d) **Aging or annealing**: the cutting and milling process induce internal stress, this lead to reacts very rapidly with mercury. **Aging is done by:**
- heating the powder at 100C for 6-8 hours
- By storing the powder at room temperature for several months.
Production of the spherical and spheroidal alloy powder particles

a) The spherical: produced by melting the alloy ingredients together and then spraying into a closed chamber (4-40 micron).

b) The spheroidal: are produced by atomizing the molten alloy in water.
CLASSIFICATION OF DENTAL AMALGAM ALLOY

1. CLASSIFICATION OF DENTAL AMALGAM ALLOY ACCORDING TO THE NUMBER OF ALLOYED METALS
   - Binary alloys contain silver and tin.
   - Ternary alloys contain silver, tin, and copper.
   - Quaternary alloys contain silver, tin, copper, and zinc or indium.

2. ACCORDING TO THE SHAPE OF THE PARTICLES
   - Irregular: Alloy particles are irregular in shape in the form of spindles or shaving.
   - Spherical: Alloy particles have a smooth spherical shape.
3) ACCORDING TO THE COPPER CONTENT OF THE ALLOY:
Low copper alloys - contain copper in the range of 2% to 6%.
High copper alloys - contain copper in the range of 12% to 30%.
4. ACCORDING TO ZINC CONTENT Zinc-containing:

alloys - contain zinc in the range of 0.01% to 1% Zinc-free alloys - contain less then 0.01% zinc
5. ACCORDING TO WHETHER THE ALLOY IS UNMIXED OR ADMIXED:

Single composition or unicompositional alloys - each particle of the alloy has the same chemical composition. Admixed alloys - these alloys are a physical blend of lather-cut and spherical particles.
6) ACCORDING TO THE PRESENCE OF NOBLE METALS:

Noble metal alloy - contain small amounts of palladium or gold. Non-noble metal alloy - do not contain any noble metals.
1- low copper amalgam

Amalgamation (setting) reaction of low-copper amalgam:

a) Wetting
b) Diffusion
c) Surface reaction:
   - silver – mercury: centered cubic structure, gamma one phase
   - tin – mercury: hexagonal structure, gamma two phase.
Low copper amalgam

Conventional Low-Copper Alloys

- Dissolution and precipitation
- Hg dissolves Ag and Sn from alloy
- Intermetallic compounds formed

\[
\text{Ag}_3\text{Sn} + \text{Hg} \rightarrow \text{Ag}_3\text{Sn} + \text{Ag}_2\text{Hg}_3 + \text{Sn}_8\text{Hg}
\]
Conventional Low-Copper Alloys

Gamma ($\gamma$) = Ag$_3$Sn
- Unreacted alloy
- Strongest phase and corrodes the least
- Forms 30% of volume of set amalgam

$$\text{Ag}_3\text{Sn} + \text{Hg} \Rightarrow \text{Ag}_3\text{Sn} + \text{Ag}_2\text{Hg}_3 + \text{Sn}_8\text{Hg}$$
Conventional Low-Copper Alloys

- Gamma 1 (γ₁) = Ag₂Hg₃
- Matrix for unreacted alloy and 2nd strongest phase
- 10 micron grains binding gamma (γ)
- 60% of volume

\[ \text{Ag}_3\text{Sn} + \text{Hg} \rightarrow \text{Ag}_3\text{Sn} + \text{Ag}_2\text{Hg}_3 + \text{Sn}_8\text{Hg}_5 \]
Conventional Low-Copper Alloys

Gamma 2 ($\gamma_2$) = Sn$_8$Hg

- weakest and softest phase
- corrodes fast, voids form
- corrosion yields Hg which reacts with more gamma ($\gamma$)

10% of volume

- volume decreases with time due to corrosion

\[ \text{Ag}_3\text{Sn} + \text{Hg} \Rightarrow \text{Ag}_3\text{Sn} + \text{Ag}_2\text{Hg}_3 + \text{Sn}_8\text{Hg} \]
Microstructure of Set Low Copper Amalgam.
The excess mercury increases the amount of gamma one and gamma two, which lead to:
1- decreased strength
2- decreased corrosion resistance.
3- increased setting expansion.
4- increased creep.
High copper amalgam alloy

1- high copper admixed amalgam.
2- high copper unicompositional amalgam.
Admixed High-Copper Alloys

- Ag enters Hg from Ag-Cu spherical eutectic particles
  - Eutectic
    - An alloy in which the elements are completely soluble in liquid solution but separate into distinct areas upon solidification
- Both Ag and Sn enter Hg from Ag$_3$Sn particles

\[
\text{Ag}_3\text{Sn} + \text{Ag-Cu} + \text{Hg} \Rightarrow \text{Ag}_3\text{Sn} + \text{Ag-Cu} + \text{Ag}_2\text{Hg}_3 + \text{Cu}_6\text{Sn}_5
\]
Admixed High-Copper Alloys

- Sn diffuses to surface of Ag-Cu particles
- Reacts with Cu to form (eta) Cu₆Sn₅ (η)
- Around unconsumed Ag-Cu particles

\[
\text{Ag}_3\text{Sn} + \text{Ag-Cu} + \text{Hg} \Rightarrow \text{Ag}_3\text{Sn} + \text{Ag-Cu} + \text{Ag}_2\text{Hg}_3 + \text{Cu}_6\text{Sn}_5
\]
Admixed High-Copper Alloys

Gamma 1 ($\gamma_1$) ($\text{Ag}_2\text{Hg}_3$) surrounds eta phase ($\text{Cu}_6\text{Sn}_5$) and gamma ($\gamma$) alloy particles ($\text{Ag}_3\text{Sn}$)

$$\text{Ag}_3\text{Sn} + \text{Ag-Cu} + \text{Hg} \Rightarrow \text{Ag}_3\text{Sn} + \text{Ag-Cu} + \text{Ag}_2\text{Hg}_3 + \text{Cu}_6\text{Sn}_5$$
Microstructure of Set High-Copper Admixed Amalgam.

$\gamma_1$($\text{Ag}_2\text{Hg}_3$)

Eutectic($\text{Ag}_3\text{Cu}_2$)

$\eta$($\text{Cu}_6\text{Sn}_5$)

$\gamma$($\text{Ag}_3\text{Sn}$)
Irregular Ag Sn particles + spherical Ag-Cu eutectic particles lead to drawbacks:

a. **Sedimentation** of one of particles in the bottom of the container which affects the distribution of the alloy powder particles.

b. **Surface oxidation** of the silver-copper eutectic particles during storage.
Single Composition
High-Copper Alloys

Gamma sphere (γ) (Ag₃Sn)
with epsilon coating (ε)
(Cu₃Sn)
Ag and Sn dissolve in Hg

Ag₃Sn + Cu₃Sn + Hg → Ag₃Sn + Cu₃Sn + Ag₂Hg₃ + Cu₆Sn₅
Single Composition High-Copper Alloys

- Gamma 1 ($\gamma_1$) ($Ag_2Hg_3$) crystals grow binding together partially dissolved gamma (\(\gamma\)) alloy particles ($Ag_3Sn$)
- Epsilon (\(\varepsilon\)) ($Cu_3Sn$) develops crystals on surface of gamma particle ($Ag_3Sn$) in the form of eta (\(\eta\)) ($Cu_5Sn_5$)
  - Reduces creep
  - Prevents gamma-2 formation

$$Ag_3Sn + Cu_3Sn + Hg \rightarrow Ag_3Sn + Cu_3Sn + Ag_2Hg_3 + Cu_5Sn_5$$
Other amalgam systems and/or alternative alloys:

1- palladium-containing high-copper amalgam:
Addition of palladium to some high-copper amalgam 0.5-1% has improved some properties:
- increased especially the tensile strength.
- The creep was decreased.
- The corrosion resistance was improved.

This due may be due to the formation of Cu pd compound at the gamma one phase grain boundaries.
2- indium-containing high copper amalgams:
- the addition of about 4% indium, increases strength, hardness and decreases creep.
- Admixed amalgam containing 10-15% indium in the mercury. the addition of indium to mercury:
  . Decreases the amount of mercury needed for amalgamation.
  . Decreases the mercury vapor during setting.
  . Increases the wetting.
This due to:

Low creep
Lower early compressive strength
Higher final strength.
3- gallium alloy plastic restorative materials: The drawbacks:

- difficulty in handling.
- Low tarnish and corrosion resistance.
- excessive expansion.
Properties of Dental Amalgam
Properties of Dental Amalgam

1. Compressive strength
2. Tensile Strength
3. Elastic Modulus
4. Creep
5. Dimensional Changes
6. Tarnish and Corrosion:
Properties of Dental Amalgam

1. Compressive strength
   - Amalgam is strongest in compression and much weaker in tension and shear.
   - HCU materials have the highest compressive strength 450-500 MPa.
Properties of Dental Amalgam

2. Tensile Strength:
   - Amalgam is strongest in compression and much weaker in tension and shear.
   - HCU materials have the highest early tensile strength 60 MPa.
Thank you!