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(71) Applicant : **THE FURUKAWA ELECTRIC CO., LTD.**
6-1, 2-chome, Marunouchi Chiyoda-ku
Tokyo (JP)

(72) Inventor : **Hattori, Masanori**
3-4, Tatsumidai-higashi
Ichihara-shi, Chiba (JP)
Inventor : **Yamamoto, Shoji**
1094-1 Otsubo
Ichihara-shi, Chiba (JP)
Inventor : **Oishi, Yoshiaki**
2385-42 Nakatacho, Wakaba-ku
Chiba-shi, Chiba (JP)

(74) Representative : **Calamita, Roberto**
Frank B. Dehn & Co., Imperial House, 15-19 Kingsway
London WC2B 6UZ (GB)

(54) **Foamed plastic insulated wires and coaxial cables using the same.**

(57) A foamed plastic insulated wire which comprises a conductor, a foamed polymer insulation layer formed on the periphery of the conductor, and at least one multifilament of a plastic material having no aromatic ring in its molecular structure, the multifilament being longitudinally extended or spirally wound on the periphery of the foamed polymer insulation layer so as to be fixed thereto. This wire, having a shorter time delay in signal propagation and enjoying higher density-normalized tensile strength, can be a useful electronic signal transmission line for a computer, and improves in bending strength, laser cutting properties, and cable assembly performance.

EP 0 540 322 A2

The present invention relates to foamed plastic insulated wires for electronic signal transmission, used in electronic apparatuses, and coaxial cables using the same, and more specifically, to foamed plastic insulated wires subject to a shorter time delay, improved in mechanical properties, and adapted for use as high-speed electronic signal transmission lines of computers, and coaxial cables using the same.

In general, electric wires used in electronic signal transmission lines of computer systems are manufactured by twisting a plurality of wires of a predetermined diameter together into a stranded conductor, and covering this conductor with a foamed polymer insulation layer in order to ensure electrical insulation and increase the velocity of propagation of the insulated conductor. In some cases, the conductor may be a solid wire used in place of the stranded conductor.

Also used are coaxial cables in which a drain wire, formed of e.g. an annealed copper wire plated with tin or silver, is paralleled to the periphery of the foamed polymer insulation layer of the foamed plastic insulated wire, and a laminated tape, made of an aluminum foil and a polyethylene terephthalate film, for example, is wound around the resulting structure, and is then shielded by means of an insulation material such as polyvinyl chloride.

In these wires, the foamed polymer insulation layer is formed by wrapping an expanded, amorphous-locked polytetrafluoroethylene tape (hereinafter referred to as E(xpanded)PTFE tape) around the conductor, as is disclosed in Published Examined Japanese Utility Model Application No. 2-34735, for example.

In a method disclosed in Published Unexamined Japanese Patent Application No. 1-173511 or U.S. Patent No. 4,711,811, moreover, a foaming agent is blended with a tetrafluoroethylene-perfluoroalkyl vinyl ether (PFA), tetrafluoroethylenehexafluoropropylene copolymer (FEP), ethylenetetrafluoroethylene copolymer (ETFE) or ethylenechlorotrifluoroethylene copolymer (ECTFE), which is capable of heat fusion, and the resulting material is extrusion-foamed on the peripheral surface of the conductor.

The latter method for forming the foamed polymer insulation layer has an advantage over the former method in being lower in cost. If the expansion ratio for the extrusion foaming is made higher in order to increase the propagation velocity, however, the mechanical strength of the resulting insulated layer is greatly lowered. As a result, the foamed polymer insulation layer may be crushed during the manufacture of the coaxial cable, so that the electrical properties of the cable are lowered. Even though the cable is manufactured with great care, moreover, rupture of the insulation layer and remarkable crushing may be caused when a jacket or shield layer is removed from the peripheral surface of the cable as the cable is attached to a connector.

Recently, therefore, there has been proposed a method in which a resin outer layer is prepared on the periphery of the foamed polymer insulation layer formed by the latter method, thereby improving the strength of the whole structure.

In this case, the resin outer layer is made of thermoplastic polyimide, polyether sulfone, polyether ether ketone, polyarylate, polycarbonate, or other resin such that the propagation speed and characteristic impedance cannot be influenced thereby, and has a dielectric constant of 4 or less, density normalized tensile strength (DNTS) of 500 kgf/g/cm or more, and thickness of 0.010 to 0.030 mm.

The DNTS is a value obtained by dividing the tensile strength of a sample of 20-cm length by the weight per unit length. The larger the DNTS value of the material, the higher the strength of the outer layer can be, despite its thin structure.

Usually, the DNTS value of the composite layer, formed of the foamed polymer insulation layer and the resin outer layer, is 300 kgf/g/cm or more, which is larger than the DNTS value of about 250 kgf/g/cm for the case of the layer using the EPTFE tape. Therefore, this composite layer is highly resistant to crushing or the like. As mentioned before, moreover, its formation entails lower cost. On the other hand, the resin outer layer mentioned above is lacking in flexibility, and the insulation layer buckles when the foamed plastic insulated wire is bent during its arrangement.

If the foamed polymer insulation layer and the resin outer are cut by means of a laser beam during cable assembly, moreover, the outer layer inevitably yellows or is carbonized. If a heated cutter is used for the cable assembly, furthermore, the operation requires so much care that its efficiency becomes low.

In Published Unexamined Japanese Utility Model Application No. 2-111016 is disclosed a foamed plastic insulated wire comprising a conductor, a foamed polymer insulation layer formed around the conductor, and a skin layer (resin outer layer) formed around the insulation layer, wherein the skin layer is reinforced by glass fibers which are located inward of the skin layer along the length thereof, or which are embedded in the skin layer. Glass fibers, however, have no extensibility and thus are extremely lacking in flexibility. Accordingly, the above foamed plastic insulated wire including glass fibers at an outer portion thereof has little flexing capability, and the shield layer itself cannot be cut with a laser beam when the wire is subjected to cable assembly operation.

An object of the present invention is to provide foamed plastic insulated wires to be used for signal transmission, which enjoy improved mechanical characteristics, e.g., high resistance to crushing or the like, and in which a foamed polymer insulation layer cannot be ruptured or crushed during cable assembly operation, despite the value of the time delay substantially equal to that of the conventional wires, and coaxial cables using the same.

Another object of the present invention is to provide foamed plastic insulated wires which are free from yellowing and carbonization even during cable assembly operation using a laser, and coaxial cables using the same.

In order to achieve the above object, according to the present invention, there is provided a foamed plastic insulated wire which comprises a conductor, a foamed polymer insulation layer formed on the periphery of the conductor, and at least one multifilament made of a plastic material having no aromatic ring in its molecular structure, the multifilament being longitudinally extended or spirally wound on the periphery of the foamed polymer insulation layer so as to be fixed thereto. Also provided is a coaxial cable in which a drain wire is extended longitudinally on the periphery of the foamed plastic insulated wire, a common conductor foil is wound around the drain wire and the foamed plastic insulated wire, and a shield layer is formed on the common conductor foil.

Fig. 1 is a sectional view showing an example of a foamed plastic insulated wire of the present invention; and

Fig. 2 is a sectional view showing an example of a coaxial cable according to the present invention.

In a foamed plastic insulated wire according to the present invention, a foamed polymer insulation layer, which covers the peripheral surface of a conductor, is composed of a foam, such as a polyolefin, e.g., a blend of high- and low-density polyethylene, a blend of high- and medium-density polyethylene, a blend of high-, medium-, and low-density polyethylene, a blend of an ethylene-propylene copolymer and high-density or high molecular polyethylene, or a blend of ethylene-methyl methacrylate and an ethylene-propylene copolymer; or a thermoplastic fluoropolymer resin, e.g., polychlorotrifluoroethylene, tetrafluoroethylene-hexafluoropropylene copolymer, or tetrafluoroethylene-perfluoroalkyl vinyl ether copolymer.

Among these materials, the blend of high- and low-density polyethylene containing at least 50% by weight of high-density polyethylene, the blend of 90 to 95% by weight of ethylene-methyl methacrylate, containing 2 to 10% by weight of methyl methacrylate, and 5 to 10% by weight of an ethylene-propylene copolymer, the blend of 80 to 90% by weight of an ethylene-propylene copolymer, containing 5 to 10% by weight of ethylene, and 10 to 20% by weight of high-density polyethylene, and a tetrafluoroethylene-perfluoroalkyl vinyl ether copolymer having a melt flow rate of 10 g/10 min. or more are suitably used as foams.

The respective expansion ratios of these foams should be 60% or more, preferably 70% or more.

In the case of a low-expansion foam having a expansion ratio lower than 60%, the velocity of propagation of the insulated conductor is so low that high-speed signal transmission cannot be enjoyed.

Preferably, the resin is foamed by extrusion in the method for forming the foamed plastic insulation layer on the periphery of the conductor. A conventional method may be used for this foam extrusion without any restrictions.

Plastic multifilaments (mentioned later) are fixed on the periphery of the foamed polymer insulation layer.

Preferred plastic multifilaments are those made of a plastic material having no aromatic ring in the molecular structure thereof, e.g., polyethylene multifilaments, polytetrafluoroethylene (PTFE) multifilaments, nylon multifilaments, etc. In consideration of the lower effective relative dielectric constant, the polyethylene and PTFE filaments are preferred in particular.

Multifilaments made of a plastic material having an aromatic ring in its molecular structure, e.g., diallyl phthalate, polyarylate, polyether imide, polyether ether ketone, etc. are not desirable because yellowing or carbonization occurs during laser cutting operation.

Preferably, the tensile strength of these multifilaments should be 10 kg/mm^2 or more. This is because multifilaments having a tensile strength lower than 10 kg/mm^2 cannot produce a satisfactory effect to reinforce the foamed polymer insulation layer.

More preferably, the multifilaments are each obtained by stranding four or more monofilaments of 5 to 20 deniers. If less than four monofilaments which are each thinner than 5 deniers are used for the multifilament, disconnection is liable to occur when the multifilament is laid on the periphery of the foamed polymer insulation layer, thus significantly lowering the working efficiency. If, on the other hand, monofilaments of more than 20 deniers are used, the overall outer diameter of the multifilament becomes 50 μ m or more. Thus, the roundness of the multifilament is almost lost and the pliability lowers.

Preferably, moreover, the multifilament thickness should range from 20 to 200 deniers.

Multifilaments thinner than 20 deniers have so low a tensile strength that they are liable to snap during wire arrangement, resulting in a substantial reduction in productivity. In the case of multifilaments thicker than 200 deniers, on the other hand, the outer diameter of the resulting foamed plastic insulated wire is too large to ensure necessary electrical properties.

Preferably, the thickness of the polyethylene multifilaments should range from 20 to 100 deniers, and that of the PTFE multifilaments from 40 to 200 deniers, for example.

The foamed plastic insulated wire according to the present invention is manufactured by longitudinally extending or spirally winding the plastic multifilaments around the foamed polymer insulation layer and then fixing the multifilaments to the periphery of the insulation layer.

The number of multifilaments used and the pitch of coiling (for the case of the spiral winding) are selected so that the mechanical strength of the composite layer, formed of the foamed polymer insulation layer and the multifilaments, ensures crushing strength and tensile strength high enough to prevent the insulation layer from being crushed or ruptured during the manufacture or assembly of coaxial cables.

Preferably, the above number and pitch are selected so that the DNTS value of the composite layer is 250 kgf/g/cm or more. Normally, it is necessary only that one to six multifilaments be fixed to the periphery of the foamed polymer insulation layer.

There are some methods for fixing the multifilaments to the periphery of the foamed polymer insulation layer. According to one method, the multifilaments arranged around the insulation layer are coated with, e.g., an ultraviolet-curing resin to a suitable thickness, and the resin is cured by ultraviolet irradiation. In another method, a polyolefin-based adhesive is applied and heated to put the foamed polymer insulation layer and the multifilaments together. In still another method, a low-dielectric material, such as polyethylene or polypropylene, is deposited to a thickness of 10 to 50 μ m on the peripheral surface of the insulation layer by extrusion coating.

Embodiment 1

As shown in Fig. 1, PFA, containing fluorocarbon as a foaming agent and 1% by weight of boron nitride as a nucleating agent and having a melt flow rate of 20 g/10 min., was extrusion-foamed on the periphery of a conductor 1 with a diameter of 0.2 mm, whereupon a foamed polymer insulation layer 2 was formed having an expansion ratio of 65% and thickness of 0.3 mm.

Then, six PTFE multifilaments (TOYOFLON 100-15-100 from Showa Kogyo Co., Ltd.; tensile strength: 18.9 kg/mm^2, thickness: 200 deniers) 3 were arranged around this foamed PFA layer in parallel relation, and the resulting structure was covered by means of a polypropylene layer (resin outer layer) 4 with a thickness of 30 to 50 μ m, whereupon a foamed plastic insulated wire was obtained.

Then, a drain wire 5 with a diameter of 0.2 mm was paralleled to the periphery of the resulting foamed plastic insulated wire, and at the same time, a laminated tape 6, made of an aluminum tape with a thickness of 9 μ m and a polyethylene terephthalate tape with a thickness of 4 μ m, respectively, was wound around the structure, as shown in Fig. 2. Thereafter, a sheath 7 of polyvinyl chloride with a thickness of 0.5 mm was put on the resulting structure to form a coaxial cable.

The time delay (ns/m) of this coaxial cable was measured by means of TDR (Time Domain Reflectometry), using an IE-0120 TDK System manufactured by Iwatsu Denshi K.K. The conductor 1 was drawn out of the foamed plastic insulated wire shown in Fig. 1, and the DNTS value of the composite layer, formed of the foamed PFA layer 2, PTFE multifilaments 3, and polypropylene layer 4, was measured.

The foamed plastic insulated wire was wound around a mandrel having a outer diameter twenty times as large as the outer diameter of the wire, and the composite layer was checked for buckling to examine its buckling strength. Further, a laser beam was applied to the wire to cut the composite layer completely, and the wire was then checked for yellowing or carbonization to examine its laser working properties.

Also, the polyvinyl chloride sheath and the shield tape were stripped off together from the coaxial cable, at a distance of 50 mm from its end, by means of a stripper produced by Carpenter MFG. Co., Inc., U.S.A., and the foamed PFA layer 2 was then checked for rupture to examine the cable assembly performance.

Table 1 collectively shows the results of these examinations.

Embodiment 2

A stranded conductor was formed by twisting seven wires with a diameter of 0.1 mm together, and polyolefin, which was composed mainly of ethylenemethyl methacrylate containing 2 to 10% by weight of polypropylene and which was loaded with a foaming agent, was extrusion-foamed on the periphery of the conductor, whereupon a foamed polymer insulation layer was formed having an expansion ratio of 70%, outer diameter of 0.90 to 0.93 mm, and thickness of 0.3 to 0.32 mm.

Then, three polyethylene multifilaments (TEKMILON(R) NA210 from Mitsui Petrochemical Industries, Ltd.; tensile strength: 150 kg/mm^2, thickness: 100 deniers) were uniformly arranged around the insulation layer in parallel relation, and were fixed by means of PPET 1303S (trademark; polyolefin-based adhesive from Toa

Gosei-Kagaku Kogyo Co., Ltd.).

A coaxial cable was manufactured using the resulting foamed plastic insulated wire in the same manner as in Embodiment 1. This coaxial cable was checked for the time delay, DNTS value of the composite layer, buckling strength, laser working properties, and cable assembly performance. Table 1 shows the results.

Embodiment 3

A foamed plastic insulated wire was manufactured in the same manner as in Embodiment 1, except that two PTFE multifilaments were arranged around the PFA layer. Using this wire, a coaxial cable was manufactured in the same manner as in Embodiment 1.

This coaxial cable was checked for the time delay, DNTS value of the composite layer, buckling strength, laser working properties, and cable assembly performance. Table 1 shows the results.

Embodiment 4

A foamed plastic insulated wire and a coaxial cable were manufactured in the same manner as in Embodiment 2, except that the foamed polymer insulation layer was made of a blend of 50% by weight of high-density polyethylene and 50% by weight of low-density polyethylene (melt flow rate: 0.35 g/10 min.).

This coaxial cable was checked for the time delay, DNTS value of the composite layer, buckling strength, laser working properties, and cable assembly performance. Table 1 shows the results.

Embodiment 5

A foamed plastic insulated wire and a coaxial cable were manufactured in the same manner as in Embodiment 2, except that the foamed polymer insulation layer was made of a blend of 15% by weight of high-density polyethylene and 85% by weight of an ethylene-propylene copolymer containing 7% by weight of ethylene (melt flow rate: 2.7 g/10 min.).

This coaxial cable was checked for the time delay, DNTS value of the composite layer, buckling strength, laser working properties, and cable assembly performance. Table 1 shows the results.

Comparative Example 1

A wire having only the foamed PFA layer of Embodiment 1 thereon was manufactured, and a coaxial cable was manufactured using this wire. This coaxial cable was checked for the time delay, DNTS value, buckling strength, laser working properties, and cable assembly performance. Table 1 shows the results.

Comparative Example 2

A resin outer layer with a thickness of 40 to 50 μm was formed on the periphery of the foamed PFA layer of the wire of Comparative Example 1 by extrusion-coating the layer with PFA (PFA 340J from Mitsui Du-Pont Fluorochemicals Co., Ltd.).

The resulting wire was checked for the time delay, DNTS value, buckling strength, laser working properties, and cable assembly performance. Table 1 shows the results.

Comparative Example 3

A wire was manufactured in the same manner as in Comparative Example 2, except that the resin used for the resin outer layer was polyarylate (U-8000 from Unitika Ltd.).

The resulting wire was checked for the time delay, DNTS value, buckling strength, laser working properties, and cable assembly performance. Table 1 shows the results.

Table 1

	Time Delay (ns/m)	DNTS Value (kg/g/cm)	Buckling None/Some	Yellowing or Carbonization None/Some	Rupture of Insulation Layer None/Some
Embodiment 1	3.82	300	None	None	None
Embodiment 2	3.85	3000	None	None	None
Embodiment 3	3.82	200	None	None	None
Embodiment 4	3.86	2700	None	None	None
Embodiment 5	3.85	3200	None	None	None
Comparative Example 1	3.75	60	None	None	Some
Comparative Example 2	3.83	90	None	None	Some
Comparative Example 3	3.83	297	Some	Some	None

Claims

1. A foamed plastic insulated wire comprising:
   a conductor;
   a foamed polymer insulation layer formed on the periphery of said conductor; and

at least one multifilament made of a plastic material having no aromatic ring in the molecular structure thereof, the multifilament being longitudinally extended or spirally wound on the periphery of the foamed polymer insulation layer so as to be fixed thereto.

2. A foamed plastic insulated wire as claimed in claim 1, wherein the density-normalized tensile strength of a composite layer formed of said foamed polymer insulation layer and said plastic multifilament fixed thereon is 250 kgf/g/cm or more.

3. A foamed plastic insulated wire a claimed in claim 1 or claim 2, wherein said foamed polymer insulation layer is formed by extrusion molding.

4. A foamed plastic insulated wire as claimed in any one of the preceding claims, wherein the expansion ratio of said foamed polymer insulation layer is 60% or more.

5. A foamed plastic insulated wire as claimed in any one of the preceding claims, wherein the expansion ratio of said foamed polymer insulation layer is 70% or more.

6. A foamed plastic insulated wire as claimed in any one of the preceding claims, wherein said foamed polymer insulation layer is made of a thermoplastic fluoropolymer resin.

7. A foamed plastic insulated wire as claimed in claim 6, wherein said thermoplastic fluoropolymer resin is a tetrafluoroethylene-perfluoroalkyl vinyl ether copolymer.

8. A foamed plastic insulated wire as claimed in any one of claims 1 to 5, wherein said foamed polymer insulation layer is made of a thermoplastic polyolefin resin.

9. A foamed plastic insulated wire as claimed in claim 8, wherein said thermoplastic polyolefin resin is a blend of high-density polyethylene and low-density polyethylene.

10. A foamed plastic insulated wire as claimed in claim 8, wherein said thermoplastic polyolefin resin is a blend of 15 to 30% by weight of high-density polyethylene and 70 to 85% by weight of an ethylenepropylene copolymer containing 5 to 10% by weight of ethylene.

11. A foamed plastic insulated wire as claimed in claim 8, wherein said thermoplastic polyolefin resin is a blend composed mainly of ethylene-methyl methacrylate and containing 2 to 10% by weight of polypropylene.

12. A foamed plastic insulated wire as claimed in any one of the preceding claims, wherein said multifilament is a multifilament made of expanding high molecular polyethylene.

13. A foamed plastic insulated wire as claimed in any one of the preceding claims, wherein the thickness of said multifilament is 100 deniers or more.

14. A foamed plastic insulated wire as claimed in any one of the preceding claims, wherein said multifilament is fixed to the foamed polymer insulation layer by means of a polyolefin-based adhesive.

15. A foamed plastic insulated wire as claimed in any one of claims 1 to 12, wherein said multifilament is a multifilament made of expanding polytetrafluoroethylene.

16. A foamed plastic insulated wire as claimed in any one of the preceding claims, wherein the thickness of said multifilament is 200 deniers or more, and six or more plastic multifilaments are fixed to the foamed polymer insulation layer.

17. A foamed plastic insulated wire as claimed in any one of the preceding claims, wherein said multifilament is fixed by means of a thermoplastic resin layer with a thickness of 50 μm or less.

18. A foamed plastic insulated wire as claimed in claim 1, wherein said foamed polymer insulation layer is a layer made of a tetrafluoroethylene-perfluoroalkyl vinyl ether having an expansion ratio of 60% or more, six or more expanded multifilaments of tetrafluoroethylene each having a thickness of 200 deniers or more are longitudinally extending on the periphery of the insulation layer, and said expanded multifilaments are fixed by means of an ethylene-propylene copolymer layer with a thickness of 10 to 60 μm.

19. A foamed plastic insulated wire as claimed in claim 1, wherein said foamed polymer insulation layer is a layer made of 90 to 98% by weight of ethylene-methyl methacrylate and 2 to 10% by weight of polypropylene and having an expansion ratio of 60% or more, one or more expanded multi-filaments of high molecular polyethylene each having a thickness of 100 deniers or more are longitudinally extending on the periphery of the insulation layer, and said expanded multifilaments are fixed by means of a polyolefin-based adhesive.

20. A coaxial cable comprising:

a foamed plastic insulated wire consisting of a conductor, a foamed polymer insulation layer formed on the periphery of the conductor, and at least one multifilament made of a plastic material having no aromatic ring in the molecular structure thereof, the multifilament being longitudinally extended or spirally wound on the periphery of the foamed polymer insulation layer so as to be fixed thereto;

a drain wire extending longitudinally on the periphery of the foamed plastic insulated wire;

a common conductor foil wound around the drain wire and the foamed plastic insulated wire; and

a shield layer covering said conductor foil.

21. A method of manufacturing a foamed plastic insulated wire, said method including the steps of forming a foamed polymer insulation layer on the periphery of a conductor, and longitudinally extending or spirally winding on the periphery of the foamed polymer insulation layer so as to fix thereto at least one multifilament made of a plastic material having no aromatic ring in the molecular structure thereof.

FIG. 1

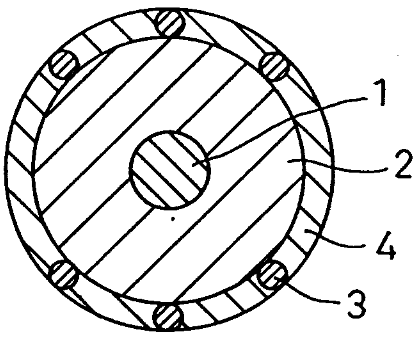

FIG. 2