

DESCRIPTION

SELF-BONDING MAGNET WIRE

5

TECHNICAL FIELD

The present invention relates to self-bonding magnet wire which can be applied to general applications of enameled wire used mainly in coils and motors of electrical equipment, of electronic equipment, of communication equipment, and of automotive electronic components, and also relates to a self-bonding insulating material for use in
10 such a wire.

BACKGROUND ART

Self-bonding magnet wire is insulated wire in which a method such as heating is used to soften a self-bonding layer to enable sections of the wire to be fused together, and
15 is used for purposes such as improving the strength of a coil or preparing a coil with a particularly complex shape. Furthermore, because such self-bonding magnet wire is coiled in a similar manner to conventional enameled wire, it is essential that cracks and the like do not occur in the coated film during the coiling process.

In order to meet these requirements, the bonding layer of the self-bonding magnet
20 wire must use a resin that not only exhibits fusibility, but also exhibits favorable flexibility, and in practice, thermoplastic polymers with a molecular weight of at least 20,000 or 30,000, such as polyvinyl butyral resins, polyamide resins, polyvinyl formal resins, and polyhydroxyether resins, are used.

However, if these types of thermoplastic polymers are used for equipment that
25 requires heat resistance, then a high melting point resin must be selected, and the

resulting treatment at high temperature can cause deterioration of the insulating layer or equipment. As a result, in those cases where self-bonding magnet wire is used in equipment that requires heat resistance, a self-bonding magnet wire having a coated film of thermosetting type is typically used. Specifically, as a typically used material, a
5 varnish in which a cross-linking agent such as a phenol resin, an amino resin or an isocyanate is added to a thermoplastic resin with excellent coating flexibility and with a molecular weight of at least 20,000 or 30,000 is subjected to enameling in a semi-cured state so as to form a thermosetting self-bonding layer.

However, because the active groups of thermoplastic resins do not exist as much
10 as improving heat resistance through cross-linking with a cross-linking agent, the cross-linking agent is usually added in excess, to enable the heat resistance to be improved through polymerization between cross-linking agent molecules. However, a semi-cured self-bonding layer generated in this manner exhibits poor stability, meaning the production conditions during enameling must be controlled within narrow ranges.

15 In addition, in the case of applications under special conditions, such as within an insulating oil or within a refrigerant, a further problem arises in that any excess cross-linking agent (in the case of a material with 3 or more functional groups, this also includes any unreacted residues left after cross-linking reaction) can react with any of the variety of different chemical substances contained within the insulating oil or refrigerant.

20 An object of the present invention is to provide a self-bonding magnet wire that exhibits improved chemical stability with no degradation in heat resistance or flexibility, as well as a self-bonding insulating material for use with such wire.

DISCLOSURE OF THE INVENTION

As a result of intensive research aimed at resolving the problems associated with the conventional technology described above, the inventors of the present invention discovered that by using a self-bonding magnet wire described below, the above problems could be eliminated, and they were hence able to complete the present invention.

1) The use of a polyhydroxyether resin with a molecular weight of at least 20,000, in order to improve the flowability during fusing, and to make fusing easier to occur.

2) The use of a cross-linking agent with two active groups within each molecule, in order to enable formation of a three dimensional structure with minimal excess residues, thus enabling the chemical stability to be improved with no degradation in heat resistance or flexibility.

3) The use of a polysulfone based resin in order to improve the strength and heat resistance of the bonding layer. In addition, where required, the use of an epoxy resin with an epoxy equivalent of 1,000 to 5,000.

A first aspect of the present invention for resolving the above problems (hereafter referred to as the first aspect of the present invention) provides a self-bonding magnet wire including: a conductor; and a thermosetting self-bonding insulating material coated and baked onto the conductor either directly or via an insulating layer, wherein the thermosetting self-bonding insulating material includes, as an effective component, a resin varnish consisting of: a base resin consisting of a polyhydroxyether resin with a molecular weight of at least 20,000 and a polysulfone based resin; and a cross-linking agent containing two functional groups within each molecule.

A second aspect of the present invention for resolving the above problems (hereafter referred to as the second aspect of the present invention) provides a self-bonding magnet wire including: a conductor; and a thermosetting self-bonding insulating

material coated and baked onto the conductor either directly or via an insulating layer, wherein the thermosetting self-bonding insulating material includes, as an effective component, a resin varnish consisting of: a base resin consisting of a polyhydroxyether resin with a molecular weight of at least 20,000 and a polysulfone based resin; an epoxy resin with an epoxy equivalent of 1,000 to 5,000; and a cross-linking agent containing two functional groups within each molecule.

Furthermore, in preferred aspects of the present invention, the polysulfone based resin is either a polysulfone resin or a resin with a partial polysulfone resin structure; the cross-linking agent containing two functional groups within each molecule is selected from a group consisting of bivalent stabilized isocyanates, urea resins, benzoguanamine resins, bivalent organic acids, and derivatives of bivalent organic acids; the mass ratio between the polyhydroxyether resin and the polysulfone based resin, calculated in terms of the respective non-volatile fractions, is within a range from 20/80 to 90/10, and the quantity of the cross-linking agent containing two functional groups within each molecule is within a range from 10 to 40 parts by mass (for the non-volatile fraction) per 100 parts by mass (for the non-volatile fraction) of the combination of the polyhydroxyether resin and the polysulfone based resin; and the mass ratio between the polyhydroxyether resin and the polysulfone based resin, calculated in terms of the respective non-volatile fractions, is within a range from 20/80 to 90/10, the quantity of the cross-linking agent containing two functional groups within each molecule is within a range from 10 to 40 parts by mass (for the non-volatile fraction) per 100 parts by mass (for the non-volatile fraction) of the combination of the polyhydroxyether resin and the polysulfone based resin, and the quantity of the epoxy resin is within a range from 5 to 40 parts by mass per 100 parts by mass (for the non-volatile fraction) of the combination of the polyhydroxyether resin and the polysulfone based resin.

A third aspect of the present invention for resolving the above problems (hereafter referred to as the third aspect of the present invention) provides a self-bonding insulating material for use in the aforementioned self-bonding magnet wire.

5 BEST MODE FOR CARRYING OUT THE INVENTION

As follows is a more detailed description of the present invention. The polyhydroxyether resin with a molecular weight of at least 20,000 that functions as one of the base resins of the first aspect of the present invention can use a phenoxy resin, a polyvinyl formal resin or a polyvinyl butyral resin. Specific examples of suitable
10 commercially available resins include Epikote 1256, 4250, 4275 and 1255HX30 (all manufactured by Japan Epoxy Resins Co., Ltd.), PKHC, PKHH and PKHJ (all manufactured by UCC), YP-50, YP-40ASM40, YP-50EK35 and YP-50CS25 (all manufactured by Tohto Kasei Co., Ltd.), Denka Butyral #2000-L, #3000-1, #3000-2, #3000-K, #4000-1, #4000-2, #5000-A and #6000-C (all manufactured by Denki Kagaku
15 Kogyo Co., Ltd.), and Vinylec K, L, H and E (all manufactured by Chisso Corporation).

The polysulfone based resin that functions as the other base resin of the first aspect of the present invention is either a polysulfone resin or a resin with a partial polysulfone resin structure. Specific examples of suitable commercially available resins include UDEL P-1700, RADEL A-200A and A-300A (all manufactured by Solvay
20 Advanced Polymers LLC, U.S.A.), and YPS-007-A30 and YPS-030-A30 (both manufactured by Tohto Kasei Co., Ltd.). Furthermore, resins generated through a polymerization reaction of bisphenol S, bisphenol A, and epichlorohydrin can also be used.

The mass ratio between the polyhydroxyether resin and the polysulfone based
25 resin, reported in terms of the respective non-volatile fractions, is preferably within a

range from 20/80 to 90/10, and even more preferably from 30/70 to 80/20. If this mass ratio exceeds 90/10, then the fusibility in a 100°C atmosphere tends to degrade, whereas if the ratio is less than 20/80, then a satisfactory level of fusibility cannot be achieved.

The cross-linking agent with two functional groups within each molecule that is
5 contained in the resin varnish of the first aspect of the present invention is a bivalent stabilized isocyanate, a urea resin, a benzoguanamine resin, a bivalent organic acid, or a derivative of a bivalent organic acid. Specific examples of suitable bivalent stabilized isocyanates include materials in which an isocyanate such as tetramethylene diisocyanate, hexamethylene diisocyanate, paraphenylene diisocyanate, 2,4-tolylene diisocyanate, 2,6-
10 tolylene diisocyanate, xylylene diisocyanate, diphenylmethane-4,4'-diisocyanate or diphenylether-4,4'-diisocyanate is masked with a compound containing a phenolic hydroxyl group or alcoholic hydroxyl group.

Specific examples of suitable commercially available resins include Millionate MS-50 and Coronate 2501, 2507, 2513 and 2515 (all manufactured by Nippon
15 Polyurethane Industry Co., Ltd.), and Duranate 17B60-PX, TPA-B80X, MF-B60X, MF-K60X and E402-B80T (all manufactured by Asahi Kasei Corporation).

Examples of suitable commercially available urea resins include UFR65 and UFR300 (both manufactured by Nihon Cytec Industries Inc.), and examples of suitable commercially available benzoguanamine resins include Cymel 1123, and Mycoat 102,
20 105, 106 and 1128 (all manufactured by Nihon Cytec Industries Inc.).

Examples of suitable bivalent organic acids include phthalic acid, isophthalic acid, terephthalic acid, oxalic acid, malonic acid, succinic acid, glutaric acid, adipic acid, maleic acid and fumaric acid. Examples of suitable derivatives of bivalent organic acids include the acid chlorides of the above acids.

The quantity of the cross-linking agent containing two functional groups within each molecule, per 100 parts by mass (calculated as the non-volatile fraction) of the combination of the polyhydroxyether resin and the polysulfone based resin, is preferably within a range from 10 to 40 parts by mass (calculated as the non-volatile fraction), and even more preferably from 15 to 30 parts by mass. If this quantity is less than 10 parts by mass, then the bonding strength at high temperatures is prone to weakening, whereas if the quantity exceeds 40 parts by mass, fusion is problematic.

As described above, by selecting appropriate materials from the chemicals described above, blending the required quantities, and then dissolving the mixture in an organic solvent such as cyclohexanone, the strength and heat resistance of the bonding layer can be improved, a three dimensional structure with minimal excess residues is formed, and a self-bonding insulating material with improved chemical stability can be obtained with no degradation in heat resistance or flexibility. A lubricant such as polyethylene, modified polyethylene or polytetrafluoroethylene may also be blended with the self-bonding insulating material.

Subsequently, a self-bonding magnet wire is produced by coating and baking the aforementioned self-bonding insulating material onto a conductor, either directly or via another insulating layer.

The second aspect of the present invention is a self-bonding magnet wire produced by applying and coating a self-bonding insulating material, produced by blending an additional epoxy resin with an epoxy equivalent of 1,000 to 5,000 onto the resin varnish according to the first aspect of the present invention, onto a conductor, either directly or via another insulating layer. The other chemical materials are identical with those described in the first aspect. By blending this epoxy resin, the strength and heat resistance of the bonding layer can be further improved. If the epoxy equivalent of

the epoxy resin is less than 1,000 then the flexibility degrades, whereas if the epoxy equivalent exceeds 5,000, no improvement in the strength and heat resistance of the bonding layer is observed.

The quantity of the epoxy resin (calculated as the non-volatile fraction), per 100 parts by mass (calculated as the non-volatile fraction) of the combination of the polyhydroxyether resin and the polysulfone based resin, is preferably within a range from 5 to 40 parts by mass, and even more preferably from 10 to 35 parts by mass. If the quantity is less than 5 parts by mass, then the bonding strength at high temperatures is prone to weakening, whereas if the quantity exceeds 40 parts by mass, fusion becomes problematic.

Specific examples of suitable commercially available epoxy resins with an epoxy equivalent within a range from 1,000 to 5,000 include Epikote 1007, 1009 and 1010 (all manufactured by Japan Epoxy Resins Co., Ltd.), and YD-017, 019, 020, 907, 909, 927 and 929 (all manufactured by Tohto Kasei Co., Ltd.).

The third aspect of the present invention is the self-bonding insulating material used in these types of self-bonding magnet wire, and is as described above.

EXAMPLES

As follows is a more detailed description of the present invention based on a series of examples.

In the following composition tables for the examples and comparative examples, labeled Table 1 and Table 2, the polyhydroxyether resin denoted *1 refers to PKHH (product name; manufactured by UCC), the polysulfone based resin denoted *2 refers to YPS-007 (product name; manufactured by Tohto Kasei Co., Ltd.), the epoxy resin denoted *3 refers to Epikote 1009 (product name; manufactured by Japan Epoxy Resins

Co., Ltd.), the bivalent isocyanate denoted *4 refers to Millionate MS-50 (product name; manufactured by Nippon Polyurethane Industry Co., Ltd.), the urea resin denoted *5 refers to UFR300 (product name; manufactured by Nihon Cytec Industries Inc.), the benzoguanamine resin denoted *6 refers to Mycoat 102 (product name; manufactured by Nihon Cytec Industries Inc.), the amino resin denoted *7 refers to Cymel 370 (product name; manufactured by Nihon Cytec Industries Inc.), the polyfunctional (trifunctional or higher) isocyanate denoted *8 refers to Coronate AP stable (product name; manufactured by Nippon Polyurethane Industry Co., Ltd.), and the phenol resin denoted *9 refers to Plyophen 5592 (product name; manufactured by Dainippon Ink and Chemicals, Inc.).

10 Example 1

90 parts by mass of PKHH as a polyhydroxyether resin with a molecular weight of at least 20,000, and 10 parts by mass (non-volatile fraction) of YPS-007 as a polysulfone based resin were added to, and dissolved in, 300 parts by mass of cyclohexanone that had been heated to 80°C. The thus obtained solution was cooled to room temperature, 20 parts by mass of Millionate MS-50 was added and dissolved as an isocyanate containing two functional groups within each molecule, and additional cyclohexanone was added to adjust the non-volatile fraction to 30% (by mass), thus completing preparation of a self-bonding insulating material.

Copper wire of diameter 1.0 mm was coated with a polyesterimide varnish (Neoheat 8600, manufactured by Totoku Toryo Co., Ltd) and enameled, yielding an insulated wire with an insulating layer of 30 μm , and this insulated wire was then coated with the aforementioned self-bonding insulating material to generate a layer of 15 μm , which was then baked to complete production of a self-bonding magnet wire.

Examples 2 to 4, and 8 to 10

Using the blend compositions shown in Table 1, self-bonding magnet wire samples were produced using the same method as the example 1.

Example 5

Using the blend composition shown in Table 1, production was conducted in the same manner as the example 1, but once the non-volatile fraction had been adjusted to 30% (by mass), 2 parts by mass of polytetrafluoroethylene (manufactured by Daikin Industries Ltd.) was added to, and uniformly dispersed within 120 parts by mass (calculated in terms of the non-volatile fraction) of the self-bonding insulating material in order to improve the lubrication, thus yielding a thermosetting self-bonding insulating material. The same method as the example 1 was then used to produce a self-bonding magnet wire.

Examples 6 and 7

With the exception of replacing the Millionate MS-50 from the example 1 with either the urea resin UFR300 (example 6) or the benzoguanamine resin Mycoat 102 (example 7), self-bonding magnet wire was produced in the same manner as the example 1, using the blend compositions shown in Table 1.

Example 11

50 parts by mass of PKHH, 50 parts by mass (calculated as the non-volatile fraction) of YPS-007, and 5 parts by mass of Epikote 1009 as an epoxy resin with an epoxy equivalent of 1,000 to 5,000 were added to, and dissolved in, 200 parts by mass of cyclohexanone that had been heated to 80°C. The thus obtained solution was cooled to room temperature, 10 parts by mass of Millionate MS-50 was added and dissolved, and additional cyclohexanone was added to adjust the non-volatile fraction to 30% (by mass), thus completing preparation of a self-bonding insulating material. The same method as the example 1 was then used to produce a self-bonding magnet wire.

Examples 12 to 15

Using the blend compositions shown in Table 1, self-bonding magnet wire samples were produced using the same method as the example 11.

Comparative Example 1

5 100 parts by mass of PKHH was added to, and dissolved in, 300 parts by mass of cyclohexanone that had been heated to 80°C. The thus obtained solution was cooled to room temperature, 40 parts by mass (calculated in terms of the non-volatile fraction) of Cymel 370 was added and dissolved as an amino resin, and additional cyclohexanone was added to adjust the non-volatile fraction to 30% (by mass), thus completing
10 preparation of a self-bonding insulating material. The same method as the example 1 was then used to produce a self-bonding magnet wire.

Comparative Example 3

With the exception of replacing the Cymel 370 from the comparative example 1 with Millionate MS-50, a self-bonding magnet wire was produced in the same manner as
15 the comparative example 1, using the blend composition shown in Table 2.

Comparative Example 4

With the exception of replacing the PKHH from the comparative example 3 with YPS-007, a self-bonding magnet wire was produced in the same manner as the comparative example 3.

20 Comparative Example 5

With the exception of replacing the 100 parts by mass of PKHH from the comparative example 3 with 80 parts by mass of PKHH and 20 parts by mass of Epikote 1009, a self-bonding magnet wire was produced in the same manner as the comparative example 3.

25 Comparative Example 2

With the exception of replacing the 100 parts by mass of PKHH from the comparative example 1 with 50 parts by mass of PKHH and 50 parts by mass of YPS-007 (calculated in terms of the non-volatile fraction), a self-bonding magnet wire was produced in the same manner as the comparative example 1.

5 Comparative Examples 6 to 8

With the exception of replacing the 40 parts by mass of Cymel 370 from the comparative example 2 with 20 parts by mass of Cymel 370 (comparative example 6), 20 parts by mass of a polyfunctional isocyanate resin Coronate AP stable (comparative example 7), or 20 parts by mass of a phenol resin Plyophen 5592 (comparative example 8), self-bonding magnet wire was produced in the same manner as the comparative example 2.

Table 1

	Example														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Polyhydroxyether resin ^{*1}	90	70	50	50	50	50	50	50	35	20	50	50	50	50	50
Polysulfone based resin ^{*2}	10	30	50	50	50	50	50	50	65	80	50	50	50	50	50
Epoxy resin ^{*3}											5	5	5	20	40
Bivalent isocyanate ^{*4}	20	35	10	20	20			40	20	20	10	20	40	20	20
Urea resin ^{*5}						20									
Benzoguanamine resin ^{*6}							20								
Polytetrafluoroethylene					2										
Flexibility	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Δ
Fusibility (room temperature) (100°C)	○	○	○	○	○	○	○	Δ	○	Δ	○	○	Δ	○	Δ
	Δ	○	Δ	○	○	○	○	Δ	○	Δ	Δ	○	Δ	○	Δ
Oil resistance (external appearance) (fusibility)	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Δ	○	Δ	○	○	○	○	Δ	○	Δ	Δ	○	Δ	○	Δ

Table 2

	Comparative example							
	1	2	3	4	5	6	7	8
Polyhydroxyether resin ^{*1}	100	50	100		80	50	50	50
Polysulfone based resin ^{*2}		50		100		50	50	50
Epoxy resin ^{*3}					20			
Bivalent isocyanate ^{*4}			20	20	20			
Urea resin ^{*5}								
Amino resin ^{*7}	40	40				20		
Polyfunctional isocyanate resin ^{*8}							20	
Phenol resin ^{*9}								20
Flexibility	O	O	O	×	O	O	O	O
Fusibility (room temperature) (100°C)	O	O	O	×	O	O	O	O
	Δ	—	×	—	×	O	O	O
Oil resistance (external appearance) (fusibility)	×	×	O	O	O	×	×	×
	Δ	—	×	—	×	O	O	O

(Test Examples)

5 The flexibility, dielectric breakdown voltage, fusibility, fusibility under high temperature, and oil resistance of each of the samples of self-bonding magnet wire produced in the above examples and comparative examples were tested and measured using the methods described below.

1) Flexibility

10 Tested in accordance with JIS C-3003.

2) Dielectric breakdown voltage

Tested in accordance with JIS C-3003

3) Fusibility

Tested in accordance with NEMA MW1000 3.57. The fusing conditions for the samples involved 2 hours at 160°C.

5 4) Fusibility under high temperature

Tested using the same method as the above fusibility tests, but with the measurement temperature set to 100°C

5) Oil resistance

Each sample was immersed in an insulating oil including Suniso 4GS (product name, manufactured by Japan Sun Oil Co., Ltd.) containing 2% (by mass) of added tricresyl phosphate (guaranteed reagent grade, manufactured by Wako Pure Chemical Industries Ltd.), the sample was then heated at 150°C for 500 hours, and the dielectric breakdown voltage and the fusibility were measured using the methods described above, thereby testing the oil resistance of the sample. Furthermore, the external appearance of the insulating oil was also inspected visually to check for any turbidity.

(Evaluation Standards)

- Fusibility (room temperature)

O: at least 100 N, Δ: at least 80 N but less than 100 N, ×: less than 80 N

- Fusibility (100°C)

20 O: at least 80 N, Δ: at least 60 N but less than 80 N, ×: less than 60 N

- Oil resistance (fusibility)

O: at least 80 N, Δ: at least 60 N but less than 80 N, ×: less than 60 N, —: unmeasurable

(Test Results)

CLAIMS

1. A self-bonding magnet wire comprising:

a conductor; and

5 a thermosetting self-bonding insulating material coated and baked onto the conductor either directly or via an insulating layer, wherein

the thermosetting self-bonding insulating material comprises, as an effective component, a resin varnish consisting of: a base resin consisting of a polyhydroxyether resin with a molecular weight of at least 20,000 and a polysulfone based resin; and a
10 cross-linking agent containing two functional groups within each molecule.

2. A self-bonding magnet wire comprising:

a conductor; and

a thermosetting self-bonding insulating material coated and baked onto the
15 conductor either directly or via an insulating layer, wherein

the thermosetting self-bonding insulating material comprises, as an effective component, a resin varnish consisting of: a base resin consisting of a polyhydroxyether resin with a molecular weight of at least 20,000 and a polysulfone based resin; an epoxy resin with an epoxy equivalent of 1,000 to 5,000; and a cross-linking agent containing
20 two functional groups within each molecule.

3. A self-bonding magnet wire according to either one of claim 1 and claim 2, wherein the polysulfone based resin is either a polysulfone resin, or a resin with a partial polysulfone resin structure.

4. A self-bonding magnet wire according to either one of claim 1 and claim 2, wherein the cross-linking agent containing two functional groups within each molecule is selected from a group consisting of bivalent stabilized isocyanates, urea resins, benzoguanamine resins, bivalent organic acids, and derivatives of bivalent organic acids.

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5. A self-bonding magnet wire according to either one of claim 1 and claim 2, wherein a mass ratio between the polyhydroxyether resin and the polysulfone based resin, calculated in terms of respective non-volatile fractions, is within a range from 20/80 to 90/10, and a quantity of the cross-linking agent containing two functional groups within each molecule is within a range from 10 to 40 parts by mass (calculated as a non-volatile fraction) per 100 parts by mass (calculated as a non-volatile fraction) of a combination of the polyhydroxyether resin and the polysulfone based resin.

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6. A self-bonding magnet wire according to claim 2, wherein a mass ratio between the polyhydroxyether resin and the polysulfone based resin, calculated in terms of respective non-volatile fractions, is within a range from 20/80 to 90/10, a quantity of the cross-linking agent containing two functional groups within each molecule is within a range from 10 to 40 parts by mass (calculated as a non-volatile fraction) per 100 parts by mass (calculated as a non-volatile fraction) of a combination of the polyhydroxyether resin and the polysulfone based resin, and a quantity of the epoxy resin is within a range from 5 to 40 parts by mass per 100 parts by mass (calculated as a non-volatile fraction) of a combination of the polyhydroxyether resin and the polysulfone based resin.

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7. A self-bonding insulating material for use in self-bonding magnet wire according to any one of claim 1 through claim 6.

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