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COPPER ALLOY

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My invention relates to the alloys of copper and more particularly to the copper-base alloys containing silicon, and at least 75% copper.

The object of my invention is to provide copper-silicon alloys with improved properties.

It is well known that copper-base alloys containing up to 5% of silicon have the desirable properties of high strength, high ductility, and excellent corrosion resistance. The most important alloys of this type usually contain one or more elements beside copper and silicon such as manganese, iron, zinc, tin, and selenium, which are added to impart certain properties.

I have discovered that boron added to the copper-silicon alloys improves them. For example, the addition of boron to copper-silicon alloys permits a close control of the grain size. Also, the addition of boron has a fluxing effect so that the alloys flow more readily in casting and welding. A further advantage gained from the presence of boron in the composition is that the scale formed on the surface of the alloy annealed in an oxygen-bearing atmosphere is reduced in quantity and modified in composition so that it can be removed more easily. In relatively larger amounts the boron has the added value of improving the resistance of the alloys to mechanical wear.

To illustrate the grain refining effect of boron, there is given below a table showing the grain size of three copper-silicon-manganese alloys, two of which contained boron. The compositions by chemical analysis were:

Alloy	#771	#772	#775
Copper	95.99	95.83	95.10
Silicon	2.89	2.93	2.98
Manganese	1.09	1.14	1.13
Iron	0.09	0.14	0.10
Boron	0.00	0.06	0.58

Each of these alloys was cast in a chill mold, hot forged, and then cold rolled to .040" ga. strip with anneals at 750° C., as required. The final reduction in thickness by cold rolling was 37.5%. Specimens were cut, annealed for 30 minutes at the temperatures noted and examined microscopically to determine the grain size. The following table shows that for any given annealing temperature, the grain size will be smaller when boron is present.

Diameter of average grain—mm.

Annealing temperature °C.	Alloy		
	#771	#772	#775
600	.031	.030	.015
750	.150	.040	.025
900	.200+	.065	.030

Tests of the copper-silicon-manganese alloys with and without boron additions show that the tensile strength is increased somewhat by the boron. For example, the hard-rolled samples of Alloy #771 without boron had a tensile strength of 100,000 lb./sq. in. while Alloy #775 with 0.58% boron and in the same gauge and temper had a tensile strength of 112,000 lb./sq. in.

It is well known that borax and boric acid anhydride are an important constituent of practically all welding and brazing fluxes. I have found that when boron is present in the silicon-copper alloys, some of it oxidizes to boric acid anhydride when the alloys are melted, and has a fluxing effect. The boric anhydride is a mobile, non-volatile liquid at the casting, brazing, and welding temperatures employed, and has a great solvent power for other oxides. Furthermore, boron itself is so active chemically that it actually reduces the oxides of many metals such as iron, tin, manganese, zinc, copper, and others, thus producing cleaner and more ductile alloys. Boron renders the alloy very free flowing as compared to the alloy without the boron. All these things result in sounder metal with better surfaces whenever the boron-bearing alloys are cast or welded. Because of this fluxing effect and the grain refining effect as well as the increased fluidity these alloys make very good solders and welding rods.

Phosphorus is an efficient deoxidizer for copper alloys but it has the disadvantage (as compared to boron) that the phosphoric acid anhydride produced begins to sublime at 347° C. so that the protective liquid covering and oxide solvent effect is not obtained with the phosphorus as it is with boron.

One of the most troublesome features in the

production of silicon-copper alloys in wrought forms is the pickling operation necessary for removing the film of oxide formed when the alloy is annealed in atmospheres containing oxygen. This scale resists attack by acids such as those used in pickling brass, for example. When stronger or hotter acid is used the surfaces of the silicon-copper alloys become roughened by the etching before the scale has been removed. I have found that when a small amount of boron is present in the silicon-copper alloy, the pickling operation is much easier and quicker. The presence of boron modifies the scale so that it can be removed by acids which do not etch the underlying metal.

This may be due partly to the fact that the scale has a different coefficient of expansion than the metal, and cracks into small pieces on cooling, and partly due to the fact that the scale is made up of more easily soluble boron-bearing compounds.

One further advantage of having boron present in the silicon-copper alloys is that it increases their wear resistance. The boron in amounts up to 2% and higher forms numerous, small, hard particles of an intermetallic compound uniformly distributed throughout the alloy, but the matrix of the alloy is comparatively soft. This structure is similar to that of the white alloys commonly used for bearing materials, and its greater hardness results in a greatly superior wear resistance.

In producing my new alloys, I melt and alloy the copper-silicon, and other metals in the customary manner. I then add to the melt a boron alloy such as cupro-boron, ferro-boron, manganese boron, or boron itself. It is a difficult matter to introduce boron into copper alloys with most of the available boron alloys and compounds, but I have obtained excellent results with an alloy of boron 2% to 5%, balance copper. I may also add the boron by one of the methods of my copending application for a process for producing boron-copper alloys, Serial No. 188,471, filed February 3, 1938.

The quantity of boron introduced may vary from .005% up to about 4.5%. Usually I prefer to keep the quantity as low as possible to save expense, the preferred range being up to about 0.5% as this is sufficient for most applications. The range of silicon may be from 0.1% to 5%, the preferred range being 1% to 4% as this is the range of alloys which are the more easily workable and have the better properties.

After the boron has been added, I bring the melt to the proper pouring temperature and cast it in suitable molds. Thereafter the castings may be used as castings, or they may be rolled, drawn, forged, extruded, or worked hot or cold in any way into any desired form, such as sheet, rod, wire, tubes, profiles, and shapes.

I have mentioned silicon-copper alloys and silicon-copper alloys containing one or more of the metals manganese (up to 4%), tin (up to 5%), iron (up to 3%), zinc (up to 20%), or selenium (up to 4%). These are the ones which appear to be of the most commercial value at present. Other elements may also be present such for example as cadmium (up to about 3%), lead (up to about 5%), aluminum (up to 10%), and magnesium (up to 2%). It is at once obvious to those skilled in the art that the advantages resulting from the presence of boron are due to the boron alone, and not to the presence of other elements. Therefore, I consider that any of the numerous possible copper-base alloys of silicon and boron fall within the scope of this invention.

Having thus set forth the nature of my invention, what I claim is:

1. A copper-base alloy comprising 0.1% to 5.0% silicon, 0.005% to 4.5% boron, and balance substantially all copper.

2. A copper-base alloy comprising 1% to 4% silicon, 0.005% to 0.5% boron, and balance substantially all copper.

3. A copper alloy comprising 0.1% to 5.0% silicon, 0.005% to 4.5% boron, and balance principally copper and at least 90.5% or over, and which alloy is characterized by finer grain size, by fluxing and free flowing qualities in welding and casting, and is also characterized by a modified scale due to annealing which is more easily removed than that formed on the same alloy without the boron.

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