United States Patent

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[54] METHOD OF PRODUCING MATERIALS HAVING A HIGH STRENGTH, A HIGH ELECTRICAL CONDUCTIVITY, AND A HIGH HEAT RESISTANCE

9 Claims, 4 Drawing Figs.

[52] U.S. Cl. 148/11.5, 148/13.2, 148/32
[51] Int. Cl. C22f 1/08
[50] Field of Search 148/13.2, 11.5, 32

[56] References Cited

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ABSTRACT: Materials having a high strength, a high electrical conductivity and a high heat resistance are produced by directly internally oxidizing a wire or plate of dilute copper alloy consisting of less than 0.2% Be, less than 0.5% mg. less than 1.0% Ti, less than 0.2% Zr, either single-componentwise or multicomponentwise, or therewith less than 0.9% Al and/or less than 0.9% Si with the total addition amount not in excess of 1%, the remainder being copper, at a temperature above 600° C. and at an internal oxidation velocity no smaller than a critical value. Such a production is carried preferably out by coating the wire or plate, with a slurry composed of cuprous oxide, a heat-stable sinter inhibitor, and water or an organic solvent, completely drying said slurry-coated wire or plate and then embedding said slurry-coated wire or plate in a protective agent and then effecting the internal oxidation.

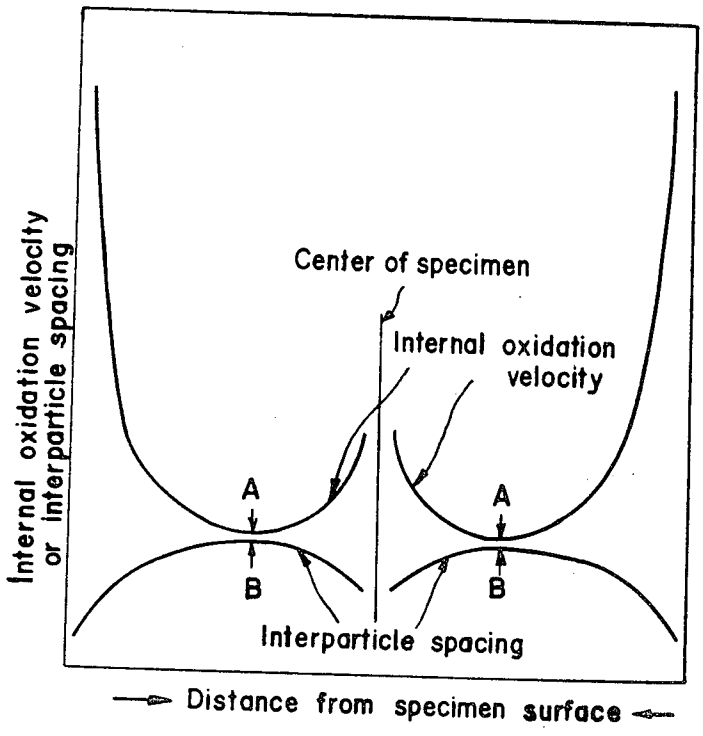

Fig. 1

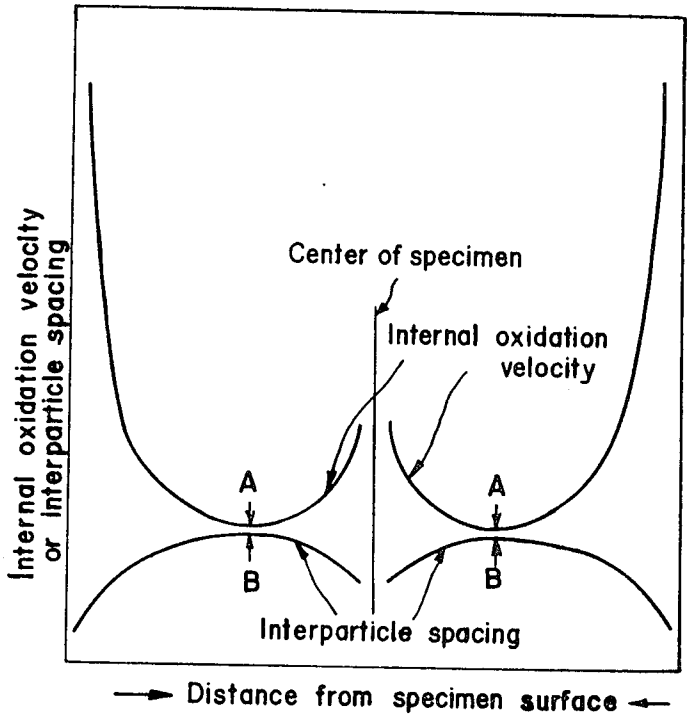

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Fig. 2

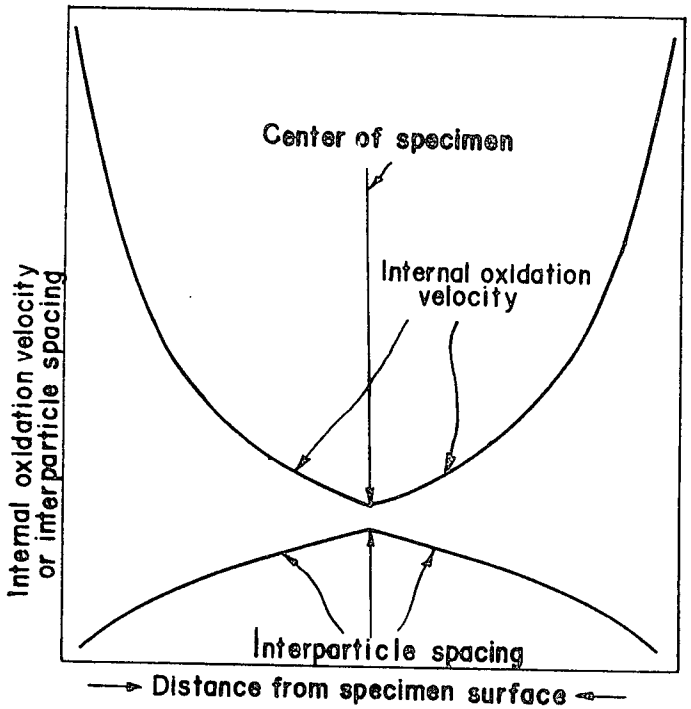

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Fig. 3

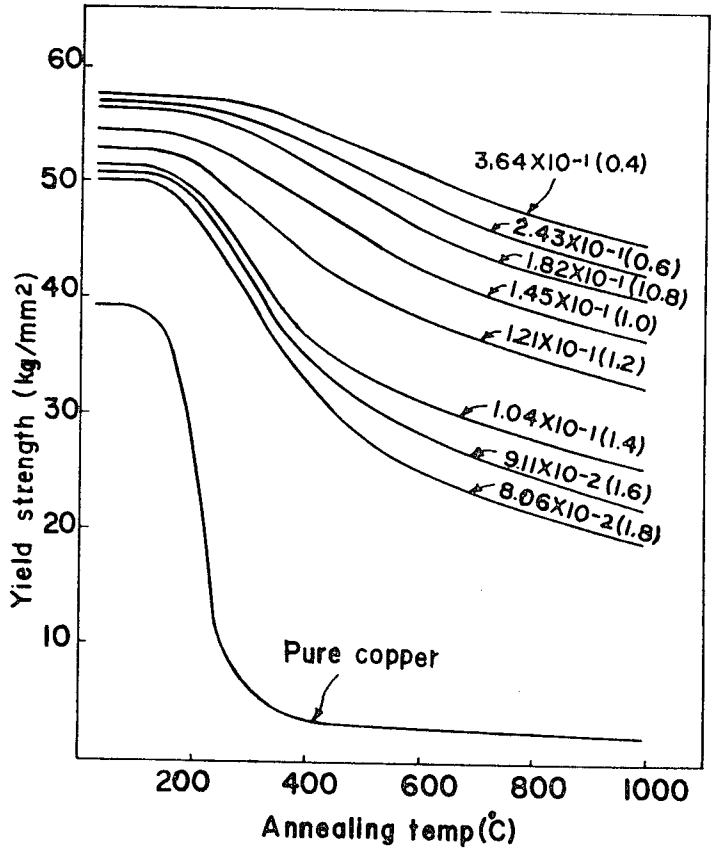

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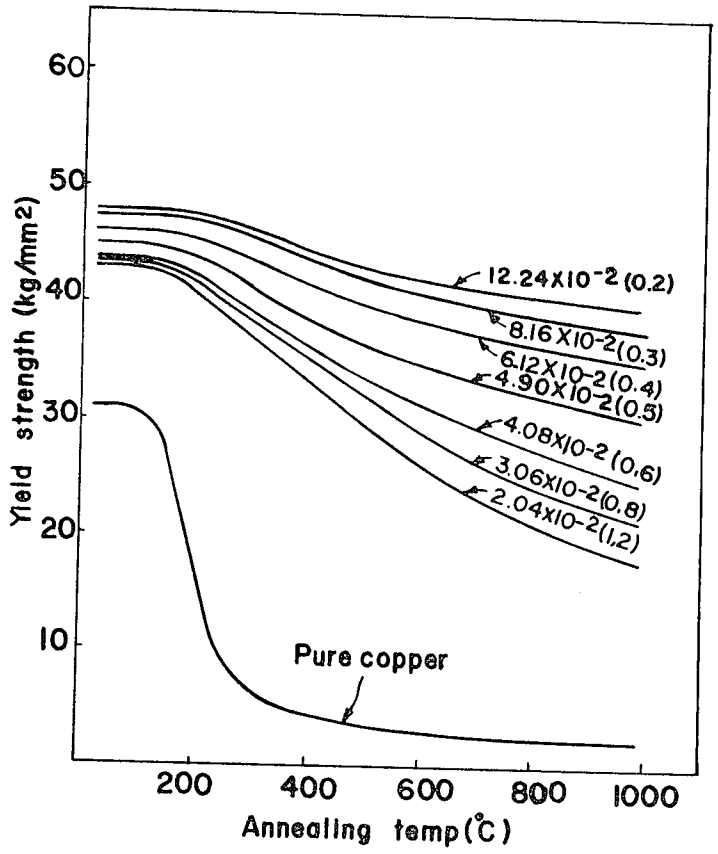
Fig. 4



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METHOD OF PRODUCING MATERIALS HAVING A HIGH STRENGTH, A HIGH ELECTRICAL CONDUCTIVITY, AND A HIGH HEAT RESISTANCE

The present invention relates to a method of producing materials having a high strength, a high electrical conductivity, and a high heat resistance.

The object of the present invention is to provide materials having more excellent strength, electrical conductivity, and heat resistance than ordinary materials, by means of direct internal oxidation of a wire or plate of a copper alloy containing a small amount of metal elements which have a higher negative free energy than the matrix and are selectively oxidized under well-defined conditions to be explained below, said wire or plate thus treated acquiring a high strength and a high conductivity, being recrystallization-resistant, and maintaining these properties even when annealed at high temperatures after working.

Ordinary high-strength, high-conductivity, high-heat-resistance materials such as Cu-Ti-Ni, Cu-Ti-Si, Cu-Ag, Cu-Ni-Si, Cu-Cr alloys and the like, are all a precipitation-hardened type of Cu-base alloys in which high strength and high conductivity are achieved firstly by quenching the alloys from a temperature higher than the precipitation temperature, whereby the solutes being forcedly dissolved in the matrix, and subsequently by annealing them at relatively low temperatures, whereby the solutes being precipitated from the matrix. These alloys are incapable of retaining the strength and conductivity thus obtained against annealing at a temperature high enough for the precipitates to redissolve into the matrix.

The recent remarkable development of electric and electronic devices such as motors, generators, computers, and electronic switching systems, clearly indicates a trend toward increased capacity, miniaturization, compactization of components, and further progress is possible only with the appearance of materials of better quality.

Among the typical materials widely used in this field, Cu-Ti-Ni alloys, the most heat resistant of all the precipitation hardened Cu-base alloys, lose considerably their strength when annealed above 600° C., and Cu-Ag alloys of the highest conductivity have a value of only about 83 percent IACS.

In these circumstances, dispersion strengthening has recently been proposed as a promising method for obtaining a material having a high strength, a high conductivity, and a high heat resistance. Conventional alloys of this type are produced either by internally oxidizing a powder of Cu-Al, Cu-Si, Cu-Be alloys, etc., or by mechanically mixing copper powder with Al_2O_3, SiO_2, or BeO powder, and subjecting the oxidized powder or the mixture to compression and sintering with or without further extrusion. The dispersion of fine oxides in the matrix is responsible for the enhancement of the concerned properties of these alloys. However, the highest electrical conductivity reached by these methods is only about 80 percent IACS. Moreover, these dispersion-strengthened alloys are too brittle to withstand subsequent drawing or rolling.

Former attempts at direct internal oxidation of a wire or plate of copper alloy did not yield a satisfactory result because of the failure in meeting various requirements for solute concentration, specimen size, atmosphere, oxidation temperature, etc.

The present invention aims at removing the difficulties connected with the conventional direct internal oxidation processes. The inventors have made extensive studies on the factors governing internal oxidation, and succeeded in controlling them and producing in an economical way materials having desired properties.

The present invention consists of a wire or plate of dilute copper alloy, said wire or plate being internally oxidized at a temperature above 600° C. and at an oxidation velocity higher than a critical value, and if necessary, said oxidized wire or plate being worked and heat-treated.

After extensive studies on the process of internal oxidation, the inventors have found that the final properties of internally oxidized materials are critically dependent on the internal oxidation velocity, or the interparticle spacings of dispersed oxides.

For a better understanding of the invention, reference is made to the accompanying drawings, wherein

FIGS. 1 and 2 show the internal oxidation velocity and interparticle spacings as a function of depth for a wire and plate respectively, while

FIGS. 3 and 4 show the yield strength versus annealing temperature for internally oxidized and cold-worked wires and plates respectively, with internal oxidation velocity (cm./hr.) and specimen size (mm.) (in parentheses) as parameters.

In FIGS. 1 and 2, point A is where the internal oxidation velocity becomes minimum, and point B where the interparticle spacings become maximum.

In general, the minimum internal oxidation velocity or the maximum interparticle spacings depend on solute concentration, form and size of specimen, internal oxidation temperature, oxygen pressure, pressures, etc. Alloys internally oxidized at a low velocity acquire a better electrical conductivity but no better strength than by conventional methods, and are susceptible to recrystallization around the position of the maximum interparticle spacings on a subsequent working and annealing at relatively low temperatures. The ascent of strength may be effected by increasing the minimum internal oxidation velocity, by increasing the solute concentration, or by lowering the internal oxidation temperature. The recrystallization temperature also can be raised in the same manner.

From the studies of the internal oxidation processes of dilute copper alloys containing, in addition to not more than 0.2% Zr (hereinafter percent means weight percent unless otherwise stated), at least one element selected from the group consisting of Be, Mg, Ti, Al and Si in the percentage of not more than 0.2% Be, not more than 0.5% Mg, not more than 1.0% Ti, not more than 0.9% Al and not more than 0.9% Si, the total addition amount including Zr not exceeding 1% of the dilute copper alloy, the inventors have reached the idea of a critical internal oxidation velocity. As long as the minimum internal oxidation velocity equals or exceeds this critical velocity, the oxidized alloys acquire a high strength, a high conductivity, and a high resistance to recrystallization, and these desirable properties can be further improved by subsequent working and heat treatment. Electron microscopic examination of said worked and annealed alloys showed no appreciable rearrangement of dislocations, which may account for the retention of as-worked strength against annealing. Further, the improvement in conductivity of said worked alloys upon annealing may then be ascribed to the annihilation of positive and negative dislocations lying within a short range, or to that of point defects, their clusters, and stacking faults, all contributing to the reduction of scattering areas for conduction electrons.

In general, the minimum internal oxidation velocity decreases with increase in specimen size, other conditions being equal. Therefore, a specimen of a size large enough for its minimum internal oxidation velocity to become smaller than the critical value acquires a relatively high electrical conductivity but only at the cost of strength, and is still more susceptible to recrystallization on cold working and annealing at high temperatures.

The present invention makes use of a series of dilute copper alloys containing, in addition to not more than 0.2% Zr, at least one element selected from the group consisting of Be, Mg, Ti, Al and Si in the percentage of not more than 0.2% Be, not more than 0.5% Mg, not more than 1.0% Ti, not more than 0.9% Al and not more than 0.9% Si, the total addition amount including Zr not exceeding 1% of the dilute copper alloy.

The limitations to the kind and concentration of solutes are based on the investigations by the inventors into the influence of the solutes on the mechanical, electrical, structural properties of an oxidized wire or plate. The size of dispersed oxide particles increases in the order of beryllium, magnesium, zirconium, aluminum, titanium, and silicon, namely, in the

decreasing order of negative free energy oxide formation. Conversely, in order to obtain given interparticle spacings for the same volume content of oxides, the addition amount may be in the reversed order. Moreover, the electrical conductivity of an internally oxidized alloy containing a given volume contact of oxide decreases in the order of silicon, titanium, aluminum, zirconium, magnesium, and beryllium, namely, in the increasing order of negative free energy of oxides decreases in the order of silicon, titanium, have a sufficient solubility in copper, and the workability of an oxidized wire or plate decreases in decreasing order of solubility, or increasing degree of segregation of solutes along grain boundaries. Zirconium is meant as a grain finer as well as an oxide former. Its presence makes the working of an internally oxidized alloy easier than otherwise.

In the presence of more than 0.2% Zr, or more than 0.2% Be, or more than 0.5% Mg, or more than 1.0% Ti, or more than 0.9% Al, or more than 0.9% Si, or in the presence of these elements to a total of over 1% of the alloy, the optimum conductivity is no longer attainable, and the segregation of oxides along grain boundaries makes subsequent working of oxidized alloys extremely difficult or impossible.

In order to obtain materials of superior quality, it is preferable to use copper alloys containing, in addition to 0.01 to 0.15% Zr, at least one element selected from the group consisting of Be, Mg, Ti, Al, and Si in the percentage of 0.01 to 0.1% Be, 0.05 to 0.4% Mg, 0.05 to 0.8% Ti, 0.05 to 0.8% Al, and 0.05 to 0.8% Si, the total addition amount including Zr not exceeding 1% of the dilute copper alloy. The most desirable compositions are 0.01 to 0.15% Zr, 0.01 to 0.1% Be, and the remainder Cu; 0.01 to 0.15% Zr, 0.05 to 0.8% Al and the remainder Cu; and 0.01 to 0.15% Zr, 0.01 to 0.1% Be, 0.05 to 0.8% Al and the remainder Cu.

In the present invention, the internal oxidation is carried out by heating the solid alloy in the presence of cuprous oxide (Cu_2O) to a temperature and for a length of time sufficient to insure the complete oxidation of the solute of the alloy. By taking advantage of the dissociation of oxygen from the cuprous oxide, all of the complications arising from the control of oxygen pressure may be easily avoided.

The novel aspects of the internal oxidation processes of the invention consist in, prior to heating, coating the solid alloy, in the form of wire or plate, with a slurry composed of Cu_2O, an inhibitor, and a solvent, completely drying the slurry-coated alloy, protecting the alloy in a pack of shroud powder from ambient air, and then heating the alloy to a temperature above 600° C. and at an internal oxidation velocity not smaller than a critical value.

In the conventional procedure of internal oxidation, the alloy is heated in a pack of a shroud powder consisting of Cu_2O or a mixture of Cu_2O and Cu powder. It has now been found by experience that heating the solid alloy, particularly in the form of coils, be it of a wire or plate, in a pack of conventional shrouds, is inevitably accompanied by the sintering of the coils at the positions of mutual contact, the agglomeration of shroud powder particles, and the sticking of the particles to the surface of the alloy, which causes great trouble to the packing and unpacking of the alloy.

Now according to the present invention, it has been found that, if the alloy coils, usually in a bundle, are pervasively immersed in a slurry composed of Cu_2O powder, another oxide powder called inhibitor, and a solvent, dried, embedded in a pack of shroud powder, and then heated, one can completely suppress the sintering between coils. Examples of the inhibitor are Al_2O_3, MgO, $MgZrO_3$, CuO, SiO_2, and a mixture thereof. It has been further found by experience that the desired effects of the invention are produced not in the presence of an inhibitor alone but only in the simultaneous presence of an inhibitor and Cu_2O in the slurry. Examples of the slurry are a mixture of Cu_2O and Al_2O_3 powder at a weight ratio of 3:7; a mixture of Cu_2O and MgO at a weight ratio of 5:5; a mixture of Cu_2O and SiO_2 at a weight ratio of 3:7. Examples of the solvent are water, methanol, ethanol.

In the conventional internal oxidation procedure, Cu_2O was a major constituent of the shroud. In the present invention, however, the major constituent of the shroud is any one of the inhibitor group oxides, and whether or not the shroud contains Cu_2O is immaterial, for it is already present in the slurry. In this way the agglomeration of the shroud particles due to sintering, or the surface roughening of the alloy due to the sintering or the shroud particles thereon may be easily avoided. Further, considerable economies may be achieved in the use of Cu_2O, which is another advantage of the invention.

Both the inhibitor and the shroud must be thermally stable and inactive against the materials to be oxidized. They may be alumina, magnesia, magnesium zirconate, silica, cupric oxide, or a mixture thereof. The solvent to be used for the slurry may be water or highly volatile organic compounds having a boiling point lower than 200° C. and being inactive against the material to be oxidized and slurry components.

The limitation of internal oxidation temperature to above 600° C. is made by the following reason. Internal oxidation can be effected at any temperature within this range. At temperatures below 600° C., the time necessary to complete internal oxidation becomes so long that there is no industrial benefit.

However, below 800° C., grain boundaries tend to be selectively oxidized, which results in the segregation of oxides there, while above 1,000° C., the oxides tend to make harmful growth, both to a varying degree depending on the kind of alloy to be oxidized. For this reason, it is preferable to carry out internal oxidation in the temperature range of 800° C. to 1,000° C.

The following examples are given in illustration of the present invention and are not intended as limitations thereof.

EXAMPLE 1

Cu-0.038% Be alloy wires having various diameters were internally oxidized at 1,000° C., cold drawn to 60 percent of the original cross-sectional area, and then annealed at various temperatures for 1 hour. FIG. 3 shows the yield strengths of these annealed wires, with internal oxidation velocity (cm./hr.) and specimen size (mm.) (in parentheses) as parameters. As seen from this figure, increasing internal oxidation velocity has the effect of suppressing the decreasing tendency of yield strength with temperature. Electron microscopic examination revealed that the decrease of yield strength with temperature is mainly due to the occurrence of recrystallization. To be more specific, for a minimum internal oxidation velocity of $8.06–9.11\times10^{12}$ cm./hr., recrystallization sets in at a temperature as low as 300° C. and strength begins to fall down there, and for a velocity of 1.04×10^{11}, the recrystallization temperature rises as high as 600° C., and finally for a velocity higher than 1.21×10^{11}, even an annealing at 1,000° C. cannot induce recrystallization. In other words, this Cu-0.038% Be wire has a critical internal oxidation velocity of 1.21×10^{11} cm./hr.

Plates of Cu-0.083% Be alloy having various thicknesses were internally oxidized at 1,000° C., cold rolled to 50 percent of the original thickness, and annealed at various temperatures for 1 hour. FIG. 4 shows the yield strengths of these plates against annealing temperatures. As in the case of wires, the recrystallization temperature rises and the decreasing degree of strength with temperature is suppressed, with increasing minimum internal oxidation velocity. A plate internally oxidized at a minimum velocity larger than 4.90×10^{12} cm./hr. resists recrystallization even on an annealing at a temperature as high as 1,000° C. That is, the critical internal oxidation velocity of this Cu-0.083% Be alloy plate is 4.90×10^{12} cm./hr.

EXAMPLE 2

Wires of various diameters having the compositions as shown in table 1 were treated with a slurry made of methyl alcohol, 3 parts of cuprous oxide and 7 parts of silica, and after

complete drying, embedded in a protective agent composed of 1 part of alumina and 9 parts of cupric oxide powder, and completely internally oxidized at 1,000° C. The oxidized wires were cold drawn to about 90 percent of the original cross-sectional area, and then annealed at either 800° C. or 1,000° C. for 1 hour. The critical internal oxidation velocities measured at 1,000° C. are listed in the right-hand column of table 1.

Table 1

Alloy composition (% by weight)	Critical internal oxidation velocity (cm./hr.)
Cu–0.03 Be	1.34×10^{11}
Cu–0.05 Al–0.02 Be	1.14×10^{11}
Cu–0.03 Be–0.02 Zr	1.19×10^{11}
Cu–0.10 Al–0.02 Zr	1.28×10^{11}
Cu–0.20Al–0.02 Zr	4.97×10^{12}
Cu–0.05 Al–0.10 Mg	9.23×10^{12}
Cu–0.05 Al–0.02 Be–0.02 Zr	1.05×10^{11}
Cu–0.10 Si–0.08 Al–0.02 Zr	9.54×10^{12}
Cu–0.10 Ti–0.02 Be–0.02 Zr	9.30×10^{12}

Table 2 shows the mechanical and electrical properties of 0.4 mm. diameter wires which were completely internally oxidized and cold drawn in the same manner as described above and subjected to various thermal and mechanical treatments as shown at the headings of the same table. The size 0.4 mm. thick was chosen so that the minimum internal oxidation velocity be greater than the critical velocity.

TABLE 2

Alloy composition (percent by weight)	As internally oxidized			As 90% cold drawn		
	Yield strength (kg./mm.²)	Tensile strength (kg./mm.²)	Conductivity (IACS percent)	Yield strength (kg./mm.²)	Tensile strength (kg./mm.²)	Conductivity (IACS percent)
Cu-0.03 Be	26.7	39.4	94.9	62.6	62.6	91.1
Cu-0.05 Al-0.02 Be	24.1	36.9	96.0	57.6	57.6	92.2
Cu-0.03 Be-0.02 Zr	26.9	40.1	93.6	6.30	63.5	89.8
Cu-0.10 Al-0.02 Zr	16.8	29.5	97.1	56.6	58.0	91.8
Cu-0.20 Al-0.02 Zr	23.3	34.2	96.4	58.6	59.5	92.2
Cu-0.05 Al-0.10 Mg	16.5	30.4	93.9	52.3	52.3	89.9
Cu-0.05 Al-0.02, Be-0.02 Zr	24.6	38.5	90.9	58.2	58.5	87.4
Cu-0.10 Si-0.08, Al-0.02 Zr	17.0	29.3	95.0	55.9	56.1	91.3
Cu-0.10 Ti-0.02, Be-0.02 Zr	24.0	35.9	92.2	57.3	57.5	83.3

Cold drawn and annealed one hour at 800° C.			Cold drawn and annelaed one hour at 1,000° C.		
Yield strength (kg/mm.²)	Tensile strength kg./mm.²)	Conductivity (IACS percent)	Yield strength (kg./mm.²)	Tensile strength (kg./mm.²)	Conductivity (IACS percent)
41.5	45.8	92.9	38.2	44.0	93.0
39.1	44.9	94.1	36.5	43.6	94.0
41.7	46.3	91.5	37.4	43.8	91.4
38.8	44.6	94.3	33.8	40.8	94.6
40.3	47.2	93.7	35.1	42.2	93.6
36.8	42.9	91.5	32.5	39.6	91.5
40.1	45.2	88.9	37.2	43.5	88.9
36.6	43.9	92.9	31.4	38.9	93.0
38.7	45.3	90.2	35.7	41.8	90.3

Plates of various thicknesses having the compositions as shown in table 3 were internally oxidized and mechanically as well as thermally treated in the same manner as with the above wires except that the reduction applied is 50 percent of the original thickness. The critical internal oxidation velocities found are listed at the right-hand column of the same table.

Table 3

Alloy composition (% by weight)	Critical internal oxidation velocity (cm./hr.)
Cu–0.083 Be	4.90×10^{12}
Cu–0.13 Al–0.04 Zr	1.67×10^{12}

Table 4 shows the mechanical and electrical properties of 0.4 mm. thick plates which were completely internally oxidized and subsequently subjected to various thermal and mechanical treatments as shown at the headings of the same table. The size 0.4 mm. thick was chosen so that the minimum internal oxidation velocity be greater than the critical velocity.

As tables 2 and 4 show, the materials internally oxidized by the present method possess an excellent strength and conductivity even in its as-oxidized state, and are capable of withstanding subsequent severe working which further improves the strength with very little sacrifice of conductivity, and the worked materials are highly recrystallization resistant and maintains most of their as-deformed strength even after annealing at very high temperatures.

TABLE 4

Alloy composition (percent by weight)	As internally oxidized (kg./mm.²)		As 50% cold rolled (kg./mm.²)		Cold rolled and annealed one hour at 800° C. (kg./mm.²)		Cold rolled and annealed one hour at 1,000° C. (kg./mm.²)	
	Yield strength	Tensile strength	Yield strength	Tensile strength	Yield strength	Tensile strength	Yield strength	Tensile strength
Cu-0.083 Be	26.4	32.1	47.0	47.2	41.0	43.8	39.8	42.7
Cu-0.13 Al-0.04 Zr	18.9	27.5	38.6	38.7	28.8	33.8	27.7	33.5

EXAMPLE 3

Wires and a plate having the size and compositions as shown in table 5 were coated with slurries as shown in table 6, and after complete drying, embedded in protective agent as shown in table 7, and internally oxidized at 1,000° C. The size 0.4 mm. thick was chosen so that the minimum internal oxidation velocity be greater than the critical velocity.

Table 5

Alloy composition (% by weight)	Shape of material
Cu–0.03 Be–0.02 Zr	0.4 mm. wire
Cu–0.03 Be	0.4 mm. wire
Cu–0.13 Be–0.04 Zr	0.4 mm. plate

Table 6

Slurry composition	Mixing ratio (weight ratio)	Solvent
Cuprous oxide-alumina powder	3:7	methyl alcohol
Cuprous oxide-magnesia	5:5	acetone
Cuprous oxide-silicon oxide	3:7	water

Table 7

Protective agent	Mixing ratio (weight ratio)
Cupric oxide-alumina	5:5
Alumina	
Alumina-magnesia	5:5

The oxidized wires and plate had a quite smooth surface. No conglomeration of powders or sticking thereof to said wire and plate or sintering of said wire and plate was observed. Table 8 shows the mechanical and electrical properties of these oxidized wires and plate upon various thermal and mechanical treatments as shown at the headings of the same table.

These results indicate that the present method of internal oxidation including the preparation of slurries was a quite adequate one. Besides, the overall operation turned out very simple and easy.

What is claimed is:

1. A method of producing high-strength, high electrical conductivity and high-heat-resistance material by direct internal oxidation which comprises, forming a dilute copper alloy, in the form of wire or plate, which contains Zr present in an amount up to 0.2 percent and at least one more element selected from the group consisting of Be, Mg, Ti, Al, and Si in the percentage of not more than 0.2% Be, not more than 0.5% Mg, not more than 1.0% Ti, not more than 0.9% Al, and not more than 0.9% Si, thereby the total addition amount including Zr not exceeding 1 percent of the alloy and the remainder copper, coating the alloy with a slurry composed of Cu_2O, an inhibitor, and a solvent, drying the slurry-coated alloy, protecting the coated alloy in a pack of shroud powder from ambient air, and then heating the alloy to a temperature above 600° C. and at an internal oxidation velocity not smaller than a critical value, said critical value rendering the alloy substantially recrystallization resistant.

2. The method as claimed in claim 1, wherein said alloy contains, besides 0.01 to 0.15% Zr, at least one element of the group consisting of 0.01 to 0.1% Be, 0.05 to 0.4% Mg, 0.05 to 0.8% Ti, 0.05 to 0.8% Al, and 0.05 to 0.8% Si, with the total addition amount not exceeding 1 percent, and the remainder copper.

3. The method as claimed in claim 1, wherein said alloy consists of 0.01 to 0.1% Be, 0.01 to 0.15% Zr, and the remainder copper.

4. The method as claimed in claim 1, wherein said alloy consists of 0.05 to 0.8% Al, 0.01 to 0.15% Zr, and the remainder copper.

5. The method as claimed in claim 1, wherein said alloy consists of 0.05 to 0.8% Al, 0.01 to 0.1% Be, 0.01 to 0.15% Zr, with the total addition amount not in excess of 1 percent, and the remainder copper.

6. The method as claimed in claim 1, wherein said internally oxidized wire or plate is further worked.

7. The method as claimed in claim 1, wherein said internally oxidized wire or plate is further worked and heat treated.

8. The method as claimed in claim 1, wherein said inhibitor is from the group consisting of alumina, magnesia, magnesium zirconate, cupric oxide, silica, and a mixture thereof.

9. The method as claimed in claim 1, wherein said shroud is from the group consisting of alumina, magnesia, magnesium zirconate, cupric oxide, silica, and a mixture thereof.

TABLE 8

Alloy composition (percent by weight)	Shape, mm.	As internally oxidized			As cold worked (90% for wires, 50% for plate)			Cold worked and annealed one hour at 800° C.			Cold worked and annealed one hour at 1,000° C.		
		Yield strength (kg./mm.²)	Tensile strength (kg./mm.²)	Conductivity (IACS percent)	Yield strength (kg./mm.²)	Tensile strength (kg./mm.²)	Conductivity (IACS percent)	Yield strength (kg./mm.²)	Tensile strength (kg./mm.²)	Conductivity (IACS percent)	Yield strength (kg./mm.²)	Tensile strength (kg./mm.²)	Conductivity (IACS percent)
Cu-0.03 Be-0.02 Zr	[1] 0.4	26.9	40.1	93.6	63.0	63.5	89.8	41.7	46.3	91.5	37.4	43.8	91.4
Cu-0.03 Be	[1] 0.4	26.7	39.4	94.9	62.6	62.6	91.1	41.5	45.8	92.9	38.3	44.0	93.0
Cu-0.13 Al-0.04 Zr	[2] 0.4	18.9	27.5		38.6	38.7		28.8	33.8		27.7	33.5	

[1] Wire.
[2] Plate.