New cable materials compatible with the environment

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Various characteristics of a metal cable are required depending on the application. In recent years, consideration to the environment is strongly demanded in design and manufacturing of products. In addition to accordance to RoHS or REACH, the environmental load reduction such as eliminating halogen, energy saving and recycling are also critical issues. This paper describes Fujikura's recent development of materials compatible to the environmental requirement.

1. Introduction

Metal cables are used in a wide range of fields including electric power, communications, electronic equipment, vehicles such as automobiles and robots. If we may compare the cables to organs in the human body, they play the roles of arteries and nerves. Metal cables comprise mainly conductor material that carries electricity and insulating material that blocks the leak of electricity. The conductor material requires high conductivity and insulating material a high level of insulating performance. As well as electrical properties, mechanical properties such as strength, elasticity and fatigue properties have been studied for years. Recently, in addition to those properties, a demand for the environmental properties has been added, and the materials should meet the compatibility with the environment in terms of energy saving by downsizing, reduction in weight, elimination of harmful substances and improved recyclability. This paper reports our activity in material development of environment-conscious conductor and insulating materials.

2. Environment-conscious cable material

2.1 Lightweight conductor material

Copper, aluminum, and alloys of these metals are typical examples of conductor materials, and high strength and high conductivity are essential requirements for the conductor. In addition to these requirements, the environmental requirement is imposed on the cable conductor, that is, the conductor should be light in weight and small in diameter for saving energy, and also should be recyclable and free of hazardous material. To achieve the above-mentioned characteristics, we have been developing novel alloys and composite conductors. As an example of composite conductor, a newly developed copper-clad aluminum wire shows lightweight, high conductivity, and excellent characteristics for high frequency. Another type of copper-clad steel wire has achieved very high strength and high fatigue resistance simultaneously. Those excellent characteristics are not achievable by an alloy-type conductor. The novel composite materials composed of plural metals provide the electrical wires and cables with new functions.

Wire harness is one of the major components which contribute to the weight of an automobile. Copper and copper alloys are normally used as conductor material of the wire harness. Recently, with an aim to reduce the weight of wire harness we have developed novel aluminum alloy which provides outstanding mechanical properties and high conductivity. To connect or to terminate the new aluminum alloy wires, we have also developed connecting technology which offers low electrical resistance and reliable termination with high mechanical strength. The weight of the wire harness has been reduced 20% compared with conventional one.

2.2 Halogen-free insulating material and carbon-neutral material

Polyethylene, polypropylene and rubber are typically used for insulation in an electrical cable. The insulating material should meet the electrical and mechanical requirements and durability in use environment of the cable. The electrical requirements are breakdown or withstanding voltage, dielectric loss and so on, and the mechanical requirements are elongation, strength and tear resistance. The insulating material also should keep thermal resistance, flame resistance and weather resistance for short-tem and long-term.

In recent years the environmental requirements other than the above-mentioned properties are imposed on the cable material, that is, it is essential to follow the regulations such as RoHS and REACH. Elimination of halogen and phosphorous is often required to an electrical cable for reduction of the environmental load of the material. We are developing insulating material with low-specific gravity which

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contributes to downsizing and lightweight of the cable. We have also developed another insulating material which is easily recycled. The following introduces two new insulating materials.

The first one is material for a high heat resistant cable used in Hybrid Electric Vehicles (HEVs) where the temperature is higher than a conventional car because an engine and an electric motor are aligned together in a narrow space, and the electric current or voltage increases. We have developed completely halogen-free and inexpensive insulating material, and applied it to a high heat-resistant and flexible cable which is easily routed or wired in a car.

The second new insulating material is polylactic acid which is featured by its biodegradability and carbon neutrality. Fujikura has shown that cables and wires using polylactic acid satisfy the electrical requirements, and improved the forming process like extrusion by adding plasticizers and additives. We are still improving the characteristics of the polylactic plastic such as durability at a high temperature.

3. Products

3.1 New aluminum alloy and its connecting technology

With the aim of reducing the vehicle weight as an energy-saving measure, we developed new aluminum alloy and its connecting technology. The target was to substitute a 0.75 mm^2 aluminum alloy cable for a conventional 0.5 mm^2 copper cable.

To develop new aluminum alloy that would satisfy strength, conductivity and elasticity requirements, we accelerated dispersion of Fe crystal and solution of Mg, Cu and the fifth element. The micro-dispersion of particles of Fe crystal shown in Fig. 1 and the additive of the fifth element have successfully realized the targeted properties shown in Table 1.

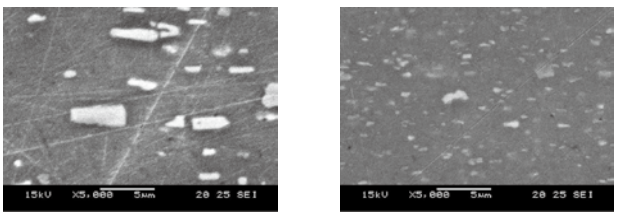
Connection or termination of metal wires and cables often cause difficult issues such as low mechanical strength, high contact resistance and corrosion caused by contact with different kinds of metal. To solve those problems, we have developed connecting technology which has optimized the crimping condition for the solder-less terminals and an original waterproofing process. As shown in Fig. 2, good contact resistance is maintained even in a long-term on-board test for approximately 2,500 hours.

The wire harness employing a combination of the newly developed aluminum alloy wire and copper-clad aluminum wire has achieved 20% reduction in weight compared with conventional harness of copper alone. We believe that the new product will contribute to energy saving not only in automobiles but also in other fields.

3.2 High heat-resistant cable

Close arrangement of an engine together with an electric motor in an HEV increases the temperature and which requires high heat-resistance of wires and cables in the engine room. Flexible cables are also required for easy wiring and routing of them in a limited space. Although heat-resistant fluoro-rubber is widely used in automotive applications because of flexibility, it is extremely costly and sometimes induces the environmental problem because it contains fluorine as halogen. To solve these problems, we focused on silicon rubber which is heat-resistant and free of halogen. As usual silicon rubber is degraded by chemicals such as gasoline and diesel oil [1)], we compounded additives in the silicone rubber. Fig.3 shows a result. Even after exposed to gasoline, the new silicone rubber keeps almost 100% of mechanical properties of the original ones.

Fig. 4 shows the softening properties at high temperatures. While a conventional material softens up around 80˚C, the developed material demonstrates a high degree of stability even at high temperatures over 150˚C with no degradation of strength. In addition, other properties of the rubber have passed ISO 6722 Class D automotive electric cable standard.



(a) Large Fe particles (b) Fine Fe particles

Fig. 1. Condition of dispersion of Fe particles.

Table 1. Properties of developed aluminum wire.

	Tensile strength (M Pa)	Elongation (%)	Conductivity (%IACS)
Target	≧140	≧10	≧58
Developed	145.9	13.0	59.4

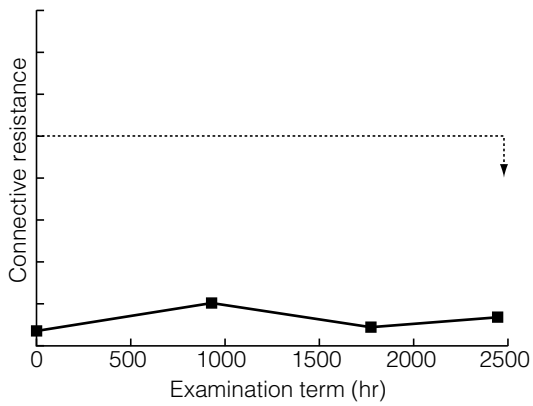


Fig. 2. Contact resistance during long-term on-board test.

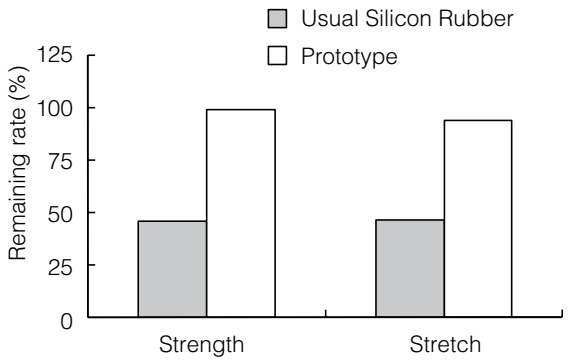


Fig. 3. Remaining rate of mechanical properties after gasoline in chemical test.

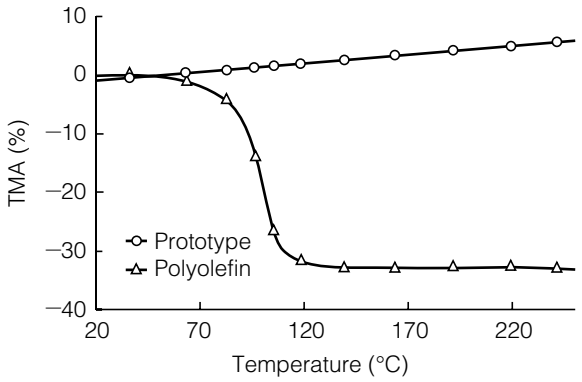


Fig. 4. Results in thermo mechanical analysis.

The new silicone rubber insulated cable , as shown in Fig. 5, is the first halogen-free inexpensive automobile cable which shows high heat-resistance, bending flexibility and outstanding resistance to chemicals. We will apply the cable to not only HEVs but also a variety of applications where thermal resistance is required.

3.3 Polylactic acid cable

Polylactic acid (PLA) derived from agricultural products is used as plastic because of its biodegradability, and it is formed by extrusion or molding to a variety of shapes such fiber, film, sheet and tray. In order to reduce CO_2 emissions based on "carbon-neutral" concept which saves fossil fuel resources, PLA is increasingly used in components of electronic equipment or automobiles.

The electrical properties of PLA resin have been reported in many papers, and it is believed that PLA is applicable to electric wires and cables as an insulator. PLA, however, is hard, fragile and lack in elasticity, so improvements were needed in flexibility and heat resistance to use it for the electric cables. The countermeasures were to add plasticizers and additives in PLA[2]. We tried to manufacture a prototype cable and put it in an environmental test. [3)4)]

emperature dependence of resistivity of an electrical cable insulated with polylactic acid. High electrical insulating performance even at 90°C was observed. A

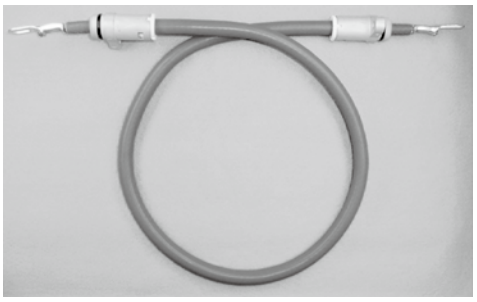


Fig. 5. New silicon rubber cable.

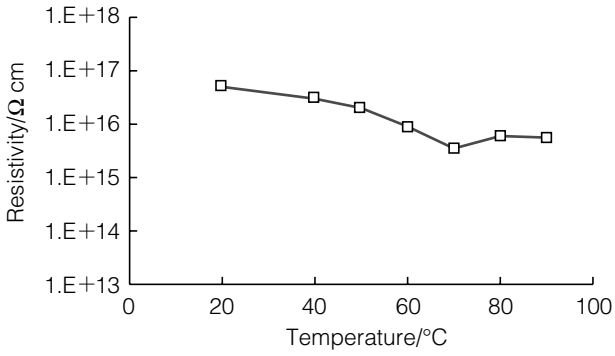


Fig. 6. Temperature dependence of insulating property.

deformation test was performed on the PLA cable at a temperature of 90°C for 2,800 hours. A 10% of deformation remained after the test. On the other hand, insufficient flexibility and low resistance to humidity still remain as issues to solve. When we focus on biodegradability of material and carbon-neutral concept, PLA is still attractive in spite of the above disadvantage. One of the approaches is to blend PLA with petroleum-derived resin instead of using PLA solely.

4. Summary

This paper has introduced environment-conscious cable materials Fujikura has studied and developed. We have been focusing not only on materials themselves, but also on material processing technology which decreases process temperature, reduces the number of process steps and eliminates use of harmful chemicals. We will continue the research and development of environment-conscious cables which contribute to the society and the environment.

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