

1

3,698,965

## HIGH CONDUCTIVITY, HIGH STRENGTH COPPER ALLOYS

Elmars Ence, Hamden, Conn., assignor to  
Olin Corporation

No Drawing. Filed Apr. 13, 1970, Ser. No. 28,023

Int. Cl. C22c 9/06; C22f 1/08

U.S. Cl. 148—32.5

7 Claims

### ABSTRACT OF THE DISCLOSURE

New and improved copper base alloys combining high conductivity with excellent strength, with the composition consisting essentially of from 0.2 to 4.0% iron, from 0.2 to 2.5% cobalt, from 0.01 to 0.5% phosphorus and a material selected from the group consisting of tin from 0.1 to 1.0%, magnesium from 0.1 to 1.0% and mixtures thereof, and the balance essentially copper, with the total iron plus cobalt content being from 1 to 5%.

It is, of course, highly desirable to obtain high conductivity copper alloys exhibiting the highest possible strength characteristics. However, alloys having high conductivity and high strength characteristics are either not readily available or quite expensive.

In copper base alloys a common method for obtaining good strength characteristics is by alloying. Alloying, however, normally lowers the conductivity, for example, solid solution hardening depends upon keeping alloying additions in solution. This is mutually incompatible with high conductivity.

There are other strengthening phenomena, such as precipitation hardening, dispersion hardening, order-disorder reactions, and martensite reactions. These also require the presence of alloying additions which in general are not completely removed from the copper matrix and, therefore, detract from the conductivity of the alloy.

Copending application SN 862,529 for "High Conductivity Copper Alloys" by Elmars Ence, now U.S. Pat. No. 3,640,779, discloses a high strength, high conductivity copper alloy containing iron, cobalt and phosphorus and/or boron. The alloy achieves good results by utilizing alloying elements which generally form complex intermetallic compounds which precipitate from solid solution. Such precipitation depletes the copper matrix of the solute elements resulting in high electrical conductivity. Simultaneously, strength of the matrix is increased by the fine dispersion of the precipitating phases.

The strength developed by this system, however, depends strongly on the rate of quench following homogenization and solutionizing and the temperature from which the material is quenched. Therefore, the final strengths which can be obtained by commercial processing are severely dependent upon the available quenching conditions.

Accordingly, it is a principal object of the present invention to obtain high conductivity copper base alloys.

It is a further object of the present invention to obtain high conductivity copper base alloys having good strength characteristics.

It is a still further object of the present invention to obtain alloys as aforesaid at a reasonable cost.

It is an additional object of the present invention to obtain a copper base alloy as aforesaid which develops high strength and high conductivity with relative insensitivity to quenching rate.

Further objects and advantages of the present invention will appear hereinafter.

In accordance with the present invention it has now been found that the foregoing objects and advantages may be readily obtained. The novel alloys of the present inven-

2

tion consist essentially of from 0.2 to 4.0% iron, 0.2 to 2.5% cobalt, phosphorus in an amount from 0.01 to 0.5% and either tin in an amount from 0.1 to 1.0% or magnesium in an amount from 0.1 to 1.0% or both tin and magnesium in the foregoing amounts, and the balance essentially copper, with the total iron plus cobalt content being from 1 to 5%.

In accordance with the present invention it has been found that the foregoing alloy retains high conductivity while having improved strength characteristics. For example, the conductivity of the foregoing alloy is in excess of 50% IACS while the yield strength at 0.2% offset is generally in excess of 80,000 p.s.i.

It is a surprising finding of the present invention that the addition of tin and/or magnesium to the foregoing alloy system causes a relative insensitivity to quenching rate with the result that strengths are improved with only a minor loss of conductivity.

In accordance with the present invention the improved copper base alloys contain from 0.2 to 4% iron and preferably from 0.7 to 2.8% and from 0.2 to 2.5% cobalt and preferably from 0.3 to 1.5%. In addition, the present alloys containing phosphorus from 0.01 to 0.5% and preferably from 0.03 to 0.15%. The alloy also contains tin from 0.1 to 1.0% and/or magnesium from 0.1 to 1.0%. All percentages of ingredients are percentages by weight.

In accordance with the present invention, the total iron plus cobalt content should be between 1 and 5%. It has been found that when these limits are adhered to a high strength and high conductivity relationship is best achieved and the alloy can be readily fabricated.

While excessive amounts of impurities are to be avoided, small amounts of impurities or other alloying additions may, of course, be tolerated provided that they do not greatly reduce the strength or conductivity characteristics. Also, naturally, alloying additions may be utilized in order to achieve a particular result.

The matrix of the alloy of the present invention is characterized by containing a fine, uniform dispersion of alloying additions which contains complex intermetallic compounds.

In accordance with the present invention the melting and casting of the copper base alloys of the present invention are not particularly critical, although in the higher iron and cobalt ranges, higher melting and casting temperatures may be necessary. The alloys may be melted and cast in accordance with conventional techniques for copper base alloys, e.g., the alloys may be prepared using conventional induction melting techniques with the alloying additions preferably made in the form of copper master alloys. It is a particular advantage of the present invention that such melting techniques and standard melt covers, e.g., graphite, charcoal, etc., can be employed in the preparation of this alloy.

After casting the ingots are heated for hot rolling to a temperature of between 700 and 1000° C. and preferably 850 to 975° C. A holding time at this temperature of at least 30 minutes is preferred. The ingots are then hot rolled in the above temperature range to convenient gage, i.e., hot rolling should commence in this temperature range. This hot rolling could, if desired, be the final rolling step. The amount of reduction in the hot rolling step is not particularly critical. If desired a separate heat treatment step may be utilized, especially where the material is not hot rolled.

After hot rolling, or after heat treating, the material may be cooled to room temperature at any desired rate due to the surprising relative insensitivity to cooling rates which characterizes the alloys of the present invention. It should be noted that somewhat higher strengths are obtained when the cooling rate is increased.

## 3

The alloy should be cold rolled after cooling. The cold rolling step is optional and generally depends upon gage requirements. The cold reduction step may attain a reduction up to 96% in one or more passes. The temperature of the cold reduction is not particularly critical but is generally below 200° C.

The material should ultimately receive a thermal aging treatment. In fact, in order to obtain preferred conductivities, the aging treatment is required. This aging treatment may also serve as an interanneal or final anneal when cold rolling is used. This aging treatment should be at 250 to 575° C. for at least 1 hour and preferably less than 50 hours.

If desired, the strip may be interannealed once or more between cold rolling passes. Strip annealing techniques may be used, in which case the holding times are usually short, i.e., for 15 seconds to 5 minutes, and possibly as long as one hour, and the temperature is from 250 to 600° C. Batch annealing techniques may also be used, in which case temperature of 250–575° C. for up to 24 hours may be used. If interanneals are employed, the total time at temperature for all anneals should preferably be less than about 30 hours in order to achieve preferred properties. Cooling rates from this temperature range are not critical.

The resultant alloy attains the aforementioned desirable combination of strength and conductivity without critical quenching rates.

The present invention will be more readily apparent from a consideration of the following illustrative examples.

## EXAMPLE I

A series of alloys were prepared by conventional techniques used for separation of alloys of this type including an induction furnace, a suitable crucible material, and protection of the molten metal from oxygen by an inert or reducing atmosphere.

OFHC-grade copper was melted down and the temperature of the melt raised to about 1200 to 1300° C. Iron and cobalt were added in elemental form. After the alloying additions had completely dissolved, phosphorus was added to the melt in the form of a copper-10 to 15% phosphorus master alloy. The tin and magnesium were then added to the melt in elemental form, with the magnesium being added at about 1200° C. The melt was then held at temperature for about 5 to 10 minutes during which time the melt was stirred and cast into cast iron molds. The composition of the resultant alloys is indicated in the table below.

TABLE I

Percent by weight					
Alloy	Iron	Cobalt	Phosphorus	Tin	Magnesium Copper
A-----	1.5	0.7	0.1	-----	Substantially balance.
B-----	1.5	0.7	0.1	0.4	Do.
C-----	2.5	1.5	0.1	-----	Do.
D-----	2.5	1.5	0.1	0.4	Do.
E-----	2.5	1.5	0.1	-----	Do.
F-----	2.5	1.5	0.1	0.2	0.2 Do.

## EXAMPLE II

The ingots prepared in Example I were hot rolled at 980° C. to 0.5" thickness and subsequently solution heat treated for one hour at 980° C. The materials were then subjected to a simulated commercial hot rolling thermal history as follows: cool rapidly to 860° C., hold 10 minutes, water quench, cold roll 70%, age at 450° to

## 4

500° C. for from 8 to 16 hours and cold roll 90%. The matrix was characterized by containing a fine, uniform dispersion of alloying additions which contains complex intermetallic compounds. The properties are given in Table II below.

TABLE II

Alloy	Yield strength, 0.2% offset, k s.i.	Ultimate tensile strength, k s.i.	Percent elongation	Percent IACS conductivity
A-----	83	90	3	60
B-----	92	98	3.5	>50
C-----	85	94	4.5	60
D-----	93	102	4.5	>50
E-----	104	112	3	>50
F-----	100	106	3	50

The foregoing data show the surprising improvements obtained by the alloys of the present invention. For example, Alloy B obtains about 10% greater strengths than Alloy A at comparable ductility with only minor loss of conductivity. Alloys D, E and F show similar advantages over Alloy C.

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

What is claimed is:

1. A high conductivity, high strength wrought copper base alloy consisting essentially of from 0.2 to 4.0% iron, 0.2 to 2.5% cobalt, from 0.01 to 0.5% phosphorus, a material selected from the group consisting of tin from 0.1 to 1.0%, magnesium from 0.1 to 1.0% and mixtures thereof, and the balance copper, with the iron plus cobalt content being from 1 to 5%, said alloy containing a fine, uniform dispersion of alloying additions which contains complex intermetallic compounds.

2. An alloy according to claim 1 having a yield strength in excess of 80,000 p.s.i. and conductivity in excess of 50% IACS.

3. An alloy according to claim 1 wherein the iron is present in an amount of from 0.7 to 2.8%.

4. An alloy according to claim 1 wherein the cobalt is present in an amount from 0.3 to 1.5%.

5. An alloy according to claim 1 wherein phosphorus is present in an amount from 0.03 to 0.15%.

6. An alloy according to claim 1 in the rolled temper.

7. An alloy according to claim 1 in the rolled and aged condition.

## References Cited

## UNITED STATES PATENTS

3,522,039	7/1970	McLain	75—153 X
2,210,670	8/1940	Kelly	75—154
2,127,596	8/1938	Hensel et al.	75—153
2,164,065	6/1939	Hensel et al.	75—153
2,171,697	9/1939	Hensel et al.	75—153
2,243,276	5/1941	Hensel et al.	75—153
2,147,844	2/1939	Kelly	75—153

CHARLES N. LOVELL, Primary Examiner

U.S. Cl. X.R.

75—153; 148—11.5,12.7