Heat-resistant (UL90°C) Thin-Foamed Insulator for the Transmission Cable

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Further improvement in the transmission properties of the transmission cable in high-frequency region has become necessary. In addition, for the transmission cable, the improvements that the insulator should be thinner and the heat-resistant property should be progressed are also required strongly. To achieve good transmission properties, it is important to improve the performance of the insulator. Therefore, materials of low dielectric constant and low dielectric loss tangent are used, and the insulator is foamed. In order to get the finer cable, a thinner foamed insulator is required. But the problem with the thinner foamed insulator is that it is easily crushed. Consequently, we have developed the heat-resistant (UL90°C) thin foamed crush-proof insulator made by using a new material having good dielectric properties.

1. Introduction

As the transmission speed and capacity have increased in recent years, there is a need for further improvement in the transmission properties of the transmission cable as the operating frequency has shifted to a higher frequency region [1)~4)]. Moreover, it is required to be thinner and more heat resistant.

The developed thin foamed insulator is used in signal wires. Figure 1 is an example of the transmission cable. This cable has a pair of signal lines and a pair of power lines. On the other hand, to get the finer cable, adoption of thinner foamed insulator is required.

Usually, for insulator, polyethylene (PE) with a low εr and a low $\tan\delta$ is adopted, but the thinner foamed polyethylene insulator has the problem that it is easy to crush and the heat-resistant specification test (UL90°C test) also can not pass.

Consequently, we have developed the heat-resistant (UL90°C) thin foamed crush-proof insulator from a new material having better dielectric properties compared to PE.

2. Target

The conductor size of the transmission cable used between devices usually is between AWG24 to AWG28. Therefore, we established the target conductor size of the developed transmission cable to be AWG32. The other target is shown in Table 1.

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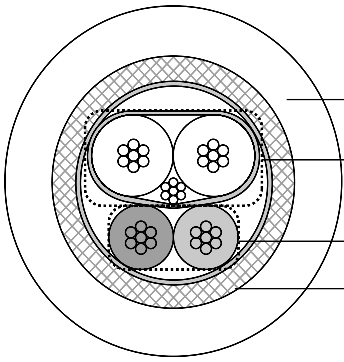

Fig. 1. Example of the transmission cable.

3. Development of the heat-resistant (UL90°C) thin foamed insulator

3.1 Development of the new material and evaluation of the characteristics

We already know from our present knowledge that a foamed material having sufficient molten breaking strength and superior dielectric characteristics is needed [3)~4)]. We evaluated molten breaking strength by using a capillary rheometer. The schema is shown in Fig. 2. Further, we evaluated the dielectric characteristics using sheet samples that were made by defoaming foamed materials at 3-18 GHz using the cavity resonator method [5)]. The instrument is shown in Fig. 3. In this way we selected and developed a new material that is heat-resistant and crush-proof, and has sufficient molten breaking strength and good dielectric properties. The main characteristics of newly developed material are shown in Table 2.

Panel 1. Abbreviations, Acronyms, and Terms.

PE—Polyethylene
TMA—Thermo-mechanical Analyzer
UL—Underwriters Laboratories, Inc.

Table 1. Demand characteristic.

Grouping		Article	Condition	Target
Conductor size				AWG32 (7/0.08mm)
Material	Dielectric characteristics	εr, tanδ	5.7GHz	under conventional PE
Insulator	Foamed cells properties	Average		under PE product
	Lateral pressure resistance property	Deformation	25°C, 500g	under PE product
	Heat resistance property	Deformation	121°C, 250g	under 50%
	The other properties (*1)	Heat aging	97.3°C, 150day	no cracks
		Heat shock	121°C, 1h	no cracks
		Cold bend	−10°C, 4h	no cracks

*1: UL 90 degrees C class (UL758)

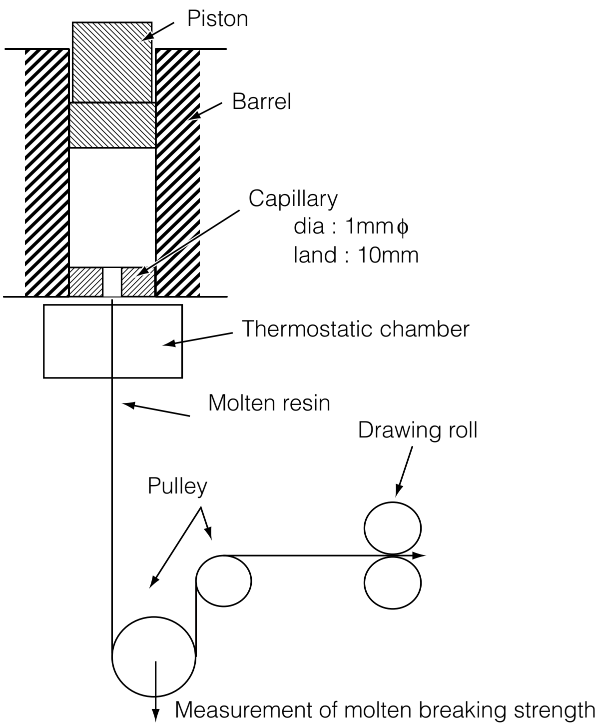

Fig. 2. Basic concept of a molten breaking strength.

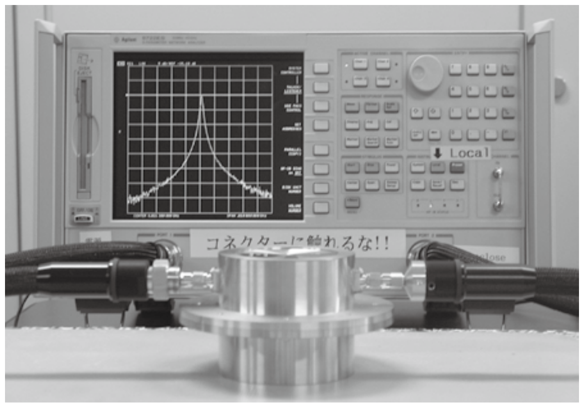

Fig. 3. System for the precise measurement of the dielectric properties using cavity resonator.

3.2 Fabrication of foamed insulation cable

In this trial fabrication, a single screw extruder was used to make the foamed insulation cable. The selected material was extruded on the conductor of AWG32 size. The characteristics of foamed insulation cable are shown in Table 3. Also, we fabricated comparative foamed insulation cable using the existing/conventional PE.

3.3 Evaluation of statistical analysis of foam

The aforesaid cable made by using the new material was compared with conventional PE products. Photographs of cross-sectional area of the insulator are shown in Fig. 4. To evaluate the foaming state of the insulator, a foam cell diameter analysis was performed. Results are shown in Fig. 5. In the new material, the average diameter of cells decreased from 29 μm of conventional PE products to 19 μm; the standard deviation of cell diameter also decreased from 8 μm to 6 μm. In this way, we could develop a foamed insulator with improved fineness and uniformity ; the foamed cells of the new material possessed high melten breaking strength.

3.4 Evaluation of heat resistance and lateral pressure resistance

We evaluated the heat resistance and lateral pressure resistance of the foamed insulator. This time, we estimated the properties with the thermo-mechanical analyzer (TMA). TMA is able to determine the deformation volume with a high degree of accuracy com-

Table 2. Results of the dielectric properties and the molten breaking strength.

Material					Conventional PE	New material
Transmission speed	Dielectric characteristics	$\tan\delta$ ($\times 10^{-4}$)	5.7GHz	–	3.0	2.0
		εr	5.7GHz	–	2.36	2.27
Thinner diameter	Melting characteristics	Molten breaking strength	200°C	mN	20	35
		Molten breaking drawing speed	200°C	m/min	110	110
Heat resistance		Melting point	–	°C	about 130°C	about 170°C

Table 3. Specification of the foamed insulator.

Conductor	AWG32 (7/0.08mm)
Insulation diameter	0.59mm
Foamed degrees	30%

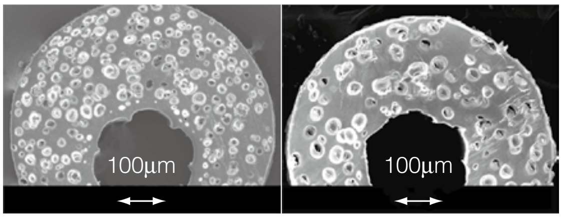

Fig. 4. The section of the foamed insulator.

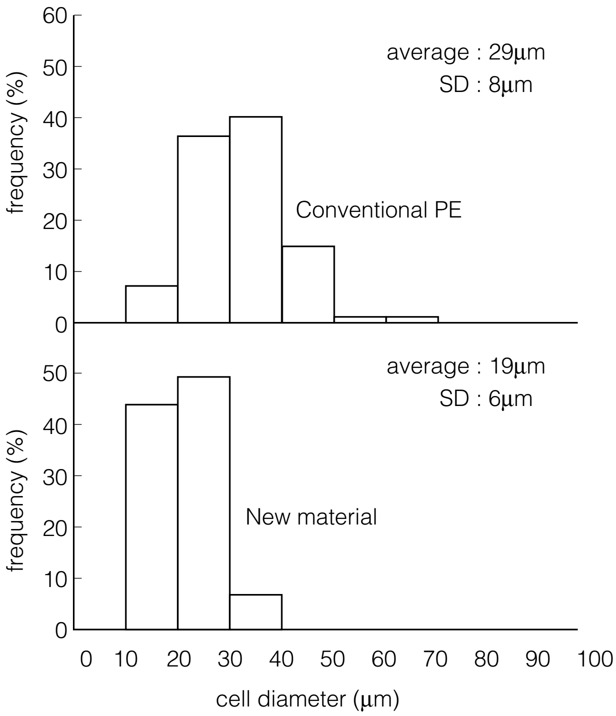

Fig. 5. Analysis of the foamed cell.

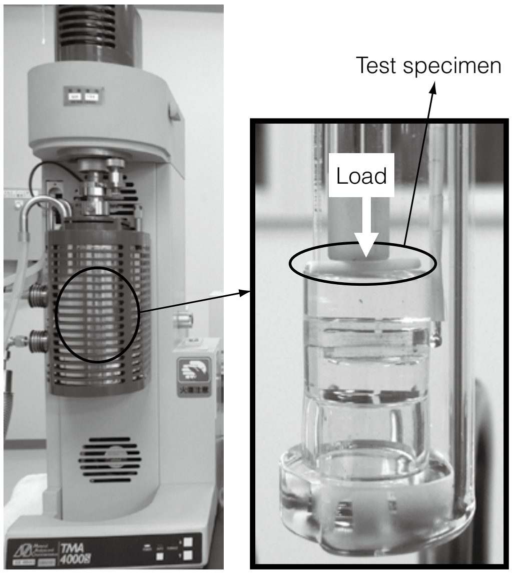

Fig. 6. Measurement system of TMA(thermo-mechanical analyzer).

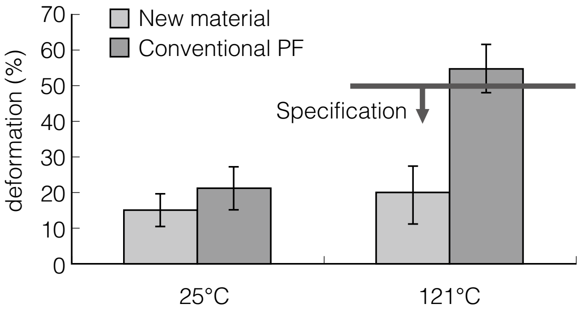

Fig. 7. Results of the crush-proof and heat- resistant properties.

pared to the conventional thermal deformation tester. The instrument is shown in Fig. 6. To evaluate the lateral pressure resistance property, we estimated the deformation of the foamed insulator at 25°C with the TMA. Further, to estimate the heat-resistant UL90°C, we measured the deformation of the foamed insulator at bog-standard 121°C. The results are shown in Fig. 7. As for the insulator with the new material, the lateral pressure resistance property was improved compared with the insulator with conventional PE and the target value was attained.

3.5 Evaluation of other properties (UL758 AWM)

The heat-resistant (UL90°C) class need to pass other specification tests. These are the heat shock test, the cold bend test, the flexibility after air-oven aging test, and so on. The results of these tests are shown in Table 4. The product with the new material was able to pass these tests.

4. Conclusion

We developed new material whose heat resistance,

Table 4. Results of demand characteristic for the heat-resistant (UL90 °C).

Grouping	Article	Condition	Target	Conventional PE	New material
Lateral pressure resistance property	Deformation	25°C, 500g	under PE product	21%	15%
Heat resistance property	Deformation	121°C, 250g	under 50%	55%	20%
The other properties (*1)	Heat aging	97.3°C, 150day	no cracks	OK	OK
	Heat shock	121°C, 1h	no cracks	OK	OK
	Cold bend	−10°C, 4h	no cracks	OK	OK

*1: UL 90 degrees C class (UL758)

lateral pressure resistance and dielectric property are superior to those of conventional materials, and produced the new foamed insulator applied to the cables of conductor size AWG32 with this material. The fineness and uniformity of the new insulator are excellent; also, the new insulator has the properties to be able to pass the heat-resistant (UL90°C) specification tests. After this work, we aim to evaluate the transmission cable having twinax structure [6] and develop a thinner insulator with high degree of foaming.

References

1) T. Abe, et al.: “InfiniBand™ Cable”, Fujikura Giho, No. 104, pp. 25-27, 2003
2) T. Watanabe, et al.: “Dielectric Properties of Frame Retardant Polyethylene” , Fujikura Giho, No. 109, pp. 51-54, 2005
3) R. Watanabe, et al.: “Highly-foamed Insulator for Coaxial Cable”, Fujikura Giho, No.110, pp.42-45, 2006
4) R. Watanabe, et al.: “Low-loss Coaxial Cable with Highly Foamed Insulator”, Fujikura Technical Review, No. 37, pp. 43-48, 2008
5) JIS R-1641: Measurement method for dielectric of fine ceramic plates at microwave frequency, 2007
6) T. Abe, et al.: “High-speed Cable”, Fujikura Giho, No. 102, pp. 38-41, 2002