Dental Amalgam

DR. AHMED MAGDY SAYED
LECTURER OF DENTAL BIOMATERIALS

Definitions

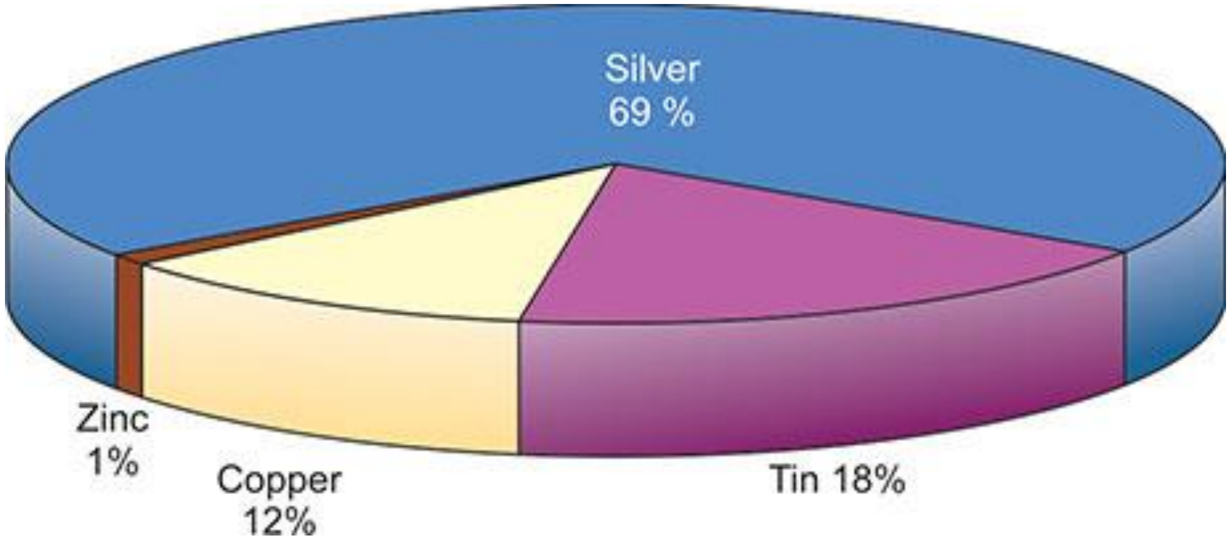
Amalgam:

Any alloy containing mercury.

Definitions

Dental Amalgam Alloy:

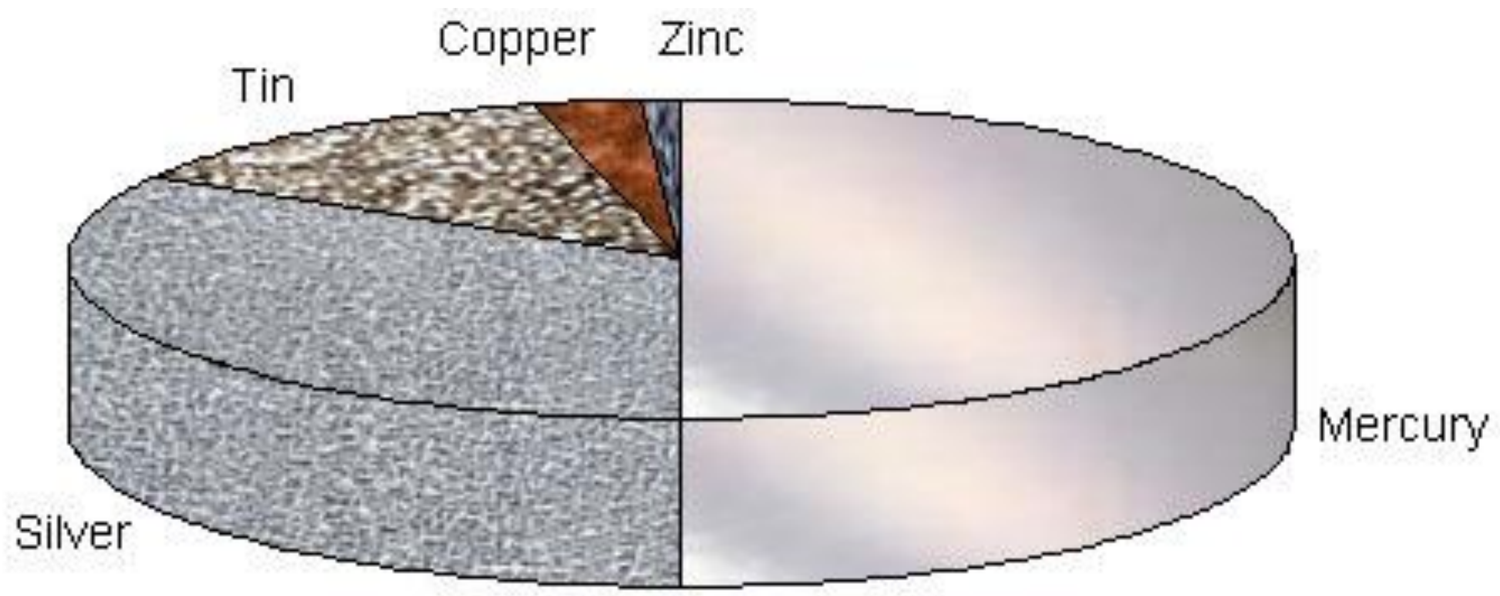
It is a distinct alloy that is formed of silver, tin, copper and occasionally zinc.



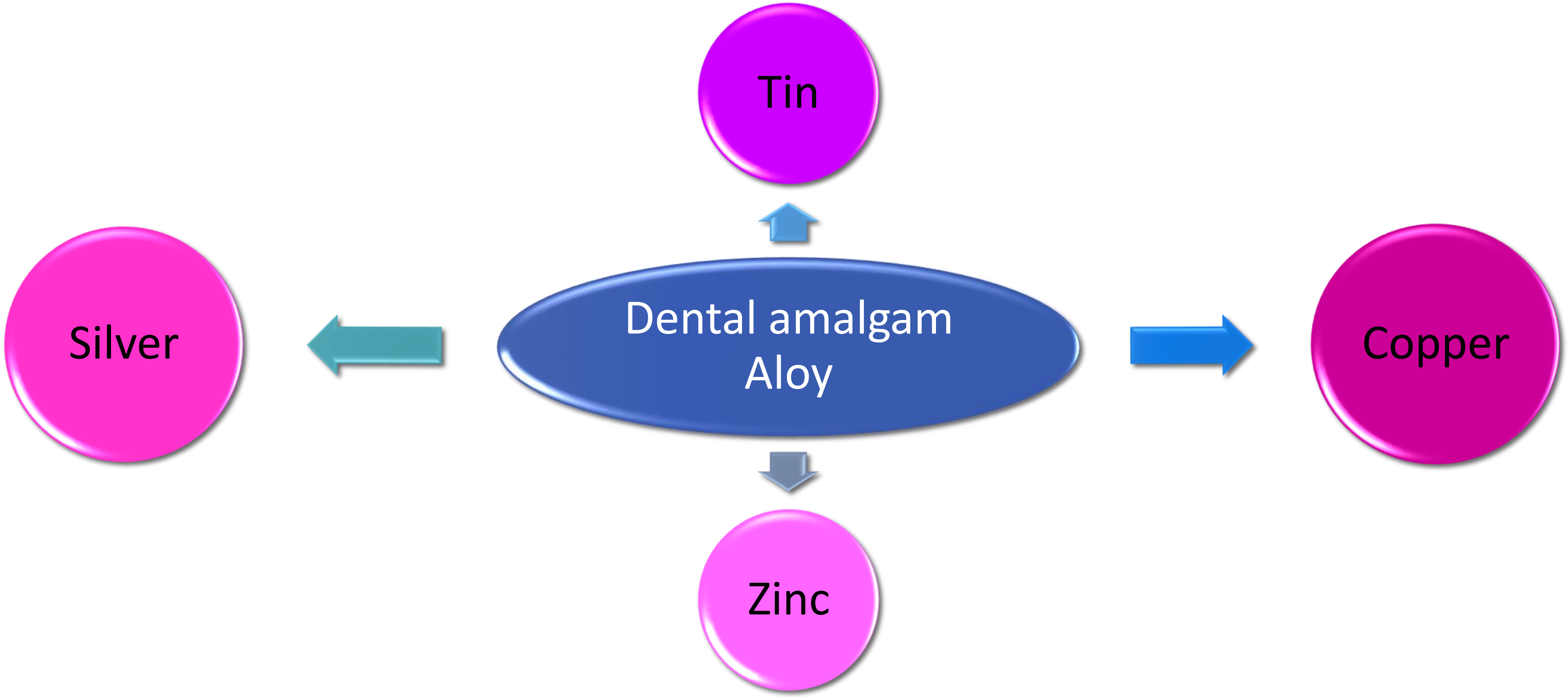
Definitions

Dental Amalgam:

It is the restoration results from mixing dental amalgam alloy with mercury at room temperature to give a plastic mix that is placed into the prepared cavity.



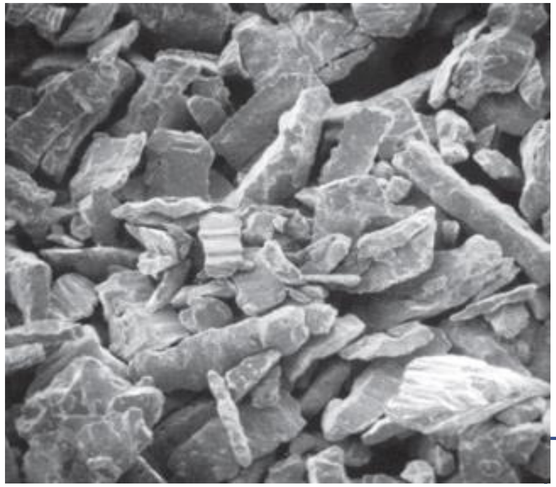
Composition of Dental amalgam:



Composition of Dental amalgam:

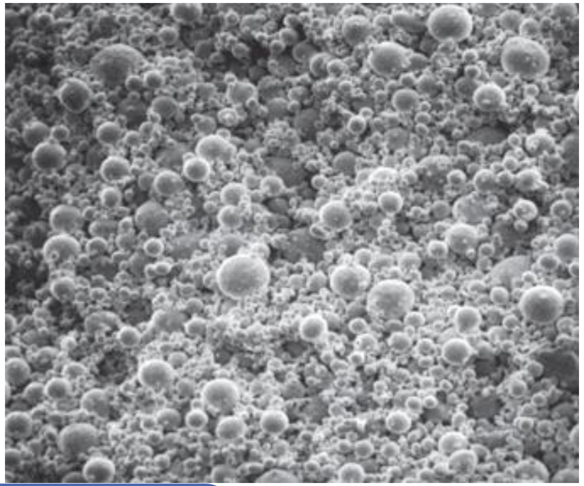
	Silver	Tin	Copper	Mercury
Main role	It is the main element of the reaction	It controls the reaction between silver and mercury		As a liquid, it forms the plastic mix of restoration
Strength	↑	↓	↑	↓
Setting expansion	↑	↓	↑	↓
Corrosion resistance	↑	↓	↑	↓
Creep	↓	↑	↓	↑

Classification of dental amalgam:



According to particle shape

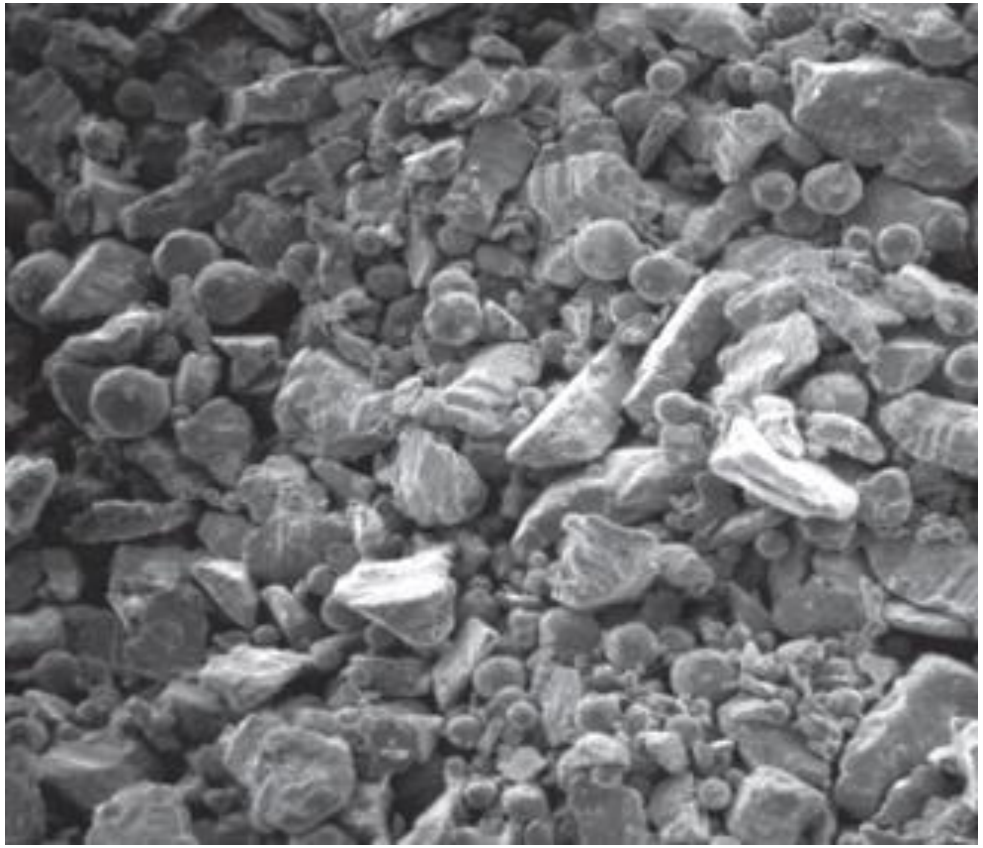
- Lathe cut (irregular)
- Spherical
- Spheroidal



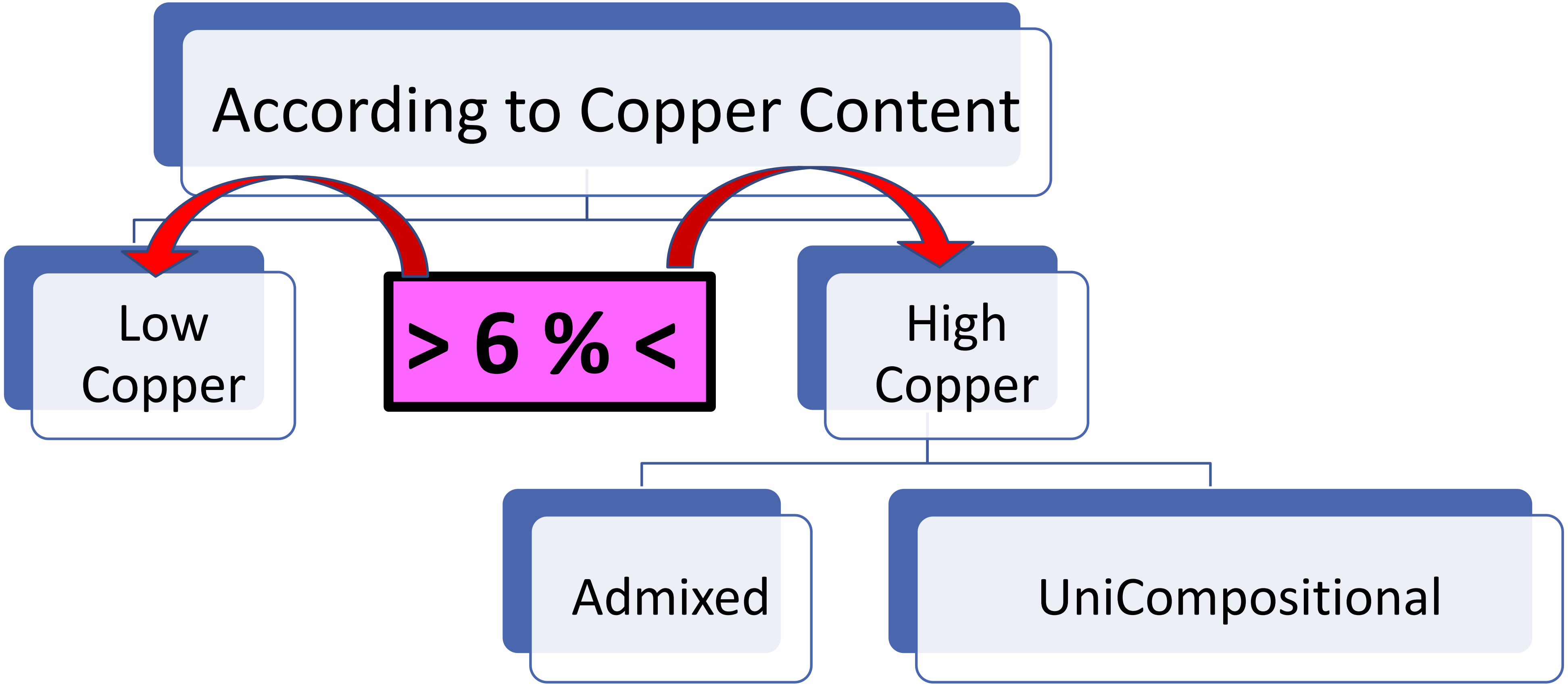
Classification of dental amalgam:

Admixed amalgam

It is amalgam with spherical and irregular silver alloy particles.



Classification of dental amalgam:



Classification of dental amalgam:

According to Zinc Content

- Zinc containing
- Zinc Free

Delayed Expnsion

> 0.01 % <

Percentage Composition of Dental Amalgam Alloys

	Low copper amalgam	High copper amalgam		
		Admixed		Unicompositional
		Lathe cut (2/3)	Spherical (1/3)	
Silver	63 – 70%	40 – 70%	40 – 65%	40 – 60%
Tin	26 – 29%	26 – 30 %	0 – 30%	22 – 30%
Copper	2 – 5 %	2 – 30 %	20 – 40%	13 – 30%
Zinc	0 – 2%	0 – 2 %	0%	0 – 2%

Manufacturing of dental amalgam:

1. **Ingot production:**
   - The constituent elements are melt and cast into a cylindrical ingot (≈3.8 X 25 cm).
   - It is slowly cooled under 480° C to produce an intermetallic compound Ag_3Sn (γ-phase)
   - It is non-homogenous in nature (cored structure).

Manufacturing of dental amalgam:

2. **Homogenization heat treatment:**
   - The cored ingot should be subjected to homogenization heat treatment to improve mechanical properties and corrosion resistance.
   - It is done by heating the ingot at 400^{o} C for 24 hours.

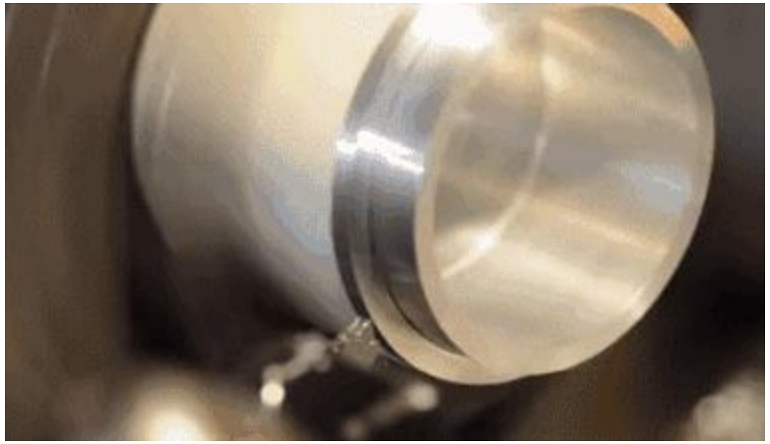
Manufacturing of dental amalgam:

3. **<u>Powder production:</u>**

<u>Lathe cut:</u>

The constituent elements are melted and cast into an ingot.

The ingot is lathe cut or ball milled into irregular particles.



Manufacturing of dental amalgam:

3. **Powder production:**

Spherical:

The constituent elements are melt and atomized (sprayed) into inert gas.

Manufacturing of dental amalgam:

3. **Powder production:**

Spheroidal:

The constituent elements are melt and atomized (sprayed) into water.

Manufacturing of dental amalgam:

4. **Aging or annealing heat treatment:**
   - Lathe cutting develops internal stresses in the powder.
   - The internal stresses lead to very fast setting and severe setting expansion.
   - Aging or annealing eliminates the internal stresses.

Manufacturing of dental amalgam:

4. **Aging or annealing heat treatment:**
   - Aging ➔ store the powder at room temperature for several months.
   - Annealing ➔ heat the powder at 100^{o} C for 1-6 hours.

Manufacturing of dental amalgam:

4. **<u>Aging or annealing heat treatment:</u>**

   - Spherical and spheroidal particles require homogenization heat treatment only. They do not require aging or annealing heat treatment.

Manufacturing of dental amalgam:

<u>Advantages of spherical particles over lathe cut:</u>

1. Have lower surface area ➔ requires less mercury to obtain homogenous mix ➔ produce amalgam with superior properties (↑ mechanical properties and ↑ corrosion resistance).
2. Produce smooth surface during carving and finishing.
3. Requires less condensation pressure.

Amalgamation reaction:

Phase	Name	Composition
γ	Gamma	Ag_3Sn
γ_1	Gamma 1	Ag_2Hg_3
γ_2	Gamma2	Sn_8Hg
η	Eta	Cu_6Sn_5
ε	Epsilon	Cu_3Sn

Amalgamation reaction:

1. **<u>Low Copper amalgam:</u>**

The powder is formed mainly of γ (Ag_3Sn) phase.

After amalgam mixing with the alloy powder, the following stages occurs:

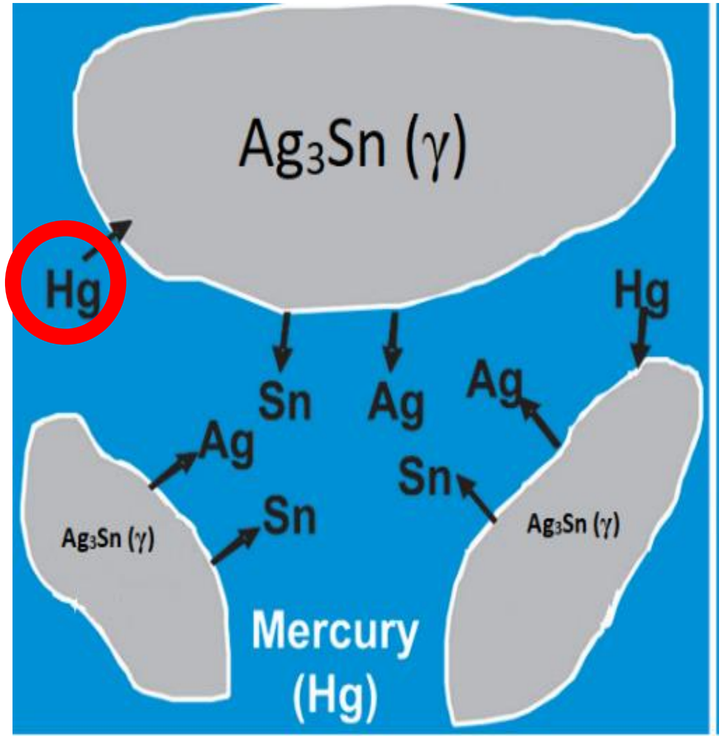
a) **Wetting.**
b) **Diffusion.**
c) **Surface reaction.**

Amalgamation reaction:

1. **<u>Low Copper amalgam:</u>**

a) **Wetting:**

- The liquid mercury is added to the powder alloy and **triturated** (vigorous mix).
- The mercury wets the **surface** of the γ (Ag_3Sn) particles.

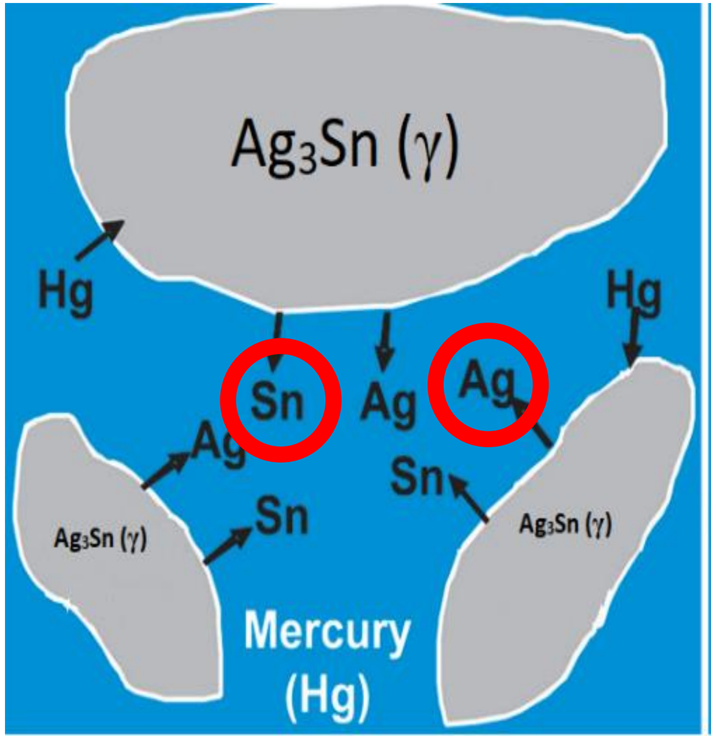


Amalgamation reaction:

1. **Low Copper amalgam:**

b) **Diffusion:**

- The mercury diffuses into the outer layer of the γ phase leads to its dissolution in to silver and tin.

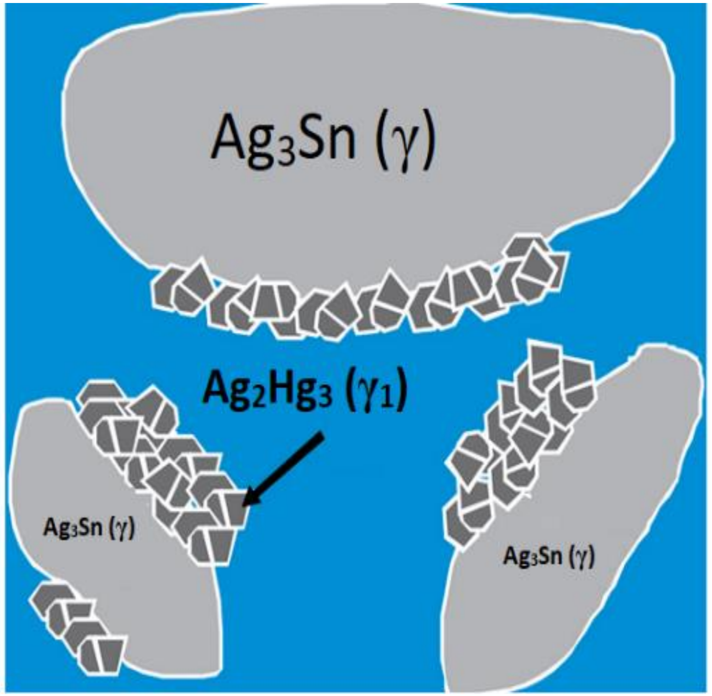


Amalgamation reaction:

1. **Low Copper amalgam:**

c) **Surface reaction:**

- The mercury reacts with the silver and tin leading to formation of new phases ($\gamma 1$ phase Ag_2Hg_3 “silver-mercury phase” and $\gamma 2$ phase Sn_8Hg “tin-mercury phase”).

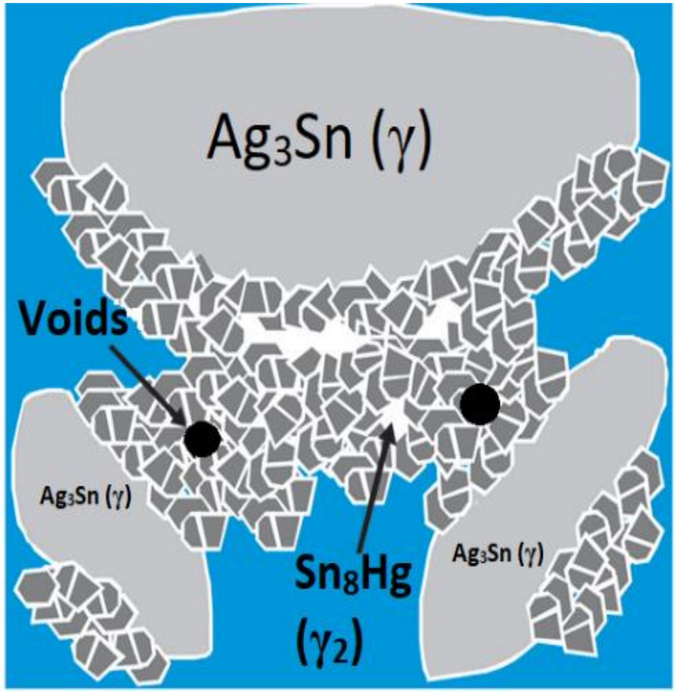


Amalgamation reaction:

1. **Low Copper amalgam:**

c) **Surface reaction:**

- The new phases production increase with time leading to hardening of the plastic mix.
- The new phases (γ_1 & γ_2) surrounds and bound the unreacted parts of γ phase.

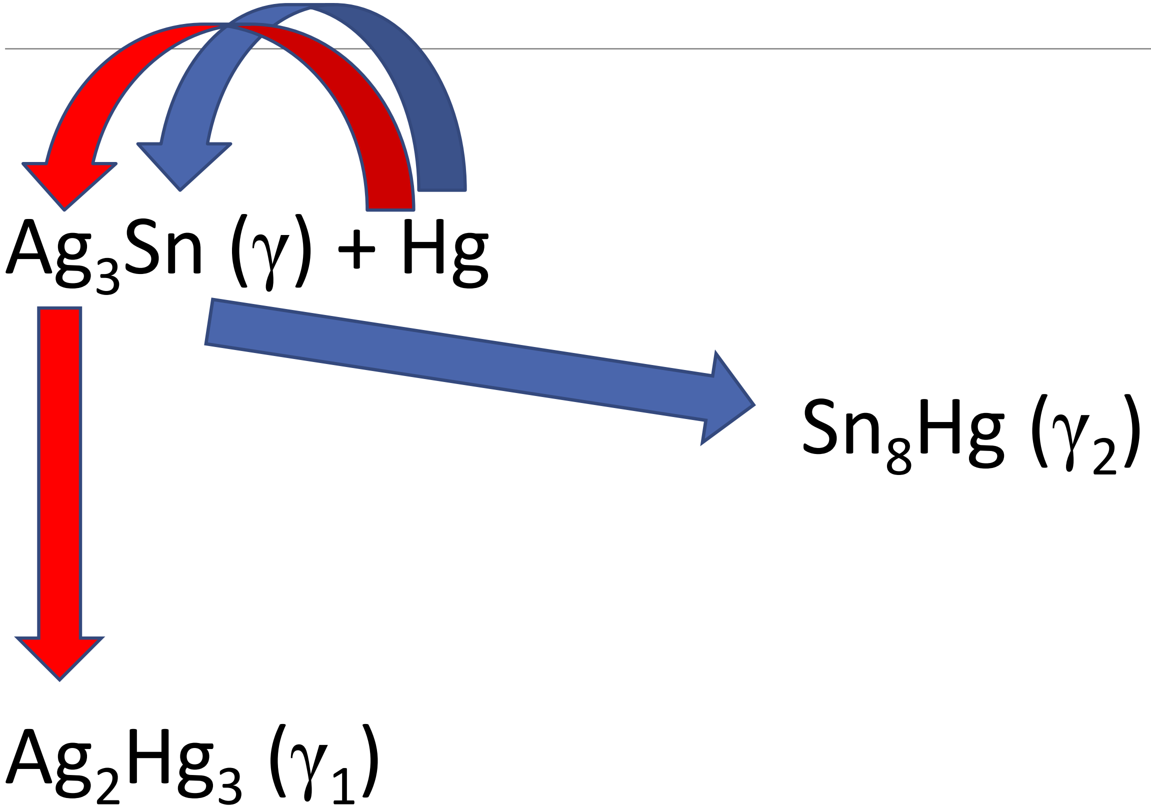


Setting reaction:

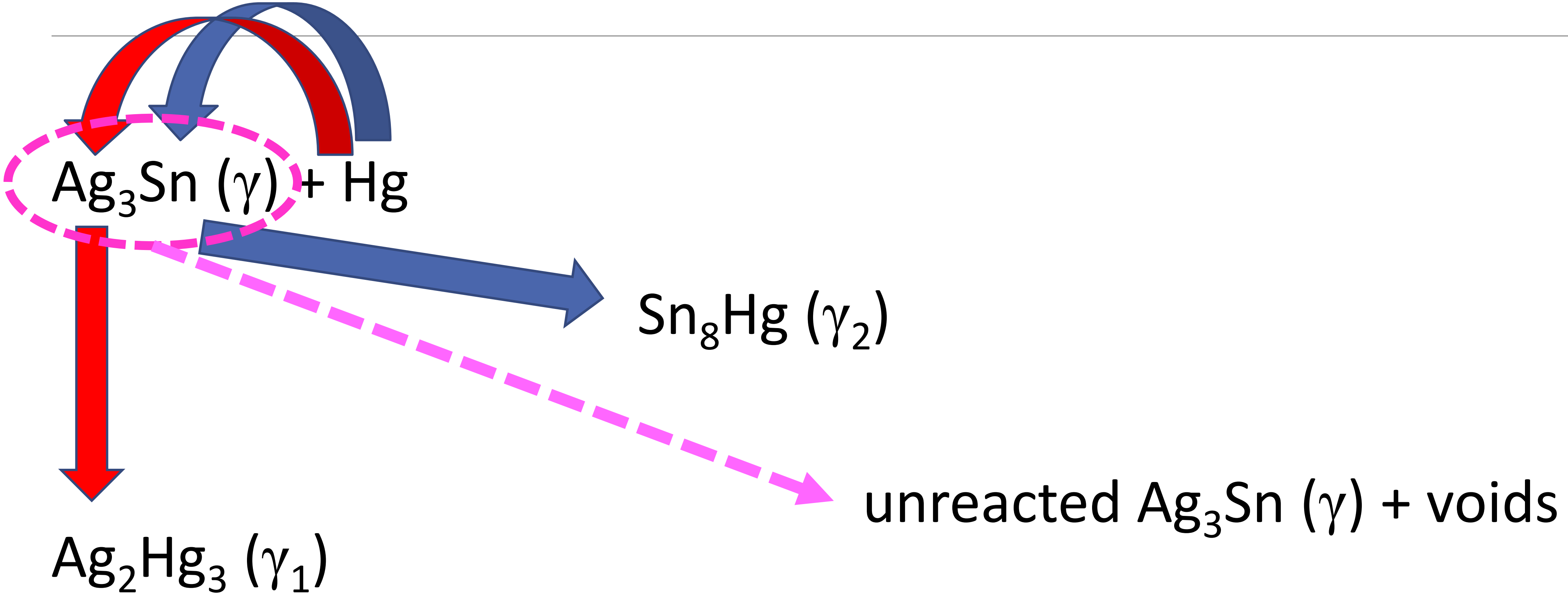
$Ag_3Sn\ (\gamma) + Hg \longrightarrow Ag_2Hg_3\ (\gamma_1) + Sn_8Hg\ (\gamma_2)$ + unreacted

$Ag_3Sn\ (\gamma)$ + voids

Setting reaction:



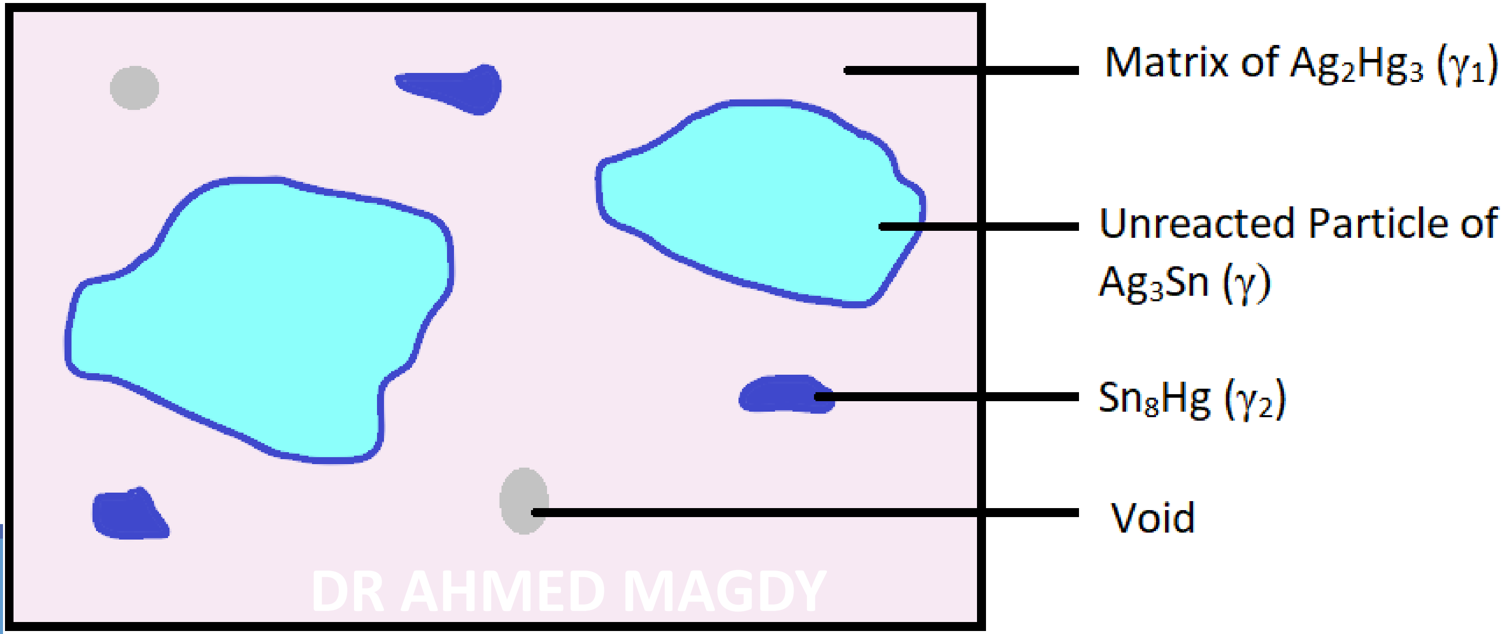
Setting reaction:



Microstructure:

Cored structure

- Formed of unreacted Ag_3Sn (γ) + Sn_8Hg (γ_2).
- They are surrounded and bounded by a matrix of Ag_2Hg_3 (γ_1) with some voids.



Properties of the different phases:

- Ag_3Sn (γ) phase: the strongest and most resistant to corrosion.
- Ag_2Hg_3 (γ_1) phase: less strong and less resistant to corrosion.
- Sn_8Hg (γ_2) phase: the weakest and least resistant to corrosion.

Phase	Tensile strength
γ	170 MPa
γ_1	30 MPa
γ_2	20 MPa

Properties of the different phases:

- **Excess mercury** will produce more γ_1 and γ_2 on the expense of γ phase will lead to:
  - Decrease strength.
  - Decrease corrosion resistance.
  - Increase creep.

Properties of the different phases:

- Elimination of Sn_8Hg (γ_2) phase will lead to improve dental amalgam properties.

High copper amalgam (γ_2 free amalgam):

Increasing the copper content of the dental amalgam alloy will lead to elimination of Sn_8Hg (γ_2) phase and improving the dental amalgam properties.

The copper content varies from 13 – 30%.

Admixed high copper amalgam:

The copper content of the alloy powder is increased by mixing two alloys particles:

- Silver copper (Ag-Cu) eutectic alloy.
- Silver-tin Ag_3Sn (γ) alloy.

Setting reaction:

The setting reaction occurs in two steps:

1. Amalgamation reaction.
2. Solid-state reaction

Setting reaction:

1. **Amalgamation reaction:**

Like the low copper amalgamation reaction.

The silver-copper eutectic alloy does not participate in the reaction.

Ag_3Sn (γ) + Ag-Cu (eutectic) + Hg $\longrightarrow$ Ag_2Hg_3 (γ_1) + Sn_8Hg (γ_2) + unreacted Ag_3Sn (γ) + unreacted Ag-Cu (eutectic) + voids.

Setting reaction:

2. **Solid-state reaction:**

   - It is the Sn_8Hg (γ_2) phase elimination step.
   - The reaction between Ag-Cu (eutectic) and Sn_8Hg (γ_2) takes place slowly resulting in formation of Ag_2Hg_3 (γ_1) and a new phase Cu_6Sn_5 (η) "eta phase" as a reaction zone around Ag-Cu eutectic particles.

Setting reaction:

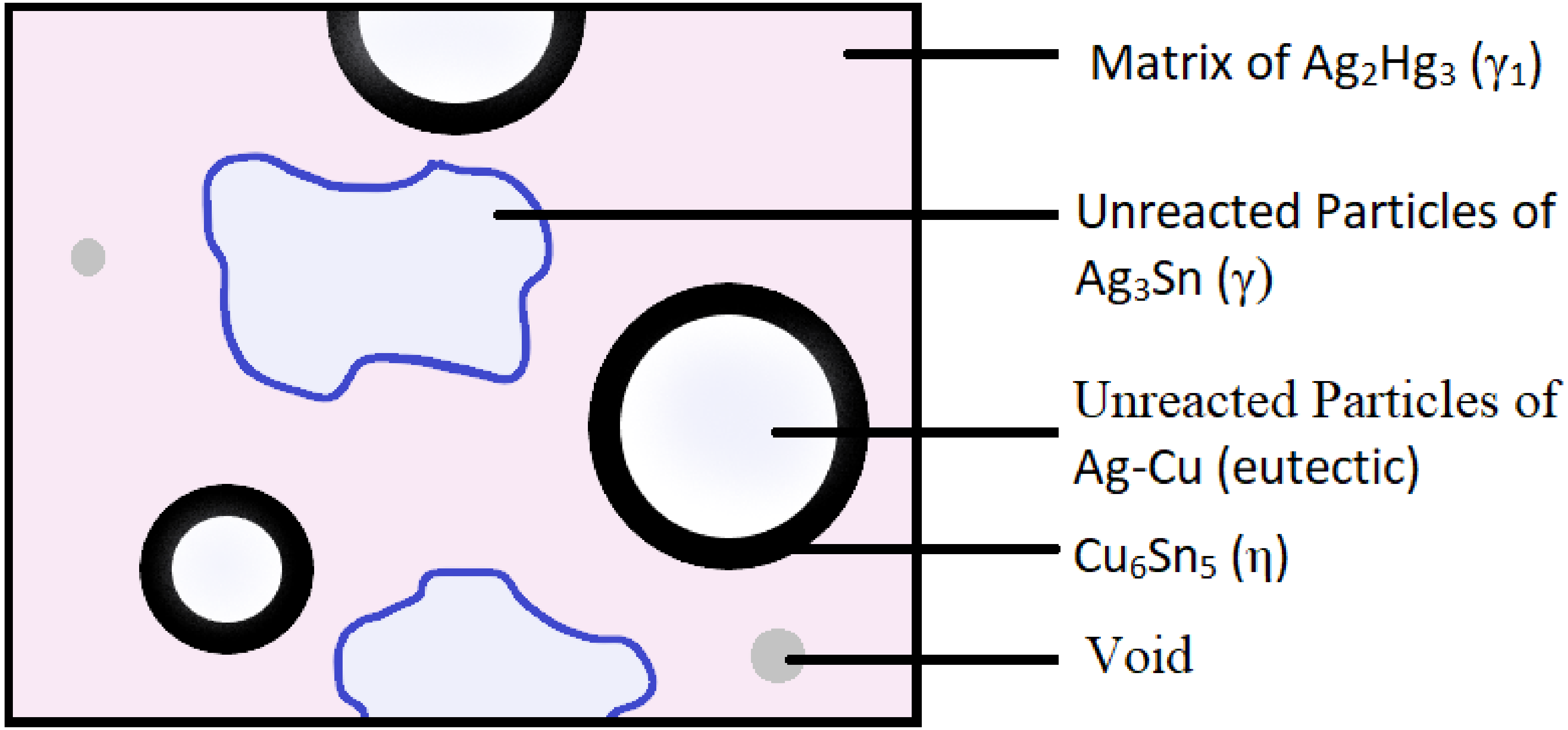
2. **Solid-state reaction:**

$$\text{Ag-Cu (eutectic)} + Sn_8Hg\ (\gamma_2) \longrightarrow Ag_2Hg_3\ (\gamma 1) + Cu_6Sn_5\ (\eta)$$

Microstructure:

- **Cored structure**
- It is formed of a matrix of Ag_2Hg_3 (γ_1) surrounds the unreacted Ag_3Sn (γ) and unreacted Ag-Cu (eutectic).
- The Ag-Cu (eutectic) particles is surrounded by halos of Cu_6Sn_5 (η).

Microstructure:



Drawbacks of admixed high copper amalgam

1. Uneven distribution of the two particles in the powder due to sedimentation of one particle in the container.
2. Surface oxidation of the silver-copper eutectic alloy.

Unicompositional high Copper amalgam

- The amalgam alloy powder is formed of one particle type with a copper content 13 – 30%.
- Each particle contains Ag_3Sn (γ) and Cu_3Sn (ε) “epsilon” phases.

Unicompositional high Copper amalgam

- This unicompositional form overcome the drawbacks of admixed type.
- The Sn_8Hg (γ_2) phase is eliminated at the beginning of the reaction.

Setting Reaction:

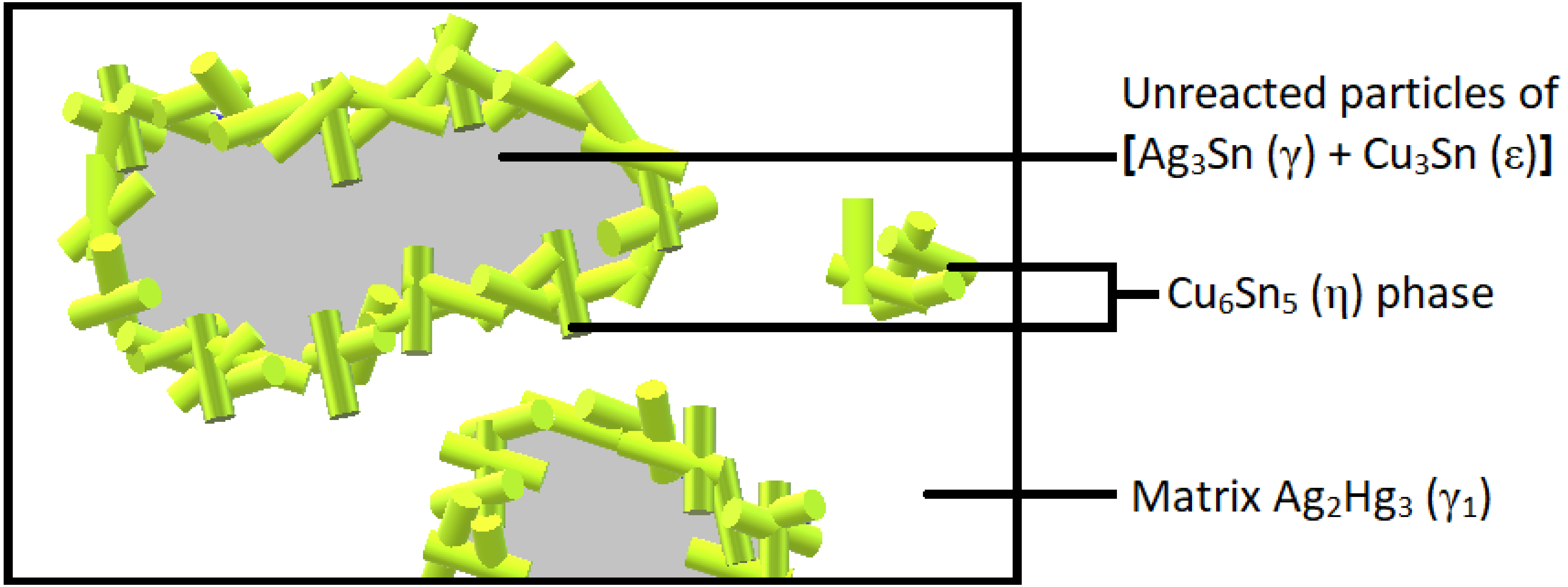
$[Ag_3Sn\ (\gamma) + Cu_3Sn\ (\varepsilon)] + Hg \longrightarrow Ag_2Hg_3\ (\gamma_1) + Cu_6Sn_5\ (\eta) +$

unreacted $[Ag_3Sn\ (\gamma) + Cu_3Sn\ (\varepsilon)]$

Microstructure:

- **Cored structure**
- It is formed of a matrix Ag_2Hg_3 (γ_1) surrounds unreacted particles of [Ag_3Sn (γ) + Cu_3Sn (ε)].
- The Cu_6Sn_5 (η) phase formed in a rod shape structure.
- The Cu_6Sn_5 (η) phase surrounds the unreacted particles of [Ag_3Sn (γ) + Cu_3Sn (ε)] and embedded as crystals in Ag_2Hg_3 (γ_1) phase.

Microstructure:

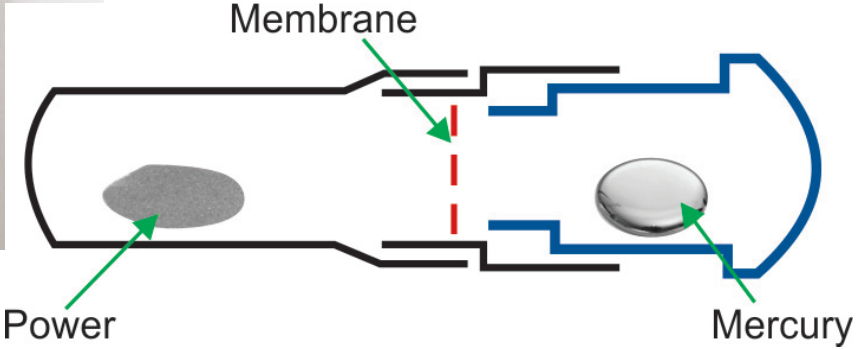


Manipulation of Dental Amalgam

Mode of presentation:

1. Tablets and mercury.
2. Preproportioned capsules.
3. Powder and mercury.

Manipulation of Dental Amalgam



Manipulation of Dental Amalgam

Selection of the alloy:

- According to several factors such as; particle shape, particle size, zinc content and copper content.

Manipulation of Dental Amalgam

Proportioning:

Two techniques are recommended:

1. **Wet technique**: the mercury/alloy ratio is slightly more than 1:1.
2. **Dry technique** (Eam's technique): the mercury/alloy ratio is 1:1.

Manipulation of Dental Amalgam

Proportioning:

Preproportioned capsules are widely used nowadays. .

Manipulation of Dental Amalgam

Proportioning:

Excess mercury leads to more formation of γ_1 and γ_2 on the expense of stronger γ phase.

This results in ↓: strength, ↓ corrosion resistance, ↑ setting expansion and ↑ creep.

Manipulation of Dental Amalgam

Proportioning:

Less mercury leads to not wetting of all powder particles with mercury.

This results in friable mix, ↑ voids, ↓strength and ↓corrosion resistance.

Manipulation of Dental Amalgam

Trituration:

It is the vigorous mixing of dental amalgam alloy with the mercury.

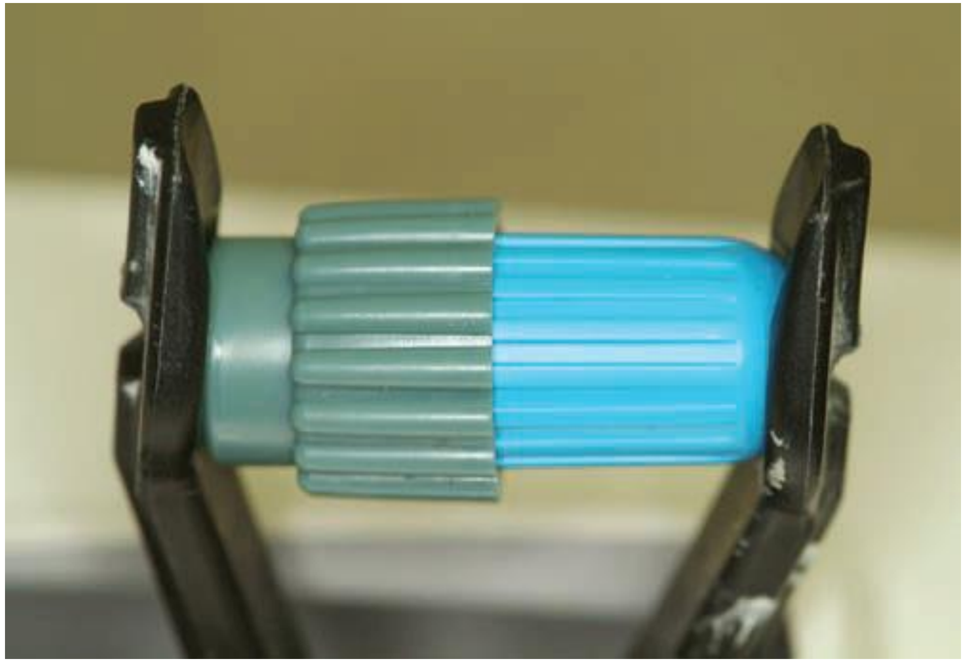
Trituration could be performed manually (using mortar and pestle) or mechanically (using amalgamator).

Manipulation of Dental Amalgam

Trituration:

Manipulation of Dental Amalgam

Trituration:



Manipulation of Dental Amalgam

Advantages of mechanical trituration:

1. Less risk of mercury exposure.
2. Lower mercury/ alloy ratio can be used.
3. More uniform and reproducible mix.
4. Save time and effort.

Manipulation of Dental Amalgam

The properly triturated mix:

- It has a shiny surface and soft consistency.
- It results in the best mechanical properties and corrosion resistance.

Manipulation of Dental Amalgam

Over trituration (increasing time or speed):

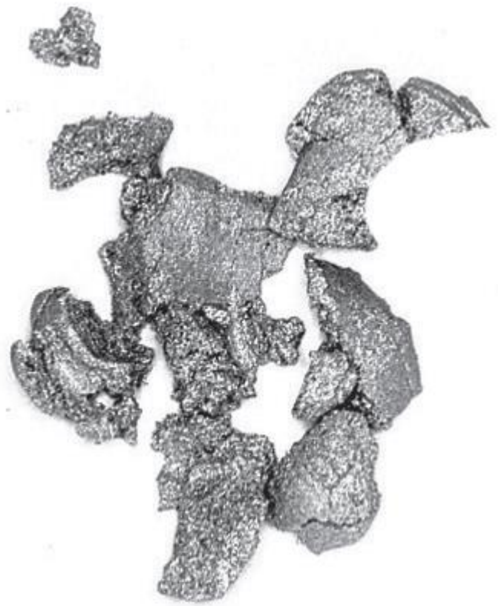
- It tends to crumble and sticks to the capsule.
- It is difficult to condense.
- It has lower working time.
- It has higher contraction and creep.

Manipulation of Dental Amalgam

<u>Under trituration (decreasing time or speed):</u>

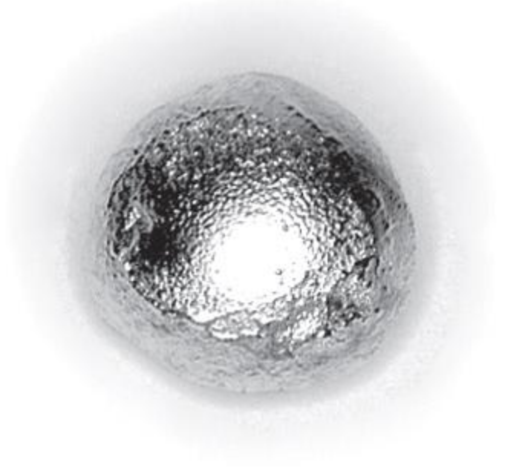
- It is grainy and friable with dull appearance.
- It has lower working time and more excess mercury (Poor Properties).

Manipulation of Dental Amalgam



Under Triturated

Proper Triturated



Over Triturated

Manipulation of Dental Amalgam

Under Triturated Proper Triturated Over Triturated

Manipulation of Dental Amalgam

Mulling:

It is the rubbing of the triturated mix into a rubber finger-stall.

Manipulation of Dental Amalgam

Condensation:

It is the packing of the triturated amalgam mix inside the prepared cavity incrementally with condensation of each increment separately.

Manipulation of Dental Amalgam

Condensation:

Manipulation of Dental Amalgam

Condensation:

Manipulation of Dental Amalgam

Condensation:

Manipulation of Dental Amalgam

Condensation:

Manipulation of Dental Amalgam

Condensation:

Manipulation of Dental Amalgam

Condensation:

Manipulation of Dental Amalgam

Objectives of condensation:

1. Increase adaptation of the restoration to the cavity wall.
2. Decrease the mercury content by express excess mercury to the surface.
3. Reduce the porosity providing a strong compact mass.

Manipulation of Dental Amalgam

Condensation:

Condensation **should not** be done after 3 minutes from trituration.

Manipulation of Dental Amalgam

Effect of delayed condensation (after 3 minutes from trituration):

1. Reduce strength due to breaking up of partially formed matrix.
2. Partially set matrix contains excess mercury and excess porosities.
3. Decrease the adaptation to the cavity wall due to decrease plasticity.
4. Decrease the bonding between increments.

Manipulation of Dental Amalgam

Carving:

The cavity is overfilled, then the top mercury-rich layer is carved.

Manipulation of Dental Amalgam

Objectives of carving:

1. Reproduce the anatomy of the tooth.
2. Removal of the top mercury-rich layer.

Manipulation of Dental Amalgam

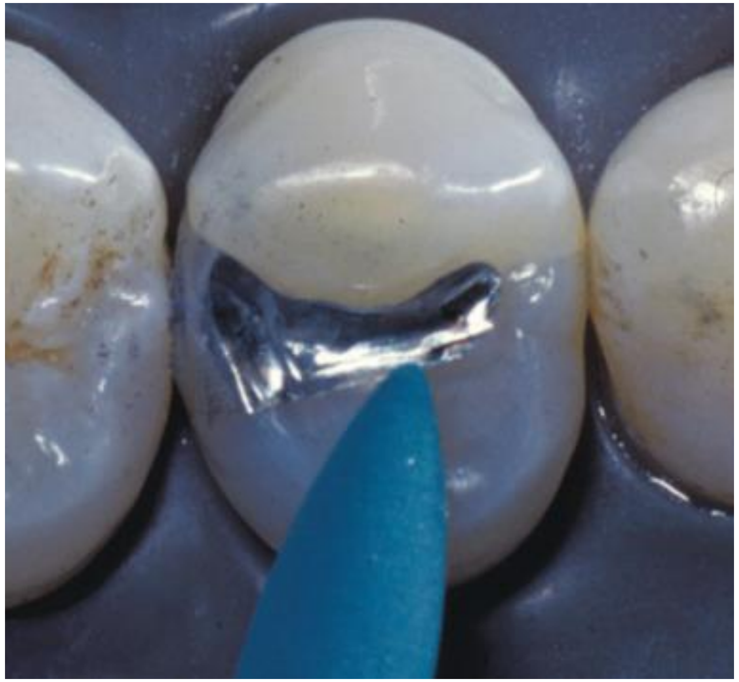
Finishing and polishing:

Finishing is done using finishing burs.

Polishing is done using rubber cups and soft brushes with pumice.

Manipulation of Dental Amalgam

Finishing and polishing:



Manipulation of Dental Amalgam

Timing of finishing and polishing:

Conventional low copper amalgam → after 24 hours.

High copper amalgam → shortly after insertion.

Manipulation of Dental Amalgam

Timing of finishing and polishing:

Avoid overheating of restoration to prevent raising the mercury to the surface.

Manipulation of Dental Amalgam

Objectives of finishing and polishing:

1. Increase patient acceptance to restoration.
2. Increase corrosion resistance by obtaining smooth surface.

Properties of Dental Amalgam:

1. Dimensional Changes (Immediate + Delayed).
2. Flow and Creep
3. Strength
4. Bond to tooth structure
5. Biological properties

Dimensional Changes

- Ideally, any restoration should be dimensionally stable during setting.

Dimensional Changes

- **<u>Contraction of restoration:</u>**

It leads to leakage at the tooth-restoration interface. This leakage leads to recurrent caries and hypersensitivity.

Dimensional Changes

- **Expansion of restoration**

It leads to tooth fracture or protrusion of the restoration form the cavity

Protrusion occlusally ➔ overhanging margins that may ditch or accumulate food.

Protrusion gingivally ➔ gingival irritation.

Dimensional Changes

- **Dimensional changes during setting**

It is the dimensional changes between 5 minutes and 24 hours after amalgam insertion.

It should be less than ±20 µm/cm according to ADA specification which is achieved by all types of dental amalgam.

Dimensional Changes

➢ **Dimensional changes during setting**

After trituration, the following changes occurs:

1. Initial contraction in the first 30 minutes due to solubility of amalgam powder by mercury.
2. Expansion due to outward pressure of growing γ_1 crystals.
3. Dimensional changes became constant after 6 – 8 hours.

Dimensional Changes

➢ **Dimensional changes during setting**

Any manipulative variable that ↓ mercury ratio leads to contraction:

1. Lower Hg/alloy ratio.
2. High condensation pressure.
3. Small particle size (high surface area that react with mercury).

Dimensional Changes

➢ **<u>Dimensional changes during setting</u>**

The modern dental amalgams showed net contraction due to using smaller particles and using of mechanical amalgamators (low Hg/Powder).

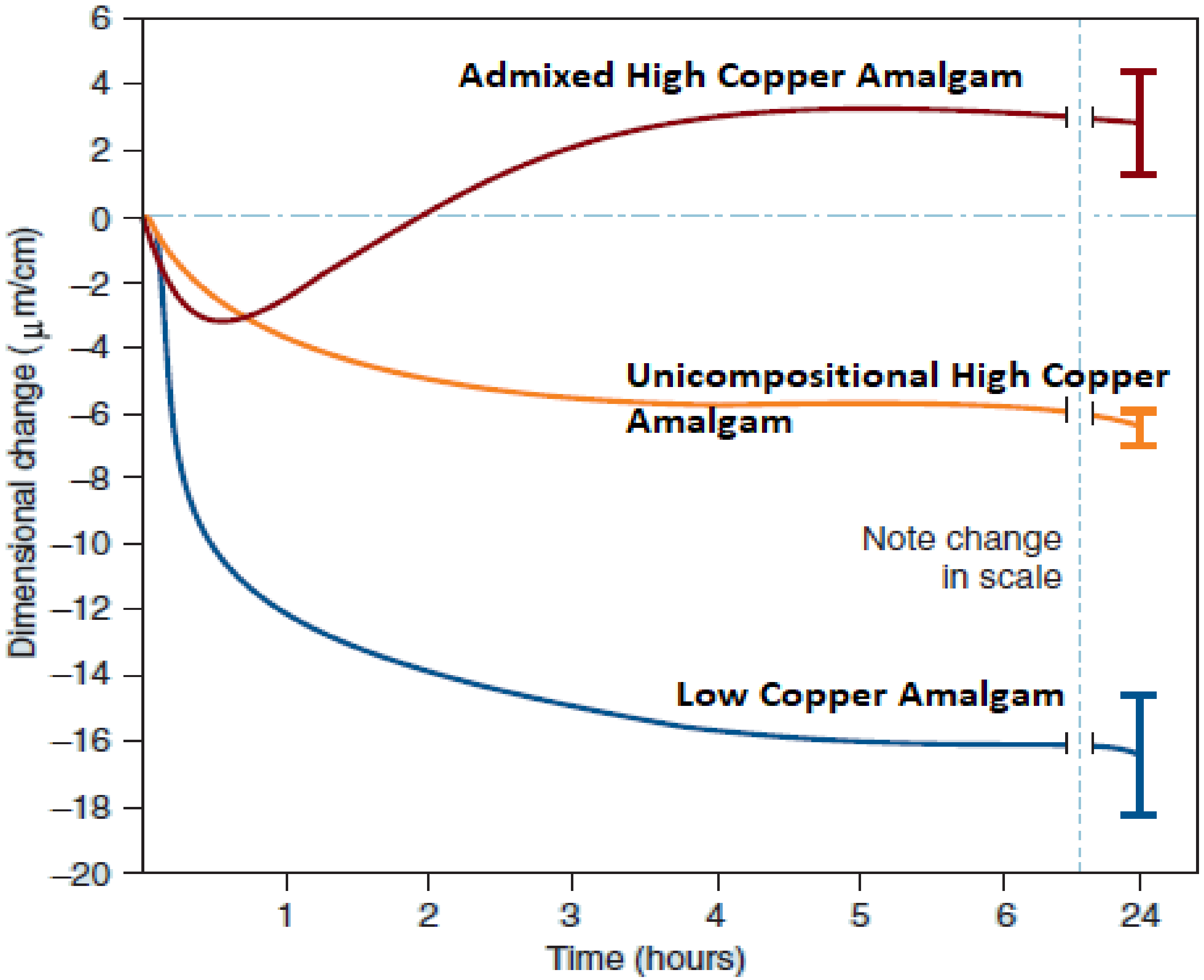
Dimensional Changes

- **<u>Dimensional changes during setting</u>**

Marginal adaptation of dental amalgam restoration achieved by:

1. Good condensation.
2. Self-seal property of dental amalgam (the corrosion products of dental amalgam are precipitated at the tooth-restoration interface and seal this gap in 2-3 months).

Dimensional Changes



Dimensional Changes

- **Delayed Expansion:**

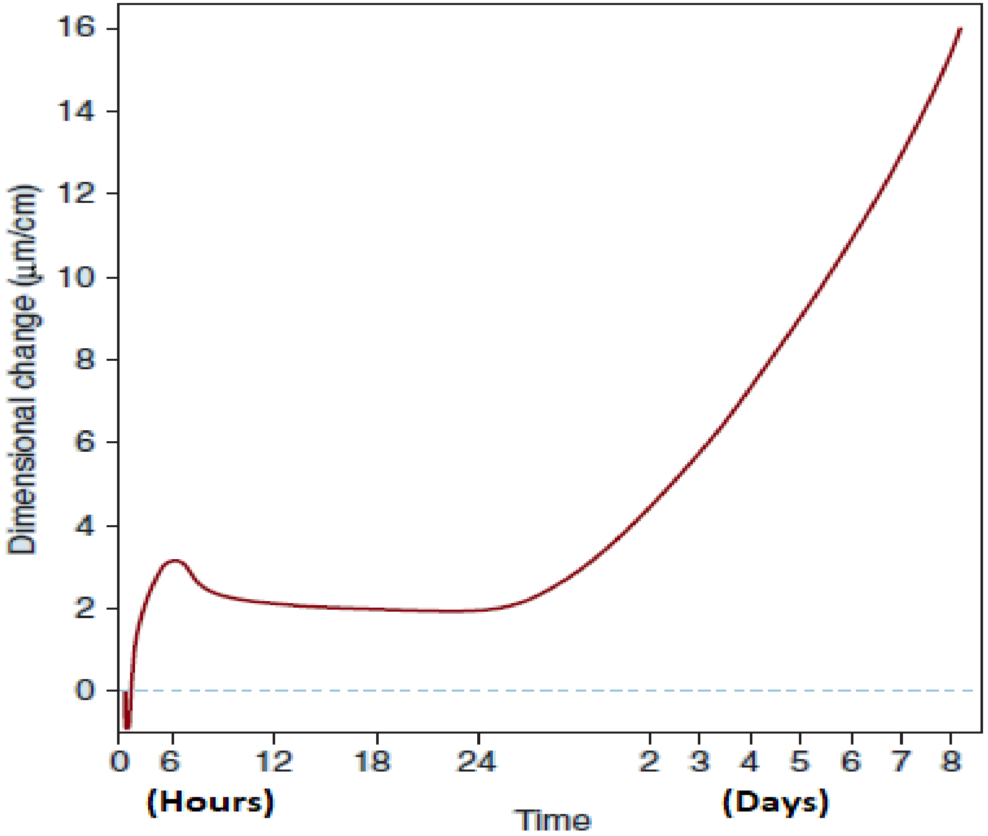
It occurs in zinc containing amalgam when exposed to moisture during trituration or condensation.

It starts after 3 – 5 days after restoration insertion and may continue for months.

Dimensional Changes

➢ **Delayed Expansion:**

Its value may reach 400 µm/cm.



Dimensional Changes

- **Delayed Expansion:**

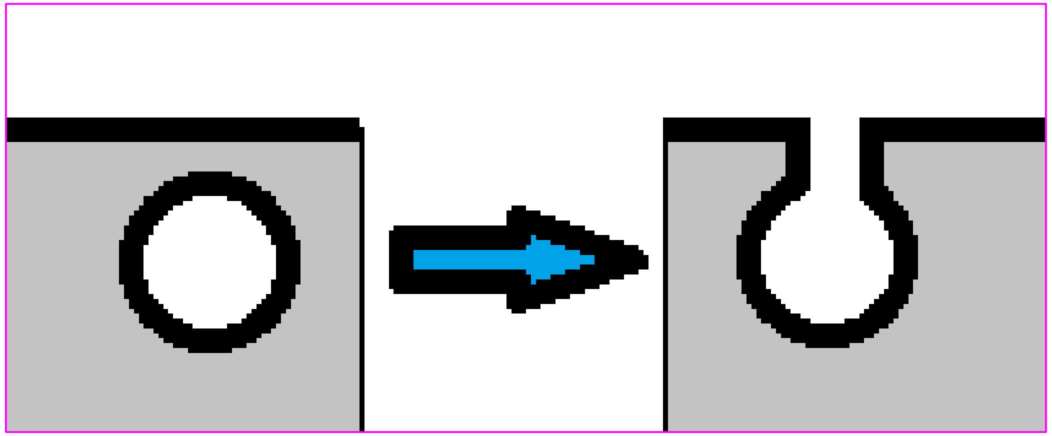
The zinc reacted with the water leads to evolution of hydrogen gas.

$$Zn + H_2O \longrightarrow ZnO + H_2 \uparrow$$

Dimensional Changes

- **Delayed Expansion:**

The H_2 gas leads to post-operative sensitivity and blistering .



Dimensional Changes

- **Delayed Expansion:**

Using zinc free amalgam is recommended in case of achieving isolation is difficult as in children, handicapped patients and inaccessible area.

Creep and Flow

Flow: It is a time dependent plastic deformation due to stresses application below the yield strength **before** complete setting of amalgam restoration.

Creep and Flow

Creep: It is a time dependent plastic deformation due to stresses application below the yield strength **after** complete setting of amalgam restoration.

Creep and Flow

Causes of creep of dental amalgam:

1. Dental amalgam is a viscoelastic material.
2. Subjected to stresses below the proportional limit inside the mouth.
3. The oral temperature near the softening temperature of amalgam

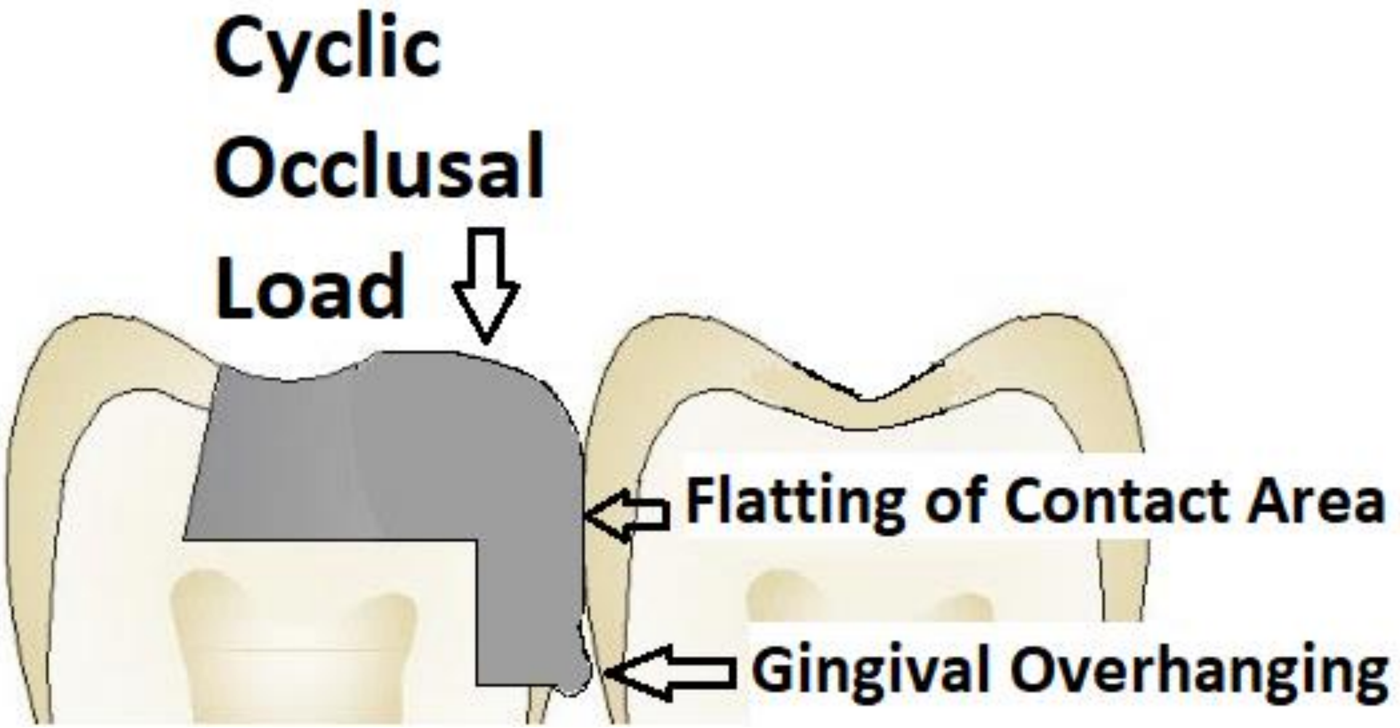
Creep and Flow

Clinical significance of creep:

1. Marginal breakdown (ditching).
2. Gingival overhanging margins → gingival irritation.
3. Flatting of the contact area.

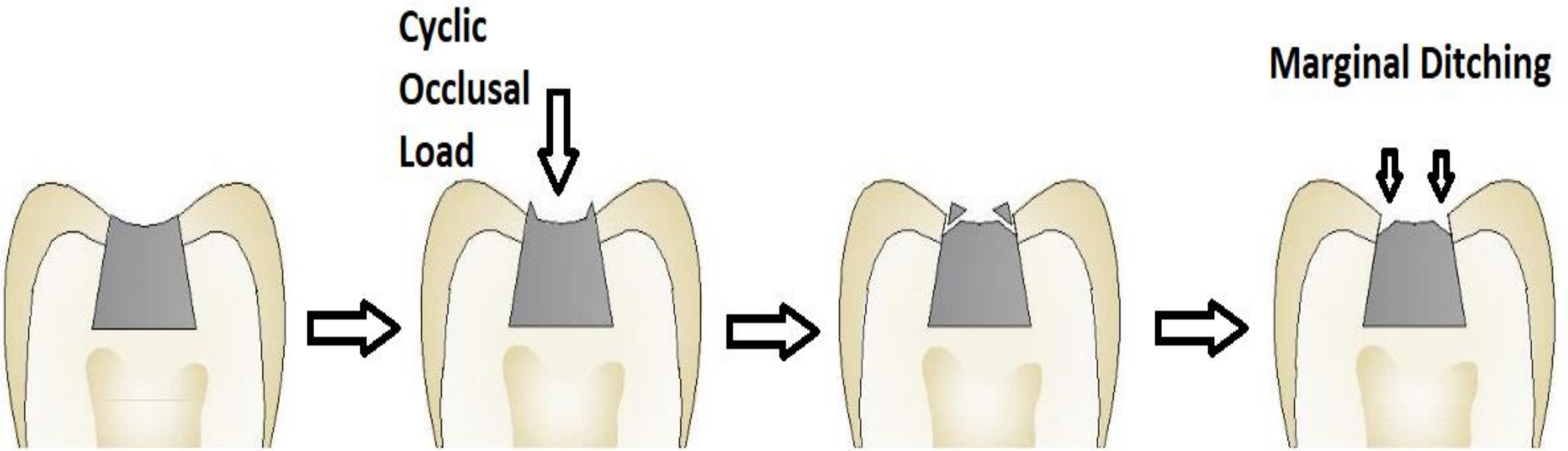
Creep and Flow

<u>Clinical significance of creep:</u>



Creep and Flow

Clinical significance of creep:



Creep and Flow

Methods of decreasing creep:

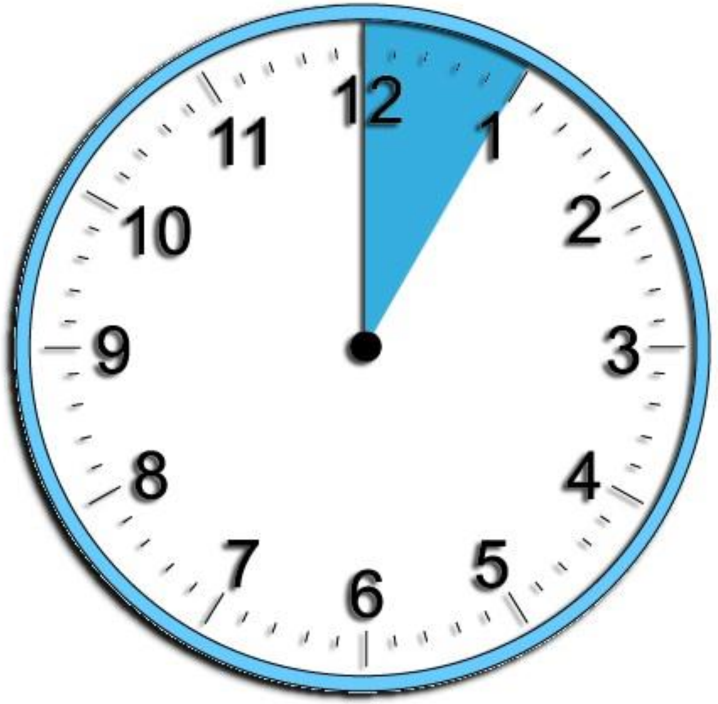
1. Use high copper alloy.
2. Decrease mercury content.
3. Proper condensation.

Strength

- Dental amalgam develops its strength slowly and reaches its final strength after 7 days.

Strength

- The dental amalgam should reach 80% of its final strength after 1 hour.



Strength

- The one-hour compressive strength is more important that the final strength to avoid fracture of the restoration by biting of the patient.

Strength

- Dental amalgam is brittle. i.e: Strong in compression but weak in tension.
- Dental amalgam is viscoelastic material. i.e: Sensitive to rate of loading.

Strength

To maximize strength of dental amalgam restoration:

1. Cavity preparation:

- Adequate cavity depth and width to provide bulky restoration.
- 90^{o} cavo-surface angle to avoid thin restoration.
- Rounding of all sharp line angles to avoid stress concentration.

Strength

To maximize strength of dental amalgam restoration:

2. Insulating Base:

- Using rigid insulating base under amalgam restoration

Strength

To maximize strength of dental amalgam restoration:

3. Amalgam manipulation:

- Selecting high copper amalgam.
- Decrease Hg/alloy ratio.

Strength

To maximize strength of dental amalgam restoration:

3. Amalgam manipulation:

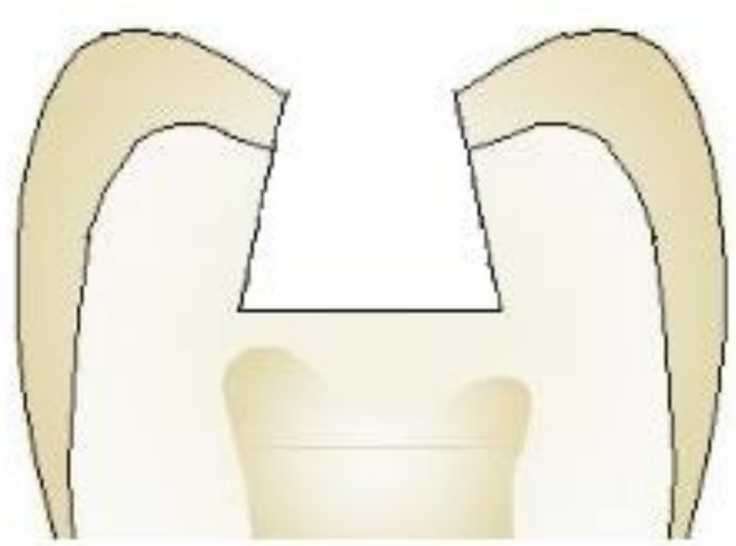
- Correct trituration time.
- Adequate condensation.
- Finish and polish restoration to decrease surface cracks and flaws.

Strength

Amalgam type	1 hour compressive strength (MPa)	7 days compressive strength (MPa)	24 hour Tensile strength (MPa)	Creep (%)
Low copper lathe cut	145	343	60	2
High copper admixed	137	431	48	0.4
High copper unicompositional	262	510	64	0.13

Bond to tooth structure:

- Dental amalgam bonds to the tooth structure by macro-mechanical retention.
- Amalgam bonding systems have been introduced.



Biological Properties

1. Corrosion.
2. Thermal Properties.
3. Mercury Toxicity.

Corrosion

- **Causes of Corrosion:**

Dental amalgam undergoes corrosion because its heterogeneous structure.

Corrosion

- **Corrosion leads to:**

1. Decreasing strength.
2. Release of metallic products inside oral cavity.

Corrosion

- **Corrosion could be decreased by:**

1. Selecting high copper amalgam alloy.
2. Decrease Hg/alloy ratio.
3. Proper condensation.
4. Finishing and polishing.

Thermal irritation

- **<u>Corrosion could be decreased by:</u>**

Dental amalgam is good thermal conductor.

In deep cavities, it should be preceded by an isolating base.

Mercury Toxicity

Properties of mercury:

- Pure mercury has high vapor pressure at room temperature.
- It is highly toxic (4000 µm/kg of body weight)

Mercury Toxicity

The main resource of the mercury exposure in dental clinic arises from:

- Accidental spills.
- Direct contact with mercury.
- Amalgamator.
- Remove old restoration.

Mercury Toxicity

Mercury hygiene:

- Using no touch technique.
- Clean up spilled mercury immediately.

Mercury Toxicity

Mercury hygiene:

- Store amalgam scrap under sodium thiosulfate (fixer of dental X-ray film processing solutions)
- Use water coolant and suction during removing old amalgam restorations.

Thank You