460	27–32	2.35	4.57
PE/EPDM 1/1	1.40	590	14–18	1.20	4.91
EVA/EPDM 3/1	1.80	370	10–11	−8.45	58.48

PVC: Formosa Plastics S70, PE: Asia Polymer C7100, EPDM: DuPont Nordel 1070, EVA: Dupont Elavax 470.
*Data obtained from test specimen 10 min conditioning after relieving from stress–strain test.
**100°C × 1 h, CD: crosswise direction, MD: machine direction.

Unmodified PE film had poor physical properties and the deformation set was 27–32%. The deformation set 11–14% of PVC was ideal for the film backing of electrical insulation tape. Several layers of electrical insulation tape wrapped two connected conductive wires. The optimum deformation set made the layers wrap closely to keep out moisture and air. High deformation set of PE film caused the layers to wrap loosely. On the contrary, the low deformation set of the rubber film caused the layers and the adhesive to separate. The PE/EPDM 1/1 film possessed improved stress–strain curve in Figure 2. The films were tested with a stretching speed of 200 mm/min. The tensile strength was continuously measured during the recovery of the film backing from the 100% displacement. The stress–strain curve was measured as stretching PE/EPDM 1/1 film similar to that of the PVC film backing without any yield point. The yield point (a transition point at which the tensile strength weakened noticeably) and higher deformation set is often observed in unmodified PE films. PE/EPDM 1/1 film indicates the same elastic characteristics that are essential for insulation tape as those of the PVC film backing. The EVA/EPDM 3/1 film had the same physical properties as PE/EPDM 1/1 film, but the heat shrinkage of the EVA/EPDM 3/1 film was too high to be acceptable in the manufacturing tape. Owing to heat drying solvent during adhesive coating process, high heat shrinkage of EVA/EPDM 3/1 film caused winding roll defects.

PE/EPDM 1/1 tape was prepared according to the method in Figure 1. A conventional PVC insulation tape and a PE/EPDM 1/1 tape were tested respectively according to UL-510 test standard. The result is as shown in Tables 2 and 3. The PE/EPDM 1/1 tape film backing containing the flame retardant had the qualified flame test result. On the contrary, the conventional PVC insulation tape had the unqualified

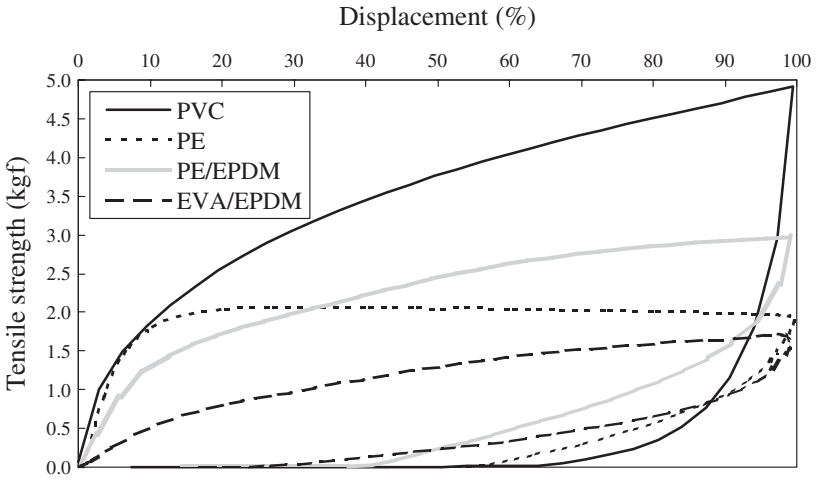

FIGURE 2. Stress–strain curves.

Table 2. Tape evaluation 1.

	Tensile strength (kgf/mm^2)	Elongation at break (%)	Breakdown voltage (KV/mm)	Flame test
UL-510 qualified standard	PVC > 1.41, PE > 1.05	PVC > 100, PE > 60	>39.4	Flame ceased within 15 s
PVC	2.2	210	79.0	Unqualified**
PE/EPDM 1/1*	1.2	560	137.5	Qualified

*PE/EPDM 1/1 100 phr + Constab flame retardant 20 phr.
**Flame never ceased.

Table 3. Tape evaluation 2.

	Exposure to heat test (113°C × 168 h)	Exposure to cold test (−10°C × 2 h)	Deformation test (100°C × 1 h) (%)	Adhesive strength peel (180°) (gf/mm)
UL-510 qualified standard	No cracking No corrosion	No cracking No corrosion	PVC<65 PE<40	>18
PVC	Qualified	Qualified	39.3	35.2
PE/EPDM 1/1*	Unqualified**	Qualified	23.6	26.0

*PE/EPDM 1/1 100 phr + Constab flame retardant 20 phr.
**Tape cracking.

flame test result. The exposure of the PE/EPDM 1/1 tape backing to heat test was unqualified and it had a cracked appearance after heating. But the other physical properties such as the exposure to cold test and the deformation test of PE/EPDM 1/1 tape were good, especially the breakdown voltage was much higher than 39.4 KV/mm, the qualified data. The thin film backing with high breakdown voltage had the same insulating quality as the thick film backing with low breakdown voltage. Therefore, PE/EPDM 1/1 tape had the advantage of material saving. All the tapes had an adhesive strength of more than 18 gf/mm, the data qualified, after coating with an acrylic pressure-sensitive adhesive.

High heat shrinkage of EVA/EPDM 3/1 film caused a manufacturing problem, unless reinforced by crosslinking agent and was difficult to recycle and reuse. The low cost of PE and elasticity of EPDM were comprised in film backing for electrical insulation tape. PE/EPDM 1/1 removed the yield point being peculiar to conventional PE that is not suitable for electrical insulation tape (see Figure 2). A back film with the yield point is unable to prevent electrical wire from moisture because the wrapping layers of tape will become loose in a short time. PE/EPDM combined flame retardant succeeded in the flame test while the conventional PVC electrical insulation tape failed. The addition of flame retardant is dependent on the requirement. PE/EPDM electrical insulation tape is well suited to low temperature and room temperature environment.

CONCLUSIONS

An electrical insulation tape film backing from PE/EPDM eco-material with improved properties can thus be achieved. PE/EPDM 1/1 film has proven to be significant in the preparation of an electrical insulation tape. The deformation set 23.6% of PE/EPDM 1/1 tape surpasses deformation set 39.3% of conventional PVC tape. Moreover, the breakdown voltage 137.5 KV/mm of PE/EPDM 1/1 tape is better than the breakdown voltage 79.0 KV/mm of conventional PVC tape, and also PE/EPDM 1/1 tape saves material compared with PVC tape. Among the evaluation tests, PE/EPDM 1/1 tape is unqualified in exposure to heat test based on the UL-510 standard. From a practical point of view, the heat resistant property of PE/EPDM electrical insulation tape is not good enough as conventional PVC electrical insulation tape and this may limit the variety of its uses. Therefore, an improvement of the heat resistant property of PE/EPDM electrical insulation tape needs to be focused on.

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