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CONTACT MATERIALS FOR VACUUM SWITCHES

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ABSTRACT OF THE DISCLOSURE

Added to nickel substantially free from oxygen, nitrogen and hydrogen is bismuth or tellurium in an amount of 1 to 10% by weight to provide a contact material for use in vacuum switch excellent in anti-welding property without any increase in cutting through current. Also, in order to improve the anti-welding property of non-magnetic contact materials for use in vacuum switches, 0.05 to 5% by weight of bismuth or tellurium and 25 to 50% by weight of copper are added to nickel substantially free from oxygen, nitrogen and hydrogen. The starting material nickel is refined through its vacuum melt with carbon. As a result of such refining treatment the refined nickel and hence the contact material may include a small amount of carbon for example, 1 to 2.2% by weight of carbon for the magnetic contact material, and 0.2 to 1.0% by weight of carbon for non-magnetic contact material.

This invention relates to improvements in contact materials for use as electrical contacts associated with switching devices commonly known as a "vacuum switch" or a "vacuum type circuit interrupter" and operative to switch the associated contacts in a high vacuum to interrupt a flow of current.

Contact materials used in conjunction with any type of switches are necessary to have the ability to resist to welding or sticking whatever. Particularly, the contact materials suitable for use as electrical contacts for vacuum switches are required to be excellent in property of resisting to welding because such contacts are apt to be very welded on each other due to their surfaces remaining clean in the associated vacuum.

It is well known that electrical contacts excellent in property of resisting to welding can be generally made of metals, having high melting temperatures, such as tungsten and the like. In the vacuum switches, a phenomenon called as "chopping" may frequently take place. This phenomenon is described as being breaking of an electric arc established across the contacts upon separating them from each other and before a magnitude of alternating current flowing through the associated circuit reaches its zero point. Since high melting point metals such as tungsten and the like have generally the extremely low vapor pressures they have the high chopping current characteristics. Thus the use of electrical contacts made of these high melting point metals in conjunction with the vacuum switches is not desirable because a high transient voltage can be induced in the associated circuit.

Also the contact metals can be produced by the so-called powder metallurgical technique in which a mixture of high melting point metals in the form of a powder is compacted and sintered into an alloyed structure. The resulting contact metals, however, have been found unsuitable for use as electrical contacts associated with the vacuum switch. This is because the particles of the powdered metals have large amounts of gaseous elements

adsorbed on their surfaces and therefore the compacted and sintered alloys can not provide the electrical contacts including only the gaseous elements in sufficiently small amounts. It is essential that the contacts suitable for use in the vacuum switches be extremely low in contents of gaseous elements.

One type of the contact materials very low in contents of gaseous elements is described in copending U.S. application Ser. No. 406,874 entitled "Process of Refining Electric Contact Materials" filed on Oct. 27, 1964 by the same applicant et al. and assigned to the same assignee as the present application. According to the cited specification a metal selected from the group consisting of nickel, cobalt, iron, molybdenum, tungsten and alloys thereof is first melted in a vacuum melting furnace in a vacuum of 10^{-2} mm. Hg or less. Then dissolved into the resulting melt is at least 0.2% by weight of carbon and the melt is maintained in its melted state in such a vacuum for a period of time, for example, 30 minutes to remove oxygen originally included in the metal from the melt as carbon monoxide. It is to be noted that the melt should be prevented from contacting any refractory oxide. Nitrogen and hydrogen which might be included in the metal is promoted in their removal as carbon monoxide thus formed escapes from the melt. Then the melt is allowed to be cooled to room temperature to be solidified.

The contact materials thus produced have the low cutting through current characteristics such that, as compared with the conventional tungsten contacts having a chopping current of approximately 10 amperes nickel-carbon alloy contacts having a cutting through current of approximately 3 amperes or less.

Accordingly, it is an object of the invention to improve the anti-welding property of the contact materials disclosed in the above mentioned specification without any increase in cutting through current characteristics thereof.

According to one aspect of the invention there is provided an electrical contact material including from 1 to 10% by weight of at least one of bismuth and tellurium and the balance being nickel and incidental impurities.

Carbon may be included in an amount of from 1 to 2.2% based upon the weight of the contact material.

According to another aspect of the invention there is provided an electrical contact material including from 0.05 to 5% by weight of at least one of bismuth and tellurium, from 25 to 50% by weight of copper and the balance being nickel and incidental impurities.

The invention will become more readily apparent from the following detailed description.

The invention is based upon the discovery that bismuth and tellurium can increase the ability of contact materials to resist to welding or sticking.

As previously described, the contact material according to one aspect of the invention includes from 1 to 10% by weight of at least one of bismuth and tellurium and the balance being nickel and small amounts of incidental impurities. The contact material may preferably include from 1 to 10% by weight of either bismuth or tellurium, from 1 to 2.2% by weight of carbon and the balance being nickel and small amounts of incidental impurities.

Since the present contact materials are intended to be used as the electrical contacts disposed within the vacuum switches it is essential that the starting material should have been preliminarily refined such that they will include a gaseous element or elements in a very small amount or amounts. In this connection, it is to be noted that the element nickel having the negligible con-

tents of gaseous elements as the starting material can be readily utilized by refining it according to the refining process using carbon as previously outlined. On the other hand, as the elements, bismuth and tellurium in their solid phase are extremely low in contents of solid solutions with gaseous elements contained therein, slow solidification of the same from their molten state can readily cause the contents of gaseous elements negligible.

The resulting nickel-carbon alloy is melted in an atmosphere of an inert gas or a vacuum and bismuth or tellurium in an amount within the range as above specified is added to the melt. This addition of bismuth or tellurium reduces the solubility of carbon in the melt to precipitate and float the excess of carbon on the surface of the melt. After the removal of the precipitate, the melt is allowed to be cooled into a solid. The resulting alloy may include from 1 to 2.2% by weight of carbon.

It has been found that the addition of either bismuth or tellurium in amount of 1% by weight or more is effective for a decrease in welding force. The addition of either bismuth or tellurium in an amount exceeding 10% is not only ineffective for improvements in the anti-welding property but also it renders brazing of the contacts difficult.

As previously described, the contact materials according to another aspect of the invention include from 0.05 to 5% by weight of at least one of bismuth and tellurium, from 25% to 50% by weight of copper and the balance being nickel and small amounts of incidental impurities. The contact material may preferably include from 0.05 to 5% by weight of either bismuth or tellurium, from 25 to 50% by weight of copper, from 0.2 to 1.0% by weight of carbon and the balance being nickel and small amounts of incidental impurities. For the same reason as described in conjunction with bismuth and tellurium, addition of copper reduces the solubility of carbon in the melt. Therefore the last-mentioned type of the present alloys is less in content of carbon than the first-mentioned type thereof.

The last-mentioned type of the present contact alloys is non-magnetic and has the improved anti-welding property. It has been found that this type of contact alloys is superior to the first-mentioned type of contact alloys in that a less amount of bismuth or tellurium has been added to the alloy to improve effectively the anti-welding property. In addition it is characterized by the non-magnetic property.

Copper is added to the alloys for the purpose of rendering the latter non-magnetic at the operating temperatures. Bismuth and tellurium serve also to render nickel non-magnetic. Therefore copper may be partially replaced by bismuth or tellurium. The use of contacts made of non-magnetic materials makes it possible to drive magnetically an arc struck upon interrupting a flow of current thereby to facilitate interruption of a heavy current whereas the use of contacts made of magnetic materials will prevent an effective magnetic field from acting on such an arc.

It is considered desirable to use copper, silver or their base alloys as a material for contacts for use in magnetically driving an arc struck upon interrupting a flow of current. The element copper or silver is relatively low in boiling point but greatly disadvantageous in that the chopping current is high due to its good thermal conductivity. To avoid this disadvantage, there has been previously proposed the utilization of contact alloys including either copper or silver and a low melting point element in a relatively large amount such as a Cu-20% Bi alloy. The use of the contact alloys including a relatively large amount of a low boiling point element (which has simultaneously a low melting point) leads to the brazing or soldering operation or the evacuating operation performed with difficulty. On contrast, the present alloys have the low chopping current characteristics without any low boiling point element added thereto and are required only to have added thereto the adding element in a small content as previously described, only for the purpose of improving their anti-welding property.

Some of contact alloys of the prior art type including copper or silver and having a suitable low boiling point element or elements added thereto for the purpose of reducing the chopping current could exhibit the increased anti-welding property as the secondary effect. Such alloys, however, had the low boiling point element or elements in a far high content or contents as compared with the present alloys. It is to be noted that in practicing the invention, all the low boiling elements do not consistently contribute to an increase in anti-welding property of the resulting contact alloys. For example, the addition of lead could rather aid in welding the resulting contacts to each other after a low current has passed through them for a long period of time. As illustrated hereinafter, the antimony is less effective for resisting to welding than bismuth and tellurium and cobalt-carbon-tellurium alloys are inferior to nickel-carbon-tellurium alloys in anti-welding property.

Numerous contact materials were produced according to the process as previously described and cut into cylinders having a diameter of 24 mm. and a height of 15 mm. One half of the cylinders was machined to be planed at both ends while the other half of the cylinders was machined to have a sprerical surface having a radius of curvature of 50 mm. at each end. The flat ended cylinders were put in contact with the round ended cylinders under a contact pressure of 18 kg. and had a flow of current having a peak magnitude I_p as specified in kiloamperes in the following Table I for a half cycle of alternating current having a period T as also specified in milliseconds in Table I. Then the welding force with which the cylinder pairs were stuck or welded to each other was measured in terms of a tensile strength in kilograms in the axial direction of the cylinders or in the direction in which the current flowed through the cylinders. The results of measurements are listed in the following Table I. For comparison purposes Table I also illustrates the welding forces for contact alloys including cobalt and antimony.

TABLE I.—MEASURED TENSILE STRENGTH IN KILOGRAMS OF STUCK CONTACTS

Heat No.	Ingredients in percent by weight	Current			
		I_p=2 ka., T/2=15 msec.	I_p=4 ka., T/2=20 msec.	I_p=6 ka., T/2=25 msec.	I_p=10 ka., T/2=40 msec.
1	Ni-2.3% C	117	57	153	481
2	Co-2.4% C	30	9	22	19
3	Ni-0.5% C-40% Cu	<1	15	26	119
4	Ni-1.8% C-10% Sb	<1	29	63	110
5	Co-1.4% C-10% Te	<1	10	45	46
6	Ni-2.2% C-0.6% Bi	<1	7	7	69
7	Ni-2.1% C-0.9% Bi	<1	7	11	33
8	Ni-1.9% C-2.9% Bi	<1	<1	10	21
9	Ni-1.6% C-4.9% Bi	<1	<1	6	40
10	Ni-1.8% C-9.5% Bi	<1	<1	<1	15
11	Ni-1.7% C-15% Bi	<1	<1	<1	----------
12	Ni-1.7% C-19% Bi	<1	<1	<1	57
13	Ni-2.2% C-0.5% Te	<1	25	35	48
14	Ni-2.0% C-0.8% Te	<1	<1	10	167
15	Ni-1.8% C-2.8% Te	<1	<1	<1	73
16	Ni-1.8% C-3.6% Te	<1	<1	1	50

TABLE I.—MEASURED TENSILE STRENGTH IN KILOGRAMS OF STUCK CONTACTS

Heat No.	Ingredients in percent by weight	Current			
		I_p=2 ka., T/2=15 msec.	I_p=4 ka., T/2=20 msec.	I_p=6 ka., T/2=25 msec.	I_p=10 ka., T/2=40 msec.
17	Ni-1.6% C-10% Te	<1	<1	8	12
18	Ni-1.5% C-15% Te	<1	<1	12	19
19	Ni-40% Cu-0.5% C-0.005% Bi	<1	37	72	149
20	Ni-40% Cu-0.5% C-0.01% Bi	<1	12	37	22
21	Ni-40% Cu-0.5% C-0.05% Bi	<1	<1	<1	4
22	Ni-40% Cu-0.5% C-0.1% Bi	<1	<1	<1	112
23	Ni-40% Cu-0.5% C-0.9% Bi	<1	<1	<1	<1
24	Ni-40% Cu-0.4% C-4.9% Bi	<1	<1	<1	263
25	Ni-40% Cu-0.3% C-10% Bi	<1	<1	<1	<1
26	Ni-40% Cu-0.5% C-0.005% Te	<1	55	78	120
27	Ni-40% Cu-0.5% C-0.01% Te	8	68	133	45
28	Ni-40% Cu-0.5% C-0.04% Te	<1	<1	7	25
29	Ni-40% Cu-0.5% C-0.1% Te	<1	<1	5	<1
30	Ni-40% Cu-0.5% C-0.9% Te	<1	<1	<1	<1
31	Ni-40% Cu-0.3% C-4.8% Te	<1	<1	<1	2
32	Ni-40% Cu-0.2% C-9% Te	<1	<1	<1	208

In Table I the heat numbers 8, 9, 10, 15, 16, 17, 21, 22, 23, 24, 29, 30 and 31 designate the contact alloys of the invention. From Table I it will be seen that the addition of bismuth or tellurium in a content of 1% or 0.5% without or with copper included respectively clearly reduced the welding force. Also Table I indicates that the addition of antimony is not so effective for improving the anti-welding property as the addition of bismuth or tellurium. Further the cobalt-carbon-tellurium alloy was inferior to the nickel-carbon-tellurium alloy in anti-welding property.

The invention also has another characteristic feature that the contact alloys prepared according to the same are relatively high in temperature at which they begin to be melted in spite of their containing a low boiling point element. On the bases of measured variations in specific heat of the present and control alloys, temperatures at which the alloys will begin to be melted were calculated and listed in the following Table II.

TABLE II.—TEMPERATURE AT WHICH ALLOY BEGINS TO BE MELTED

Heat No.:	Ingredients in percent by weight	Temperature in ° C. at which the alloys begin to be melted
Heat No.:		
9	Ni-1.6% C-4.9% Bi	650
17-A	Ni-1.6% C-4.5% Te	975
35	Co-1.8% C. 5.0% Bi	260
36	Co-1.7% C-5.0% Te	965
37	Cu-20% Bi	270

In general, vacuum devices are desirably heated to a temperature of at least 250° C. and preferably 500° C. or more upon sealing off them in order to remove any gas adsorbed on the surfaces of their components. To this end, any suitable brazing material having a melting point higher than the magnitude just specified must be used to secure the electrical contacts to their supports within the vacuum devices. Thus the fact that the contact alloys are high in temperature at which they begin to be melted is greatly advantageous.

Tellurium is somewhat difficult in handling as compared with bismuth because of its higher vapor pressure but it is superior to the latter in view of the standpoint of the temperature at which the resulting alloys begin to be melted as shown in Table II.

It will be understood that cobalt similar in properties to nickel may be used as a material for the contacts of vacuum switches after it has deoxidized with carbon. The binary alloys including cobalt and carbon are superior to the nickel-carbon alloys in that the former are less in welding force. However, cobalt-carbon-bismuth alloys have the temperatures at which they begin to be melted, less that the melting point of the element bismuth or 269° C. Further, the cobalt-carbon-tellurium alloys have the temperatures as high as the nickel-carbon-tellurium alloys as shown by way of example in Table II but the cobalt base alloys are inferior to the nickel base alloys in anti-welding property as listed in Table I. Therefore the substitution of the cobalt base alloy for the nickel base alloys has no advantage.

It is to be noted that the temperatures at which the present alloys begin to be melted remain unchanged regardless of the amount of bismuth or tellurium added as long as the contents of ingredients involved are within the ranges as previously specified. When the particular alloy has been heated to that temperature (at which it begins to be melted) all the entire weight of the alloy is not immediately melted. The alloy has its molten portion dependent upon both the degree of temperature by which the temperature of the heated alloy exceeds the melt-initiating temperature and the content of bismuth or tellurium and increased in weight as both factors increase. Accordingly, with the content of bismuth or tellurium low, the alloys are permitted to be actually heated to temperatures greatly exceeding the respective melt-initiating temperatures.

Finally, as to the permissible amounts of incidental impurities contained in the present alloys, the elements particularly harmful for the electrical contacts of the vacuum switches, for example, oxygen, nitrogen and hydrogen should be removed therefrom through sufficient refining of the starting materials in the manner as previously outlined. Other incidental impurities need not be removed from the starting materials. This allows the use of commercial grade starting materials in practicing the invention, provided that the contents of the particularly harmful gaseous impurities, such as oxygen, nitrogen, hydrogen, etc. are negligible.

As previously described, the starting materials are preliminarily refined through the use of carbon. Thus the materials may include from 0.02 to 2.5% by weight of carbon. It has been found that the presence of carbon in a content of from 0.02% to 2.5% as one of the ingredients or incidental impurities does not adversely affect the anti-welding property and the cutting through characteristics. If desired, carbon may be removed from the starting materials.

While the invention has been described in terms of bismuth or tellurium it is to be understood that the present contact material may include the total amount of at least one of bismuth and tellurium with satisfactory results.

What I claim and desire to secure by Letters Patent is:

1. An electrical contact material for use with vacuum switches including from 1 to 10% by weight of at least one metal of the group consisting of bismuth and tellurium and the balance being nickel and incidental impurities.

2. An electrical contact material according to claim 1, further including from 1.0 to 2.2% by weight of carbon.

3. An electrical contact material according to claim 1, in which said metal is bismuth only.

4. An electrical contact material according to claim 3, further including from 1.0 to 2.2% by weight of carbon.

5. An electrical contact material according to claim 1, in which said metal is tellurium only.

6. An electrical contact material according to claim 5, further including from 1.0 to 2.2% by weight of carbon.

7. An electrical contact material for use with vacuum switches including from 0.05 to 5% by weight of at least one metal of the group consisting of bismuth and tellurium, from 25 to 50% by weight of copper and the balance being nickel and incidental impurities.

8. An electrical contact material according to claim 7, further including from 0.2 to 1.0% by weight of carbon.

9. An electrical contact material according to claim 7, in which said metal is bismuth only.

10. An electrical contact material according to claim 9, further including from 0.2 to 1.0% by weight of carbon.

11. An electrical contact material according to claim 7, in which said metal is tellurium only.

12. An electrical contact material according to claim 11, further including from 0.2 to 1.0% by weight of carbon.

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