Claims

1. A lead-free solder alloy consisting of:

from 2.5 to 4 wt.% silver;

from 2.8 to 4.2 wt.% bismuth;

from 1 to 7 wt.% antimony;

from 0.4 to 0.8 wt.% copper;

from 0.01 to 0.3 wt.% nickel;

one of:

from 0.005 to 0.05 wt.% titanium,

from 0.001 to 0.02 wt.% germanium,

from 0.001 to 0.05 wt.% rare earths, selected from cerium and neodynium,

from 0.005 to 0.08 wt.% silicon,

from 0.003 to 0.015 wt.% manganese, and

the balance tin together with any unavoidable impurities, wherein:

the wt.% of antimony is greater than the wt.% of bismuth; and

the sum of the wt.% of antimony and the wt.% of bismuth greater than or equal to 6.5.

2. The solder alloy of claim 1, comprising from 2.8 to 4 wt.% bismuth, more preferably fr om 3 to 4 wt.% bismuth.

3. The solder alloy of claim 1 or claim 2, comprising from 1.0 to 6.5 wt.% antimony, pref erably from 2 to 6 wt.% antimony, more preferably from 3 to 6 wt.% antimony, even more pref erably from 3.1 to 6 wt.% antimony, still even more preferably from 3.2 to 6 wt.% antimony.

4. The solder alloy of any preceding claim, comprising from 0.02 to 0.2 wt.% nickel.

5. The solder alloy of any preceding claim, comprising from 0.007 to 0.05 wt.% titanium.

6. The solder alloy of any preceding claim, comprising from 0.02 to 0.08 wt.% silicon.

7. The solder alloy of any preceding claim consisting of:

from 2.5 to 4 wt.% silver;

from 2.8 to 4.2 wt.% bismuth;

from 3.2 to 6.2 wt.% antimony;

from 0.4 to 0.8 wt.% copper;

from 0.04 to 0.18 wt.% nickel;

one of:

from 0.007 to 0.05 wt.% titanium,

from 0.001 to 0.02 wt.% germanium, and

from 0.005 to 0.01 wt.% manganese; and

the balance tin together with any unavoidable impurities,

wherein:

the wt.% of antimony is greater than the wt.% of bismuth, and

the sum of the wt.% of antimony and the wt.% of bismuth is greater than or equal to 6.5.

8. The solder alloy of any preceding claim in the form of a bar, a stick, a solid or flux c ored wire, a foil or strip, a film, a preform, a powder or paste (powder plus flux blend), solder spheres for use in ball grid array joints, a pre-formed solder piece or a reflowed or solidified s older joint, pre-applied on any solderable material such as a copper ribbon for photovoltaic app lications or a printed circuit board of any type.

9. A soldered joint comprising the solder alloy of any of claims 1 to 8.

10. A solder paste comprising:

the solder alloy of any of claims 1 to 8, and

a solder flux.

11. A method of forming a solder joint comprising:

(i) providing two or more work pieces to be joined;

(ii) providing a solder alloy as defined in any of claims 1 to 8 or the solder paste of c laim 10; and

(iii) heating the solder alloy or solder paste in the vicinity of the work pieces to be joi ned.

12. Use of a solder alloy of any of claims 1 to 8 or the solder paste of claim 10 in a soldering method, preferably wherein the soldering method is selected from wave soldering, Surface Mount Technology (SMT) soldering, die attach soldering, thermal interface soldering, hand soldering, laser and RF induction soldering, soldering to a solar module, soldering of level 2 LED package-board, solder dipping, and rework soldering.

13. A method of manufacturing the solder alloy of any of claims 1 to 8, the method comprising:

providing the recited elements, and

melting the recited elements,

wherein the recited elements may be provided in the form of individual elements and/or in the form of one or more alloys containing one of more of the recited elements.