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HIGH ELECTRO-CONDUCTIVE COPPER ALLOY AND PROCESS FOR MAKING THE SAME

Donald K. Crampton, Marion, and John J. Vreeland, Waterbury, Conn.

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This application constitutes a continuation in part of our application Serial No. 584,572, filed January 2, 1932.

Cast copper shapes (slabs, billets, etc.) as ordinarily produced by copper refineries for reworking, usually contain up to approximately 0.08% of oxygen in the form of copper-cuprous oxide eutectic, present mainly for the purpose of insuring sound castings, free from sponginess.

The oxygen content of the cast copper shapes, just referred to, has but a slight adverse effect upon the electro-conductivity of the copper, but does act to a marked degree to adversely affect the malleability, ductility and other physical properties of the metal.

In efforts to remove the oxygen and improve the physical properties of the copper, phosphorus or other deoxidizing reagent is introduced into the same when in the molten state, with the result, however, that while the ductility, etc., is improved, the electro-conductivity of the resultant alloy is so reduced as to render it inefficient as a conductor. In this connection, it may be stated that a residual phosphorus (a copper-deoxidizing reagent) content of approximately 0.02% will reduce the conductivity of copper from approximately 100% to approximately 85% of the international annealed copper standard, inasmuch as such phosphorus will largely go into solid solution with the copper.

One of the objects of the present invention is to provide a superior copper alloy or intimate mixture combining both high electro-conductivity and superior physical properties, such as malleability and ductility.

With the above and other objects in view as will appear from the following, the present invention contemplates a high electro-conductive copper alloy, containing 99.8% or over of copper and 0.1% or less of copper-deoxidizing reagent or reagents, the major proportion of the said copper being in a form essentially free from the said copper-deoxidizing reagent in solid solution, and the latter being present in precipitated form, i. e., the major proportion and preferably all of the deoxidizing reagent being out of solid solution with the copper, and segregated therefrom and visible under the microscope as physically-distinct particles or aggregates.

Our invention further includes a high electro-conductive copper alloy having certain characteristics, as will be more fully set forth herein and particularly recited in the claims.

Our invention also contemplates a process for the manufacture of a high electro-conductive copper alloy which comprises precipitating the copper-deoxidizing reagent from a copper alloy having a preponderance of copper and a copper-deoxidizing reagent in unsaturated solid solution therewith.

Our invention further contemplates a process for the manufacture of a high electro-conductive copper alloy having certain characteristics as will be more fully set forth herein and particularly recited in the claims.

Other objects and advantages will appear to those skilled in the art, from the following.

In carrying out our invention, we employ as a "raw material," so to speak, a copper alloy containing not less than 99.9% of copper and copper-deoxidizing reagent in unsaturated solid solution therewith, in amount within the range 0.001% to 0.1%. For the purpose of convenience of description, the term "reagent," as used herein, is intended to connote one or more reagents.

The copper-deoxidizing reagent referred to is preferably present in the alloy above referred to, in an amount (0.1% or less) insufficient to saturate the copper and may be composed of one or more various deoxidizing reagents, among which may be mentioned phosphorus, silicon, manganese, lithium, aluminum, magnesium, calcium, zinc, beryllium, etc. Such deoxidizing reagents as may be suitable as a constituent part of the alloy are numerous, as indicated, and will be herein referred to as "copper-deoxidizing" reagents, by which term is meant such reagent or reagents as have the property of deoxidizing copper, even though they may or may not also possess the capacity for deoxidizing other metals. As is well known in the art, the requisite property of a copper-deoxidizing reagent is that it have a greater affinity for oxygen than oxygen has for copper.

The so-called "raw material" copper alloy above referred to, when in solid state, has its copper-deoxidizing constituent in solid solution with the copper, i. e., having some of the atoms of the deoxidizer occupying the place of copper atoms in the space-lattices of the copper crystals and is, as a result, much inferior as a conductor of eletricity as compared with the same alloy, were the said reagent to be in precipitated form, that is to say, in a physically-distinct form observable as such upon suitable microscopic examination.

The following examples will serve as illustrations of the "raw material," so to speak, from

which the improved high electro-conductive copper alloy may be produced:

	Percent		Percent	
Copper	99.95	Phosphorus	0.02	Miscellaneous balance.
Copper	99.93	Manganese	0.025	Miscellaneous balance.
Copper	99.94	Lithium	0.012	Phosphorus 0.1% Miscellaneous balance.

None of the alloys just above set forth will contain sufficient deoxidizer to saturate the copper and therefore are admirably suited for successful treatment in accordance with the present invention. It will be understood, of course, that the amount of deoxidizing reagent in such copper will vary over a relatively narrow range as between various refineries.

For the purpose of making clear the present invention, let it be supposed that the alloy chosen for treatment contains approximately 99.95% copper, and let it further be presumed that the copper-deoxidizing reagent present is phosphorus in an amount of approximately 0.02%. The copper alloy now being considered will be both ductile and malleable, but will be a relatively-poor conductor of electricity, owing to the fact that the phosphorus is present in solid solution, though in an amount insufficient to saturate the copper.

For the purpose of improving the electro-conductivity of the alloy now being discussed without destroying its ductility, etc., we treat the same while in the solid state and at an elevated temperature to precipitate the phosphorus and remove substantially all of the same from the state of being in solid solution with the copper. This precipitation may be accomplished by heating the alloy in air or other suitable oxidizing medium to a degree sufficient to cause the phosphorus contained in the alloy in solid solution to unite with oxygen and thereby be precipitated out of solid solution with the copper, in the form of small particles of oxide of phosphorus disseminated throughout the alloy or mixture and perceptible under the microscope as physically-distinct particles or aggregates.

We have found that the precipitation above described may be effected in one hour's time at a temperature of 1350 F., or higher.

The oxidizing medium employed may vary widely though the same is preferably present in a gaseous state such as air or commercially pure oxygen, the requirement being that available oxygen be present for combination with the phosphorus or other deoxidizing reagent in the alloy.

In brief, the treatment in the oxidizing atmosphere should be carried on at a temperature at which it is known that oxygen will combine with the deoxidizing reagent and should endure long enough to insure the precipitation of as near all (90.0% or over) of the deoxidizer as may be commercially feasible.

While the phosphorus is being precipitated as described, a film of oxide will usually form upon the surface of the copper, but such film or scale may be readily removed in the usual manner, if desired.

The resultant alloy, which may be termed a "finished" alloy, will possess excellent electrical conductivity, and will compare favorably with copper in which the phosphorus is not present. As a matter of fact, by the method just above described, we have been able to produce phosphorus-bearing copper having a degree of electro-conductivity equal to or exceeding 100% of the International Annealed Copper Standard.

When the alloy is finished, as above described, it will in all instances contain not less than 99.8% of copper with the combined deoxidizer together with its combined oxygen not exceeding 0.2%. Preferably, the copper will not fall under 99.95% and the combined oxygen and deoxidizer not over 0.05%.

The time and temperature factors for precipitating the copper-deoxidizing reagent will depend largely upon the nature of the particular reagent chosen, as is obvious to and readily ascertainable by those skilled in the metallurgical art, but it will be obvious from the foregoing that the reagent may be precipitated by means of any substance having free or available oxygen capable of penetrating the copper and having a greater affinity for the said reagent than the reagent has for copper.

The invention may be carried out in other specific ways than those herein set forth without departing from the spirit and essential characteristics of the invention, and the present embodiments are therefore to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

Having characterized our improved high electro-conductivity alloy and having described a novel method or process for producing the same, we claim:

1. A high electro-conductive copper alloy or intimate mixture comprising: 99.8% or over of copper and containing copper-deoxidizing reagent substantially within the range 0.001% to 0.1%; the major proportion of the said copper being in a form free from the said copper-deoxidizing reagent in solid solution; and the major proportion of the said copper-deoxidizing reagent being present in physically-distinct precipitated form.

2. A high electro-conductive copper alloy or intimate mixture comprising: 99.8% or over of copper and containing copper-deoxidizing reagent substantially within the range 0.001% to 0.1%; the major proportion of the said copper being in a form free from the said copper-deoxidizing reagent in solid solution; and at least 90% of the said copper-deoxidizing reagent being present in physically-distinct precipitated form.

3. A high electro-conductive copper alloy or intimate mixture comprising: 99.95% or over of copper and containing copper-deoxidizing reagent substantially within the range 0.005% to 0.035%; the major proportion of the said copper being in a form free from the said copper-deoxidizing reagent in solid solution; and the major proportion of the said copper-deoxidizing reagent being present in physically-distinct precipitated form.

4. A high electro-conductive copper alloy or intimate mixture comprising: 99.95% or over of copper and containing copper-deoxidizing reagent substantially within the range 0.005% to 0.035%; the major proportion of the said copper being in a form free from the said copper-deoxidizing reagent in solid solution; and at least 90% of the said copper-deoxidizing reagent being present in physically-distinct precipitated form.

5. A high electro-conductive copper alloy or intimate mixture comprising: 99.8% or over of copper and containing copper-deoxidizing reagent and oxygen; the major proportion of the said copper being in a form free from the said copper-deoxidizing reagent in solid solution; and the major proportion of the deoxidizing reagent be-

ing present in physically-distinct precipitated form, the combined content of deoxidizing reagent and oxygen falling substantially within the range 0.002% to 0.2%.

6. A high electro-conductive copper alloy or intimate mixture comprising: 99.95% or over of copper and containing copper-deoxidizing reagent and oxygen; the major proportion of the said copper being in a form free from the said copper-deoxidizing reagent in solid solution; and the major proportion of the deoxidizing reagent being present in physically-distinct precipitated form, the combined content of deoxidizing reagent and oxygen falling substantially within the range 0.002% to 0.05%.

7. A high electro-conductive copper alloy or intimate mixture comprising: 99.8% or over of copper and containing phosphorus substantially within the range 0.001% to 0.1%; the major proportion of the said copper being in a form free from the said phosphorus in solid solution; and the major proportion of the said phosphorus being present in physically-distinct precipitated form.

8. A high electro-conductive copper alloy or intimate mixture comprising: 99.8% or over of copper and containing phosphorus substantially within the range 0.001% to 0.1%; the major proportion of the said copper being in a form free from the said phosphorus in solid solution; and at least 90% of the said phosphorus being present in physically-distinct precipitated form.

9. A high electro-conductive copper alloy or intimate mixture comprising: 99.95% or over of copper and containing phosphorus substantially within the range 0.005% to 0.035%, the major proportion of the said copper being in a form free from the said phosphorus in solid solution; and the major proportion of the said phosphorus being present in physically-distinct precipitated form.

10. A high electro-conductive copper alloy or intimate mixture comprising: 99.95% or over of copper and containing phosphorus substantially within the range 0.005% to 0.035%; the major proportion of the said copper being in a form free from the said phosphorus in solid solution; and at least 90% of the said phosphorus being present in physically-distinct precipitated form.

11. A high electro-conductive copper alloy or intimate mixture comprising: 99.8% or over of copper and containing phosphorus and oxygen; the major proportion of the said copper being in a form free from the said phosphorus in solid solution; and the major proportion of the phosphorus being present in physically-distinct precipitated form, the combined content of phosphorus and oxygen falling substantially within the range 0.002% to 0.2%.

12. A high electro-conductive copper alloy or intimate mixture comprising: 99.95% or over of copper and containing phosphorus and oxygen; the major proportion of the said copper being in a form free from the said phosphorus in solid solution; and the major proportion of the phosphorus being present in physically-distinct precipitated form, the combined content of phosphorus and oxygen falling substantially within the range 0.01% and 0.05%.

13. A process for producing a high electro-conductive copper alloy or intimate mixture comprising: selecting an alloy or intimate mixture containing 99.8% or over of copper and deoxidizing reagent within the range 0.001% to 0.1%; and subjecting the said alloy to the action of heat in the presence of available oxygen to precipitate the major proportion of the said copper-deoxidizing reagent from the copper into physically-distinct particles or aggregates.

14. A process for producing a high electro-conductive copper alloy or intimate mixture comprising: selecting an alloy or intimate mixture containing 99.8% or over of copper and deoxidizing reagent within the range 0.001% to 0.1%; and subjecting the said alloy to the action of heat in the presence of available oxygen to precipitate the major proportion of the said copper-deoxidizing reagent from the copper into physically-distinct particles or aggregates; the subjection to heat as described being continued until at least 90% of the said deoxidizing reagent is precipitated and the said copper is at least 99% free of the deoxidizing reagent in solid solution.

15. A process for producing a high electro-conductive copper alloy or intimate mixture comprising: selecting an alloy or intimate mixture containing 99.8% or over of copper and phosphorus within the range 0.001% to 0.1%; and subjecting the said alloy to the action of heat in the presence of available oxygen to precipitate the major proportion of the said phosphorus from the copper into physically-distinct particles or aggregates.

16. A process for producing a high electro-conductive copper alloy or intimate mixture comprising: selecting an alloy or intimate mixture containing 99.8% or over of copper and phosphorus within the range 0.001% to 0.1%; and subjecting the said alloy to the action of heat in the presence of available oxygen to precipitate the major proportion of the said phosphorus from the copper into physically-distinct particles or aggregates; the subjection to heat as described being continued until at least 90% of the said phosphorus is precipitated and the said copper is at least 99% free of the phosphorus in solid solution.

DONALD K. CRAMPTON.
JOHN J. VREELAND.