

Novel Lead-Free Brass Alloy

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Patent Application No. 12/759,402 filed April 13, 2010 which is a continuation-in-part patent application of U.S. Patent Application No. 12/400,283, filed March 9, 2009, all of which applications are incorporated by reference herein in their entirety.

TECHNICAL FIELD

[0002] The present invention relates to brass compositions with extremely low to no lead content. The compositions exhibit good machinability and strength similar to that of conventional leaded brass alloy free machining brass. The alloys of the invention use sulfur or blends of sulfur and tellurium in lieu of added lead to improve the machinability of the brass alloys.

BACKGROUND OF THE INVENTION

[0003] It has been common practice to add up to 4.5% lead to brass compositions to improve the machinability of the resulting product. Lead, however, is a toxic substance and its use in the production of alloys is surrounded by legislation and expensive control procedures. For example, California adopted legislation which limits the amount of lead in plumbing fixtures to 0.25% or less beginning in 2010.

[0004] Furthermore, the lead phase in copper lead alloys can be affected by corrosive attacks with hot organic or mineral oil. For example, when the temperature of such an alloy rises, it has been known that the oil can break down to form peroxides and organic gases which effect a degree of leaching on the lead phase within the alloy. If this leaching progresses to any appreciable extent, the component, if it is a bearing or structural component, may eventually malfunction or fail.

[0005] Therefore, there is a considerable advantage in reducing, or if possible, eliminating the contents of lead within powder metallurgy compositions. Various proposals have been put forward for doing this. The considerable proportions of lead incorporated in powder metallurgy materials in the past has resulted in ease of machinability and durability of the

resulting product component. Replacement of part of the lead by bismuth has been proposed in International Application published under No. WO91/14012. This results in successful replacement of part of the lead without significant reduction in the machinability. It is, however, accompanied by some reduction of transverse strength of the material. For many purposes this reduction in transverse strength is not a significant problem.

[0006] Another approach has been described in U.S. Patent 5,445,665. In this product 0.1 to 1.5% graphite is added to the alloy allowing for reduction of lead to 2% of the alloy or less.

[0007] While the alloys described above yield substantially lead-free alloys, they do not possess the same machinability as the lead containing alloys. This results in the need for substantial retooling of the equipment used to produce end product, such as plumbing equipment and the like. In addition, the scrap produced during the manufacturing of the lead products often cannot be readily recycled by the end product manufacturer. Recycling typically can only be done by the manufacturer of the alloys. The cost of shipping the scrap back to the initial foundry increases the overall product cost of the end product.

[0008] Thus, there remains a need for a lead-free brass alloy which exhibits machinability similar to that of lead containing products and that can be recycled by the customer.

BRIEF SUMMARY OF THE INVENTION

[0009] The present invention comprises a brass alloy containing from about 0.20% to 1.5% tellurium, sulfur or sulfur tellurium blends as a substitute for lead, typically added to the brass composition. In one series of embodiments the tellurium, sulfur or tellurium/sulfur blend ranges from about 0.4% to about 1.0%. The resulting alloy typically has a lead content of from less than about 0.025% to less than about 0.001% which is considered "lead-free." The alloys are also essentially silicon free in that no silicon is added to the alloys. The only silicon present is a trace amount typically found in association with the other metals used in the alloy. For example, the silicon present is less than 1,000 parts per million (ppm), 100 ppm, 10 ppm, 1 ppm, 0.1 ppm, 0.01 ppm, 0.001 ppm, 0.0001 ppm, or 0.00001 ppm of the metals used in the alloy, and in some cases the metals used in the alloy are completely silicon free.

[0010] Brass alloys of the invention typically have a copper content of from about 98% to about 57%, a zinc content of from about 43% to about 2%, a tellurium content of from about 1.0% to about 0.02%, a lead content of from about 0.025% to about 0.001%, and a maximum phosphorous content of about 0.05%. Where sulfur is used in lieu of tellurium, the sulfur content will range from about 1.5% to about 0.02 % of the brass alloy. In some cases, the sulfur content will range between 1.5% and 0.5% of the brass alloy, 1.4% and 0.5% of the brass alloy, 1.2% and 0.5% of the brass alloy, 1.0% and 0.5% of the brass alloy, 0.9% and 0.5% of the brass alloy, 0.7% and 0.5% of the brass alloy, 1.5% and 0.75% of the brass alloy, 1.5% and 0.80% of the brass alloy, 1.5% and 1.0% of the brass alloy, 1.5% and 1.2% of the brass alloy, 1.5% and 1.4% of the brass alloy, 1.25% and 0.5% of the brass alloy, or 0.75% and 0.5% of the brass alloy. Where a blends of tellurium and sulfur are used, they will again range from about 1.5 to about 0.02% of the brass alloy, 1.5% and 0.5% of the brass alloy, 1.4% and 0.5% of the brass alloy, 1.2% and 0.5% of the brass alloy, 1.0% and 0.5% of the brass alloy, 0.9% and 0.5% of the brass alloy, 0.7% and 0.5% of the brass alloy, 1.5% and 0.75% of the brass alloy, 1.5% and 0.80% of the brass alloy, 1.5% and 1.0% of the brass alloy, 1.5% and 1.2% of the brass alloy, 1.5% and 1.4% of the brass alloy, 1.25% and 0.5% of the brass alloy, or 0.75% and 0.5% of the brass alloy. In some examples, the ratio of tellurium and sulfur may be in a fixed ratio with the ratio of tellurium to sulfur ranging from 1000:1 to 1:1000, 100:1 to 1:100, 10:1 to 1:10, 1000:1 to 1:1, 1:1 to 1:1000. In some examples, the amount of tellurium and sulfur may be expressed as a percentage with sulfur being a percentage of the total amount of the sulfur/tellurium blend. In those examples, the percentage of sulfur in the sulfur/tellurium blend may be 99%, 95%, 90%, 85%, 80%, 75%, 70%, 65%, 60%, 55%, 50%, 45%, 40%, 35%, 30%, 25%, 20%, 15%, 10% or 5% of the sulfur/tellurium blend or range from 1% to 99% or any range in between of the tellurium/sulfur blend.

[0011] As noted above, in addition to the use of tellurium or sulfur, blends of tellurium and sulfur can be used. These blends comprise from between about 1% to about 99% tellurium with the balance sulfur.

[0012] The resulting alloys exhibit excellent machinability and conductivity. Depending on the composition of the alloy, the tensile strength will vary between 240 MPa and 530 MPa and yield strength will vary from about 200 to about 450 MPa. Conductivity will range from about 28% to about 49% IACS. The machinability of the novel alloys of the invention is

similar to that for lead containing compositions. This eliminates or reduces the amount of retooling needed to use the novel alloys to produce finished products such as plumbing fixtures.

[0013] The composition of the novel alloys also allows the end product manufacturers to recycle the scrap from the manufacturing process itself. This eliminates the need to return the scrap to the alloy manufacturer for recycling. Yet another key feature of the present invention is that the alloys containing less than about 15% or from about 0.0001% to less than 15% zinc exhibit excellent dezincification resistance.

[0014] The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present invention.

[0015] BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Figure 1 is a photomicrograph of the alloy used in Sample C1 after draw.

[0017] Figure 2 is a photomicrograph of the alloy used in Sample C2 after draw.

[0018] Figure 3 is a photomicrograph of the alloy used in Sample C3 after draw.

[0019] Figure 4 is a photomicrograph of the alloy used in Sample E1 after draw at 1000x magnification.

[0020] Figure 5 is a photomicrograph of that alloy used in Sample E1 after draw and etching at 100x magnification.

[0021] Figure 6 is a photomicrograph of the alloy used in Sample E4 after draw at 1000x magnification.

[0022] Figure 7 is a photomicrograph of the alloy used in Sample E4 after draw and etching at 100x magnification.

[0023] Figure 8 is a photomicrograph of the alloy used in Sample E7 after draw.

[0024] Figure 9 is a photomicrograph of the alloy used for Sample E7 after draw and etching at 100x magnification.

DETAILED DESCRIPTION OF THE INVENTION

[0025] The brass alloys of the present invention are prepared by first melting copper at a temperature of about 1050°C. Zinc and tellurium are then added to the molten copper. Brass alloy is then cast into billets utilizing horizontal or vertical casting methods. Where sulfur or tellurium/sulfur blends are used, they are also added with the zinc.

[0026] The copper used to make the alloys is typically copper cathode or high grade uncontaminated and pure copper scrap comprising at least 99.95% copper and to 0.05% impurities. Lead is a typical impurity, comprising less than 0.025% of the copper used. In the formation of the alloys of the invention, copper comprises from about 57.00 to about 98.00% of the alloy.

[0027] Zinc is the next major component comprising from about 2.00% to about 43.00% of the alloy.

[0028] Tellurium, sulfur and tellurium/sulfur blends are used as a replacement for lead. Like lead, tellurium, sulfur or tellurium/sulfur blends are added to improve machinability of the alloy without the negative contribution of lead. Tellurium, sulfur or tellurium/sulfur blends are added in an amount ranging from about 0.20% to about 1.5% of the alloy. In one series of embodiments, the tellurium, sulfur or tellurium/sulfur blends range from about 0.4 to about 1.0%. In one embodiment, tellurium comprises about 0.5% of the alloy. The amount of

tellurium, sulfur or tellurium/sulfur blends used will depend, in part, on the amount of copper used in the alloy, as copper levels increase the amount of tellurium used with decrease. Like lead, the addition of tellurium, sulfur or tellurium/sulfur blends to the alloy creates discontinuities in the copper and zinc phases of the alloy like those shown in Figures 1-6. The good dispersion of these discontinuities leads to the improved machinability of the alloys.

[0029] One advantage of the present invention is that the alloys exhibit machinability similar to that of lead containing alloys while using significantly lower amounts of tellurium, sulfur or tellurium/sulfur blends.

[0030] Other materials which may be added to the brass alloys include arsenic, nickel, manganese, and phosphorous. When phosphorous is used, the amount present will typically be less than 0.05% of the alloy. Silicon is generally not added to the alloys resulting in an alloy that is silicon-free as well as lead-free.

[0031] The resulting alloys will generally exhibit excellent machinability and conductivity as indicated by Ultimate Tensile Strength (UTS) ranging from about 240 to about 530 MPa and a yield strength of from about 200 MPa to about 450 MPa as determined using ASTM method B140. The actual Tensile strength and Yield strength will depend, in part, on the actual composition of the alloy. Conductivity of the alloys will range from about 28 to about 45% IACS.

[0032] EXAMPLES

[0033] A series of brass alloys were prepared where the added lead (typically about 2%) was replaced with approximately 0.5% tellurium. The composition of each alloy is shown in Table 1.

TABLE 1						
Sample	Cu	Pb	Zn	Te	P	Sn
A	Balance	<0.01	5.10	0.5	0.011	----
B	Balance	0.00	8.82	0.57	.001	----
C	83.03	0.06	Balance	.052	0.05	0.11

D	59.41	0.02	Balance	0.17	0.05	----
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[0034] The billets were then changed into an extrusion press at a temperature ranging from about 780°C to about 860°C. The billets were then hot extruded through a variety of dies and at different pressures to produce numerous sizes. Each shot was lubricated prior to extrusion and the extrusion dies were preheated. The results are shown in Table 2.

TABLE 2				
Sample	Final Draw Size	Shot Temp	Pressure	Length
A1	31.75mm	808°C	234MPa	12m
A2	75.40mm	822°C	268MPa	18.5m
A3	19.05mm	803°C	305MPa	34m
B1	31.75mm	794°C	267MPa	12m
B2	25.40mm	800°C	289MPa	18.5m
B3	19.05mm	806°C	304MPa	34m
B4	12.70mm	870°C	265MPa	67m
C1a	25.40mm	830°C	298MPa	18.4m
C1b	25.40mm	867°C	280MPa	18.4m
C2a	50.80mm	750°C	230MPa	21.5m
C3a	22.23mm AF Hex	830°C	312MPa	21.5m
C3b	22.23mm AF Hex	837°C	324MPa	21.5m
D1a	50.8mm	640°C	128MPa	4.6m
D1b	50.80mm	637°C	142MPa	4.6m
D2a	25.4mm	650°C	234MPa	18.4m
D2b	25.4mm	660°C	214MPa	18.4m

D3a	22.23mm AF Hex	648°C	235MPa	21.5m
D3b	22.23mm	621°C	276MPa	21.5m

[0035] The bars were then passed through a bath of sulfuric pickling acid and then cold drawn so as to induce the correct mechanical properties and grain size requirements. Also this process ensures that the correct size tolerances are met. The cold drawing operation was accomplished effortlessly. The products were then tested for tensile strength, hardness, conductivity, and machinability. The results are shown in Table 3.

TABLE 3					
Sample	Reduction in Area (%)	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	ELONGATION	HARDNESS (Rb)
A1	11.24	267.9	210.3	30%	56
A2	12.8	296.5	341.3	24%	57
A3	17.71	322	279.2	16%	60
B1	11.24	302.7	241.3	26%	59
B2	12.8	322	259.2	24%	63
B3	17.71	322.7	268.9	21%	64
B4	28.32	393.7	393	12%	69
C1	12.8	350.2	291.9	20%	51
C2	11.13	354.9	295.8	20%	52
C3	13	358.8	294.1	22%	53
D1	14.10	487.8	378.2	29%	75
D2	14.10	531.6	443	20%	78
D3	14.44	485.3	407.8	19%	76

[0036] Conductivity tests were then conducted on various samples. Conductivity diminishes as the ratio of zinc content increases. The results ranged from at least about 28% to about 49% maximum.

[0037] Photomicrographs of Samples C1, C2 and C3 were taken after draw and are shown in FIGS 1-3. The micro structure in the alloys were uniform indicating good dispersion of the tellurium throughout the alloy.

[0038] Another alloy was prepared where the lead was replaced with about 0.5% sulfur. The composition of the alloy is shown in Table 4.

TABLE 4					
SAMPLE	Cu	Zn	S	Fe	Pb
E	86.0	Balance	0.537	0.02	0.01

[0039] In a manner similar to that described above, the alloy was then hot extruded through a variety of dies and at different pressures to produce numerous sizes. Each shot was lubricated prior to extrusion and the extrusion dies were preheated. The results are shown in Table 5

TABLE 5					
SAMPLE	DRAWN SIZE (mm)	EXTRUSION DIE SIZE (mm)	BILLET TEMPERATURE (°C)	BILLET LENGTH (mm)	PRESSURE (MPa)
E1	19.84	22.5	830	800	310
E2	19.84	22.5	830	800	305
E3	25.4	28.1	813	800	312
E4	25.4	28.1	829	800	315
E5	25.4	28.1	810	340	259
E6	25.4	28.1	846	800	303

E7	30.16	33	830	800	315
E8	30.16	33	834	800	312
E9	30.16	33	800	800	307

[0040] The bars were processed as described above and subjected to mechanical testing. The results are reflected in Table 6.

TABLE 6				
SAMPLE	ULTIMATE TENSILE STRENGTH (MPa)	YIELD STRENGTH (MPa)	ELONGATION	HARDNESS (Rb)
E1	363.1	322.8	12.5	71
E4	342.1	292.4	17	68
E7	337.0	290.5	16	72

[0041] As shown from the data above, the sulfur containing alloys have mechanical properties similar to those of the tellurium containing alloys.

[0042] Photomicrographs of Samples E1, E4 and E7 were taken after draw and are shown in FIGS 4, 6 and 8 at 1000x magnification. FIGS. 5, 7 and 9 are photomicrographs of the same samples after draw and etching at 100x magnification. The microstructure in the alloys were uniform indicating good dispersion of the sulfur throughout the alloy.

[0043] Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture,

compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

CLAIMS

What is claimed is:

1. A brass alloy comprising:

Copper;

Zinc;

Sulfur; and

Lead

wherein lead comprises less than 0.25% of the alloy and the Sulfur comprises from about 0.025% to about 1% of the alloy, and

wherein the alloy has a tensile strength of from about 240MPa to about 530 MPa, and

wherein the alloy is silicon free.

2. The alloy of claim 1 wherein the copper comprises from about 57% to about 98% of the alloy.
3. The alloy of claim 1 wherein the zinc comprises from about 2.0% to about 43% of the alloy.
4. The alloy of claim 1 further comprising less than about 0.02% phosphorous.
5. A brass alloy comprising:
about 57% to about 98% copper;
about 2% to about 43% zinc; and
about 0.025% to about 1.0% sulfur

wherein the alloy has a tensile strength of from about 240MPa to about 530 MPa, and

wherein the alloy is silicon free.

6. The alloy of claim 5 further comprising less than about 0.025% lead.
7. The alloy of claim 1 having a yield strength of from about 200MPa to about 450MPa.
8. The alloy of claim 1 wherein the zinc comprises about 5% of the alloy.
9. The alloy of claim 1 wherein the zinc comprises about 10% of the alloy.
10. The alloy of claim 1 wherein the zinc comprises about 15% of the alloy.
11. The alloy of claim 1 when the zinc comprises about 40% of the alloy.
12. The alloy of claim 5 having a lead content of less than about 0.5%.
13. The alloy of claim 5 having a lead content of less than about 0.01%.
14. The alloy of claim 14 having a yield strength of from about 200MPa to about 450MPa.
15. A brass alloy comprising about 57% to about 98% copper; about 2% to about 43% zinc; and about 0.025% to about 1.0 of a blend of sulfur and tellurium;

wherein the alloy has a tensile strength of from about 240 MPa to about 530 MPa, and

wherein the alloy is silicon free.