

Introduction

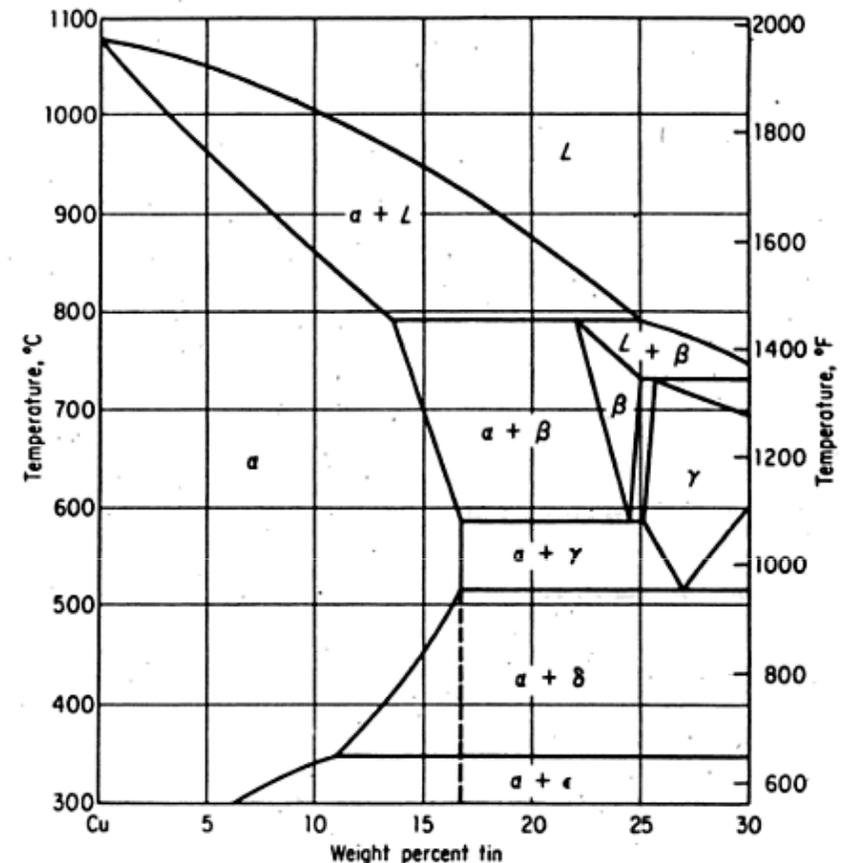
- ❑ The term bronze was originally applied to the copper-tin alloys; however, the term is now used for any copper alloy, with the exception of copper-zinc alloys, that contains up to approximately 12% of the principle alloying element.
- ❑ Bronze, as a name, conveys the idea of a higher-class alloy than brass, and it has been incorrectly applied to some alloys that are really special brasses
- ❑ Commercial bronzes are primarily alloys of copper and tin, aluminum, silicon, or beryllium. In addition, they may contain phosphorus, lead, zinc or nickel.

Tin Bronzes

- ❑ These are generally referred to as *phosphor bronzes* since phosphorous is always present as a deoxidizer in casting.
- ❑ The usual range of phosphorus content is between 0.01 and 0.5%, and of tin between 1 and 11 percent.
- ❑ The copper- rich portion of the copper-tin alloy system is shown in next page. The β phase forms as the result of a peritectic reaction at 798 °C. At 586 °C, the β phase undergoes a eutectoid reaction to form the eutectoid mixture ($\alpha+\gamma$). At 520°C, gamma (γ) also undergoes a eutectoid transformation to ($\alpha+\delta$).

Tin Bronzes

- ❑ The diagram also indicates the decomposition of the δ phase. This takes place by a eutectoid reaction at 350 °C forming $(\alpha+\epsilon)$. This reaction is so sluggish that in commercial alloys, the epsilon (ϵ) phase is nonexistent.
- ❑ The slope of the solvus line below 520 °C shows a considerable decrease in the solubility of tin in the α phase.
- ❑ The precipitation of the δ and ϵ phase due to this change in solubility is slow that, for practical purposes, the solvus line is indicated by the vertical dotted line below 520 °C.

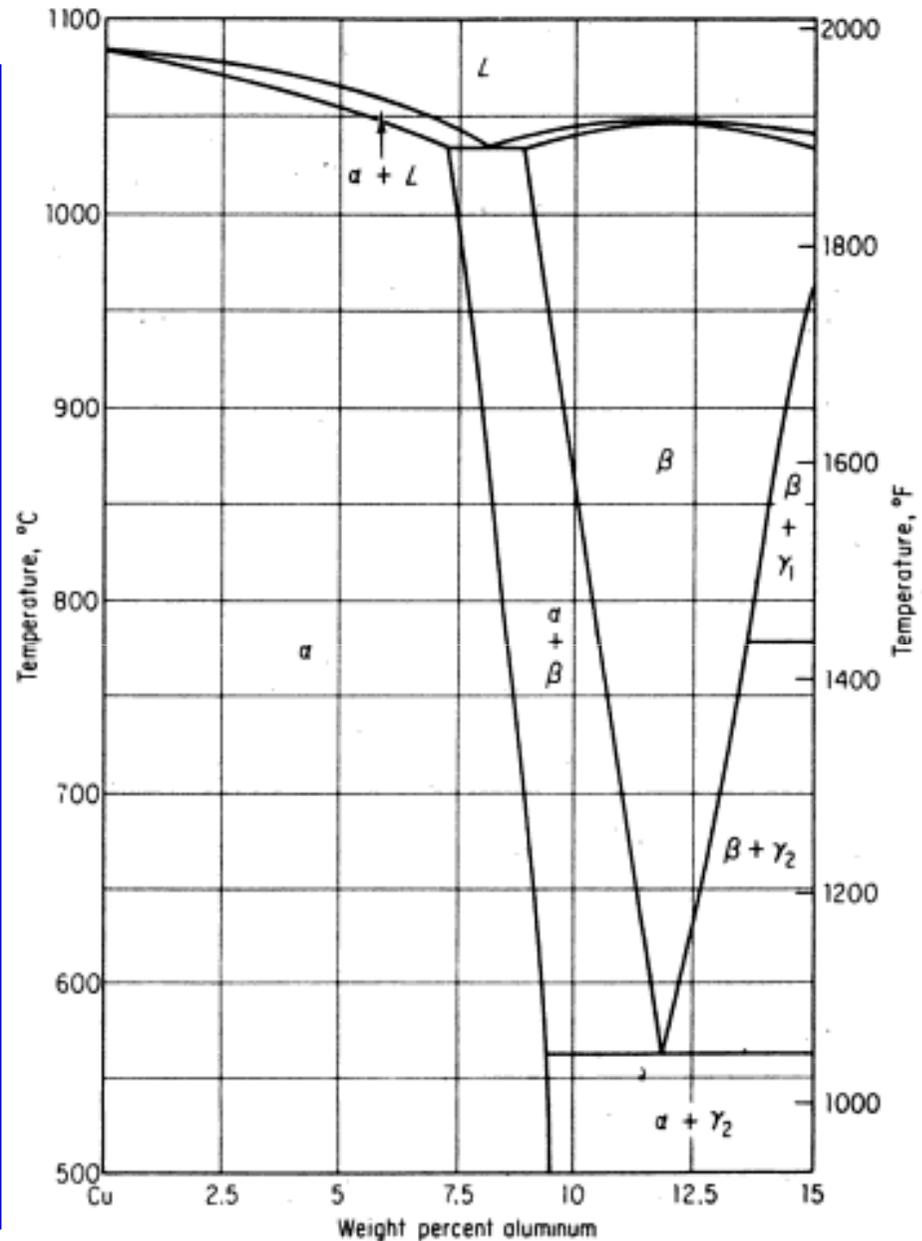


Copper-rich portion of the copper tin phase diagram

- ❑ For this reason, slow cooled cast tin bronzes containing below 7% tin generally show only a single phase, the α solid solution. There is some of the δ phase in most castings containing over 7 percent tin. *The phosphor bronzes are characterized by high strength, toughness, high corrosion resistance and freedom for season cracking .*

Aluminum Bronzes

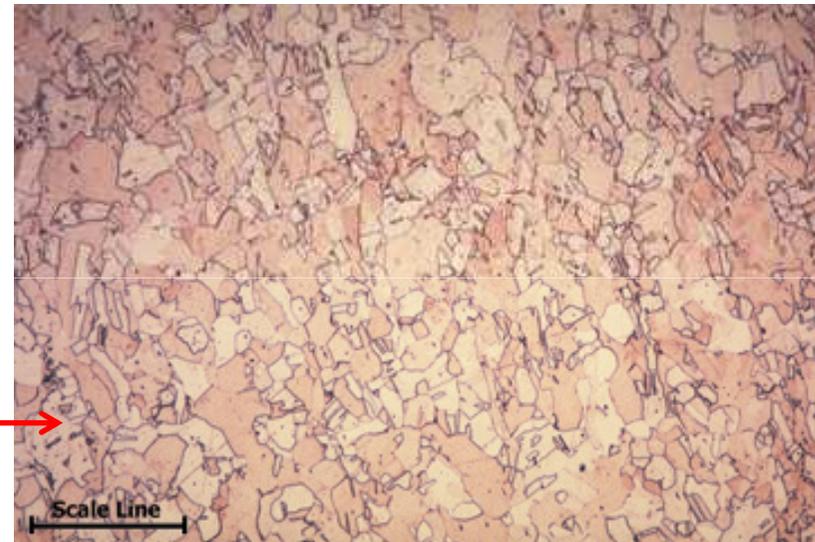
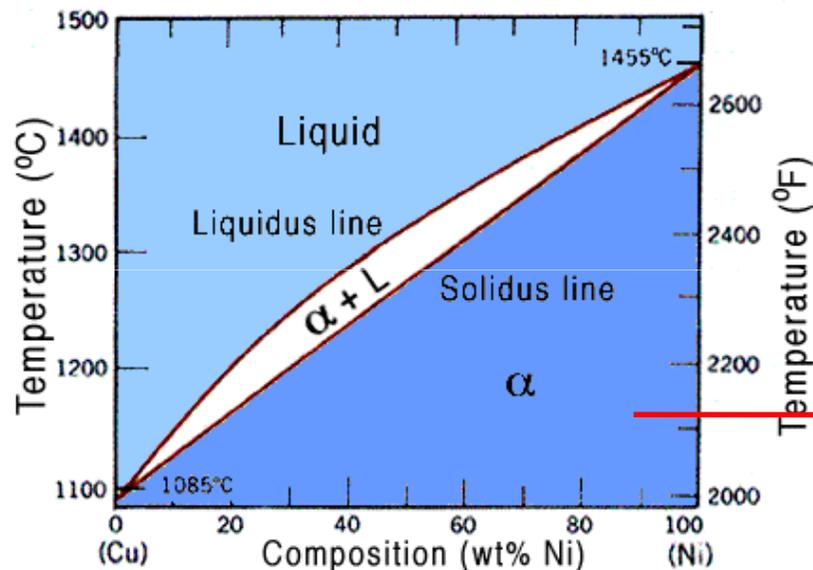
- ❑ The maximum solubility of aluminum in the α solid solution is approximately 9.5% at 565°C to form the $(\alpha+\gamma_2)$ mixture.
- ❑ Most commercial aluminum bronzes contain 4 and 11 percent aluminum. Those alloys containing up to 7.5% Al are generally single-phase alloys, while those containing between 7.5 and 11% aluminum are two phase alloys. Other elements such as iron, nickel, manganese, and silicon are frequently added to aluminum bronzes
- ❑ The single-phase aluminum bronzes show good cold working properties with good corrosion resistance to atmospheric and water attack.
- ❑ The $\alpha+\beta$ aluminum bronzes are interesting because they can be heat treated to obtain structures similar to those in steel.



Copper-rich portion of the copper aluminum phase diagram

Cupronickels

- These are copper-nickel alloys that contain up to 30% nickel. The copper-nickel binary phase diagram shows complete solubility, so that all cupronickels are single-phase alloys. They are not susceptible to heat treatment and may have their properties altered only by cold working.



- The cupronickel alloys have high resistance to corrosion fatigue and also high resistance to the corrosive and erosive action of rapidly moving sea water. They are widely used for condenser, distiller, evaporator and heat exchanger tubes for naval vessels and coastal power plants.



“ Where ever weight is the enemy

Where ever appearance matters

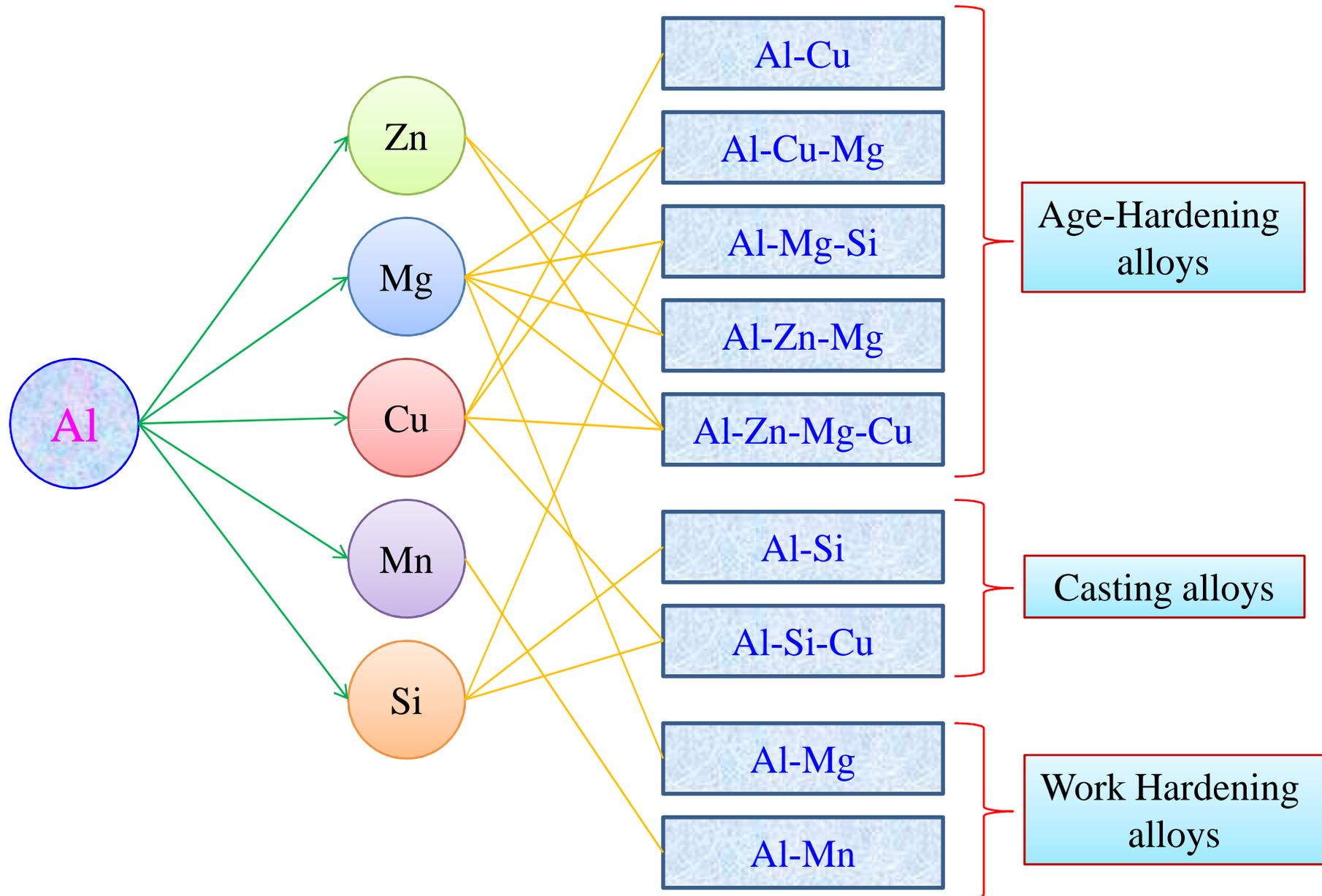
Where ever durability is required”

The answer is Aluminum & its alloys

Introduction

- ❑ Aluminum and its alloys possess many attractive characteristics including light weight, high thermal and electrical conductivities, a nonmagnetic nature, high reflectivity, high resistance to corrosion, reasonably high strength with good ductility and easy fabrication.
- ❑ Nevertheless, probably the most important characteristic of aluminum is its low density, which is about one-third that of steels and copper alloys. Because of this, certain aluminum alloys have a better strength-to-weight ratio than high-strength steels.
- ❑ Among the many alloying elements added to aluminum, the most widely used are copper, silicon, magnesium, zinc, and manganese. These are used in various combinations, and in many cases they are used together with other additions to produce classes of age hardening, casting, and work hardening alloys.
- ❑ All age hardening alloys contain alloying elements that dissolve in aluminum at elevated (solution treatment) temperatures and precipitate at lower (aging) temperatures. An example of an age hardening alloy is Al-Cu (*which will be discussed in coming slides*).
- ❑ Most casting alloys contain silicon, which improves the fluidity and mold-filling capacity of aluminum alloys and reduces their susceptibility to hot cracking and the formation of shrinkage cavities during solidification. Work hardening alloys frequently contain Mn and Mg, which form a fine dispersion of inter metallic phases and/or impart solid-solution strengthening.

Major Aluminum alloy systems



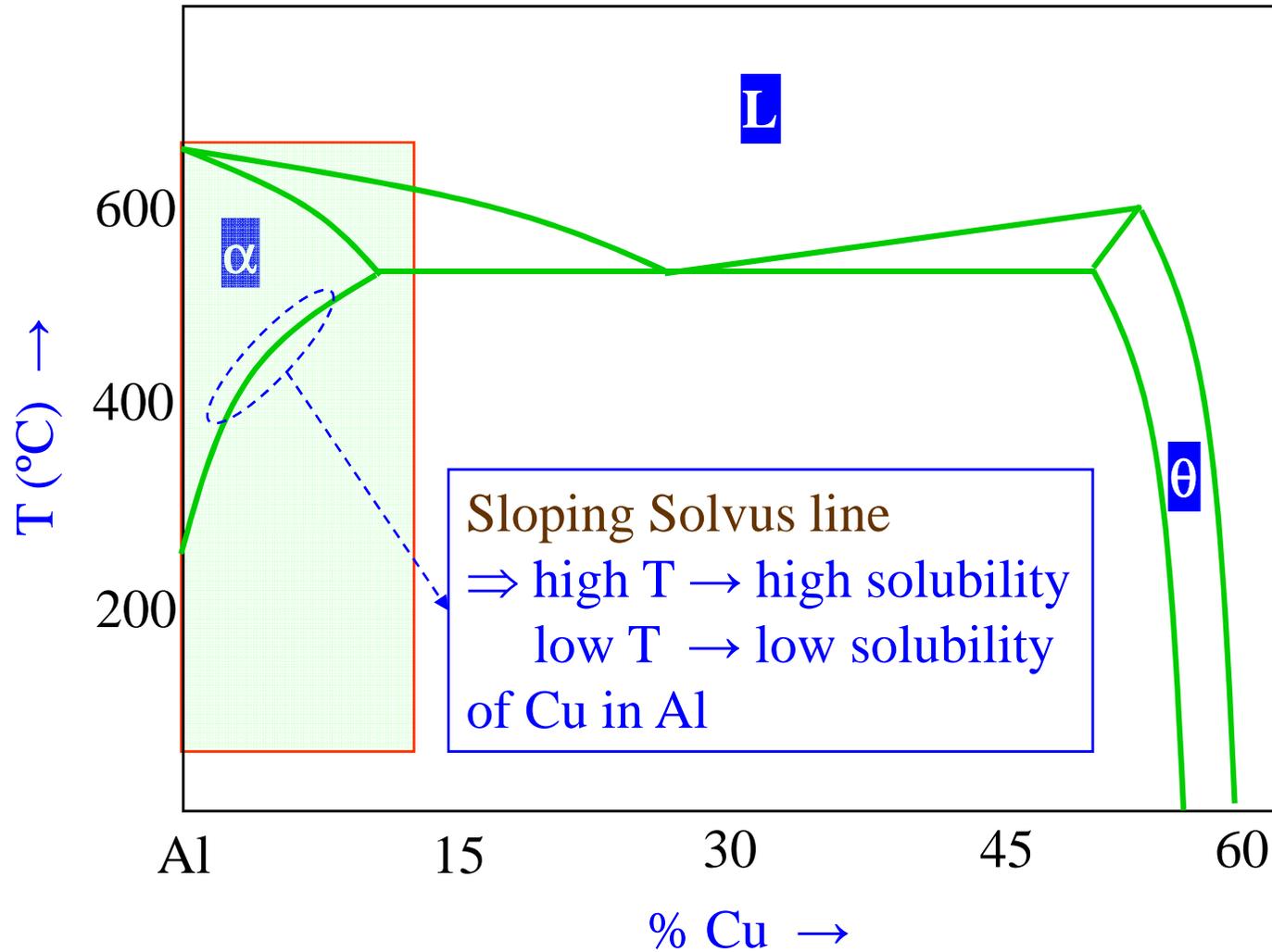
ALUMINIUM ALLOY DESIGNATION SYSTEM

| ALLOY GROUP | MAJOR ALLOYING ELEMENTS | EXAMPLE |
|-------------|-------------------------|------------------|
| AA 1XXX | Min. 90% pure Al. | AA 1050 |
| AA 2xxx | Copper | AA 2014, AA2024 |
| AA 3XXX | Manganese | AA 3003 |
| AA 4XXX | Silicon | AA 4030 |
| AA 5XXX | Magnesium | AA 5083 |
| AA 6XXX | Magnesium+Silicon | AA 6061 |
| AA 7XXX | Zinc | AA 7075, AA 7175 |
| AA 8XXX | Others | AA 8020 |

Heat treatment

- ❑ The most important heat treating process for non ferrous alloys is *age hardening*, or *precipitation hardening*.
- ❑ In order to apply this heat treatment, the equilibrium diagram must show partial solid solubility, and the slope of the solvus line must be such that there is greater solubility at a higher temperature than at a lower temperature.
- ❑ The purpose of precipitation hardening treatment is to improve strength of the materials. It can explained by with respect to dislocations.
- ❑ The presence of dislocation weakens the crystal → easy plastic deformation
- ❑ Putting hindrance to dislocation motion increases the strength of the crystal
- ❑ Fine precipitates dispersed in the matrix provide such an impediment.
- ❑ For example: Strength of Al → 100 MPa
Strength of Duralumin (Al + 4% Cu + other alloying elements) → 500 Mpa
- ❑ Two stages are generally required in heat treatment to produce age hardening:
 - ✓ Solution treatment
 - ✓ Aging

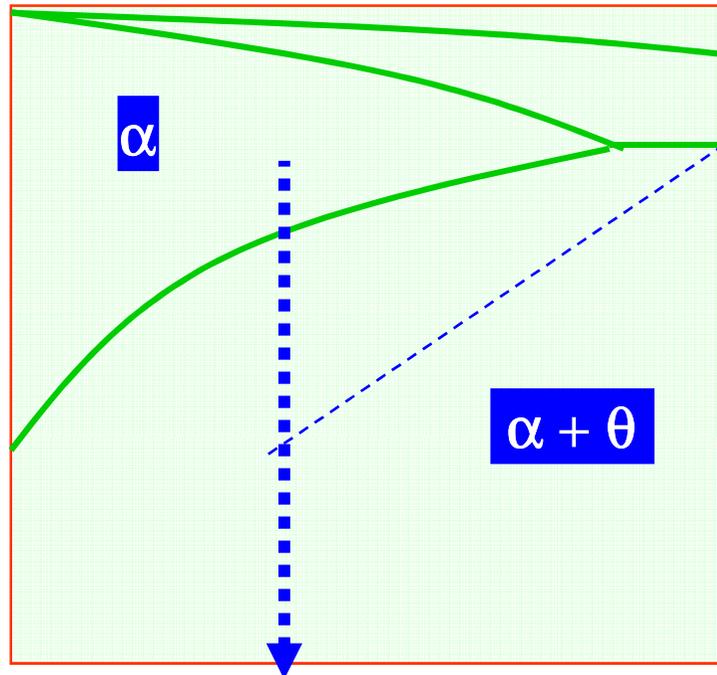
Age-Hardening



Al rich end of the Al-Cu phase diagram

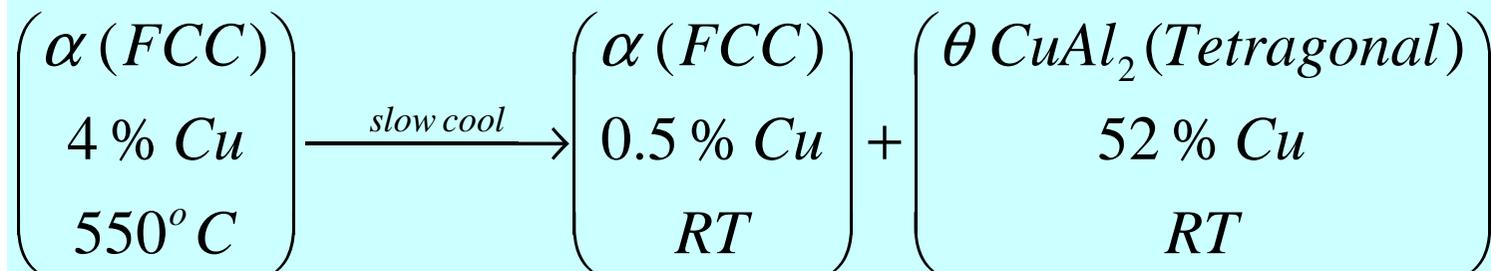
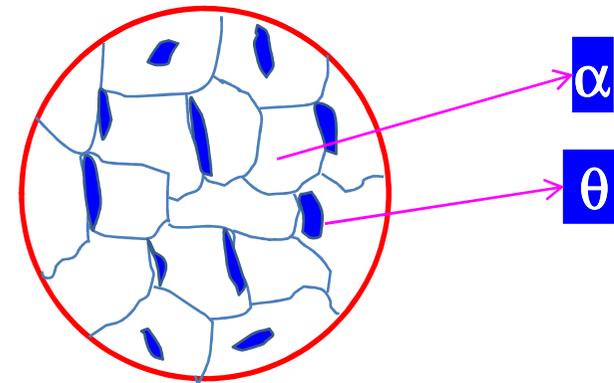
Age-Hardening

On Equilibrium cooling



4 % Cu

- $\alpha \rightarrow \alpha + \theta$
- Slow equilibrium cooling gives rise to coarse θ precipitates which is not good in impeding dislocation motion.*



Age-Hardening

To obtain a fine distribution of precipitates the cycle **A** → **B** → **C** is used

Solution treating at high temperature, then quenching (second phase is in solid solution) → Cycle A and B

A Heat (to 550°C) → solid solution α

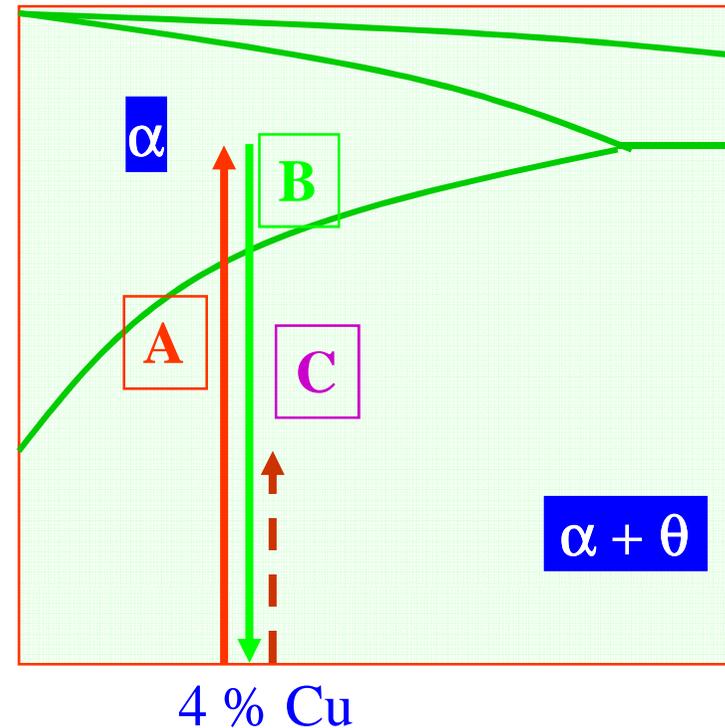
B Quench (to RT) →

supersaturated solution

Increased vacancy concentration

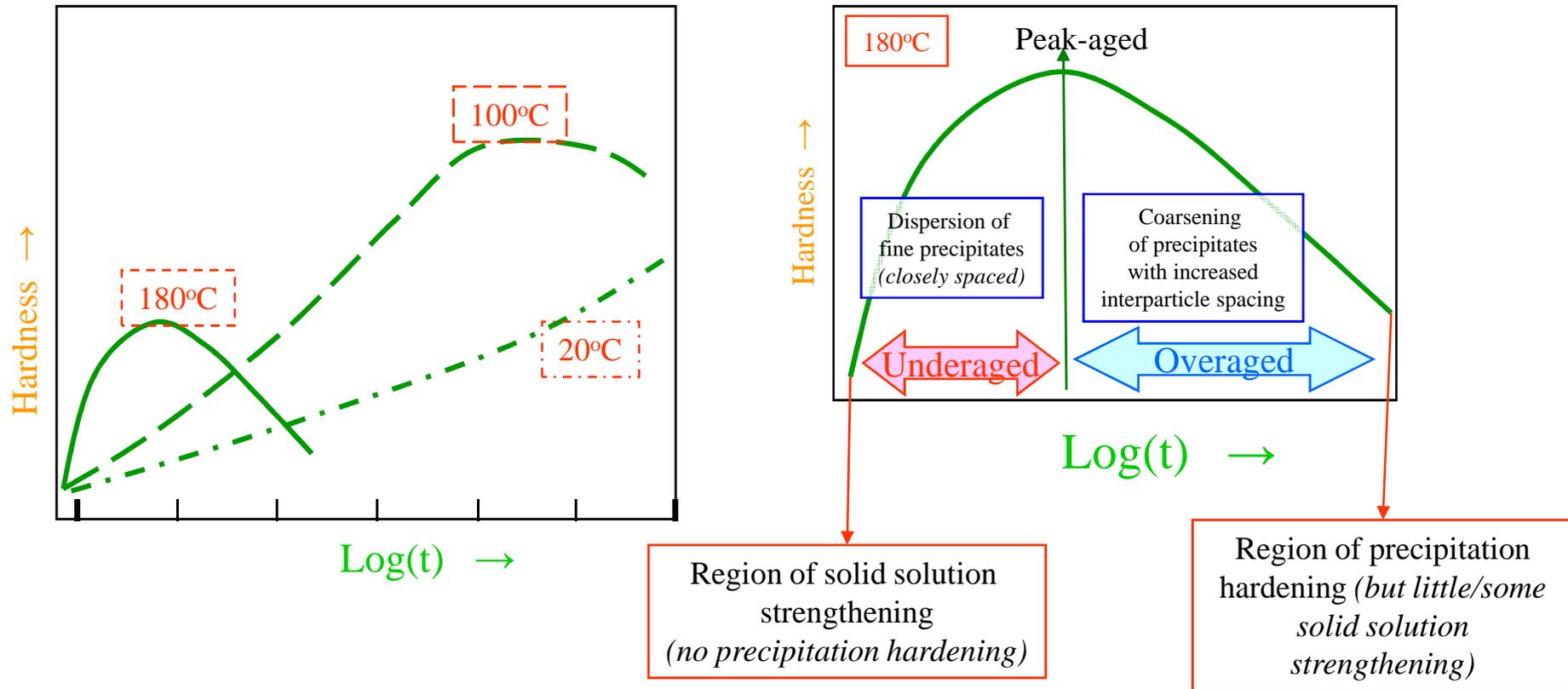
Ageing at room temperature or slightly higher temperature (Precipitation of second phase, giving strengthening effect) → Cycle C

C Age (*reheat* to 200°C) → fine precipitates



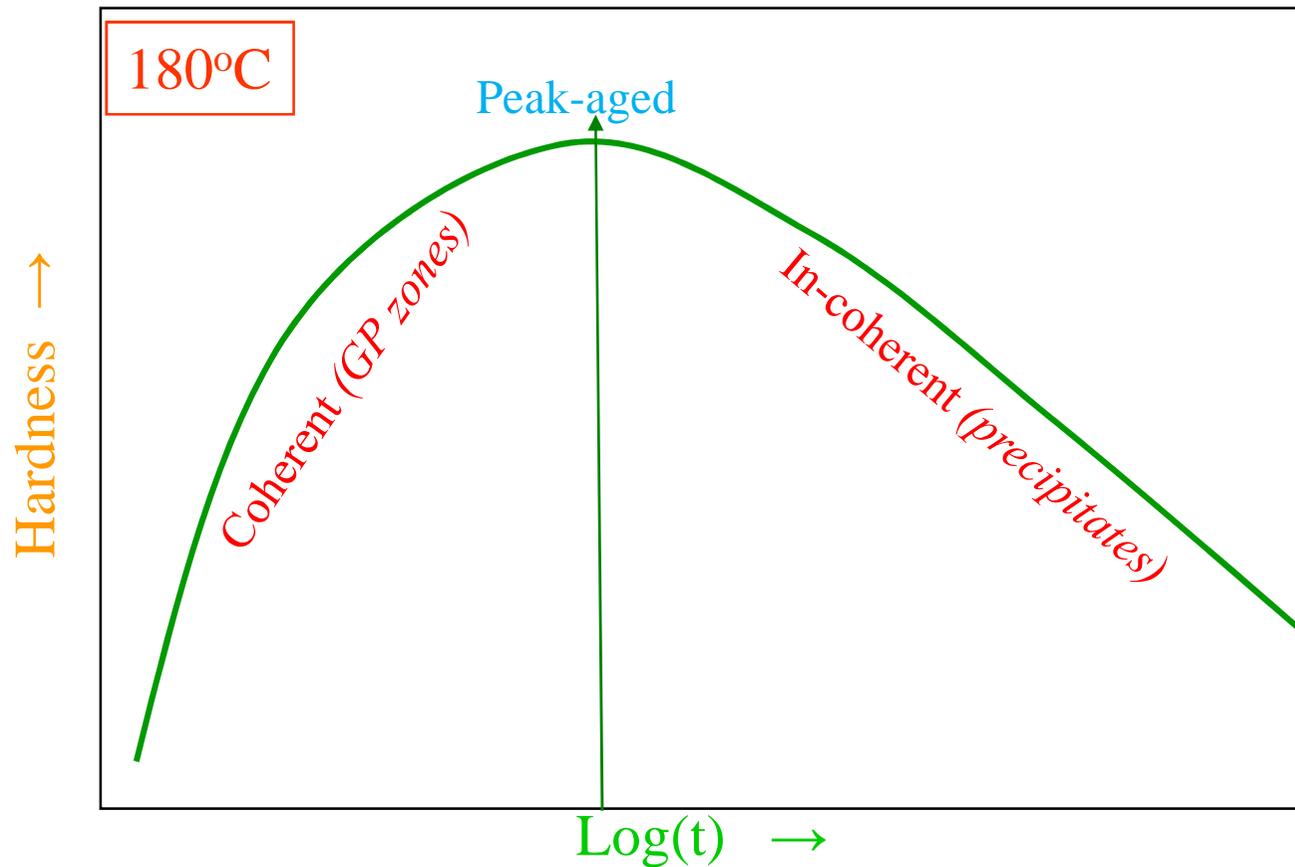
Note: Treatments A, B, C are for the same composition

Age-Hardening



- Higher temperature \Rightarrow less time of aging to obtain peak hardness
- Lower temperature \Rightarrow increased peak hardness
- \Rightarrow optimization between time and hardness required

A complex set of events are happening parallelly/sequentially during the aging process
→ These are shown schematically in the figure below

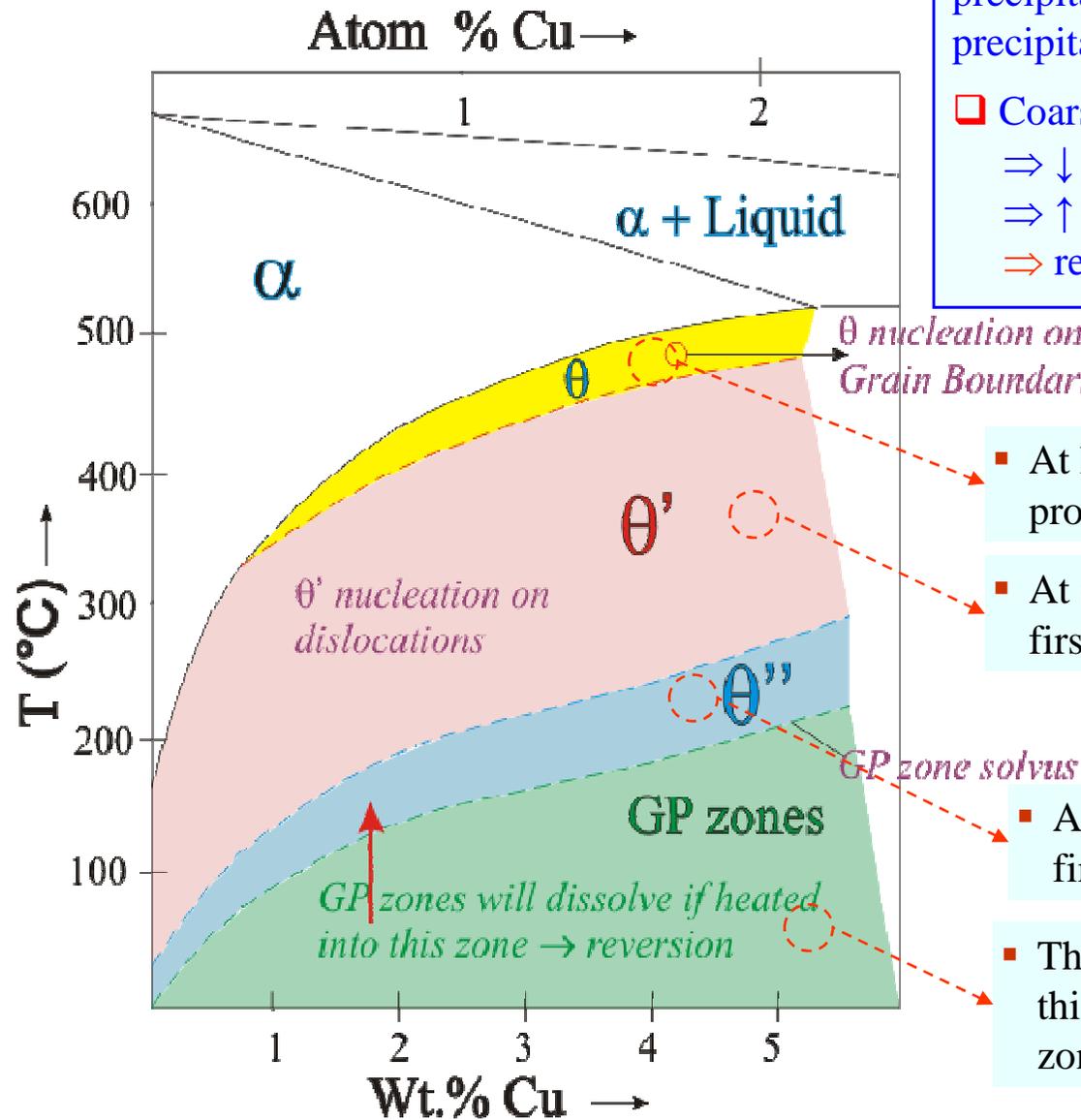


Increasing size of precipitates with increasing interparticle (inter-precipitate) spacing

Interface goes from coherent to semi-coherent to incoherent

Precipitate goes from GP zone → θ'' → θ' → θ

Age-Hardening



□ Due to large surface to volume ratio the fine precipitates have a tendency to coarsen → small precipitates dissolve and large precipitates grow

□ Coarsening

⇒ ↓ in number of precipitate

⇒ ↑ in interparticle (inter-precipitate) spacing

⇒ reduced hindrance to dislocation motion

■ At higher temperatures the stable θ phase is produced directly

■ At slightly lower temperatures θ' is produced first

■ At even lower temperatures θ'' is produced first

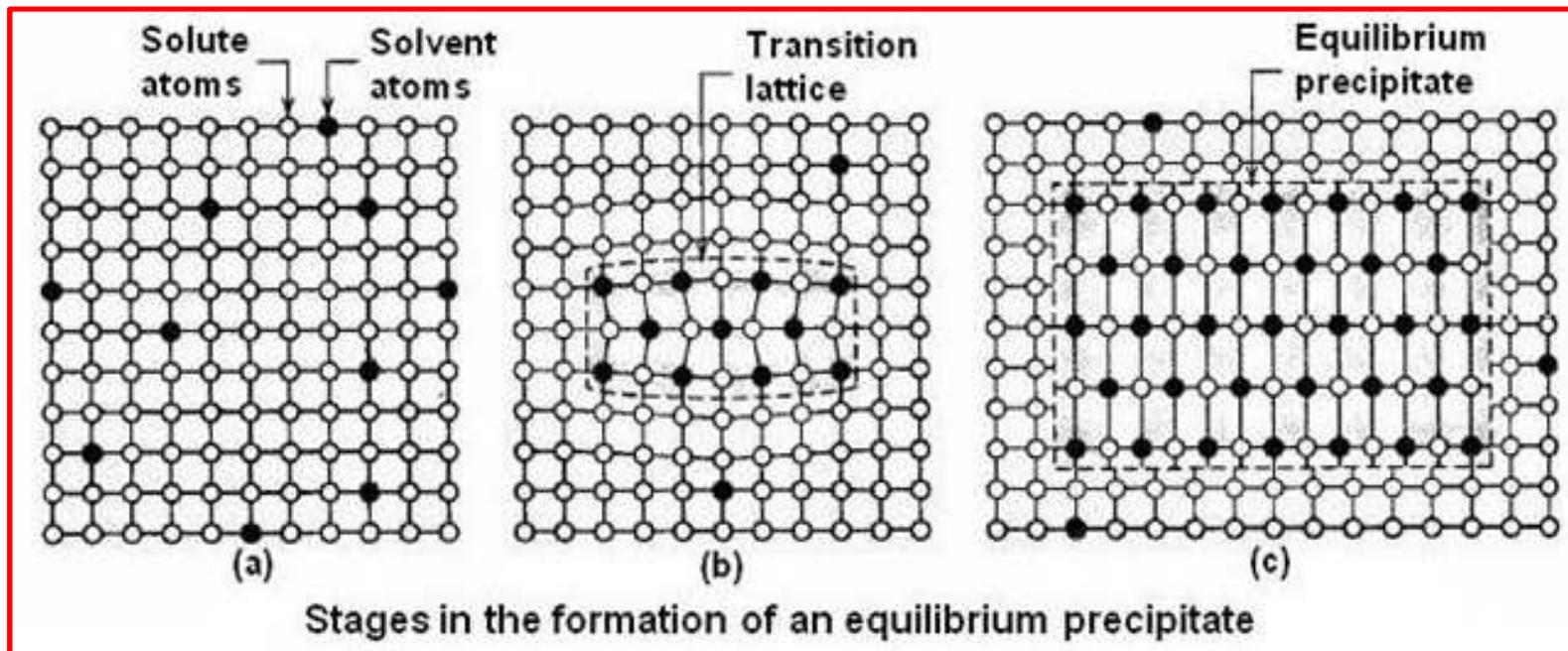
■ The normal artificial aging is usually done in this temperature range to give rise to GP zones first

Coherent lattice theory

- ❑ The strengthening of a heat-treatable alloy by aging is not due merely to the presence of a precipitate. It is due to both the uniform distribution of a finely dispersed submicroscopic precipitate and the distortion of the lattice.
- ❑ There are several theories of precipitation hardening, to explain in what manner precipitate particles harden the matrix or solvent lattice, the most useful theory is *coherent lattice theory*.
- ❑ After solution treatment and quenching, the alloy is in a supersaturated condition, with the solute atoms distributed at random in the lattice structure (Fig A).
- ❑ During an incubation period, the excess solute atoms tend to migrate to certain crystallographic planes, forming clusters or embryos of the precipitate.
- ❑ During aging, these clusters form an intermediate crystal structure, or *transitional lattice*, maintaining registry (coherency) with the lattice structure of the matrix.
- ❑ The excess phase will have different lattice parameters from those of the solvent, and as a result of the atom matching (coherency), there will be considerably distortion of the matrix (Fig B).

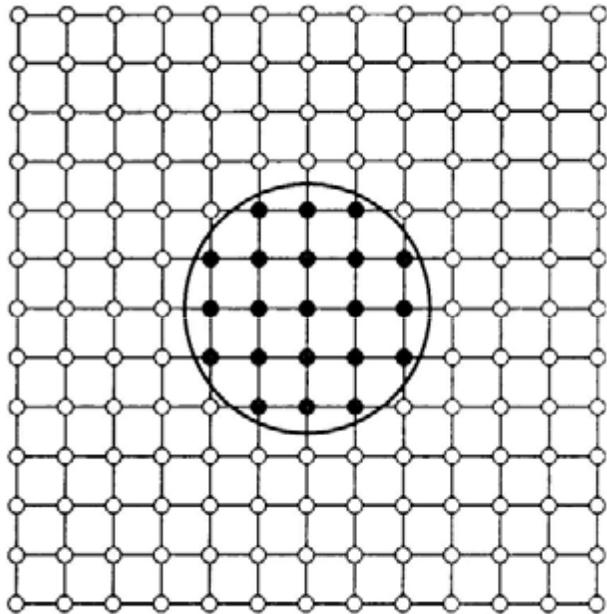
Coherent lattice theory

- ❑ The distortion of the matrix extends over a larger volume than would be the case if the excess phase were a discrete particle. Eventually the equilibrium excess phase is formed with its own lattice structure (Fig C).
- ❑ This causes a loss of coherency with the matrix and less distortion hardness and strength will decrease, and the alloy is 'over-aged'. There will now be a boundary between the excess phase and the matrix so that the precipitated particle will be visible under the microscope.

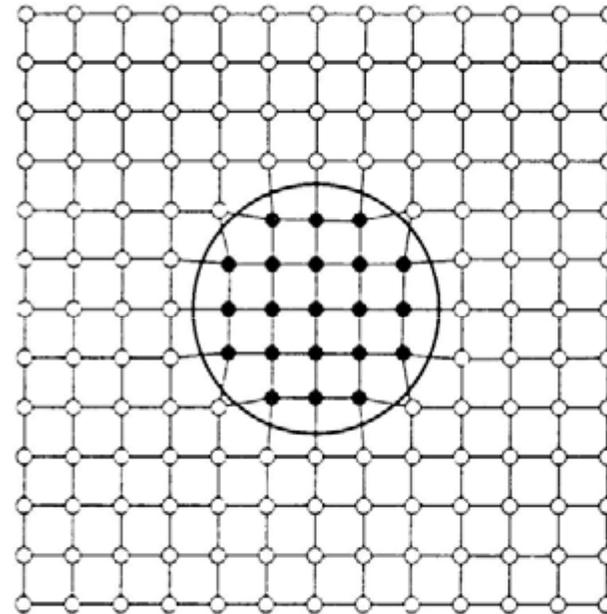


Solid-Solid Interfaces

Consider an interface between two solid phases, α and θ , arising when θ nucleates and grows in α . The interface can be of various types:

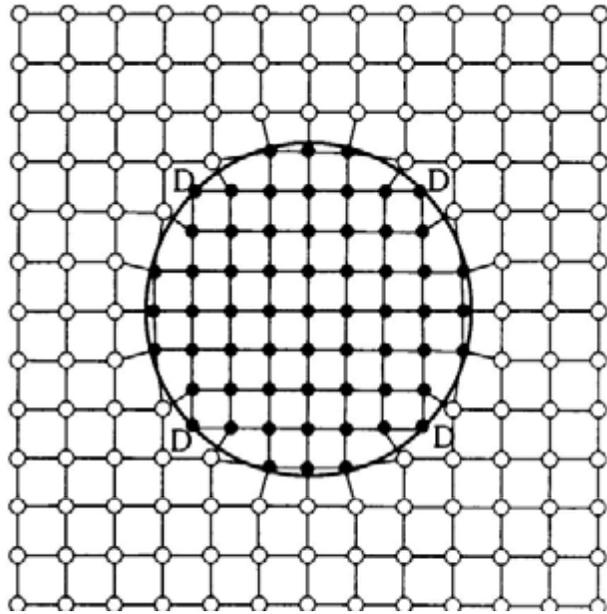


Coherent. There is perfect alignment of the lattices.

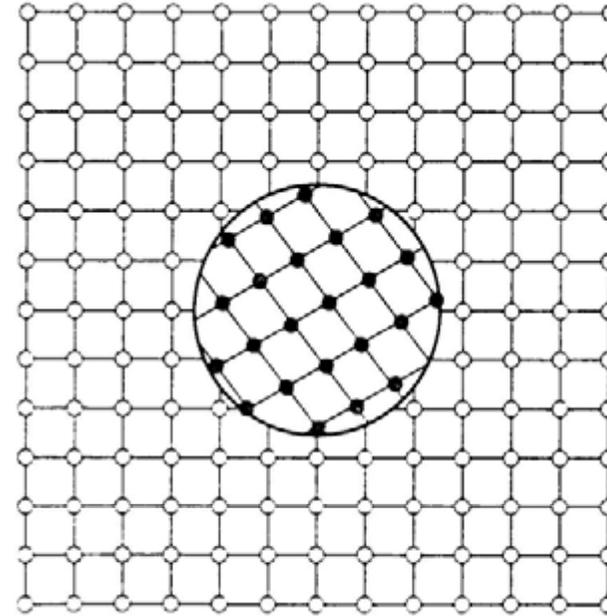


Coherent, with strain. It is likely that a coherent interface will have some elastic strain. The strain energy increases with the size of the growing particle and there will be a transition to a semi coherent interface.

Solid-Solid Interfaces

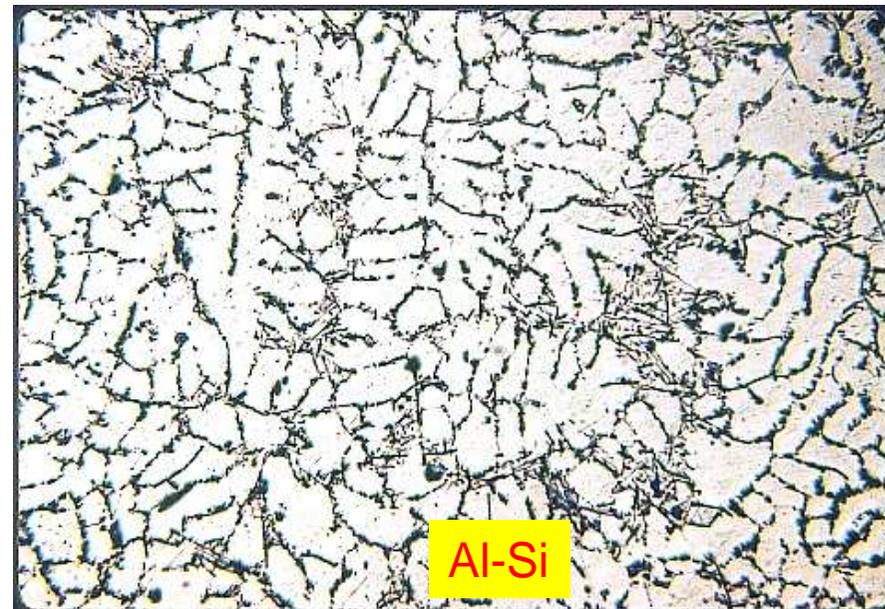
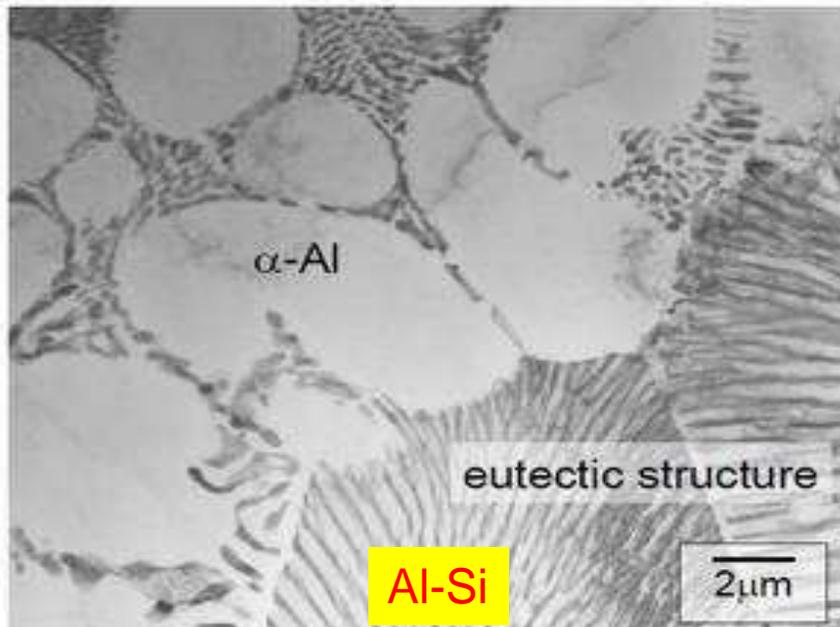
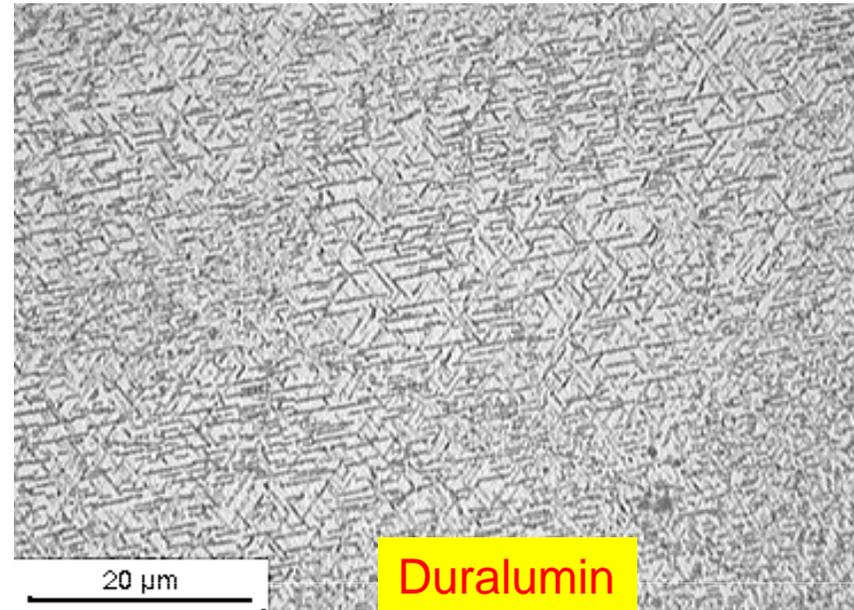
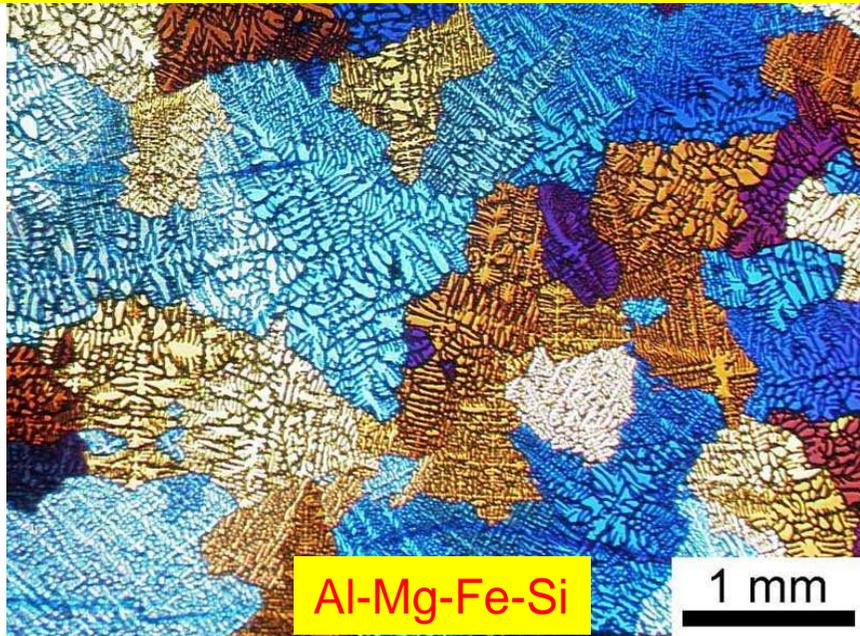


Semi-coherent. The introduction of dislocations (defects in the way the crystal is organized) reduces the overall elastic strain, although they themselves contribute to the energy of the system.



Incoherent. There is no matching at the interface

Microstructures of common aluminum alloys

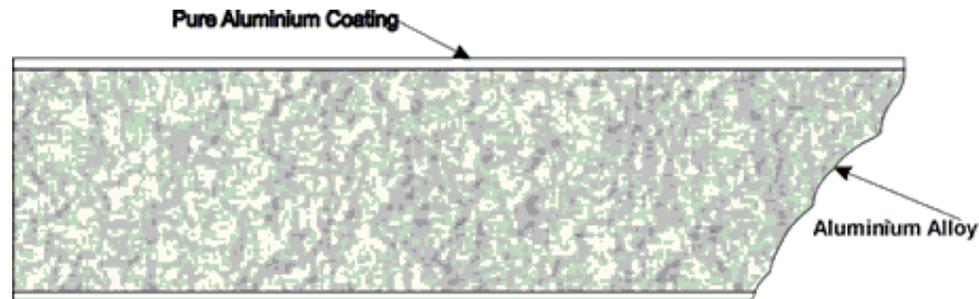


Corrosion Resistance of Al and Al-alloys

- ❑ The high corrosion resistance of aluminum is due to the self-protecting, thin, invisible oxide film that forms immediately on exposing surfaces to the atmosphere.
- ❑ This film protects the metal from further corrosion. If the oxide film is removed, in many environments, a new film will form immediately and the metal remains fully protected.
- ❑ In certain strongly acid or alkaline solutions, or in contact with moist corrosive materials that prevent access of oxygen to the aluminum surface, the protective film does not form readily. Therefore, the aluminum should be adequately protected or not used at all.
- ❑ A relatively thick oxide coating on aluminum and aluminum alloys may be produced by placing the metal into an aqueous solution containing 15 to 25% sulfuric acid. This process, known as *anodizing*, produces a clear, transparent coating containing submicroscopic pores that are usually sealed before use to prevent absorption and staining. Sealing may be accomplished by suitable heating in hot water.

Corrosion Resistance of Al and Al-alloys

- ❑ The corrosion resistance of Al-Cu alloys and Al-Zn alloys is satisfactory for most applications but is generally lower than that of the other aluminum alloys. Under certain corrosive conditions they are subject to intergranular corrosion.
- ❑ Therefore, these alloys in the form of sheet are usually clad with a high-purity alloy such as commercial aluminum or a magnesium-silicon alloy.
- ❑ The coating slabs are mechanically attached to the alloy core ingot, and the bonding is accomplished by hot rolling. The nominal cladding thickness per side is usually 1½ or 2½ percent of thickness of the base material.



- ❑ Alclad alloys are extensively used for aircraft applications because of the excellent combination of high strength and high resistance to corrosion.

Questions..?

1. Which lead – tin alloy will be ideal for joining electronic assemblies? Give reason.
2. Why is Al-12% Si alloy a very popular casting material for automotive applications?
3. Cartridge brass is easily cold worked but Muntz metal can not be cold worked. Explain why it is so.
4. Explain the applications of Bronze and Brasses.
5. What is the difference between disordered & ordered AuCu₃ alloy? How is the presence of ordered structure detected?
6. Name three common grades of steel produced by ingot route. Which of these has higher yield?
7. Why does compressive stress develops at the surface in a case carburized and subsequently case hardened steel?
8. Why low carbon content is preferred in most structural application? Is high strength not a major criterion?
9. What is the composition of the steel designated as 25Mn1S14? What is the role of sulfur in this steel?
10. Why is it possible to get much finer grain structure in steel than in aluminum?
11. How is ausforming different from austempering? Is this a hot working process?
12. What is the effect of micro-alloy addition on rolling load?

Questions..?

13. How is the mechanism of strengthening in maraging steel different from that in conventional ultra high strength steel?
14. Explain why commercial steels / alloys having lower stacking fault energy exhibit higher creep resistance.
15. Does all steel suitable for ausforming exhibit transformation induced plasticity?
16. High speed cutting tools are made of 18W4Cr1V0.6C and it is used in hardened and tempered condition. Unlike normal hardened and tempered plain carbon tool steel it does not lose its cutting ability even when it is red hot. Explain why it is so.
17. Briefly explain why ferritic and austenitic stainless steels are not heat treatable.
18. What is the main difference between brass and bronze?
19. Explain why, under some circumstances, it is not advisable to weld a structure that is fabricated with a 3003 aluminum alloy.
20. On the basis of melting temperature, oxidation resistance, yield strength, and degree of brittleness, discuss whether it would be advisable to hot work or to cold work (a) aluminum alloys, and (b) magnesium alloys.
21. What types of alloys would respond to precipitation hardening?
22. Why Aluminium alloy rivets are stored in refrigerator?
23. A batch of age hadrenable alloy has been overaged by mistake. Is there any way to salvage these?

Questions..?

24. Why non-age hardenable aluminium alloys are chosen for beverage can?
25. When can you get more than one peak in the hardness versus aging time plot of a given alloy at a given temperature?
26. Ag rich GP zones can form in a dilute Al-Ag alloy. Given that the lattice parameters of Al and Ag are 0.405nm and 4.09nm respectively. What is likely shape of these zones?
27. Under what heat treatment condition an age harden-able alloy can be machined?
28. What the principal difference is between wrought and cast alloys?
29. Give the distinctive features, limitations, and applications of the following alloy groups: titanium alloys, refractory metals, superalloys, and noble metals.
30. What is Duralumin? Give its alloy number and uses. What is the recent development in alloy for aircraft bodies and application?

Thank You!

