(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
08 April 2021 (08.04.2021)

(10) International Publication Number
WO 2021/062485 A1

(51) International Patent Classification:
C22C 9/05 (2006.01) *C22C 9/04* (2006.01)

(21) International Application Number:
PCT/AU2020/051062

(22) International Filing Date:
02 October 2020 (02.10.2020)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2019903725 03 October 2019 (03.10.2019) AU

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) Title: COPPER ALLOYS

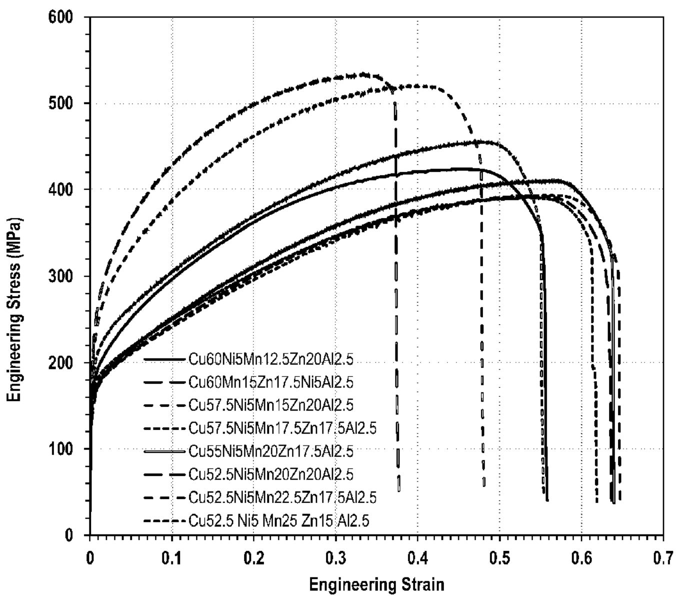

FIGURE 1

(57) Abstract: An alloy comprising or consisting of 40 to 62.5 atomic percent copper, 5 to 40 atomic percent manganese, up to 24 atomic percent nickel, 5 to 24 atomic percent zinc, and 1 to 15 atomic percent aluminium.

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TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

Copper alloys

Field of the disclosure

[0001] The present invention relates generally to alloys, and in particular, to copper alloys.

Background of the disclosure

[0002] Any discussion of the prior art throughout this specification should in no way be considered as an admission that such prior art is widely known or forms part of the common general knowledge in the field.

[0003] Copper-nickel alloys have a range of uses including in heat extractors and radiators where good thermal conductivity is desirable, and in marine settings where corrosion resistance is desirable. However, such alloys can be expensive to manufacture and difficult to work. In this context, there is a need for new alloys having improved mechanical properties. It would also be advantageous to reduce certain costs associated with manufacturing alloys.

Summary of the disclosure

[0004] In a first aspect, the present disclosure provides an alloy comprising or consisting of: 40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; up to 24 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 15 atomic percent aluminium.

[0005] In some examples, the alloy comprises or consists of: 40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; 1 to 24 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 15 atomic percent aluminium.

[0006] In some examples, the alloy comprises or consists of: 40 to 62.5 atomic percent copper; 8 to 40 atomic percent manganese; 1 to 24 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 15 atomic percent aluminium.

[0007] In some examples, the alloy comprises or consists of: 40 to 62.5 atomic percent copper; 8 to 40 atomic percent manganese; 1 to 8 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 15 atomic percent aluminium.

[0008] In some examples, the alloy comprises or consists of: 40 to 62.5 atomic percent copper; 8 to 40 atomic percent manganese; 1 to 8 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 8 atomic percent aluminium.

[0009] In some examples, the alloy comprises or consists of: 40 to 62.5 atomic percent copper; 8 to 40 atomic percent manganese; 1 to 8 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0010] In some examples, the alloy comprises or consists of: 45 to 62.5 atomic percent copper; 8 to 40 atomic percent manganese; 1 to 8 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0011] In some examples, the alloy comprises or consists of: 45 to 60 atomic percent copper; 8 to 40 atomic percent manganese; 1 to 8 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0012] In some examples, the alloy comprises or consists of: 45 to 60 atomic percent copper; 12.5 to 40 atomic percent manganese; 1 to 8 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0013] In some examples, the alloy comprises or consists of: 45 to 60 atomic percent copper; 12.5 to 35 atomic percent manganese; 1 to 8 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0014] In some examples, the alloy comprises or consists of: 45 to 60 atomic percent copper; 12.5 to 35 atomic percent manganese; 1 to 7 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0015] In some examples, the alloy comprises or consists of: 45 to 60 atomic percent copper; 12.5 to 35 atomic percent manganese; 1 to 7 atomic percent nickel; 7.5 to 24 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0016] In some examples, the alloy comprises or consists of: 45 to 60 atomic percent copper; 12.5 to 35 atomic percent manganese; 1 to 7 atomic percent nickel; 7.5 to 20 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0017] In some examples, the alloy comprises or consists of: 45 to 60 atomic percent copper; 12.5 to 35 atomic percent manganese; 3 to 5 atomic percent nickel; 12.5 to 20 atomic percent zinc; and 1 to 3 atomic percent aluminium.

[0018] In some examples, the alloy comprises or consists of: 50 to 60 atomic percent copper; 12.5 to 35 atomic percent manganese; 1 to 7 atomic percent nickel; 7.5 to 20 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0019] In some examples, the alloy comprises or consists of: 50 to 60 atomic percent copper; 15 to 35 atomic percent manganese; 1 to 7 atomic percent nickel; 7.5 to 20 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0020] In some examples, the alloy comprises or consists of: 50 to 60 atomic percent copper; 15 to 22.5 atomic percent manganese; 1 to 7 atomic percent nickel; 7.5 to 20 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0021] In some examples, the alloy comprises or consists of: 50 to 60 atomic percent copper; 15 to 22.5 atomic percent manganese; 1 to 5 atomic percent nickel; 7.5 to 20 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0022] In some examples, the alloy comprises or consists of: 50 to 60 atomic percent copper; 15 to 22.5 atomic percent manganese; 1 to 5 atomic percent nickel; 15 to 20 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0023] In some examples, the alloy comprises or consists of: 50 to 60 atomic percent copper; 15 to 22.5 atomic percent manganese; 1 to 5 atomic percent nickel; 15 to 20 atomic percent zinc; and 1 to 3 atomic percent aluminium.

[0024] In some examples, the alloy comprises or consists of: 50 to 60 atomic percent copper; 22.5 to 35 atomic percent manganese; 1 to 5 atomic percent nickel; 5 to 12.5 atomic percent zinc; and 1 to 3 atomic percent aluminium.

[0025] In some examples, the alloy comprises or consists of: 50 to 60 atomic percent copper; 22.5 to 35 atomic percent manganese; 1 to 5 atomic percent nickel; 7.5 to 12.5 atomic percent zinc; and 1 to 3 atomic percent aluminium.

[0026] In some examples, the alloy comprises or consists of: 40 to 62.5 atomic percent copper; 17 to 35 atomic percent manganese; 1 to 7 atomic percent nickel; 10 to 24 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0027] In some examples, the alloy comprises or consists of: 45 to 60 atomic percent copper; 17 to 35 atomic percent manganese; 1 to 5 atomic percent nickel; 10 to 20 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0028] In some examples, the alloy comprises or consists of: 50 to 60 atomic percent copper; 17 to 35 atomic percent manganese; 1 to 5 atomic percent nickel; 10 to 20 atomic percent zinc; and 1 to 5 atomic percent aluminium.

[0029] In some examples, (3 x atomic percent of aluminium) + atomic percent of zinc + (0.2 x atomic percent of manganese) is between 22.5% and 32.5%.

[0030] In some examples, the atomic percent ratio of copper:nickel is at least 9.

[0031] In some examples, the alloy has a tensile strain to failure of between about 40% and 65%.

[0032] In some examples, the alloy has an ultimate tensile strength of between about 390 MPa and 575 MPa.

[0033] In some examples, the alloy has an as-cast hardness (H_V) of between about 80 and 170.

[0034] In a second aspect, the present disclosure provides an alloy comprising or consisting of: 40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; up to 24 atomic percent nickel; 5 to 24 atomic percent zinc; 1 to 15 atomic percent aluminium; up to 20 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium; and up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

[0035] In some examples, the alloy comprises or consists of: 40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; up to 24 atomic percent nickel; 5 to 24 atomic percent zinc; 1 to 15 atomic percent aluminium; up to 12 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium; and up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

[0036] In some examples, the alloy comprises or consists of: 40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; up to 24 atomic percent nickel; 5 to 24 atomic percent zinc; 1 to 15 atomic percent aluminium; up to 12 atomic percent of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon or magnesium; and up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

[0037] In some examples, the alloy comprises or consists of: 40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; up to 24 atomic percent nickel; 5 to 24 atomic percent zinc; 1 to 15 atomic percent aluminium; up to 7 atomic percent chromium; up to 8 atomic percent lead; up to 8 atomic percent bismuth; up to 8 atomic percent cobalt; up to 12 atomic percent iron; up to 8 atomic percent carbon; up to 8 atomic percent tin; up to 8 atomic percent silicon; up to 2 atomic percent magnesium; up to 0.5 atomic percent arsenic; up to 0.5 atomic percent phosphorus; up to 0.5 atomic percent sulphur; and up to 0.5 atomic percent antimony.

[0038] In some examples, the alloy comprises or consists of: 40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; up to 24 atomic percent nickel; 5 to 24 atomic percent zinc; 1 to 15 atomic percent aluminium; up to 5 atomic percent chromium; up to 5 atomic percent lead; up to 2 atomic percent bismuth; up to 8 atomic percent cobalt; up to 12 atomic percent iron; up to 4 atomic percent carbon; up to 2 atomic percent tin; up to 8 atomic percent silicon; up to 2 atomic percent magnesium; up to 0.3 atomic percent arsenic; up to 0.3 atomic percent phosphorus; up to 0.3 atomic percent sulphur; and up to 0.3 atomic percent antimony.

[0039] In some examples, the alloy comprises or consists of: 85 to 95 atomic percent copper, manganese, nickel, zinc and aluminium; and balance of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin and silicon.

[0040] In some examples, the alloy comprises or consists of: 40 to 62.5 atomic percent copper; 17 to 35 atomic percent manganese; 1 to 7 atomic percent nickel; 10 to 24 atomic percent zinc; 1 to 5 atomic percent aluminium; up to 20 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium; and up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

[0041] In some examples, the alloy comprises or consists of: 45 to 60 atomic percent copper; 17 to 35 atomic percent manganese; 1 to 5 atomic percent nickel; 10 to 20 atomic percent zinc; 1 to 5 atomic percent aluminium; up to 20 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium; and up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

[0042] In some examples, the alloy comprises or consists of: 50 to 60 atomic percent copper; 17 to 35 atomic percent manganese; 1 to 5 atomic percent nickel; 10 to 20 atomic percent zinc; 1 to 5 atomic percent aluminium; up to 20 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium; and up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

[0043] In some examples, (3 x atomic percent of aluminium) + atomic percent of zinc + (0.2 x atomic percent of manganese) is between 22.5% and 32.5%.

[0044] In some examples, the atomic percent ratio of copper:nickel is at least 9.

[0045] In some examples, the alloy has a tensile strain to failure of between about 30% and 65%.

[0046] In some examples, the alloy has an ultimate tensile strength of between about 390 MPa and 575 MPa.

[0047] In some examples, the alloy has an as-cast hardness (H_V) of between about 80 and 170.

Brief description of the drawings

[0048] **Figure 1.** Engineering stress/strain curves of alloy samples in tension.

[0049] **Figure 2.** Engineering stress/strain curves of alloy samples in tension.

[0050] **Figure 3.** Side profile of Cu-Ni-Mn-Zn-Al tensile specimen fractures. From left to right: $Cu_{60}Ni_{5}Mn_{15}Zn_{17.5}Al_{2.5}$, $Cu_{60}Ni_{5}Mn_{12.5}Zn_{20}Al_{2.5}$, $Cu_{57.5}Ni_{5}Mn_{17.5}Zn_{17.5}Al_{2.5}$, $Cu_{57.5}Ni_{5}Mn_{15}Zn_{20}Al_{2.5}$, $Cu_{55}Ni_{5}Mn_{20}Zn_{17.5}Al_{2.5}$, $Cu_{55}Ni_{5}Mn_{17.5}Zn_{20}Al_{2.5}$, $Cu_{52.5}Ni_{5}Mn_{22.5}Zn_{17.5}Al_{2.5}$, and $Cu_{52.5}Ni_{5}Mn_{20}Zn_{20}Al_{2.5}$.

[0051] **Figure 4.** Side profile of Cu-Ni-Mn-Zn-Al tensile specimen fractures. From left to right: $Cu_{45}Ni_{5}Mn_{32.5}Zn_{15}Al_{2.5}$, $Cu_{45}Ni_{5}Mn_{35}Zn_{12.5}Al_{2.5}$, $Cu_{47.5}Ni_{5}Mn_{30}Zn_{15}Al_{2.5}$, $Cu_{47.5}Ni_{5}Mn_{32.5}Zn_{12.5}Al_{2.5}$, $Cu_{50}Ni_{5}Mn_{27.5}Zn_{15}Al_{2.5}$, $Cu_{50}Ni_{5}Mn_{30}Zn_{12.5}Al_{2.5}$, $Cu_{52.5}Ni_{5}Mn_{27.5}Zn_{12.5}Al_{2.5}$, and $Cu_{52.5}Ni_{5}Mn_{25}Zn_{15}Al_{2.5}$.

Detailed description

[0052] The term "about" is understood to refer to a range of +/- 10%, preferably +/- 5% or +/- 1% or, more preferably, +/- 0.1%.

[0053] Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising" will be understood to imply the inclusion of a stated element , integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps. Thus, in the context of this specification, the term "comprising" means "including principally, but not necessarily solely".

[0054] Any numerical range recited herein is intended to include all sub-ranges of the same numerical precision subsumed within the recited range. For example, a range of 1.0 to 5.0 is intended to include all sub-ranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 5.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 5.0, such as 2.1 to 4.5. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein and any minimum numerical limitation recited herein is intended to include all higher numerical limitations subsumed therein.

[0055] The present disclosure provides alloys comprising or consisting of 40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; up to 24 atomic percent nickel; 5 to 24 atomic percent zinc; and 1 to 15 atomic percent aluminium. It will be understood that the alloys described herein may comprise incidental impurities. Preferably, the incidental impurities do not exceed 0.5 at.%, or preferably, 0.1 at.%, or more preferably, 0.05 at.%.

[0056] In certain examples, the present disclosure provides an alloy comprising or consisting of: 42.5 to 65 at.% Cu; 10 to 40 at.% Mn; 0.5 to 8 at.% Ni; 5 to 24 at.% Zi; and 1 to 5 at.% Al. In certain examples, the present disclosure provides an alloy comprising or consisting of: 44 to 64 at.% Cu; 8 to 40 at.% Mn; 1 to 8 at.% Ni; 6 to 20 at.% Zi; and 1 to 4 at.% Al. In certain examples, the present disclosure provides an alloy comprising or consisting of: 42 to 62.5 at.% Cu; 8 to 40 at.% Mn; 1 to 8 at.% Ni; 6 to 20 at.% Zi; and 1 to 4 at.% Al. In certain examples, the present disclosure provides an alloy comprising or consisting of: 42.5 to 65 at.% Cu; 8 to 40 at.% Mn; 1 to 5 at.% Ni; 6 to 20 at.% Zi; and 1 to 3 at.% Al. In certain examples, the present disclosure provides an alloy comprising or consisting of: 47.5 to 62.5 at.% Cu; 8 to 40 at.% Mn; 1 to 6 at.% Ni; 6 to 15 at.% Zi; and 1 to 3 at.% Al. In certain examples, the present disclosure provides an alloy comprising or consisting of: 47.5 to 65 at.% Cu; 8 to 40 at.% Mn; 1 to 6 at.% Ni; 6 to 13 at.% Zi; and 1 to 3 at.% Al. In certain examples, the present disclosure provides an alloy comprising or consisting of: 45 to 60 at.% Cu; 12.5 to 35 at.% Mn; 3 to 5 at.% Ni; 12.5 to 20 at.% Zi; and 2 to 3 at.% Al.

[0057] In certain examples, the present disclosure provides an alloy consisting of: about 60 at.% Cu; about 5 at.% Ni; about 15 at.% Mn; about 17.5 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 60 at.% Cu; about 5 at.% Ni; about 12.5 at.% Mn; about 20 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 57.5 at.% Cu; about 5 at.% Ni; about 17.5 at.% Mn; about 17.5 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 57.5 at.% Cu; about 5 at.% Ni; about 15 at.% Mn; about 20 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 55 at.% Cu; about 5 at.% Ni; about 20 at.% Mn; about 17.5 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 55 at.% Cu; about 5 at.% Ni;

about 17.5 at.% Mn; about 20 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 52.5 at.% Cu; about 5 at.% Ni; about 20 at.% Mn; about 20 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 52.5 at.% Cu; about 5 at.% Ni; about 22.5 at.% Mn; about 17.5 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 52.5 at.% Cu; about 5 at.% Ni; about 25 at.% Mn; about 15 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 52.5 at.% Cu; about 5 at.% Ni; about 27.5 at.% Mn; about 12.5 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 50 at.% Cu; about 5 at.% Ni; about 30 at.% Mn; about 12.5 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 50 at.% Cu; about 5 at.% Ni; about 27.5 at.% Mn; about 15 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 47.5 at.% Cu; about 5 at.% Ni; about 30 at.% Mn; about 15 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 47.5 at.% Cu; about 5 at.% Ni; about 32.5 at.% Mn; about 12.5 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 45 at.% Cu; about 5 at.% Ni; about 32.5 at.% Mn; about 15 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 45 at.% Cu; about 5 at.% Ni; about 35 at.% Mn; about 12.5 at.% Zn; and about 2.5 at.% Al. The present disclosure also provides an alloy consisting of: about 59 at.% Cu; about 3 at.% Ni; about 15.5 at.% Mn; about 20 at.% Zn; and about 2.5 at.% Al.

[0058] In some examples, the present disclosure provides an alloy comprising or consisting of: 5 to 40 at.% Mn; 1 to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and a balance of Cu. In some examples, the present disclosure provides an alloy comprising or consisting of: 8 to 40 at.% Mn; 1 to 8 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and a balance of Cu. In some examples, the present disclosure provides an alloy comprising or consisting of: 8 to 40 at.% Mn; 1 to 8 at.% Ni; 5 to 24 at.% Zn; 1 to 5 at.% Al; a balance of Cu. In some examples, the present disclosure provides an alloy comprising or consisting of: 12.5 to 35 at.% Mn; 1 to 7 at.% Ni; 7.5 to 24 at.% Zn; 1 to 5 at.% Al; and a balance of Cu. In some examples, the present disclosure provides an alloy comprising or consisting of: 12.5 to 35 at.% Mn; 1 to 7 at.% Ni; 7.5 to 20 at.% Zn; 1 to 5% Al; and a balance of Cu. In some examples, the present disclosure provides an alloy comprising or consisting of: 22.5 to 35 at.% Mn; 1 to 5 at.% Ni; 7.5 to 12.5 at.% Zn; 1 to 3 at.% Al; and a balance of Cu. In some examples, the present disclosure provides an alloy comprising or consisting of: 17 to 35 at.% Mn; 1 to 8 at.% Ni; 9.5 to 20 at.% Zn; 0 to 5 at.% Al; and a balance of Cu. In some examples, the present disclosure provides an alloy comprising or consisting of: 17 to 35 at.% Mn; 1 to 8 at.% Ni; 9.5 to 20 at.% Zn; 1 to 5 at.% Al; and a balance of Cu. In some examples, the present disclosure provides an alloy comprising or consisting of: 17 to 35 at.% Mn; 1 to 8 at.% Ni; 9.5 to 15 at.% Zn; 1 to 5 at.% Al; and a balance of Cu. In some examples, the present disclosure provides an alloy comprising or consisting of: 17 to 35 at.% Mn; 1 to 8 at.% Ni; 9.5 to 12.5 at.% Zn; 1 to 5 at.% Al; and a balance of Cu. In some examples, the present disclosure provides an alloy comprising or consisting of: 17 to 35 at.% Mn; 1 to 8 at.% Ni; 9.5 to 12.5 at.% Zn; 1 to 3 at.% Al; and a balance of Cu. In some examples, the present disclosure provides an alloy comprising or consisting of: 17 to 35 at.% Mn; 1 to 5 at.% Ni; 9.5 to 12.5 at.% Zn; 1 to 3 at.% Al; and a balance of Cu.

[0059] In some examples, the present disclosure provides an alloy comprising or consisting of: 40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; up to 24 atomic percent nickel; 5 to 24 atomic percent zinc; 1 to 15 atomic percent aluminium; and up to 20 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium. In some examples, the present disclosure provides an alloy comprising or consisting of:40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; up to 24 atomic percent nickel; 5 to 24 atomic percent zinc; 1 to 15 atomic percent aluminium; and up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony. In some examples, the present disclosure provides an alloy comprising or consisting of: 40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; up to 24 atomic percent nickel; 5 to 24 atomic percent zinc; 1 to 15 atomic percent aluminium; up to 20 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium; and up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony. It will be understood that in such examples, the alloy may comprise one or more of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium, as long as the total concentration of the one or more elements does not exceed 20 at.%. Likewise, such alloys may comprise one or more of arsenic, phosphorus, sulphur and antimony, as long as the total concentration of the one or more elements does not exceed more than 1 at.%. In certain examples, arsenic, phosphorus, sulphur and antimony are present in an amount of about 0.5 at.% individually or about 0.7 at.% in total.

[0060] In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and up to 20 at.% Cr. In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and up to 20 at.% Pb. In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and up to 20 at.% Bi. In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and up to 20 at.% Co. In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and up to 20 at.% Fe. In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and up to 20 at.% C. In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and up to 20 at.% Sn. In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and up to 20 at.% Si. In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and up to 20 at.% Mg.

[0061] In some examples, the alloy comprises 0 to 7 at.% chromium, such as 0 to 5 at.% chromium, 0.5 to 4.5 at.% chromium, 0.5 to 4 at.% chromium, 0.5 to 3.5 at.% chromium, 1 to 3.5 at.% chromium, 1 to 3 at.% chromium, 1.5 to 3 at.% chromium or 1.5 to 2.5 at.% chromium. For example, the alloy may comprise about 0.5 at.%, about 0.75 at.%, about 1 at.%, about 1.25 at.%, about 1.5 at.%, about 1.75 at.%, about 2 at.%, about 2.25 at.%, about 2.5 at.%, about 2.75 at.%, about 3 at.%, about 3.25 at.%, about 3.5 at.%, about 3.75 at.%, about 4 at.%, about 4.25 at.%, about 4.5 at.%, about 4.75 at.%, about 5 at.%, about 5.25 at.%, about 5.5 at.%, about 5.75 at.%, about 6 at.%, about 6.25 at.%, about 6.5 at.%, about 6.75 at.% or about 7 at.% chromium. In some examples, chromium is not present in the alloy (ie, 0 at.%). In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and 0 to 7 at.% Cr, such as 0.5 to 5 at.% Cr.

[0062] In some examples, the alloy comprises 0 to 8 at.% lead, such as 0 to 6 at.% lead, 0.5 to 5.5 at.% lead, 0.5 to 5 at.% lead, 0.5 to 4.5 at.% lead, 1 to 4.5 at.% lead, 1 to 4 at.% lead, 1.5 to 3.5 at.% lead or 1.5 to 3 at.% lead. For example, the alloy may comprise about 0.5 at.%, about 0.75 at.%, about 1 at.%, about 1.25 at.%, about 1.5 at.%, about 1.75 at.%, about 2 at.%, about 2.25 at.%, about 2.5 at.%, about 2.75 at.%, about 3 at.%, about 3.25 at.%, about 3.5 at.%, about 3.75 at.%, about 4 at.%, about 4.25 at.%, about 4.5 at.%, about 4.75 at.%, about 5 at.%, about 5.25 at.%, about 5.5 at.%, about 5.75 at.%, about 6 at.%, about 6.25 at.%, about 6.5 at.%, about 6.75 at.%, about 7 at.%, about 7.25 at.%, about 7.5 at.%, about 7.75

at.% or about 8 at.% lead. In some examples, lead is not present in the alloy (ie, 0 at.%). In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and 0 to 8 at.% Pb, such as 0.5 to 6 at.% Pb.

[0063] In some examples, the alloy comprises 0 to 8 at.% bismuth, such as 0 to 5 at.% bismuth, 0.5 to 4.5 at.% bismuth, 0.5 to 4 at.% bismuth, 0.5 to 3.5 at.% bismuth, 1 to 3 at.% bismuth, 1 to 2.5 at.% bismuth or 1.5 to 2.5 at.% bismuth. For example, the alloy may comprise about 0.5 at.%, about 0.75 at.%, about 1 at.%, about 1.25 at.%, about 1.5 at.%, about 1.75 at.%, about 2 at.%, about 2.25 at.%, about 2.5 at.%, about 2.75 at.%, about 3 at.%, about 3.25 at.%, about 3.5 at.%, about 3.75 at.%, about 4 at.%, about 4.25 at.%, about 4.5 at.%, about 4.75 at.%, about 5 at.%, about 5.25 at.%, about 5.5 at.%, about 5.75 at.%, about 6 at.%, about 6.25 at.%, about 6.5 at.%, about 6.75 at.%, about 7 at.%, about 7.25 at.%, about 7.5 at.%, about 7.75 at.% or about 8 at.% bismuth. In some examples, the alloy comprises less than 0.7 at.% bismuth such as less than 0.5 at.% bismuth. In some examples, bismuth is not present in the alloy (ie, 0 at.%). In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and 0 to 8 at.% Bi, such as 0.2 to 2 at.% Bi, such as about 0.55 at.% or about 0.6 at.% Bi.

[0064] In some examples, the alloy comprises 0 to 8 at.% cobalt, such as 0 to 6 at.% cobalt, 0.5 to 5.5 at.% cobalt, 0.5 to 5 at.% cobalt, 0.5 to 4.5 at.% cobalt, 1 to 4.5 at.% cobalt, 1 to 4 at.% cobalt, 1.5 to 3.5 at.% cobalt or 1.5 to 3 at.% cobalt. For example, the alloy may comprise about 0.5 at.%, about 0.75 at.%, about 1 at.%, about 1.25 at.%, about 1.5 at.%, about 1.75 at.%, about 2 at.%, about 2.25 at.%, about 2.5 at.%, about 2.75 at.%, about 3 at.%, about 3.25 at.%, about 3.5 at.%, about 3.75 at.%, about 4 at.%, about 4.25 at.%, about 4.5 at.%, about 4.75 at.%, about 5 at.%, about 5.25 at.%, about 5.5 at.%, about 5.75 at.%, about 6 at.%, about 6.25 at.%, about 6.5 at.%, about 6.75 at.%, about 7 at.%, about 7.25 at.%, about 7.5 at.%, about 7.75 at.% or about 8 at.% cobalt. In some examples, cobalt is not present in the alloy (ie, 0 at.%). In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and 0 to 8 at.% Co, such as 0.5 to 5 at.% Co.

[0065] In some examples, the alloy comprises 0 to 12 at.% iron, such as 0 to 10 at.% iron, 0.5 to 9 at.% iron, 0.5 to 8 at.% iron, 0.5 to 7 at.% iron, 1 to 6.5 at.% iron, 1 to 6 at.% iron, 1.5 to 5.5 at.% iron or 1.5 to 5 at.% iron. For example, the alloy may comprise about 0.5 at.%, about 0.75 at.%, about 1 at.%, about 1.25 at.%, about 1.5 at.%, about 1.75 at.%, about 2 at.%, about 2.25 at.%, about 2.5 at.%, about 2.75 at.%, about 3 at.%, about 3.25 at.%, about 3.5 at.%, about 3.75 at.%, about 4 at.%, about 4.25 at.%, about 4.5 at.%, about 4.75 at.%, about 5 at.%, about 5.25 at.%, about 5.5 at.%, about 5.75 at.%, about 6 at.%, about 6.25 at.%, about 6.5 at.%, about 6.75 at.%, about 7 at.%, about 7.25 at.%, about 7.5 at.%, about 7.75 at.%, about 8 at.%, about 8.25 at.%, about 8.5 at.%, about 8.75 at.%, about 9 at.%, about 9.25 at.%, about 9.5 at.%, about 9.75 at.%, about 10 at.%, about 10.25 at.%, about 10.5 at.%, about 10.75 at.%, about 11 at.%, about 11.25 at.%, about 11.5 at.%, about 11.75 at.% or about 12 at.% iron. In some examples, iron is not present in the alloy (ie, 0 at.%). In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and 0 to 12 at.% Fe, such as 0.5 to 7 at.% Fe.

[0066] In some examples, the alloy comprises 0 to 8 at.% carbon, such as 0 to 6 at.% carbon, 0.5 to 5.5 at.% carbon, 1 to 5 at.% carbon, 1.5 to 5 at.% carbon, 1.5 to 5 at.% carbon, 2 to 5 at.% carbon, 2.5 to 5 at.% carbon or 3 to 5 at.% carbon. For example, the alloy may comprise about 0.5 at.%, about 0.75 at.%, about 1 at.%, about 1.25 at.%, about 1.5 at.%, about 1.75 at.%, about 2 at.%, about 2.25 at.%, about 2.5 at.%, about 2.75 at.%, about 3 at.%, about 3.25 at.%, about 3.5 at.%, about 3.75 at.%, about 4 at.%, about 4.25 at.%, about 4.5 at.%, about 4.75 at.%, about 5 at.%, about 5.25 at.%, about 5.5 at.%, about 5.75 at.%, about 6 at.%, about 6.25 at.%, about 6.5 at.%, about 6.75 at.%, about 7 at.%, about 7.25 at.%, about 7.5 at.%, about 7.75 at.% or about 8 at.% carbon. In some examples, the alloy comprises less than 0.7 at.% carbon such as less than 0.5 at.% carbon. In some examples, carbon is not present in the alloy (ie, 0 at.%). In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and 0 to 8 at.% C, such as 0.5 to 5 at.% C.

[0067] In some examples, the alloy comprises 0 to 20 at.% tin, such as 0 to 10 at.% tin, 0.5 to 8 at.% tin, 0.5 to 4 at.% tin, 0.5 to 3.5 at.% tin, 1 to 3 at.% tin, 1 to 2.5 at.% tin or 1.5 to 2.5 at.% tin. For example, the alloy may comprise about 0.5 at.%, about 0.75 at.%, about 1 at.%, about 1.25 at.%, about 1.5 at.%, about 1.75 at.%, about 2 at.%, about 2.25 at.%, about 2.5 at.%, about 2.75 at.%, about 3 at.%, about 3.25 at.%, about 3.5 at.%, about 3.75 at.%, about 4 at.%, about 4.25 at.%, about 4.5 at.%, about 4.75 at.%, about 5 at.%, about 5.25 at.%, about 5.5 at.%, about 5.75 at.%, about 6 at.%, about 6.25 at.%, about 6.5 at.%, about 6.75 at.%, about 7 at.%, about 7.25 at.%, about 7.5 at.%, about 7.75 at.% or about 8 at.% tin. In some examples, tin is not present in the alloy (ie, 0 at.%). In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and 0 to 20 at.% Sn, such as 0.5 to 9 at.% Sn.

[0068] In some examples, the alloy comprises 0 to 8 at.% silicon, such as 0 to 6 at.% silicon, 0.5 to 5.5 at.% silicon, 0.5 to 5 at.% silicon, 0.5 to 4.5 at.% silicon, 1 to 4.5 at.% silicon, 1 to 4 at.% silicon, 1.5 to 3.5 at.% silicon or 1.5 to 3 at.% silicon. For example, the alloy may comprise about 0.5 at.%, about 0.75 at.%, about 1 at.%, about 1.25 at.%, about 1.5 at.%, about 1.75 at.%, about 2 at.%, about 2.25 at.%, about 2.5 at.%, about 2.75 at.%, about 3 at.%, about 3.25 at.%, about 3.5 at.%, about 3.75 at.%, about 4 at.%, about 4.25 at.%, about 4.5 at.%, about 4.75 at.%, about 5 at.%, about 5.25 at.%, about 5.5 at.%, about 5.75 at.%, about 6 at.%, about 6.25 at.%, about 6.5 at.%, about 6.75 at.%, about 7 at.%, about 7.25 at.%, about 7.5 at.%, about 7.75 at.% or about 8 at.% silicon. In some examples, silicon is not present in the alloy (ie, 0 at.%). In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and 0 to 8 at.% Si, such as 0.5 to 5 at.% Si.

[0069] In some examples, the alloy comprises 0 to 2 at.% magnesium, such as 0 to 1.75 at.% magnesium, 0.25 to 1.75 at.% magnesium, 0.25 to 1.5 at.% magnesium or 0.5 to 1.5 at.% magnesium. For example, the alloy may comprise about 0.25 at.%, about 0.5 at.%, about 0.75 at.%, about 1 at.%, about 1.25 at.%, about 1.5 at.%, about 1.75 at.% or about 2 at.% magnesium. In some examples, magnesium is not present in the alloy (ie, 0 at.%). In some examples, the present disclosure provides an alloy comprising or consisting of 40 to 62.5 at.% Cu; 5 to 40 at.% Mn; up to 24 at.% Ni; 5 to 24 at.% Zn; 1 to 15 at.% Al; and 0 to 2 at.% Mg, such as 0.2 to 1 at.% Mg.

[0070] In some examples, the alloys of the present disclosure comprise up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony. For example, an alloy of the present disclosure may comprise about 0.1 at.%, about 0.2 at.%, about 0.3 at.%, about 0.4 at.%, about 0.5 at.%, about 0.6 at.%, about 0.7 at.%, about 0.8 at.%, about 0.9 at.% or about 1 at.% As. In some examples, the alloy may comprise about 0.1 at.%, about 0.2 at.%, about 0.3 at.%, about 0.4 at.%, about 0.5 at.%, about 0.6 at.%, about 0.7 at.%, about 0.8 at.%, about 0.9 at.% or about 1 at.% P. In some examples, the alloy may comprise about 0.1 at.%, about 0.2 at.%, about 0.3 at.%, about 0.4 at.%, about 0.5 at.%, about 0.6 at.%, about 0.7 at.%, about 0.8 at.%, about 0.9 at.% or about 1 at.% S. In some examples, the alloy may comprise about 0.1 at.%, about 0.2 at.%, about 0.3 at.%, about 0.4 at.%, about 0.5 at.%, about 0.6 at.%, about 0.7 at.%, about 0.8 at.%, about 0.9 at.% or about 1 at.% Sb.

[0071] In some examples, the present disclosure provides an alloy comprising or consisting of: 40 to 62.5 atomic percent copper; 5 to 40 atomic percent manganese; up to 24 atomic percent nickel; 5 to 24 atomic percent zinc; 1 to 15 atomic percent aluminium; and up to

0.5 atomic percent carbon or bismuth. In some examples, the present disclosure provides an alloy comprising or consisting of: 45 to 62.5 atomic percent copper; 8 to 40 atomic percent manganese; 1 to 8 atomic percent nickel; 5 to 24 atomic percent zinc; 1 to 5 atomic percent aluminium; up to 0.4 atomic percent carbon; and up to 0.4 atomic percent bismuth.

[0072] Manganese, zinc and aluminium generally reduce the stacking fault energy of a copper alloy. Of these three elements, aluminium is the most potent, reducing the stacking fault energy at a rate of about 3 x Zn. Manganese provides a smaller decrease in stacking fault energy compared to zinc, generally about 0.2 x Zn. The alloys of the present disclosure preferably comprise manganese, zinc and aluminium in amounts that confer a stacking fault energy similar to that conferred by 22.5 to 35 at.% zinc. In certain examples, the alloys of the present disclosure comprise aluminium, zinc and manganese in the following amounts:

(3 x atomic percent of aluminium) + atomic percent of zinc + (0.2 x atomic percent of manganese) is between 22.5% and 35%.

Or, expressed differently:

[(3 x at.% Al) + (at.% Zi) + (0.2 x at.%Mn)] = 22.5 to 35 at.%.

[0073] In some examples, (3 x atomic percent of aluminium) + atomic percent of zinc + (0.2 x atomic percent of manganese) is between 22.5 at.% and 35 at.%, such as between 23.5 at.% and 32.5 at.%, between 24 at.% and 31 at.%, between 24.5 at.% and 30.5 at.%, between 25 at.% and 30 at.%, between 25.5 at.% and 29.5 at.%, between 26 at.% and 29.5 at.%, between 26.5 at.% and 29.5 at.%, or between 27 at.% and 29 at.%.

[0074] The ductility of a typical brass is largely a consequence of mechanical twinning within its microstructure. The ability of an alloy to twin is directly related to its stacking fault energy. An alloy with a low stacking fault energy generally twins more easily and is more ductile than an alloy with a high stacking fault energy. Increasing the nickel content of a copper alloy typically increases the alloy's stacking fault energy, thus increasing its strength but also decreasing its ductility. This can be less desirable for industry since the alloy requires more force to work it into shape. The alloys of the present disclosure preferably have more copper than nickel in atomic percent terms and are therefore more ductile and more easily worked compared to high-nickel alloys. For example, in the alloys of the present disclosure, the atomic percent ratio of copper:nickel may be at least 2, such as at least 3, or at least 4, at least 4.5, at least 5, at least 5.5, at least 6, at least 6.5, at least 7, at least 7.5, at least 8, at least 8.5, at least 9, at least 9.5, at least 10, at least 10.5, at least 11, at least 11.5, at least 12, at least

12.5, at least 13, at least 13.5, at least 14, at least 14.5, at least 15, at least 15.5, at least 16, at least 16.5, at least 17, at least 17.5, at least 18, at least 18.5, at least 19 or at least 19.5.

[0075] Copper is also known to be highly antimicrobial in a range or environments. Accordingly, the alloys of the present disclosure may be applied in situations where microbial resistance is desired. For example, the alloys described herein may be used in the manufacture of an autoclave, a door knob, cookware or a food container.

[0076] The alloys described herein are preferably low- or non-sparking, ie, they do not readily spark when they are struck mechanically, cut by metal tools or abraded/ground, thereby making them safe for use in volatile environments.

[0077] Although being present at lower levels compared to copper, the nickel in the present alloys may confer resistance to corrosion and increase the solubility of manganese and copper. Moreover, nickel may also hinder dezincification of the alloy in service. Dezincification occurs when zinc atoms migrate to grain boundaries and to the surface, enriching these areas locally with zinc and causing localised corrosion and weakness in the alloy.

[0078] Microstructurally, certain alloys of the present disclosure may be predominantly single phase (alpha/face-centred-cubic crystal structure) or multi-phase, depending on constitution and applied heat treatment.

[0079] Certain alloys described herein may be hardenable via a crystal structure ordering mechanism or spinodal decomposition event when heat treated for long periods of time at moderate temperatures.

[0080] In certain examples, an alloy of the present disclosure has a tensile strain to failure of between about 25% and 70%, such as between about 30% and 65%, or between about 31% and 64%, or between about 35% and 65%, or between about 40% and 65%, or between about 45% and 65%, or between about 45% and 60%, or between about 50% and 65%, or between about 55% and 65% or between about 60% and 65%.

[0081] In certain examples, the alloy of the present disclosure has an ultimate tensile strength of between about 350 MPa and 600 MPa, such as between about 360 MPa and 600 MPa, or between about 370 MPa and 600 MPa, or between about 380 MPa and 600 MPa, or between about 380 MPa and 590 MPa, or between about 385 MPa and 590 MPa, or between about 385 MPa and 585 MPa, or between about 390 MPa and 585 MPa, or between about 390 MPa and 580 MPa, or between about 390 MPa and 575 MPa, or between about 394 MPa and 572 MPa.

[0082] In some examples, the alloy of the present disclosure has an as-cast hardness (H_V) of between about 70 and 190, such as between about 75 and 180, or between about 80 and 170, or between about 86 and 90, or between about 83 and 89, or between about 111 and 114, or between about 94 and 103, or between about 135 and 137, or between about 111 and 116, or between about 133 and 137, or between about 111 and 116, or between about 133 and 137, or between about 142 and 166, or between about 120 and 126, or between about 120 and 150, or between about 125 and 155, or between about 130 and 160, or between about 130 and 165, or between about 105 and 127, or between about 122 and 139, or between about 129 and 139, or between about 150 and 166, or between about 130 and 137, or between about 135 and 150, or between about 130 and 140, or between about 94 and 103.

[0083] The alloys of the present disclosure may be cast or pressure die-cast into a final product (casting alloys) at relatively low temperatures, hot forged, hot-rolled or hot-extruded into a plate or rod/tube, cold-rolled or cold forged into a plate rod or tube, deep-drawn, turned, milled or machined with metal cutting tooling to specification. The alloys may be soldered, brazed or welded. The alloys may also be chrome- or nickel-plated.

[0084] The alloys of the present disclosure may be used in general building fixtures and hardware, including door and window hinges, latches, door knobs, door locks, knockers, keys, decorative fixtures, as well as mobile phone casings, bezels, badges and medals, ornamental castings and statues. The alloys may also be suitable for use in zippers, press studs for clothing or baggage/luggage, gears, cogs, gear drive shafts, solid slip bearings, munitions/cartridge or shell cases, ammunition, marine/ship applications, air liquid/liquid/liquid heating/cooling radiators, plumbing, currency, clamps, fasteners, nuts, bolts, screws, washers, acoustic devices such as speakers, resonators, tuning forks and musical instruments (eg, trumpet or trombone), electronic contacts, electrical conducting devices, circuitry electronic couplings, hydraulic or pneumatic fluid transfer tubing couplings or connectors (high or low pressure), hydraulic or pneumatic manifolds, switches, gates and non-sparking tooling (eg, for use in explosive environments).

Examples

[0085] Cu-Ni-Mn-Zn-Al alloy charge balances with a calculated final volume of 40 cm^3 were made from additions of near-pure copper, zinc and nickel. Manganese was added using a commercial 50/50 wt.% copper-manganese master alloy. Alloys were made in a two-step process:

1. Cu-Mn-Ni buttons were made in a Buhler electric arc melting furnace via cyclic melting of the copper and nickel balances with the copper-manganese master alloy. A titanium-gettered argon atmosphere was produced via purging of the melting chamber with high purity argon three times over and then evacuating using both roughing and turbo vacuum pumps to the order of 10^{-4} mbar. The melting chamber was then filled to 60% of atmospheric pressure with high purity argon. This was followed by melting a titanium getter. Homogeneity of the Cu-Ni-Mn buttons was obtained via first melting of the nickel shot in direct contact with copper (thus allowing the copper to melt into the molten nickel). Repeated melting of the newly formed Cu-Ni alloy followed by melting of the Cu-Ni buttons into the Cu-Mn master alloy produced homogenous Cu-Ni-Mn buttons.

2. Production of the final alloy and the inclusion of zinc and aluminium was conducted using an induction furnace. The zinc and aluminium were placed at the bottom of a boron nitride-coated graphite crucible with the Cu-Ni-Mn buttons placed on top to minimise zinc evaporation. Melting of the complete Cu-Ni-Mn-Zn-Al charge balances was conducted in a circulating argon-rich environment inside the induction furnace chamber. Complete charge balances were melted twice in the induction furnace; this was found to aid with homogeneity. During the first alloying cycle, charge balances were heated to 1100 ˚C where they were held for two minutes to ensure complete melting of all charge components. Alloyed ingots were then left to cool in the crucible before being removed and mechanically cleaned/abraded to a lustrous finish, removing any oxide products. Ingots were inverted and remelted in the induction furnace, again held at 1100 ˚C for two minutes, cooled to approximately 950 ˚C, and the liquid metal poured (in air) into a 16 mm wide, 100 mm long, 50 mm deep copper mould.

[0086] The castings (100 mm x 16 mm x 35 mm) were sectioned into 50 mm x 16 mm x 35 mm blocks. One half of the casting was used for metallographic examination and hardness testing of the as-cast structure. The remaining half of the casting was processed via hot rolling and heat treatment. Initial heat treatment of the as-cast structures was conducted at 750 ˚C for two hours (with this heat treatment found to completely dissolve the as-cast microstructure in the Cu-Ni-Mn-Zn-Al alloys). Samples were then hot rolled at 750 ˚C in cross directions from a starting thickness of 16 mm down to 8 mm. The purpose of the hot rolling process was to close any casting pores or defects, consolidating the material, and to refine and recrystallise the grain structure, essentially reproducing industry processing. During the hot rolling process, samples were cyclically removed from a 750 ˚C furnace and rolled in 0.25 mm increments to their final thickness of 8 mm. Following the hot rolling process, samples received a final heat treatment of 750 ˚C for two hours to produce the final processed alloys in a hot rolled and annealed condition. At this stage, processed alloy billet had approximate dimensions of 8 mm × 35 mm × 90 mm. In order to produce tensile specimens from the processed alloy material, 8 mm × 8 mm × 62 mm strips were cut from the billet and machined into cylindrical tensile specimens with 4 mm gauge diameter and 20 mm gauge length in accordance with ASTM E8M. Tensile testing was conducted in accordance with ASTM A370 using an Instron tensile testing machine, laser extension meter and associated computer and data logger. Measured load and laser extension readings were recorded using software produced by Bluehill. Representative engineering stress-strain data are provided in Figures 1 and 2, and characteristic mechanical properties are set out in Table 1. Side profiles of alloys fractured under tension are shown in Figures 3 and 4.

[0087] Hardness testing was conducted on suitably prepared sections removed from the as-cast and processed samples. Hardness testing was conducted using a Struers duramen A300 hardness testing machine with a 1 kg load and a five second dwell time, following suitable calibration of the semiautomated machine on a 400 HV test block. Minimum 20 hardness indents were conducted for each sample.

Table 1: Compositions and characteristic mechanical properties of specific alloys (processed samples hot rolled at 750 °C and annealed at 750 °C for 2 hrs).

	As-cast hardness (HV_1)	**Processed alloy hardness (HV_1)**	**0.2% Proof Stress (MPa)**	**Ultimate Tensile Strength (MPa)**	**Tensile Elongation to Failure (Strain %)**
$Cu_{60}Ni_5Mn_{15}Zn_{17.5}Al_{2.5}$	86-90	139-153	210	495	42
$Cu_{60}Ni_5Mn_{12.5}Zn_{20}Al_{2.5}$	83-89	96-100	169	424	56
$Cu_{57.5}Ni_5Mn_{17.5}Zn_{17.5}Al_{2.5}$	111-114	85-99	165	413	61
$Cu_{57.5}Ni_5Mn_{15}Zn_{20}Al_{2.5}$	94-103	81-92	160	394	64
$Cu_{55}Ni_5Mn_{20}Zn_{17.5}Al_{2.5}$	135-137	117-127	229	533	38
$Cu_{55}Ni_5Mn_{17.5}Zn_{20}Al_{2.5}$	111-116	100-108	175	409	63
$Cu_{52.5}Ni_5Mn_{20}Zn_{20}Al_{2.5}$	133-137	122-128	225	520	39
$Cu_{52.5}Ni_5Mn_{22.5}Zn_{17.5}Al_{2.5}$	142-166	116-123	208	520	48
$Cu_{52.5}Ni_5Mn_{25}Zn_{15}Al_{2.5}$	120-126	110-132	174	455	55
$Cu_{52.5}Ni_5Mn_{27.5}Zn_{12.5}Al_{2.5}$	105-127	97-110	165	458	59
$Cu_{50}Ni_5Mn_{30}Zn_{12.5}Al_{2.5}$	122-139	115-124	190	519	42
$Cu_{50}Ni_5Mn_{27.5}Zn_{15}Al_{2.5}$	129-139	119-141	192	527	41
$Cu_{47.5}Ni_5Mn_{30}Zn_{15}Al_{2.5}$	150-166	150-159	217	572	31
$Cu_{47.5}Ni_5Mn_{32.5}Zn_{12.5}Al_{2.5}$	130-137	134-142	189	536	41
$Cu_{45}Ni_5Mn_{32.5}Zn_{15}Al_{2.5}$	135-150	137-144	253	629	29
$Cu_{45}Ni_5Mn_{35}Zn_{12.5}Al_{2.5}$	130-140	111-117	191	519	47
$Cu_{59}Ni_3Mn_{15.5}Zn_{20}Al_{2.5}$	94-103	85-95	155	390	64

[0088] While the techniques described above in this example may be suitable for laboratory scale alloy production, those skilled in the art will understand that other methods may be used, particularly for industrial scale alloy production. For example, the alloys may be produced by large scale melting of all alloy constituents in an induction or resistance heated furnace until completely molten. This may include alloying higher melting-point constituents first while progressively lowering the melt temperature as lower melting-point constituents are added to avoid off-gassing of zinc and/or manganese. Additives, fluxes or coke may be used to reduce oxygen, hydrogen and other impurities in the melt and to protect the melt surface from further oxidation or degradation. The melt may then be cast as ingots. The ingots may then be cast or pressure die-cast directly into products. The alloy could also be continuously cast through a water-cooled graphite or copper or other metal nozzle in a fixed cross section to produce plate, bar, rod or hollow-section products. Alternatively, the melt may be twin-roll strip cast into sheet products. Products may be subsequently homogenised at temperatures above 700 °C, hot rolled, hot-extruded, hot-drawn or forged to their required shape at temperatures above 600 °C. Products may be cold-worked (rolled, extruded, forged or drawn) and tempered or hardened by low-temperature annealing.

[0089] Although the invention has been described with reference to specific embodiments, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Claims

1. An alloy comprising or consisting of:
40 to 62.5 atomic percent copper;
5 to 40 atomic percent manganese;
up to 24 atomic percent nickel;
5 to 24 atomic percent zinc; and
1 to 15 atomic percent aluminium.

2. The alloy of claim 1 comprising or consisting of:
40 to 62.5 atomic percent copper;
5 to 40 atomic percent manganese;
1 to 24 atomic percent nickel;
5 to 24 atomic percent zinc; and
1 to 15 atomic percent aluminium.

3. The alloy of claim 1 or claim 2 comprising or consisting of:
40 to 62.5 atomic percent copper;
8 to 40 atomic percent manganese;
1 to 24 atomic percent nickel;
5 to 24 atomic percent zinc; and
1 to 15 atomic percent aluminium.

4. The alloy of any one of claims 1 to 3 comprising or consisting of:
40 to 62.5 atomic percent copper;
8 to 40 atomic percent manganese;
1 to 8 atomic percent nickel;
5 to 24 atomic percent zinc; and
1 to 15 atomic percent aluminium.

5. The alloy of any one of claims 1 to 4 comprising or consisting of:
40 to 62.5 atomic percent copper;
8 to 40 atomic percent manganese;
1 to 8 atomic percent nickel;
5 to 24 atomic percent zinc; and
1 to 8 atomic percent aluminium.

6. The alloy of any one of claims 1 to 5 comprising or consisting of:
40 to 62.5 atomic percent copper;
8 to 40 atomic percent manganese;
1 to 8 atomic percent nickel;
5 to 24 atomic percent zinc; and
1 to 5 atomic percent aluminium.

7. The alloy of any one of claims 1 to 6 comprising or consisting of:
45 to 62.5 atomic percent copper;
8 to 40 atomic percent manganese;
1 to 8 atomic percent nickel;
5 to 24 atomic percent zinc; and
1 to 5 atomic percent aluminium.

8. The alloy of any one of claims 1 to 7 comprising or consisting of:
45 to 60 atomic percent copper;
8 to 40 atomic percent manganese;
1 to 8 atomic percent nickel;
5 to 24 atomic percent zinc; and
1 to 5 atomic percent aluminium.

9. The alloy of any one of claims 1 to 8 comprising or consisting of:
45 to 60 atomic percent copper;
12.5 to 40 atomic percent manganese;
1 to 8 atomic percent nickel;
5 to 24 atomic percent zinc; and
1 to 5 atomic percent aluminium.

10. The alloy of any one of claims 1 to 9 comprising or consisting of:
45 to 60 atomic percent copper;
12.5 to 35 atomic percent manganese;
1 to 8 atomic percent nickel;
5 to 24 atomic percent zinc; and
1 to 5 atomic percent aluminium.

11. The alloy of any one of claims 1 to 10 comprising or consisting of:
45 to 60 atomic percent copper;

12.5 to 35 atomic percent manganese;
1 to 7 atomic percent nickel;
5 to 24 atomic percent zinc; and
1 to 5 atomic percent aluminium.

12. The alloy of any one of claims 1 to 11 comprising or consisting of:
45 to 60 atomic percent copper;
12.5 to 35 atomic percent manganese;
1 to 7 atomic percent nickel;
7.5 to 24 atomic percent zinc; and
1 to 5 atomic percent aluminium.

13. The alloy of any one of claims 1 to 12 comprising or consisting of:
45 to 60 atomic percent copper;
12.5 to 35 atomic percent manganese;
1 to 7 atomic percent nickel;
7.5 to 20 atomic percent zinc; and
1 to 5 atomic percent aluminium.

14. The alloy of any one of claims 1 to 13 comprising or consisting of:
45 to 60 atomic percent copper;
12.5 to 35 atomic percent manganese;
3 to 5 atomic percent nickel;
12.5 to 20 atomic percent zinc; and
1 to 3 atomic percent aluminium.

15. The alloy of any one of claims 1 to 13 comprising or consisting of:
50 to 60 atomic percent copper;
12.5 to 35 atomic percent manganese;
1 to 7 atomic percent nickel;
7.5 to 20 atomic percent zinc; and
1 to 5 atomic percent aluminium.

16. The alloy of claim 15 comprising or consisting of:
50 to 60 atomic percent copper;
15 to 35 atomic percent manganese;
1 to 7 atomic percent nickel;

7.5 to 20 atomic percent zinc; and
1 to 5 atomic percent aluminium.

17. The alloy of claim 15 or claim 16 comprising or consisting of:
50 to 60 atomic percent copper;
15 to 22.5 atomic percent manganese;
1 to 7 atomic percent nickel;
7.5 to 20 atomic percent zinc; and
1 to 5 atomic percent aluminium.

18. The alloy of any one of claims 15 to 17 comprising or consisting of:
50 to 60 atomic percent copper;
15 to 22.5 atomic percent manganese;
1 to 5 atomic percent nickel;
7.5 to 20 atomic percent zinc; and
1 to 5 atomic percent aluminium.

19. The alloy of any one of claims 15 to 18 comprising or consisting of:
50 to 60 atomic percent copper;
15 to 22.5 atomic percent manganese;
1 to 5 atomic percent nickel;
15 to 20 atomic percent zinc; and
1 to 5 atomic percent aluminium.

20. The alloy of any one of claims 15 to 19 comprising or consisting of:
50 to 60 atomic percent copper;
15 to 22.5 atomic percent manganese;
1 to 5 atomic percent nickel;
15 to 20 atomic percent zinc; and
1 to 3 atomic percent aluminium.

21. The alloy of any one of claims 1 to 11 comprising or consisting of:
50 to 60 atomic percent copper;
22.5 to 35 atomic percent manganese;
1 to 5 atomic percent nickel;
5 to 12.5 atomic percent zinc; and
1 to 3 atomic percent aluminium.

22. The alloy of claim 21 comprising or consisting of:
 50 to 60 atomic percent copper;
 22.5 to 35 atomic percent manganese;
 1 to 5 atomic percent nickel;
 7.5 to 12.5 atomic percent zinc; and
 1 to 3 atomic percent aluminium.

23. The alloy of claim 1 comprising or consisting of:
 40 to 62.5 atomic percent copper;
 17 to 35 atomic percent manganese;
 1 to 7 atomic percent nickel;
 10 to 24 atomic percent zinc; and
 1 to 5 atomic percent aluminium.

24. The alloy of claim 23 comprising or consisting of:
 45 to 60 atomic percent copper;
 17 to 35 atomic percent manganese;
 1 to 5 atomic percent nickel;
 10 to 20 atomic percent zinc; and
 1 to 5 atomic percent aluminium.

25. The alloy of claim 24 comprising or consisting of:
 50 to 60 atomic percent copper;
 17 to 35 atomic percent manganese;
 1 to 5 atomic percent nickel;
 10 to 20 atomic percent zinc; and
 1 to 5 atomic percent aluminium.

26. The alloy of any one of claims 1 to 25 wherein:

(3 x atomic percent of aluminium) + atomic percent of zinc + (0.2 x atomic percent of manganese) is between 22.5% and 32.5%.

27. The alloy of any one of claims 1 to 26 wherein the atomic percent ratio of copper:nickel is at least 9.

28. The alloy of any one of claims 1 to 27 wherein the alloy has a tensile strain to failure of between about 40% and 65%.

29. The alloy of any one of claims 1 to 28 wherein the alloy has an ultimate tensile strength of between about 390 MPa and 575 MPa.

30. The alloy of any one of claims 1 to 29 wherein the alloy has an as-cast hardness (H_V) of between about 80 and 170.

31. An alloy comprising or consisting of:

40 to 62.5 atomic percent copper;

5 to 40 atomic percent manganese;

up to 24 atomic percent nickel;

5 to 24 atomic percent zinc;

1 to 15 atomic percent aluminium;

up to 20 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium; and

up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

32. The alloy of claim 31 comprising or consisting of:

40 to 62.5 atomic percent copper;

5 to 40 atomic percent manganese;

up to 24 atomic percent nickel;

5 to 24 atomic percent zinc;

1 to 15 atomic percent aluminium;

up to 12 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium; and

up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

33. The alloy of claim 31 or claim 32 comprising or consisting of:

40 to 62.5 atomic percent copper;

5 to 40 atomic percent manganese;

up to 24 atomic percent nickel;

5 to 24 atomic percent zinc;

1 to 15 atomic percent aluminium;

up to 12 atomic percent of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon or magnesium; and

up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

34. The alloy of any one of claims 31 to 33 comprising or consisting of:
40 to 62.5 atomic percent copper;
5 to 40 atomic percent manganese;
up to 24 atomic percent nickel;
5 to 24 atomic percent zinc;
1 to 15 atomic percent aluminium;
up to 7 atomic percent chromium;
up to 8 atomic percent lead;
up to 8 atomic percent bismuth;
up to 8 atomic percent cobalt;
up to 12 atomic percent iron;
up to 8 atomic percent carbon;
up to 8 atomic percent tin;
up to 8 atomic percent silicon;
up to 2 atomic percent magnesium;
up to 0.5 atomic percent arsenic;
up to 0.5 atomic percent phosphorus;
up to 0.5 atomic percent sulphur; and
up to 0.5 atomic percent antimony.

35. The alloy of any one of claims 31 to 34 comprising or consisting of:
40 to 62.5 atomic percent copper;
5 to 40 atomic percent manganese;
up to 24 atomic percent nickel;
5 to 24 atomic percent zinc;
1 to 15 atomic percent aluminium;
up to 5 atomic percent chromium;
up to 5 atomic percent lead;
up to 2 atomic percent bismuth;
up to 8 atomic percent cobalt;
up to 12 atomic percent iron;
up to 4 atomic percent carbon;

up to 2 atomic percent tin;
up to 8 atomic percent silicon;
up to 2 atomic percent magnesium;
up to 0.3 atomic percent arsenic;
up to 0.3 atomic percent phosphorus;
up to 0.3 atomic percent sulphur; and
up to 0.3 atomic percent antimony.

36. The alloy of any one of claims 31 to 35 comprising or consisting essentially of:
85 to 95 atomic percent copper, manganese, nickel, zinc and aluminium; and
balance of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin and silicon.

37. The alloy of claim 31 comprising or consisting of:
40 to 62.5 atomic percent copper;
17 to 35 atomic percent manganese;
1 to 7 atomic percent nickel;
10 to 24 atomic percent zinc;
1 to 5 atomic percent aluminium;
up to 20 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium; and
up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

38. The alloy of claim 37 comprising or consisting of:
45 to 60 atomic percent copper;
17 to 35 atomic percent manganese;
1 to 5 atomic percent nickel;
10 to 20 atomic percent zinc;
1 to 5 atomic percent aluminium;
up to 20 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium; and
up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

39. The alloy of claim 38 comprising or consisting of:
50 to 60 atomic percent copper;

17 to 35 atomic percent manganese;

1 to 5 atomic percent nickel;

10 to 20 atomic percent zinc;

1 to 5 atomic percent aluminium;

up to 20 atomic percent of one or more elements selected from the group consisting of chromium, lead, bismuth, cobalt, iron, carbon, tin, silicon and magnesium; and

up to 1 atomic percent of one or more elements selected from the group consisting of arsenic, phosphorus, sulphur and antimony.

40. The alloy of any one of claims 31 to 39 wherein:

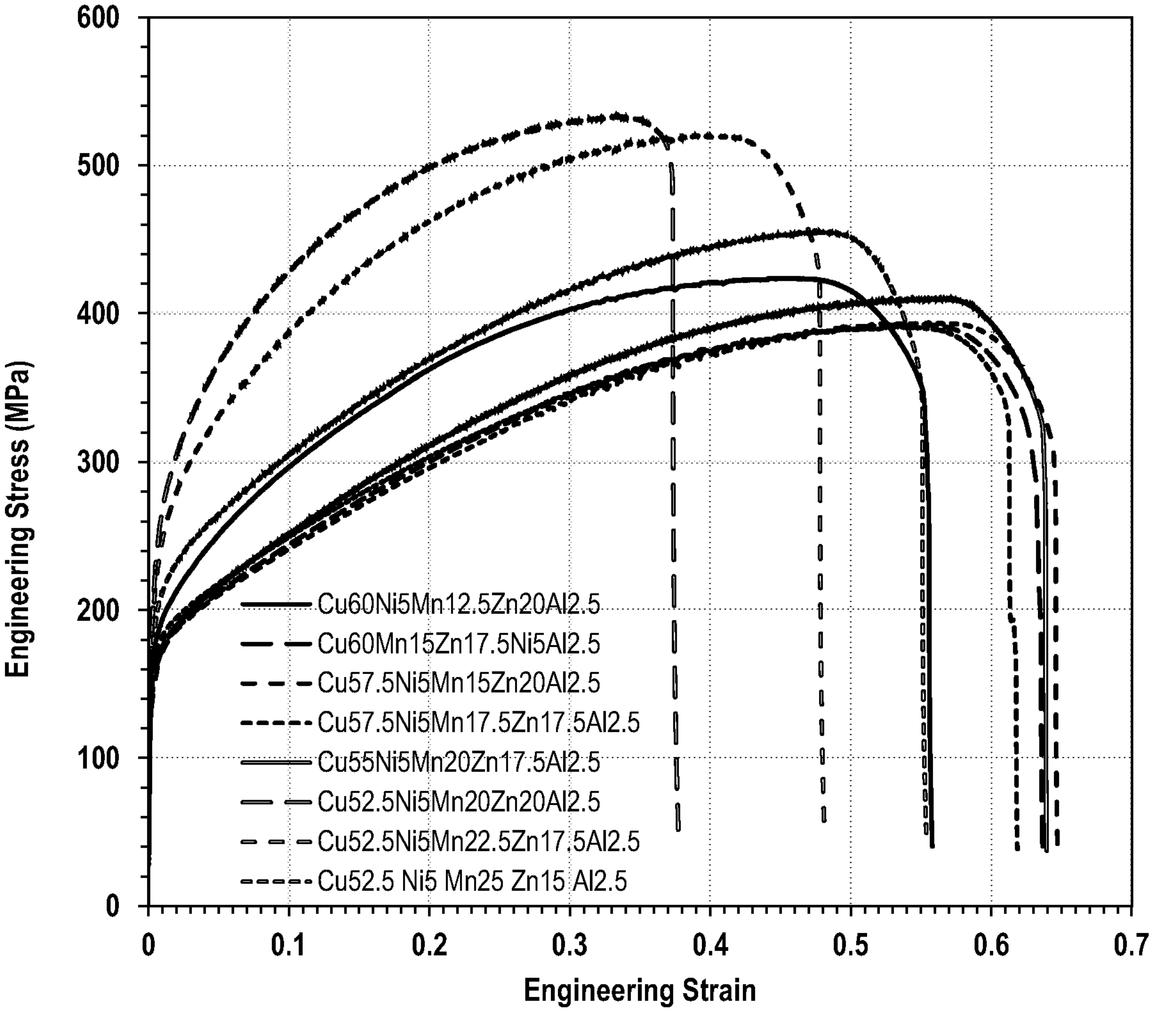
(3 x atomic percent of aluminium) + atomic percent of zinc + (0.2 x atomic percent of manganese) is between 22.5% and 32.5%.

41. The alloy of any one of claims 31 to 40 wherein the atomic percent ratio of copper:nickel is at least 9.

42. The alloy of any one of claims 31 to 41 wherein the alloy has a tensile strain to failure of between about 30% and 65%.

43. The alloy of any one of claims 31 to 42 wherein the alloy has an ultimate tensile strength of between about 390 MPa and 575 MPa.

44. The alloy of any one of claims 31 to 43 wherein the alloy has an as-cast hardness (H_V) of between about 80 and 170.


600
500
400
300
200
100
0
Engineering Stress (MPa)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Engineering Strain
Cu60Ni5Mn12.5Zn20Al2.5
Cu60Mn15Zn17.5Ni5Al2.5
Cu57.5Ni5Mn15Zn20Al2.5
Cu57.5Ni5Mn17.5Zn17.5Al2.5
Cu55Ni5Mn20Zn17.5Al2.5
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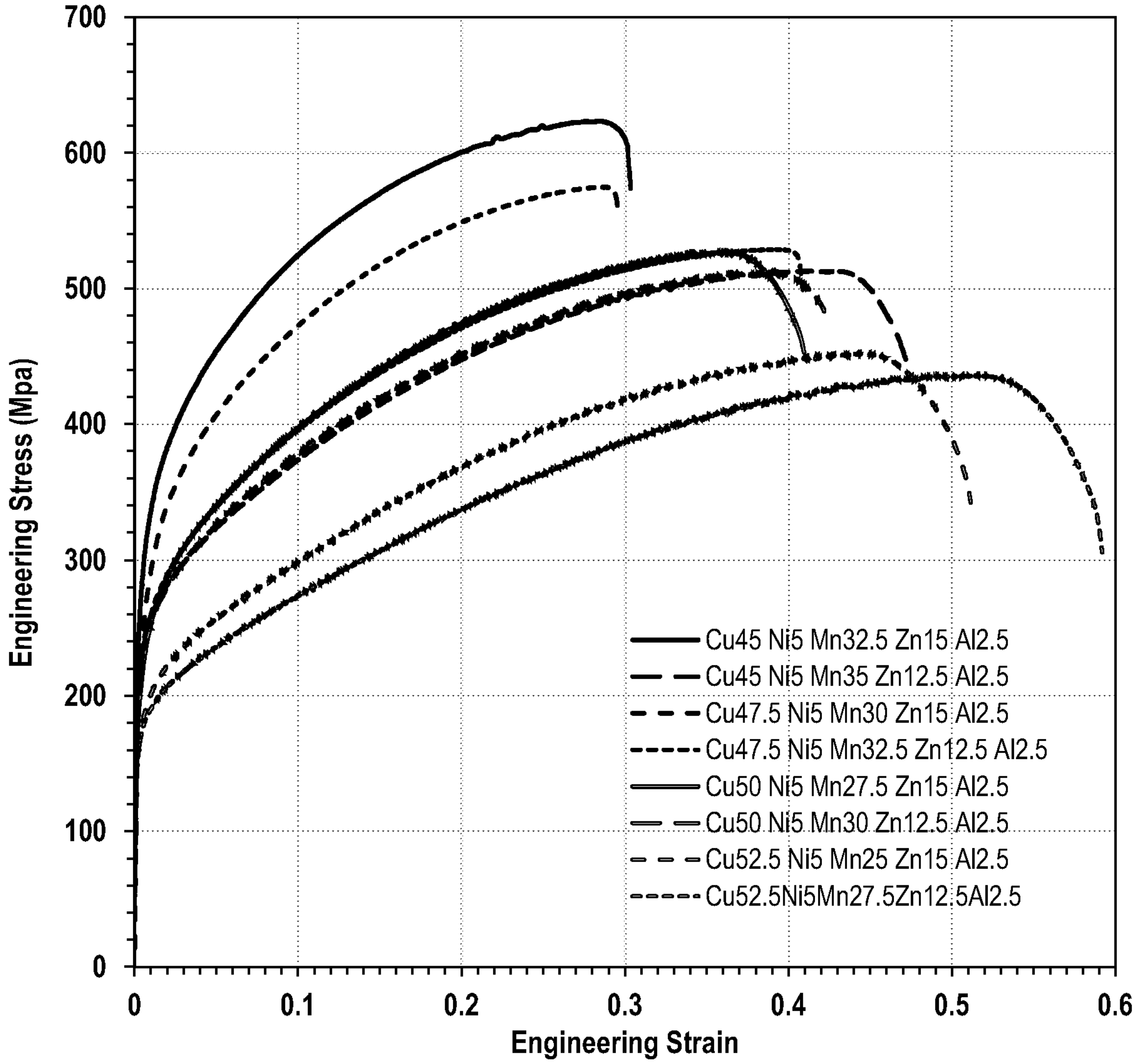
Cu52.5Ni5Mn22.5Zn17.5Al2.5
Cu52.5 Ni5 Mn25 Zn15 Al2.5

FIGURE 1


700
600
500
400
300
200
100
0
Engineering Stress (Mpa)
0
0.1
0.2
0.3
0.4
0.5
0.6
Engineering Strain
Cu45 Ni5 Mn32.5 Zn15 Al2.5
Cu45 Ni5 Mn35 Zn12.5 Al2.5
Cu47.5 Ni5 Mn30 Zn15 Al2.5
Cu47.5 Ni5 Mn32.5 Zn12.5 Al2.5
Cu50 Ni5 Mn27.5 Zn15 Al2.5
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Cu52.5 Ni5 Mn25 Zn15 Al2.5
Cu52.5Ni5Mn27.5Zn12.5Al2.5

FIGURE 2

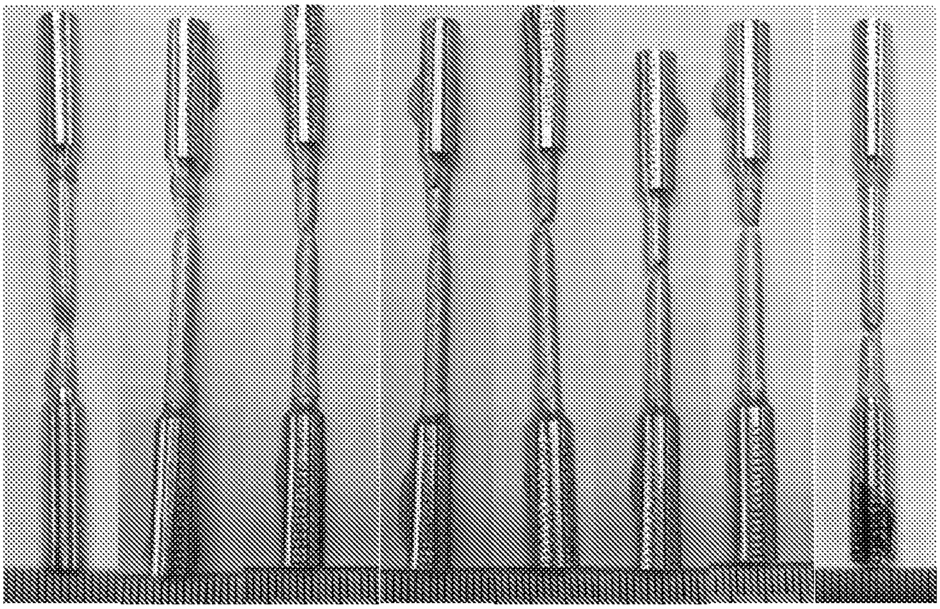

FIGURE 3

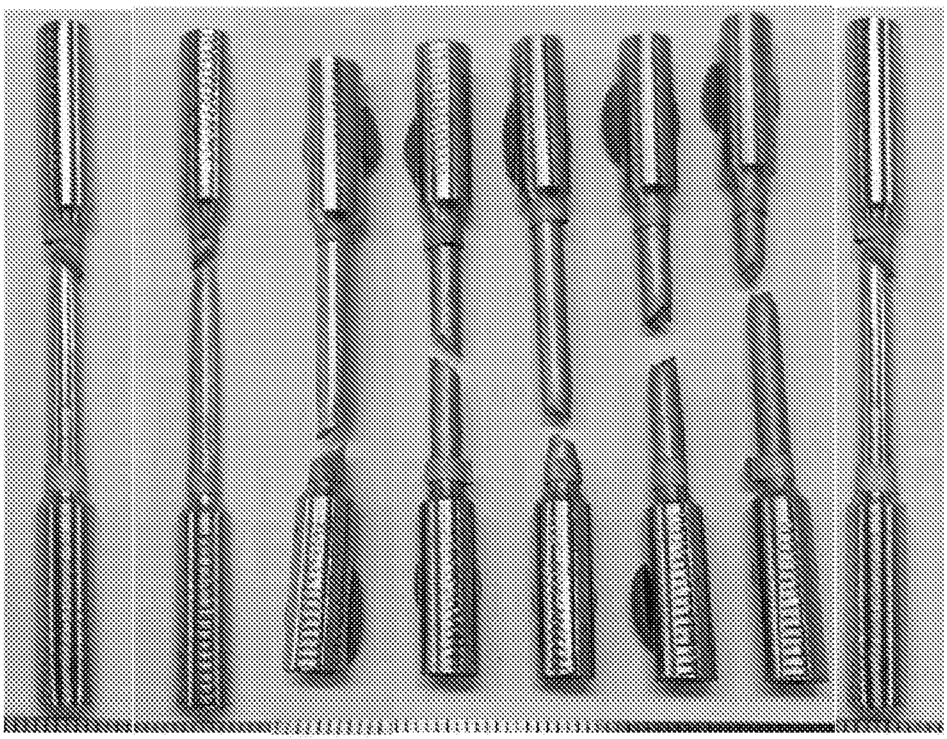

FIGURE 4

INTERNATIONAL SEARCH REPORT	International application No. **PCT/AU2020/051062**

A. CLASSIFICATION OF SUBJECT MATTER

C22C 9/05 (2006.01) C22C 9/04 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases: Google patents, Registry, CAPlus, NPS (numerical property searching cluster)

IPC/CPC: C22C9/00, C22C9/04, C22C9/05

Keywords: alloy, copper, manganese, nickel, zinc, aluminium, tensile strength, ultimate strength, atomic, composition and similar

Applicant/Inventor: Advanced Alloy Holdings, Kevin James Laws, Peter Tyrrell Nicholson, Patrick Lars Joseph Conway, Lori Cheryl Bassman, Warren Richard McKenzie

Applicant/Inventor search also conducted in IP Australia internal databases.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 November 2020	25 November 2020

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	CN 109385610 A (TAICHI MATERIAL TECH CO LTD) 26 February 2019 & English Translation available from Espacenet Paragraph 9	1-44
X	US 4587097 A (RABINKIN et al.) 06 May 1986 Column 4, lines 8-13 and table 1	1-44
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X	JP 2013120411 A (KOBE STEEL LTD) 17 June 2013 Abstract	1-44
X	KANSKY, K.E. et al., 'Quaternary Diffusion in the Cu-Ni-Zn-Mn System at 775°C', Metallurgical Transactions A, 1985, Vol. 16A, pages 1123-1132 Page 1124, table 1	1-44

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2020/051062**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
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		CN 103151090 B	01 Jun 2016

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2020/051062**

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Patent Document/s Cited in Search Report		**Patent Family Member/s**	
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		JP 5613143 B2	22 Oct 2014
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		KR 101406581 B1	11 Jun 2014
		TW 201335390 A	01 Sep 2013
		TW I537400 B	11 Jun 2016
		US 2013140066 A1	06 Jun 2013

End of Annex

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