Audio test:

Nonferrous Metals and Alloys (phase diagrams and phase transformations)

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Nonferrous metal and alloys

1

Aluminium

Magnesium

Copper

2

High temperature service

- Titanium
- Nickel
- Refractory alloys (molybdenum, niobium,tungsten, tantalum)
- Superalloys

3

Low melting point alloy

- Lead
- Zinc
- Tin

4

Beryllium

Zirconium

5

Precious metal

- gold
- silver
- platinum

6 Shape-memory alloys

7 Amorphous Alloys (Metallic Glasses)

8 Metal Foams

9 Nanomaterials

Copper alloys

Copper is one of the earliest metals to be used by humans (8500 BC, northern Iraq: Selwyn 2004[1]). **Copper alloys are often divided in four large families: pure Cu, bronzes (Cu/Sn), brasses (Cu/Zn) and quaternary alloys (Cu/Sn/Zn/Pb).** The oldest Cu alloys contained As or Sb. Zn, Pb or As are often secondary elements in bronzes whereas brasses can contain Sn or Pb. Cu/Ni, Cu/Zn/Ni and Cu/Al alloys have been developed in recent times (19th century).

https://micorr.org/scientific-bases/

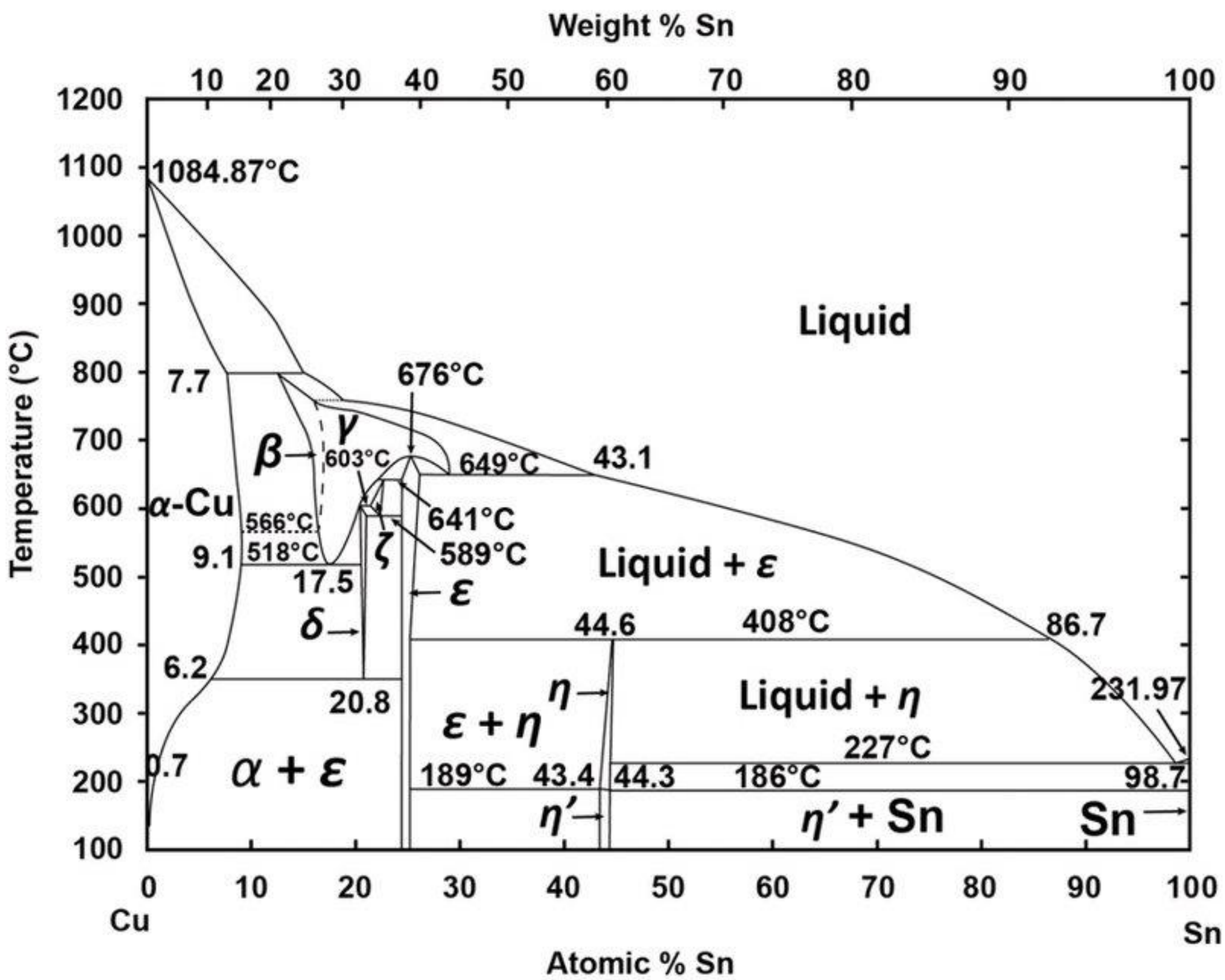
Bronze (Cu+Sn)

Bronze is a 80+% copper alloy and 90+% copper&tin alloy (commonly 12–12.5% tin) with often the addition of other metals, such as aluminium, manganese, nickel or zinc, and sometimes non-metals or metalloids such as arsenic, phosphorus or silicon. These additions produce a range of alloys that may be harder than copper alone, or have other useful properties, such as stiffness, ductility, or machinability.

Typically, pure annealed copper shows a hardness of HV1 40-50. Small additions of Sn or Sb increase this slightly, to HV1 70-100. Cast tin bronzes or alloys with final cold working show the highest hardness values (HV1 between 120 and 180).

https://en.wikipedia.org/wiki/Bronze

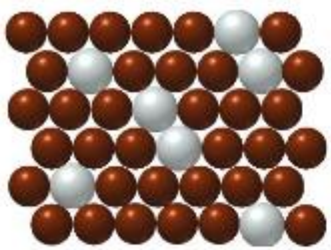
Cu-Sn Phase diagram



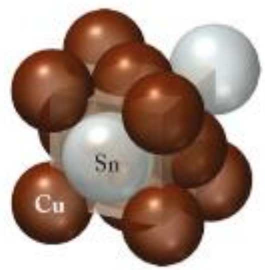
As cast, bronzes are categorized as belonging to the Cu α phase only if their Sn content does not exceed 4 mass% (Fig. 2). Above this value the alloys have an α (alpha) + δ (delta) microstructure. Depending on the Sn and secondary elements (Pb, As) content, as well as the heat treatments applied, bronzes are either constituted of Cu α phase or Cu α phase associated to the eutectoid α + δ phase. Pb (up to 7 mass% in the alloys studied) is insoluble in copper alloys and forms inclusions. Their fineness and regular distribution give high quality alloys.

Structures of phases

- **Substitutional alloy** – atoms of nonhost metal replace host atoms in the crystal lattice
- Bronze (substitutional, homogeneous):
  - Host = Cu; added element = Sn (up to 30%)

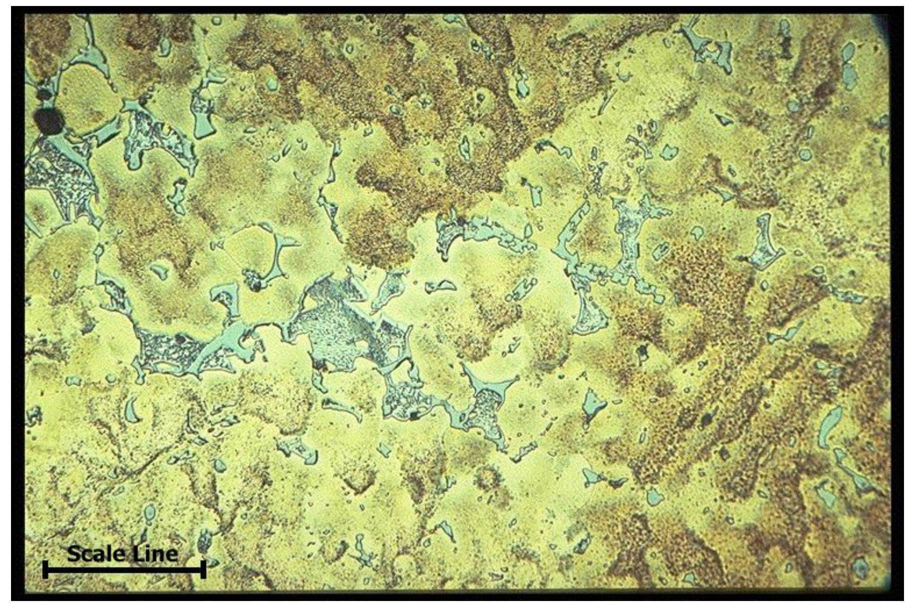


Close-packed Cu/Sn atoms



Possible unit cell for bronze

Bronze microstructure



Nominal Composition:
Cu 88-90, Sn 10-12, Pb .50, Zn .50, Ni .50, P .30, Sb .20, Fe .15, S .05, Al .005

https://www.copper.org/resources/properties/microstructure/cu_tin.html

Cu-Sn phase transformations

Brass Cu+(5-40)wt%Zn

Brass is an alloy of copper and zinc, in proportions which can be varied to achieve varying mechanical and electrical properties.[1] It is a substitutional alloy: atoms of the two constituents may replace each other within the same crystal structure.

https://en.wikipedia.org/wiki/Brass

Cu-Zn phase diagram

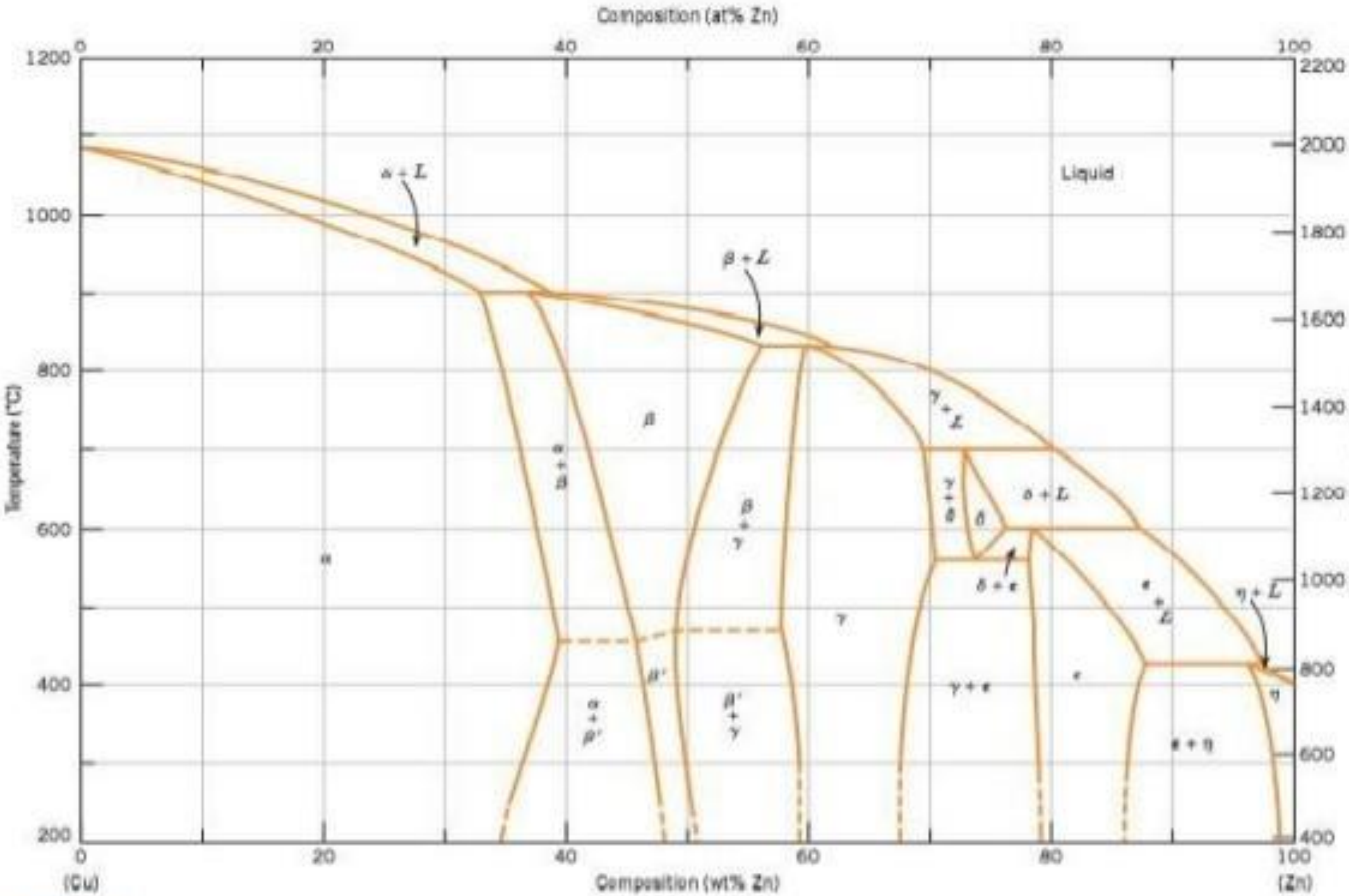
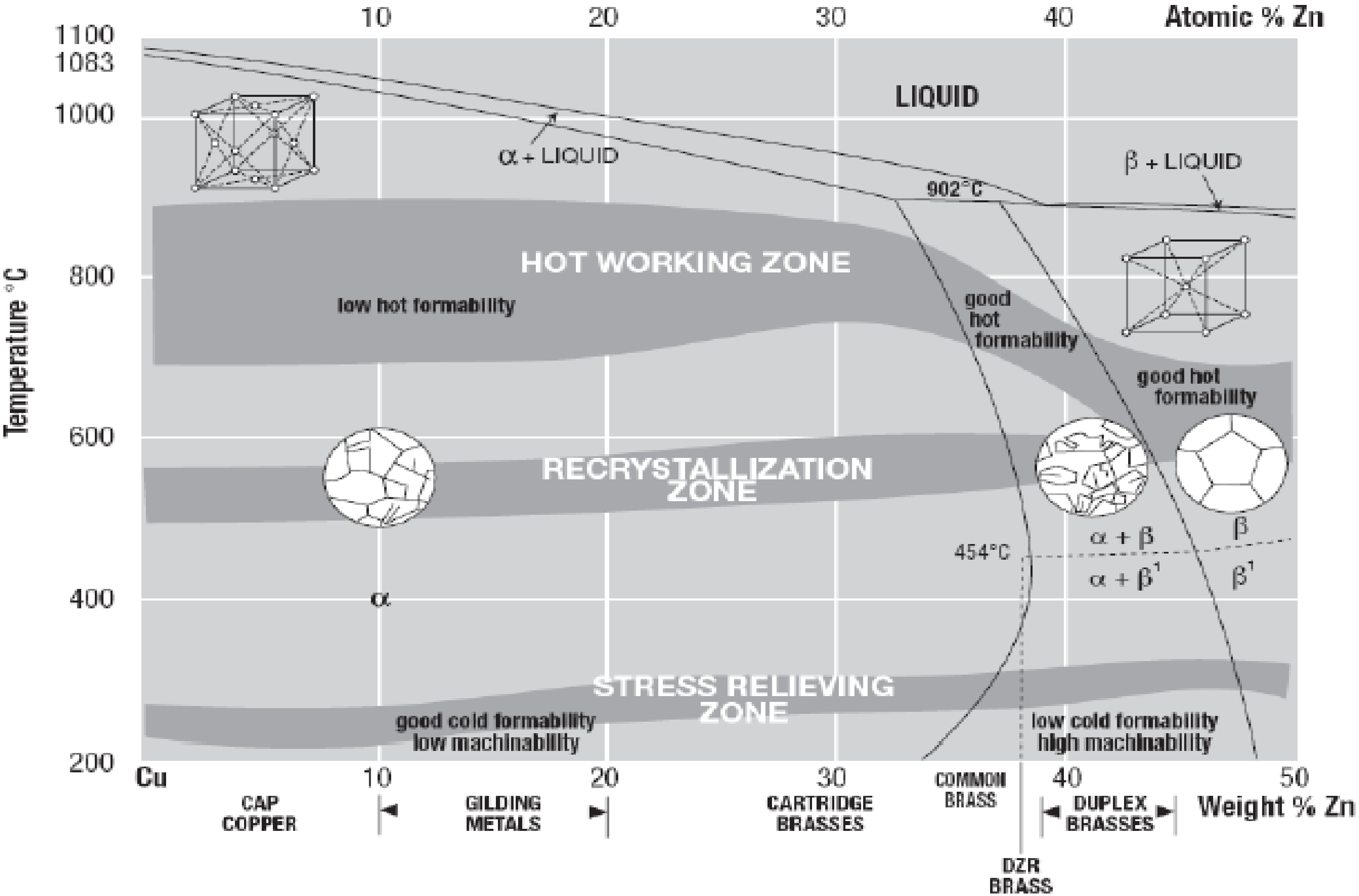
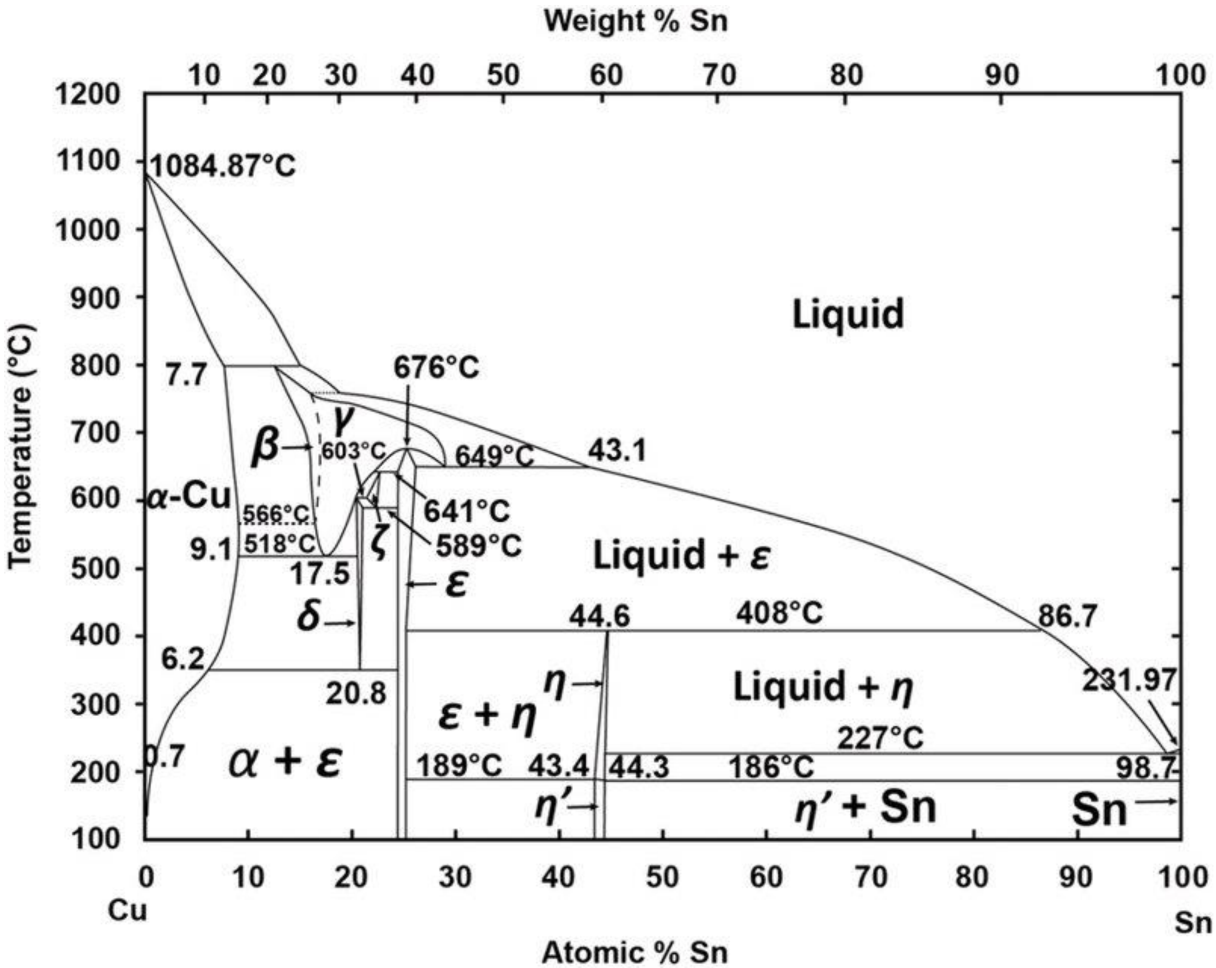


Figure 9.19 The copper–zinc phase diagram. [Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 2, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]



https://www.kme.com/fileadmin/DOWNLOADCENTER/COPPER%20DIVISON/4%20Industrial%20Rolled/4_Alloys/CuZn36.pdf

Cu-Sn phase diagram



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Hardering of Cu alloys

Copper alloys that are hardened through heat treatment are divided into two general types:

- those that are softened by high-temperature quenching and hardened by lower-temperature treatments (comprise pure Cu)
- and those that are hardened by quenching from high temperatures through martensitic-type reactions.

Alloys that harden during low-to-intermediate temperature treatments following solution quenching include

- precipitation hardening,
- spinodal-hardening
- and order-hardening types.

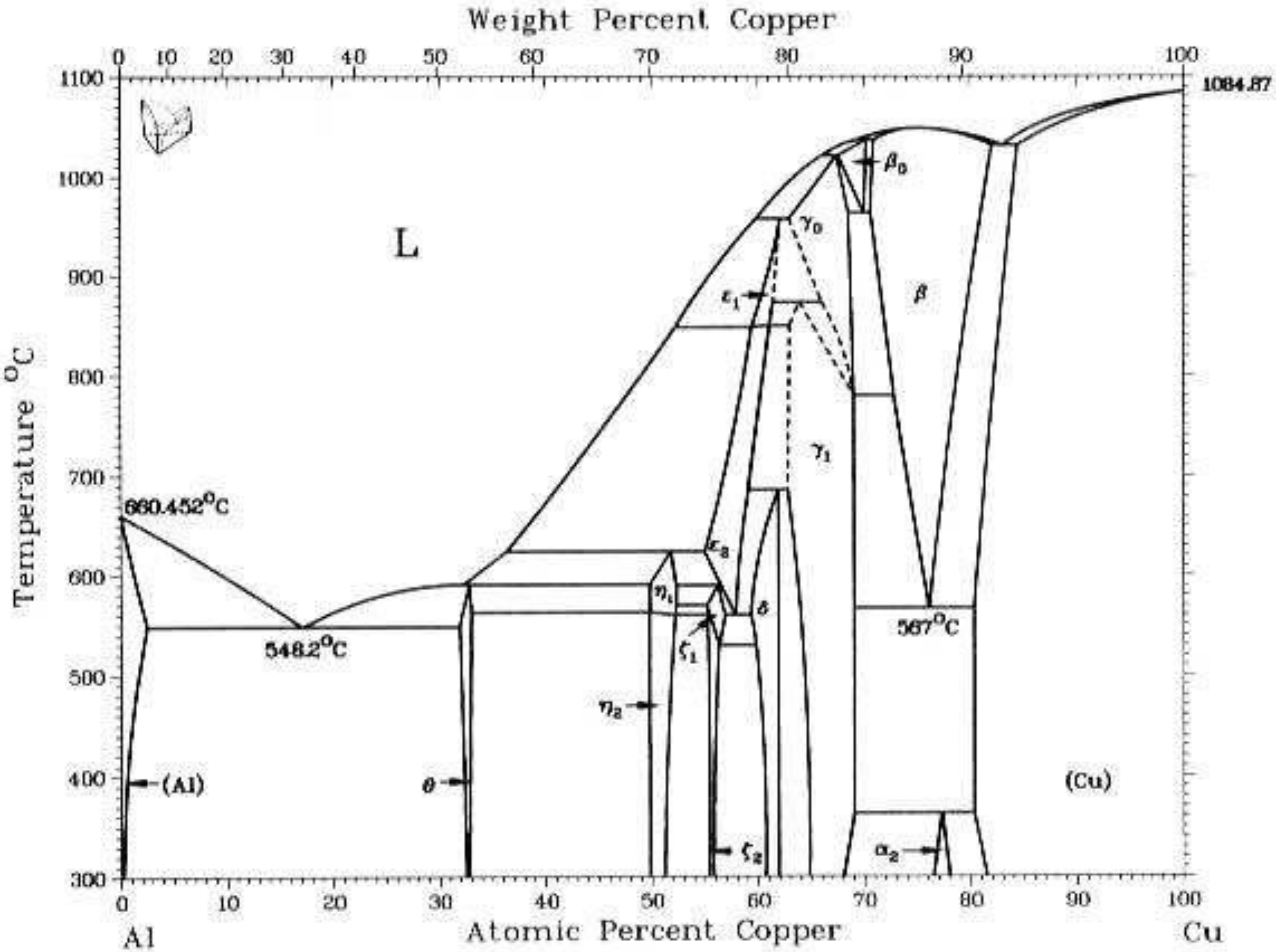
Quench-hardening alloys comprise aluminum bronzes, nickel-aluminum bronzes, and a few copper-zinc alloys.

http://www.totalmateria.com/Ar

Al alloys

Aluminium alloys were developed in the later part of the 19th century. Pure aluminium was first produced chemically at a very high cost. When electrolytic production was developed in 1886 the metal became cheap and very quickly found use as an important industrial material. **Aluminium alloys are divided in families: Al, Al/Cu, Al/Mn, Al/Si, Al/Mg, Al/Mg/Si, Al/Zn.** Some of them are cast, others are wrought alloys hardened by heat treatment (heat-treatable: Al/Cu, Al/Mg/Si and Al/Zn) or by the presence of the alloying elements (non-heat-treatable: Al, Al/Mn, Al/Mg) (Selwyn 2004[1]).

Al-Cu phase diagram



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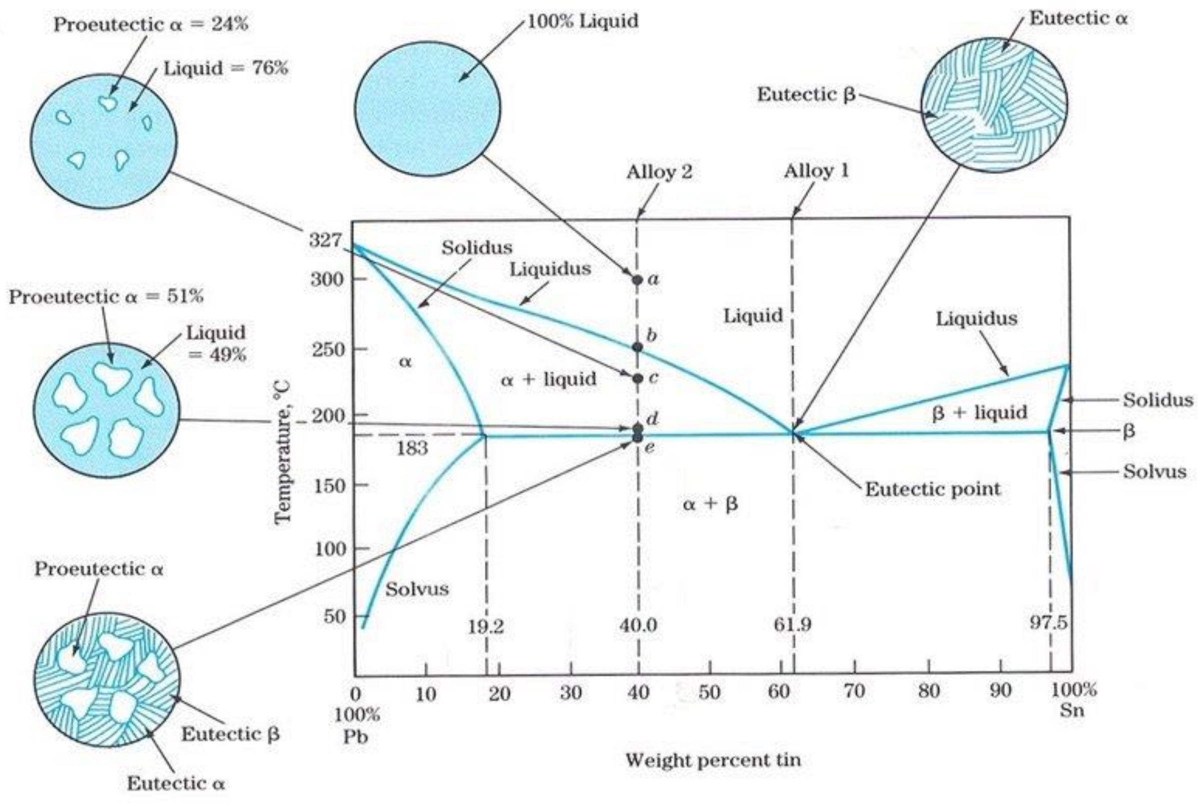
Sn-Pb alloy



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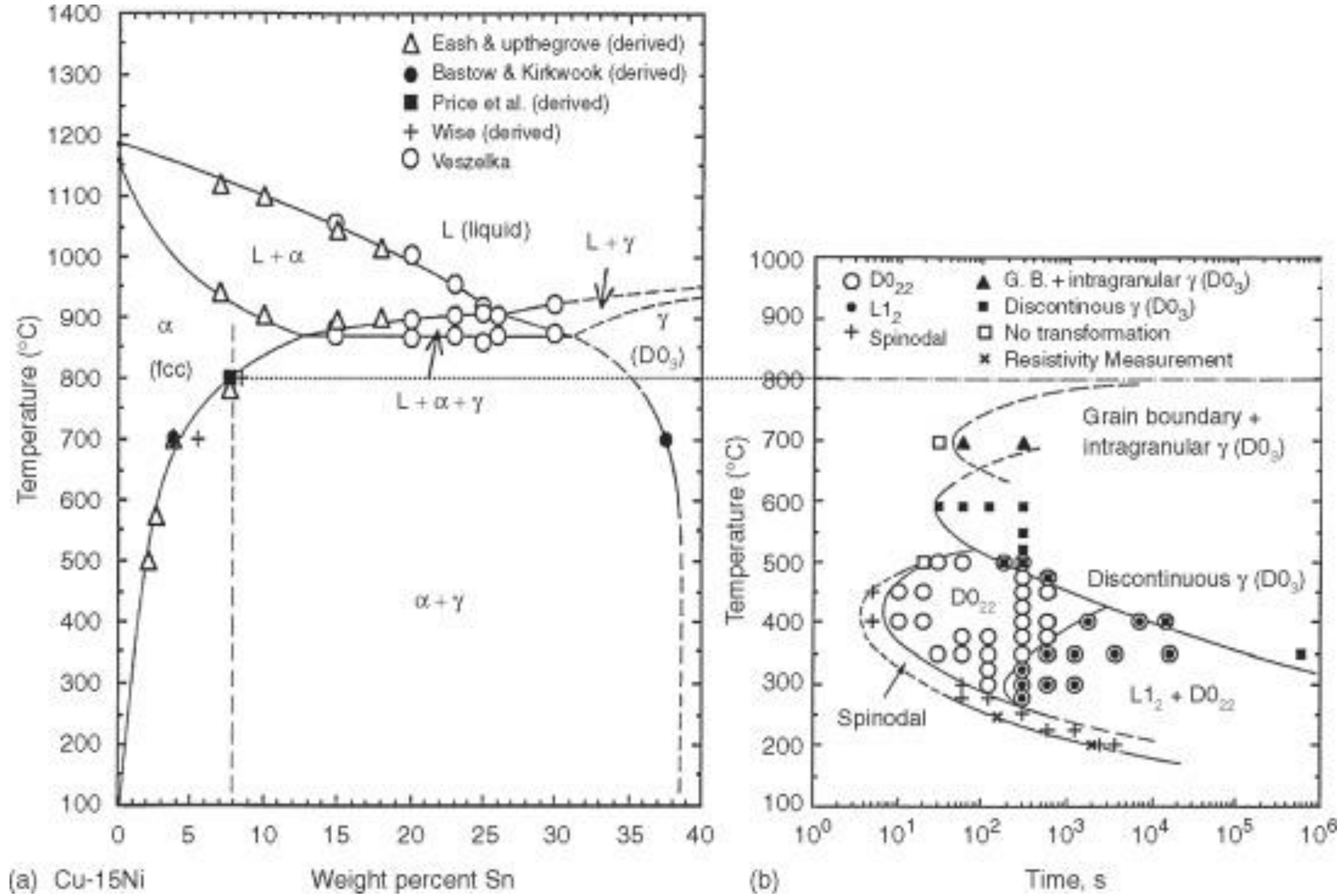
Phase diagram of Pb-Sn alloys with sketches of the microstructure observed depending on the composition of the alloy (from http://www.benbest.com/cryonics/lessons.html, accessed on January, 02 2018). The eutectic point corresponds to a mixture of elements having a unique chemical composition that solidifies at a lower temperature than any combination of the same constituent elements.



Eash & upthegrove (derived)
Bastow & Kirkwook (derived)
Price et al. (derived)
Wise (derived)
Veszelka
L (liquid)
L + α
L + γ
α
(fcc)
γ
(D0$_3$)
L + α + γ
α + γ
Temperature (°C)
Weight percent Sn
(a) Cu-15Ni
D0$_{22}$
L1$_2$
Spinodal
G. B. + intragranular γ (D0$_3$)
Discontinous γ (D0$_3$)
No transformation
Resistivity Measurement
Grain boundary + intragranular γ (D0$_3$)
Discontinuous γ (D0$_3$)
D0$_{22}$
L1$_2$ + D0$_{22}$
Spinodal
Temperature (°C)
Time, s
(b)

Discussion