Impression materials

Chemistry and properties

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Purpose:

To prepare accurate and true **replicas** of oral structures (teeth, mucosa)

The **replica** is prepared in 2 steps:

Step 1. Making a negative (impression)

Step 2. Prepare a replica - an accurate positive model of teeth and adjacent oral tissues

General requirements

Before set:

1. Good handling properties – **easy to prepare/mix, flowable-plastic before** set, but **viscous enough not to flow** out of a tray, **adequate working** and **setting times**

2. Capable to fast transformation from **plastic to rigid** body (setting time up to 5-7 min)

3. **Acceptable to a patient**
   - not toxic, not irritant, tasteless

After being set:

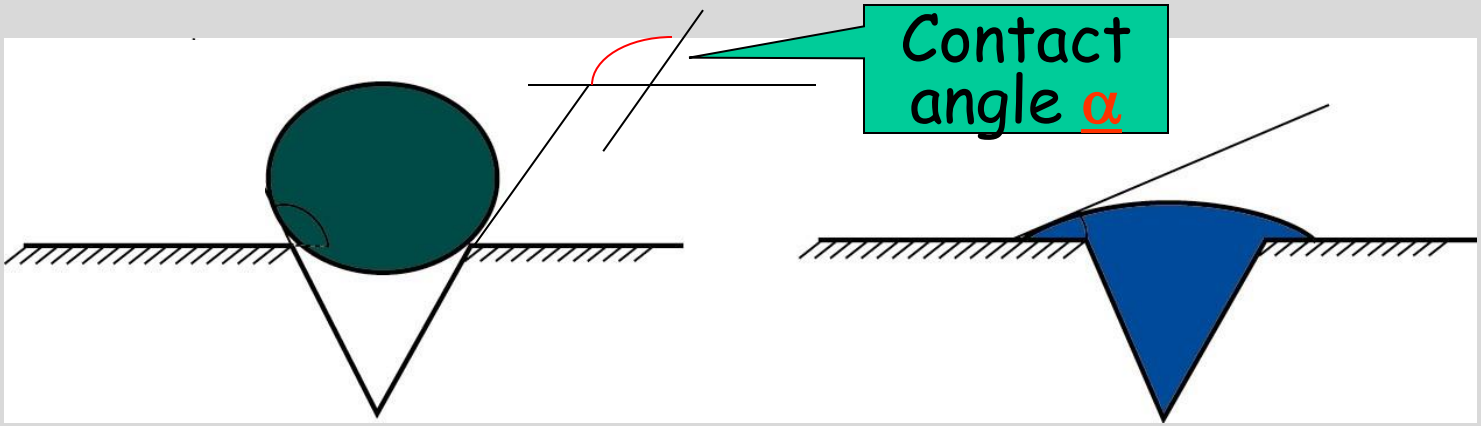
1. **Accuracy** and good **detail reproduction** (25-50μm),
2. Dimensionally stable,
3. **Elastic, tear resistant, low creep,**
4. Resistant to disinfection solutions,
5. Compatible with model (gypsum) materials,
6. Cost effective.

Important properties and terms

- Hydrophilic/hydrophobic,
- Pseudoplastic/thixotropic,
- Elastic, plastic (permanent, irreversible) deformations,
- Strength,
- Working time,
- Setting time.

Important properties of impression materials before setting

Hydrophobic/hydrophilic



Hydrophobic material ($\alpha > 90^o$)

unable to wet humid surfaces

doesn't copy wet surface

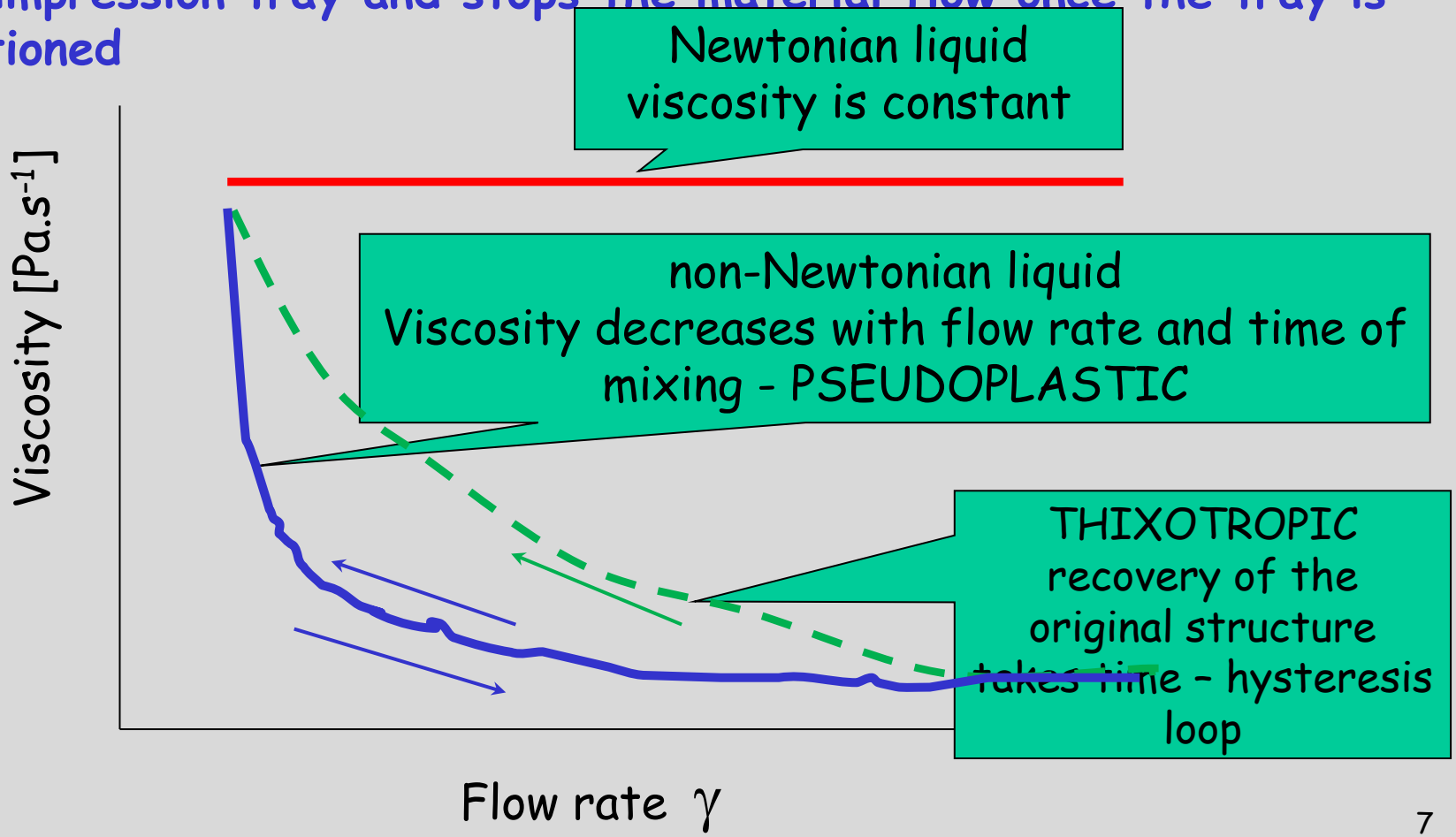
Hydrophilic material ($\alpha < 90^o$)

able to wet humid surfaces

copy wet surfaces

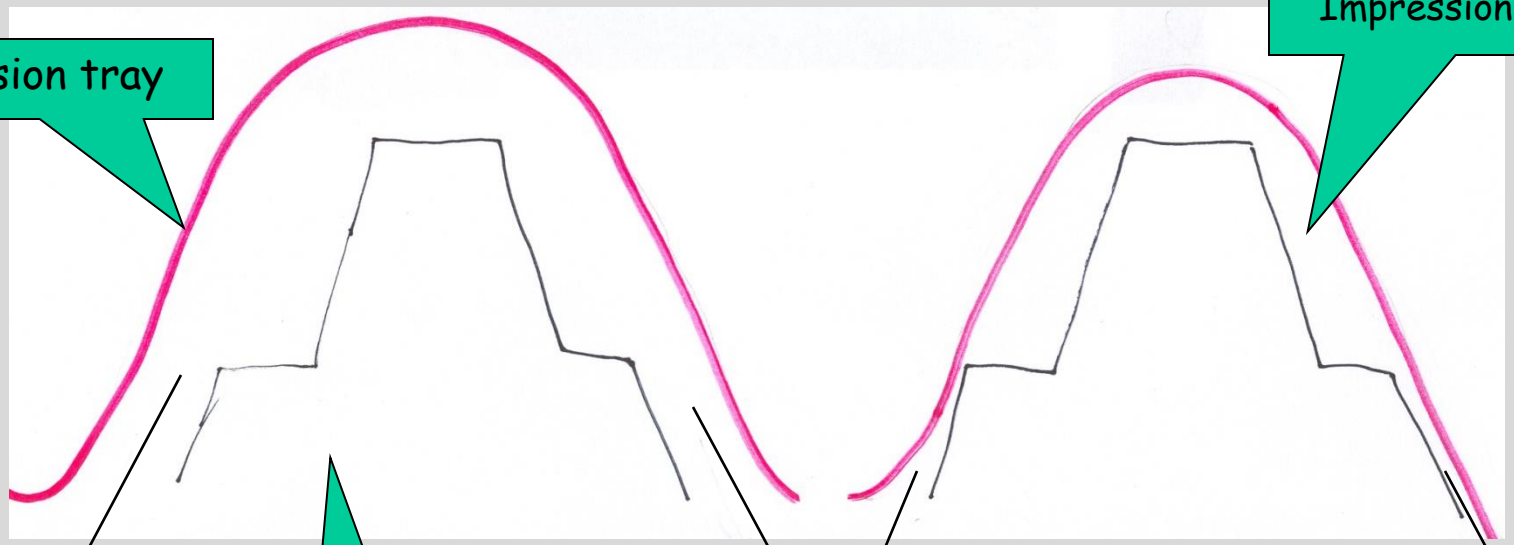
Pseudoplasticity/thixotropy (shear thinning)

A decrease in viscosity with shear rate e.g - mixing, vibrations, flow, shaking, aggitation decreasing the stress necessary to seat the impression tray and stops the material flow once the tray is positioned



Seating pressure

Seating pressure



Impression tray

Impression material

Broad „channel“ high flow at low seating pressure

Prepared tooth

Narrow „channel“ seating pressure rapidly increases

Flow in narrow channels

Poiseuille´s law:

$$\Delta P = 8.\eta.L\ .Q/\pi r^4$$

Poiseulle's law states that the flow rate Q is also dependant upon fluid viscosity η, pipe length L and the pressure difference between the ends ΔP.

Where:

ΔP is the pressure drop

L is the length of pipe

μ is the viscosity

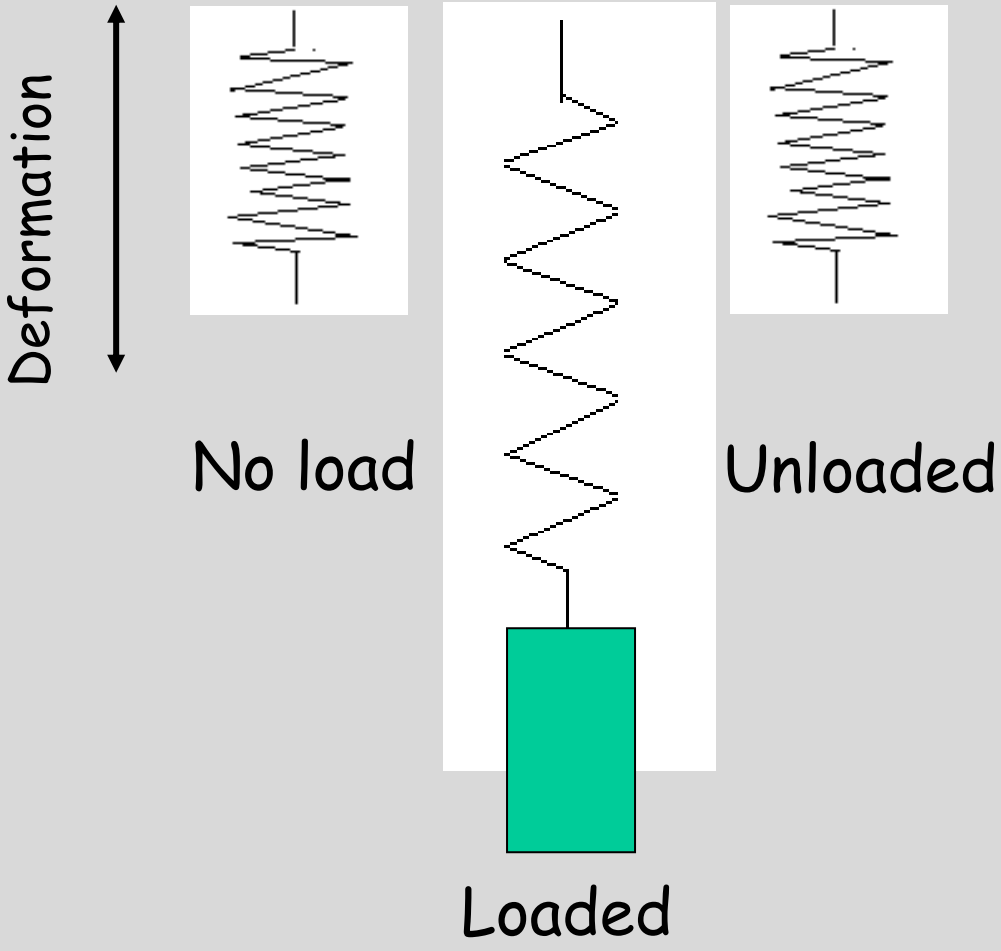
Q is the volumetric flow rate

r is the radius or a width of a tube/gap

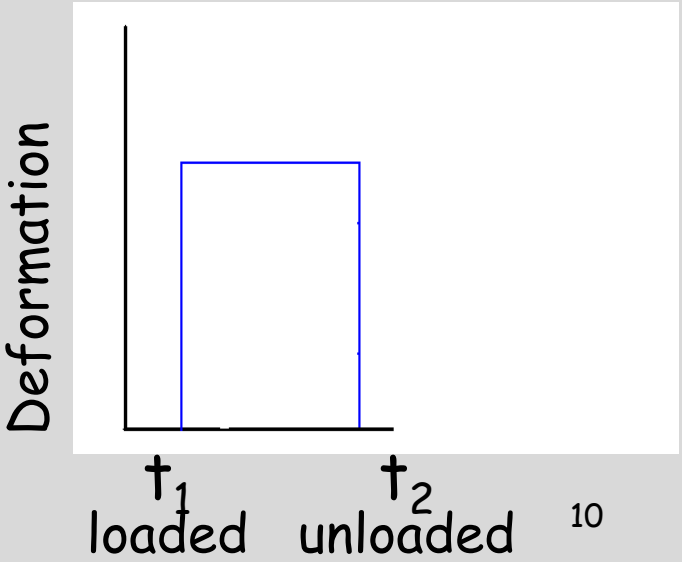
Important properties of impression materials after their setting

1. Elastic behavior

A spring – ideally elastic behavior (Hook's law)



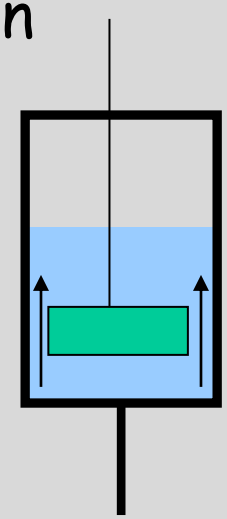
When unloaded !fully recovers!



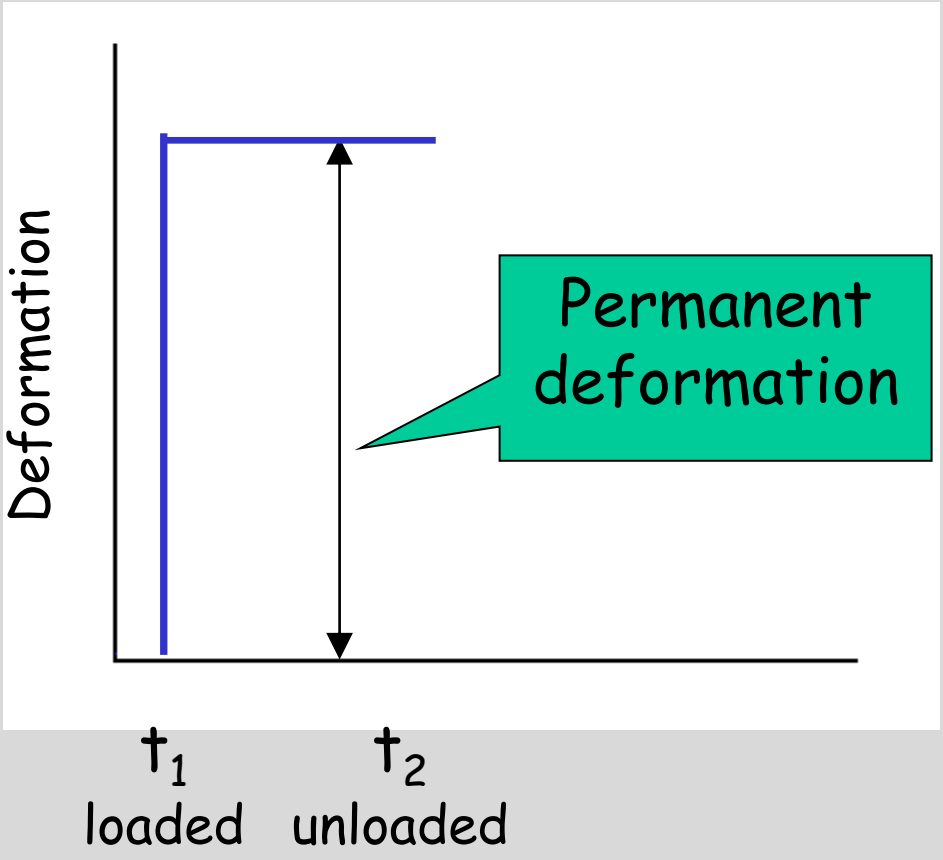
2. Plastic behavior

A dashpot – ideally plastic behavior

Plastic =
permanent/irreversible deformation

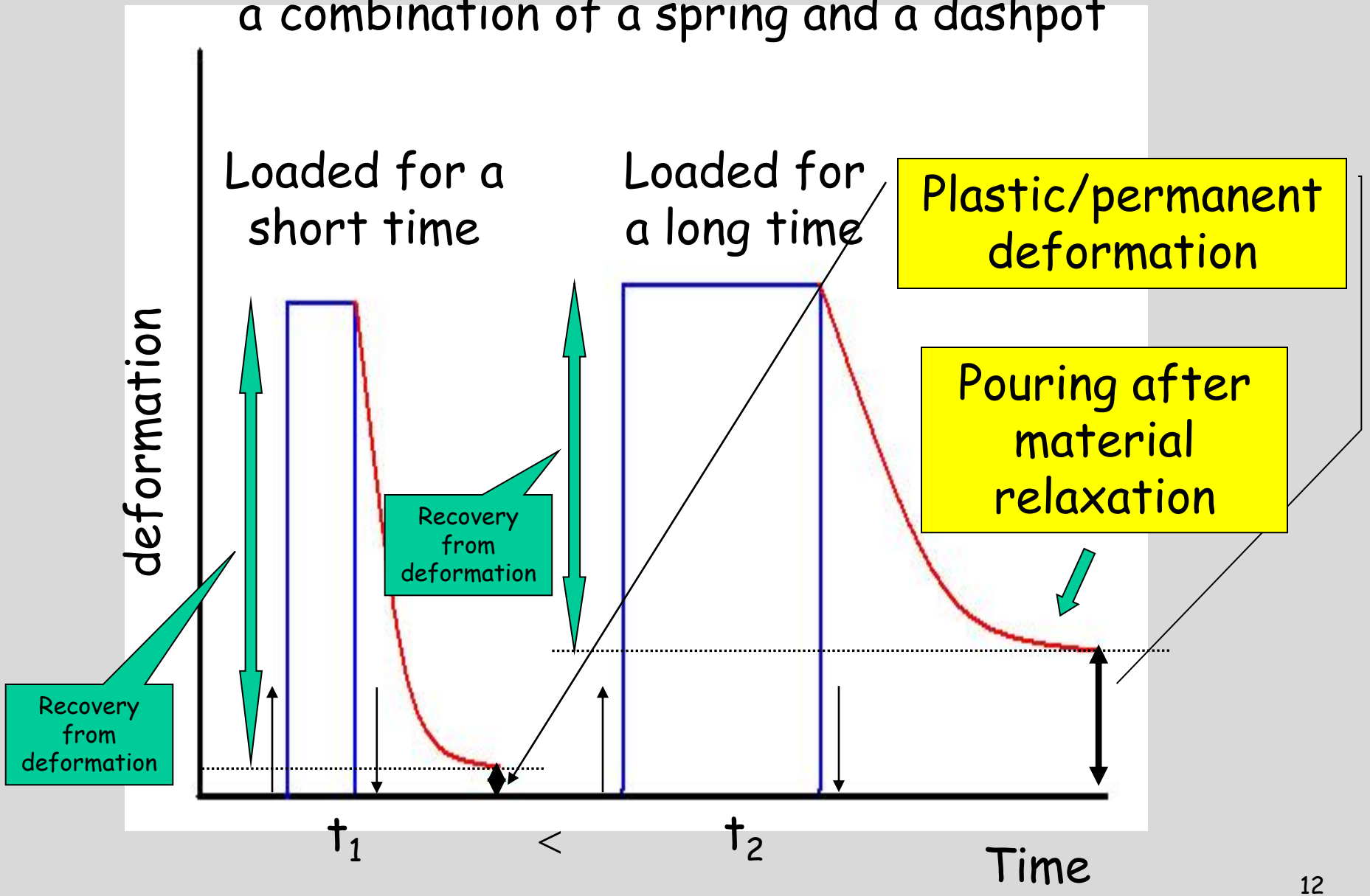


When unloaded
!No recovery!

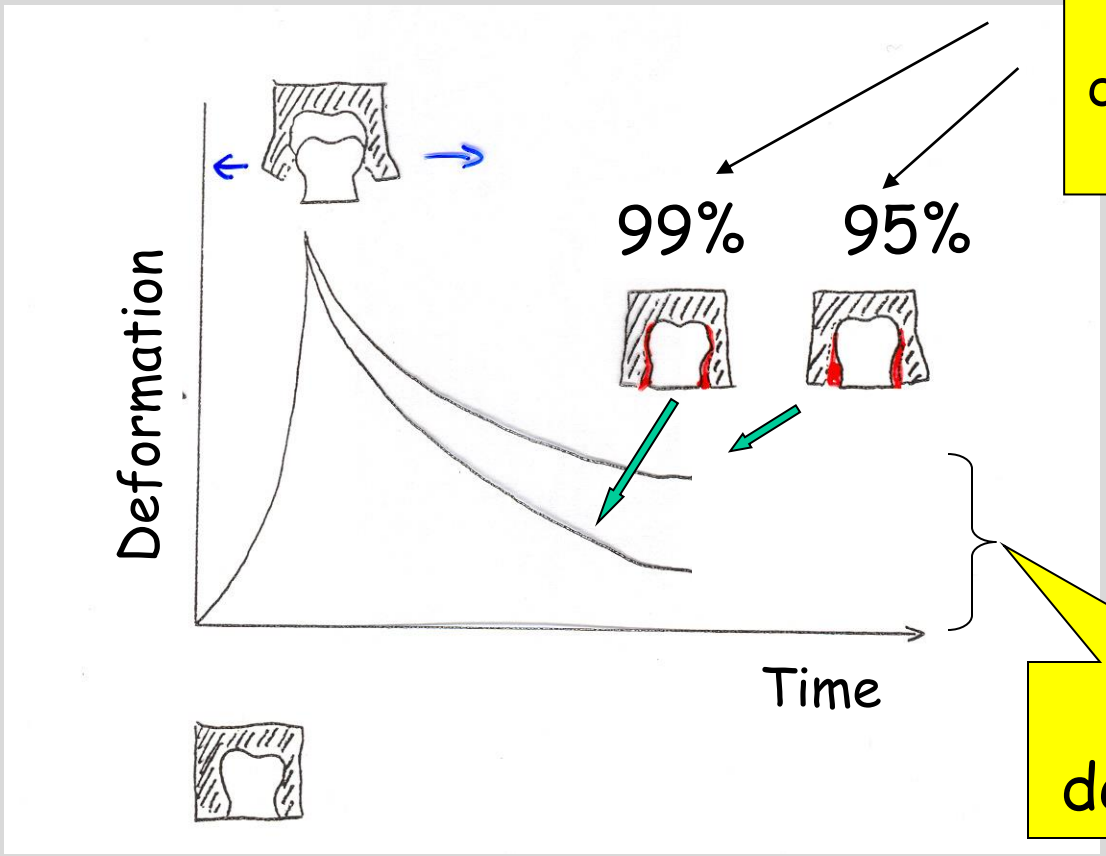


Viscoelastic behavior of real impression materials –

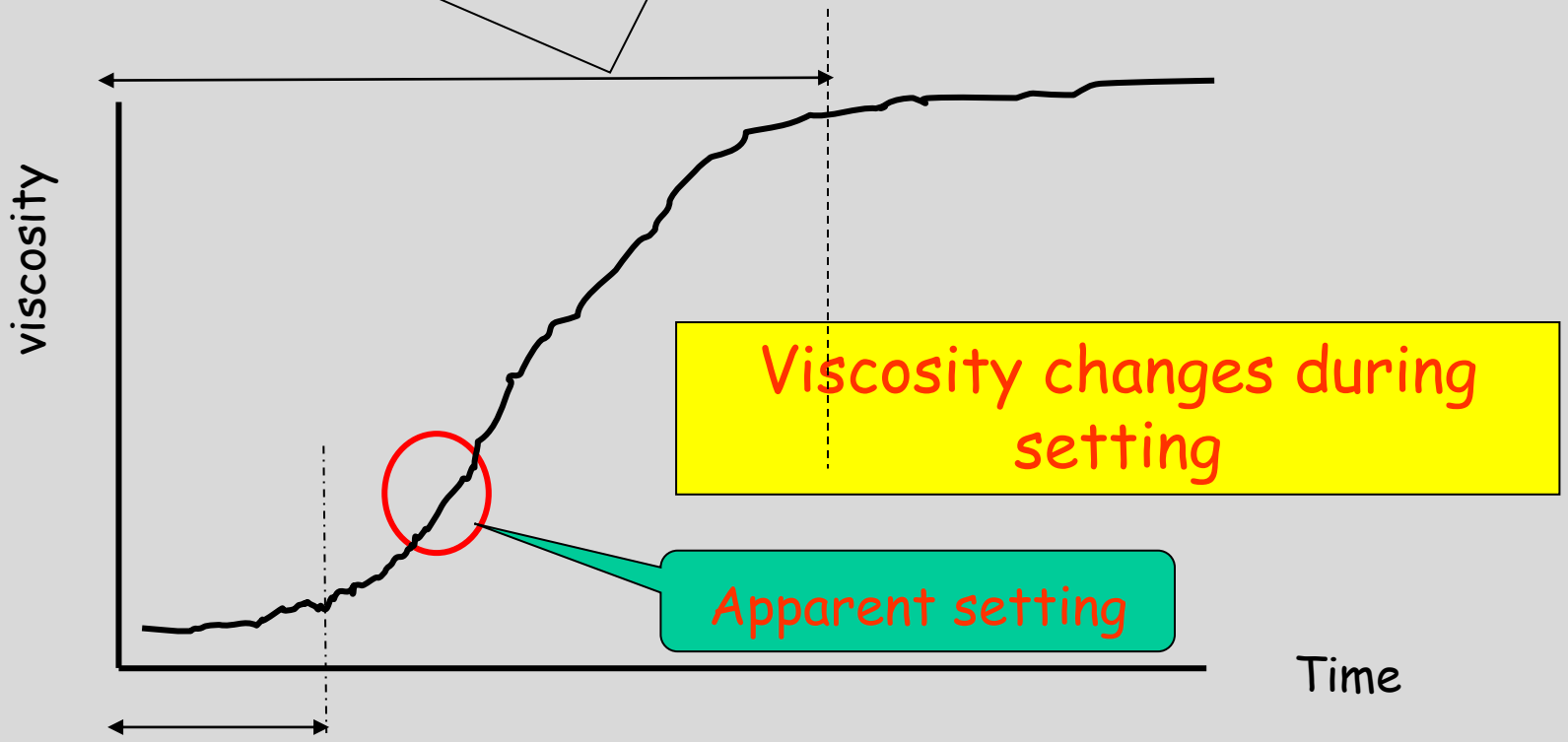
a combination of a spring and a dashpot



Effect of recovery from deformation on the accuracy of a model



Setting time – a period from the start of mixing till the impression becomes elastic enough to resist deformations during its withdrawal from the mouth



Working time – a period from the start of mixing to the final time at which the impression material can be seated in the mouth without its distorsion

Classification of impression materials

	Irreversible	Reversible*
Inelastic/rigid	Impression plaster ZnO-eugenol (ZOE)	Impression com-pounds
Elastic	Alginate Elastomeric: Polysulfide Polyether Silicone	Agar hydrocolloid

*On heating (thermoplastic)

Inelastic/rigid impression materials

A. Irreversible

1. Impression plaster

Main indication: impression of edentulous ridges

Setting reaction:

$CaSO_4.0.5H_2O + 1.5H_2O \rightarrow CaSO_4.2H_2O$ + heat +expansion

app. 0.1 lin %

Composition:

$CaSO_4 . 0.5H_2O$ β-hemihydrate

Potasium sulfate – to accelerate setting and to reduce expansion

Borax – a retarder to prolonge setting time

Diatomiceous earth, quartz, lime - to make the plaster more brittle

Advantages:

1. Cheap and long shelf life, easy to prepare
2. Very good surface detail reproduction
3. Excellent dimensional stability
4. Non toxic

Disadvantages:

1. Very rigid – often need to be fractured when
2. May dry soft tissues - unpleasant to patients

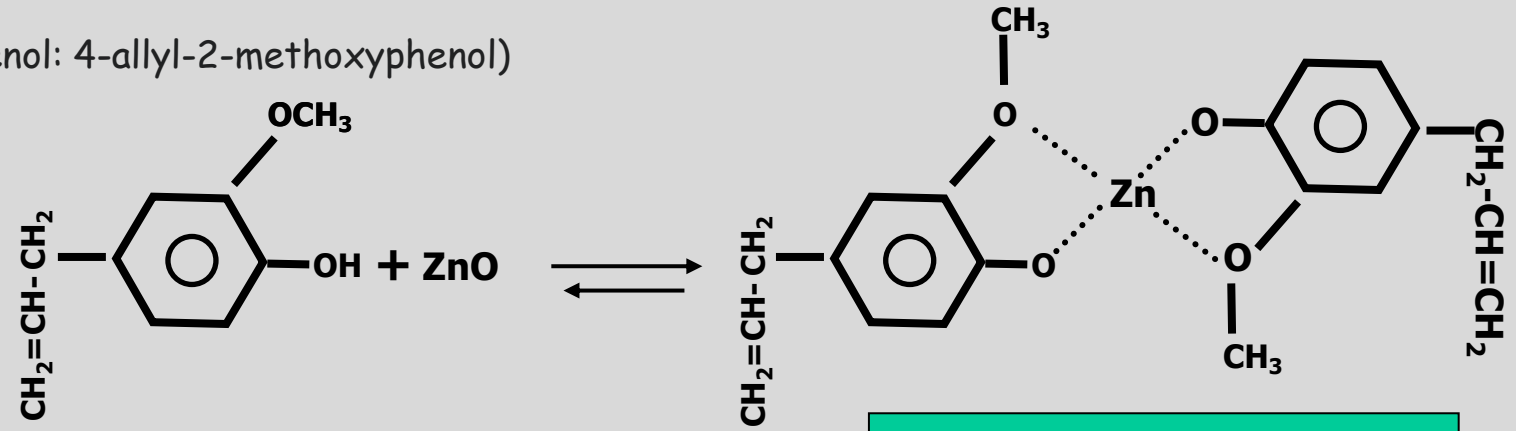
Old fashioned – not frequently used

2. Zinc-oxide eugenol impression pastes (ZOE)

Main indications: impression of edentulous ridges, surgical dressing

Setting reaction:

(eugenol: 4-allyl-2-methoxyphenol)



-OH and methoxy group in o-position

A two-paste system composed of:

Paste A – ZnO/mineral or vegetable oil as a plasticizer

Paste B – oil of claves with app. 85 % of eugenol or pure eugenol, rosins and fillers, accelerators

accelerators

H_2O, acetic acid, Zn acetate

Advantages:

1. Low viscosity – no compression of soft mucosa tissue
2. Dimensional stability (shrinkage less than 0.1 %)
3. Good surface detail reproduction
4. Low price

Disadvantages:

1. Rigid/inelastic - cannot be used in deep undercuts
2. Eugenol allergy in some patients (o-ethoxy benzoic acid [EBA] to replace eugenol)

B. Reversible rigid materials

3. Impression compounds

(Kerr's, Stent's impression compounds)

Thermoplastic material (softens when heated 50°C and hardens on cooling) for tooth impressions in a copper band

Composition:

1. Resins (wax, shellac, guttapercha)
2. Filler (talc)
3. Lubricants (stearic acid, stearin)

Advantages:

1. Can be reused, easy to use
2. Non irritant and non toxic

Disadvantages:

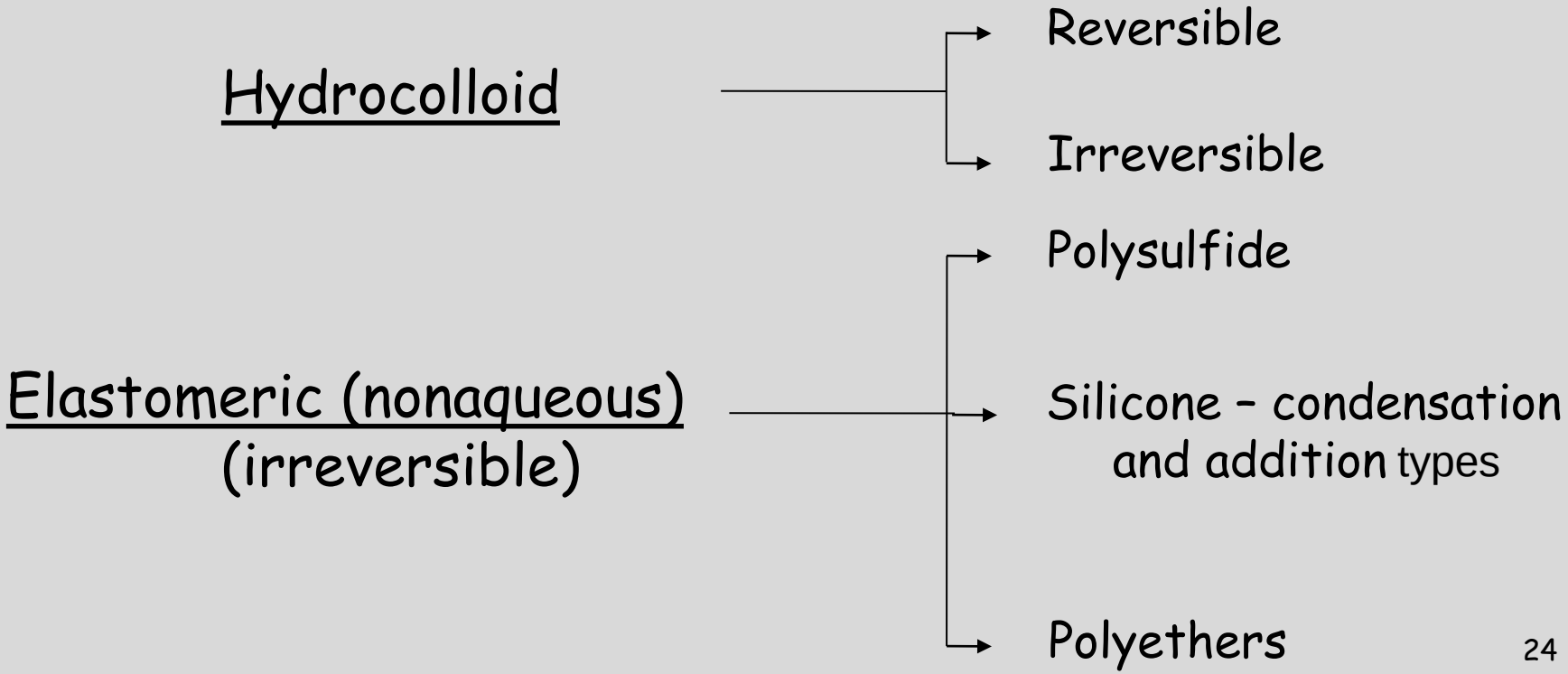
1. Poor dimensional stability
2. Easy to distort when withdrawn from the mouth

Old fashioned – not frequently used

Elastic impression materials

A. Hydrocolloid impression materials

B. Elastomeric impression materials



A. Hydrocolloid impression materials

Hydrocolloid – a colloidal system (particle size up to app. 0.5 μm) with water as a dispersion medium

so called **HYDROCOLLOID SOL** which can be tranformed to a **solid GEL by physical or chemical reactions:**

Setting reaction

reversible/agar sol ⇄ gel (Cooling →, Heating ←)

Via **intermolecular H-bond**

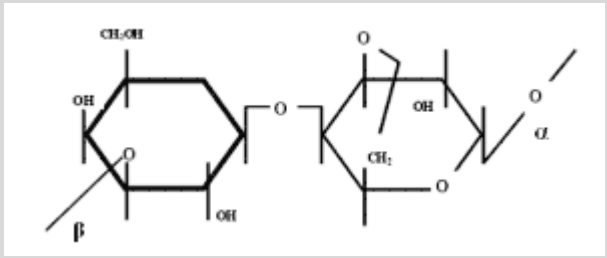
irreversible/alginate sol → gel (Coagulation →)

Via ionic bonds

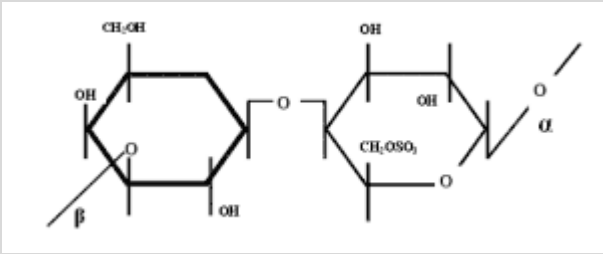
1.1. Reversible hydrocolloid

Agar impression materials
(Reversible hydrocolloid impression material)

Based on thermoreversible gelation of natural polysacharide – agar (isolated from red algae/seaweeds)



Agarose, is a strongly gelling, non-ionic polysaccharide



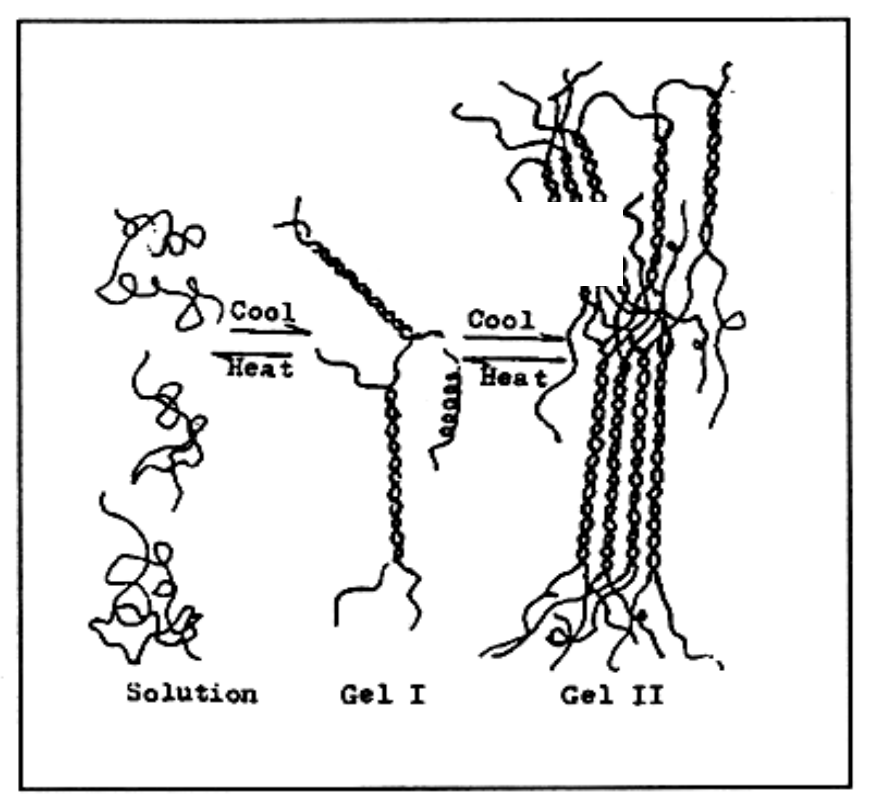
Agaropectin, is more complex polysaccharide having sulfate groups

1,3- linked β-D-galactopyranose and
1,4-linked 3,6-anhydro- α -L-galattopyranose units

Gelation:

Agar sols form gels upon cooling of a hot solution to (30 – 40)°C

Agar gels melt to sols upon heating to (90 – 95)°C



Sol
random coils

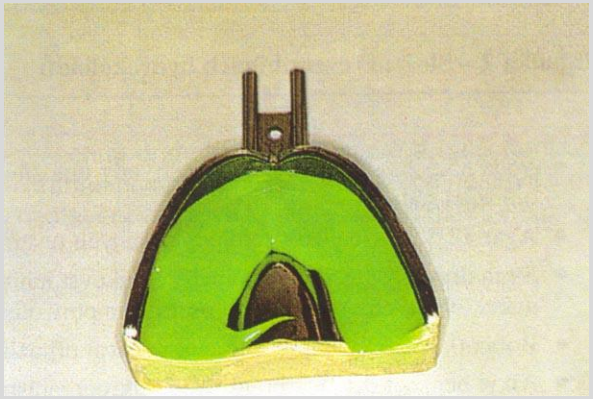
Gelation I
Double helices

Gelation II
aggregation of
helices

Composition:

1. **Agar**
2. **Borax** to increase the gel strength
3. **Potasium sulfate** as a gypsum hardener
4. **Water** – dispersion medium

Tray material



Filled tray

Material in syringes

Compartments for liquefying: 100°C, storage: 65°C and tempering the material in a tray at 45°C

Advantages:

1. Very good biological properties
2. Excelent surface detail reproduction

Disadvantages:

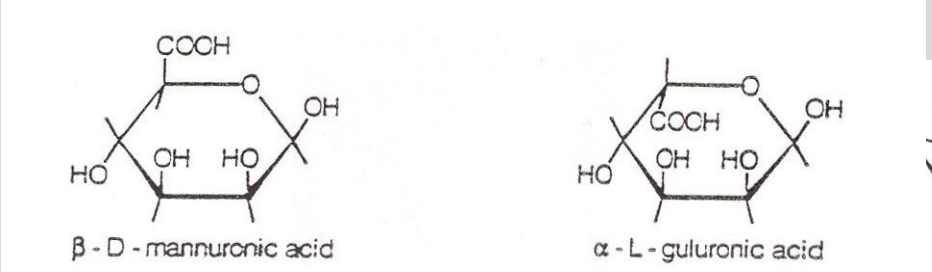
1. Need special water bath and a tray
2. Dimensional instable - evaporation or imbibition
3. Low strength and poor tear resistance
4. Slow setting time

1.2. Irreversible hydrocolloid

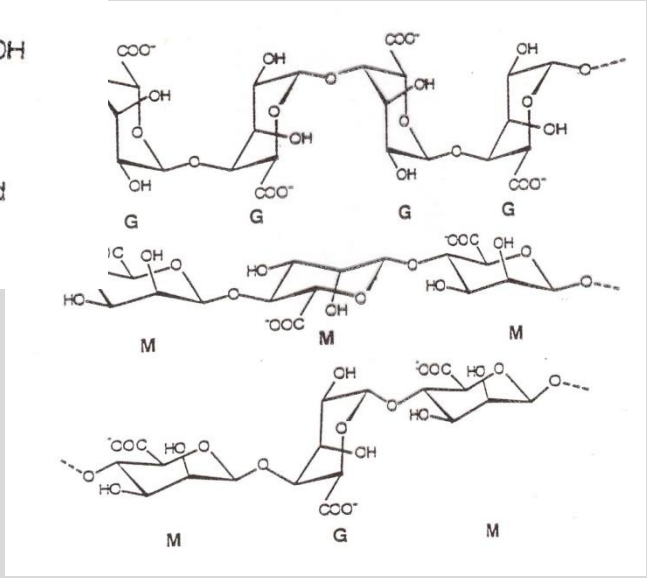
Alginate impression materials

(Irreversible hydrocolloid impression material, preliminary, orthodontic impressions etc.)

Based on natural polysacharide – Na^+, K^+, triethanol amine alginate salts (isolated from brown seaweeds)



Constituent units



Alginate chains $\bar{M}$ = 30 – 150 000

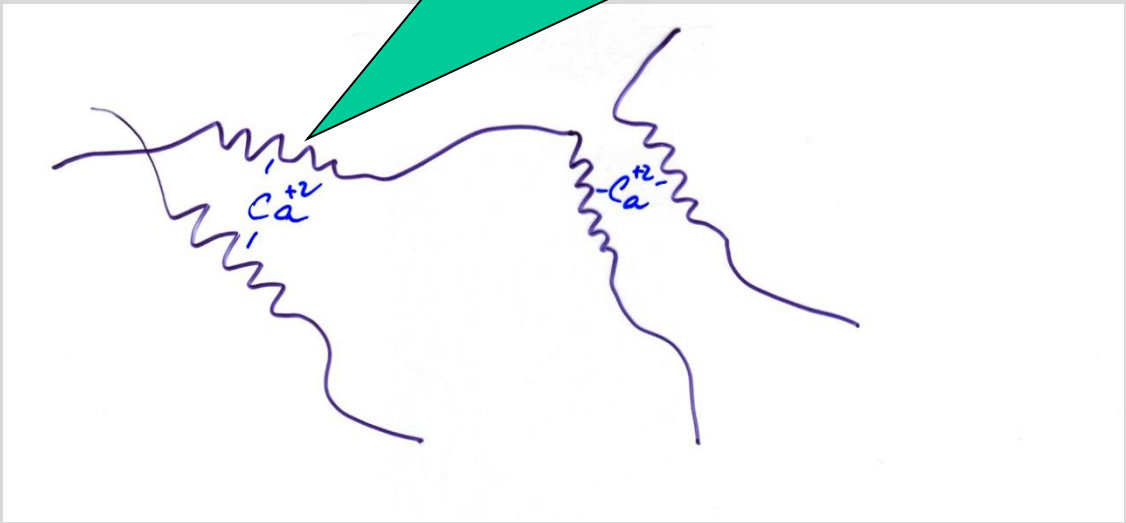
Creating viscous sols and gel in the presence of Ca^{+2} ions

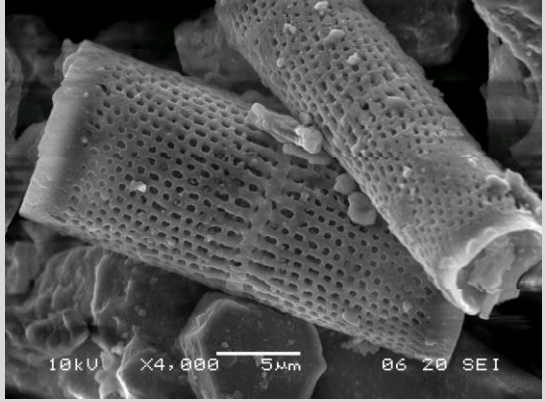
Setting/gelation reaction:

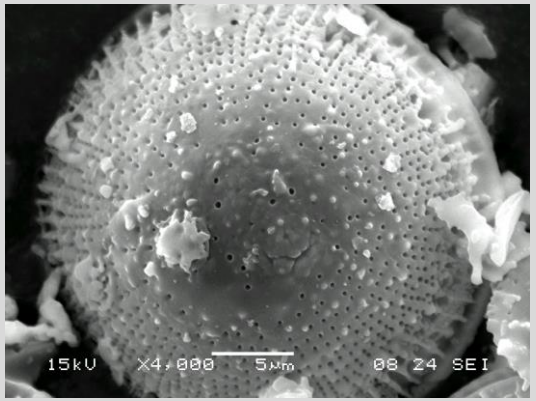
$$2nNaAlg + nCaSO_4 \xrightarrow{H_2O} nNa_2SO_4 + nCaAlg_2$$

powder → gel

Blocks of guluronic/mannuronic acid crosslinked with Ca^{2+} ions







Composition:

1. **Na/K alginate**
2. **Calcium sulfate ($CaSO_4.2H_2O$, $CaSO_4.1/2\ H_2O$)**
3. Diatomaceous earth (amorphous SiO_2)
4. *A* **retarder** – to prolonge working time sodium phosphates

$$3CaSO_4 + 2Na_3PO_4 \rightarrow 3Na_2SO_4 + Ca_3(PO_4)_2$$

5. *A* **setting accelerator** - K_2TiF_6 (makes also stone surface hard)
6. **Additives** – glycol, parafine oils – to agglomerate particles and make material „dustless"

Mixing ratio powder/water app. 10 g/20 mL

Alginates – the most frequently used impression material

Properties:

1. Set after mixing with water
2. Shrink due to lose of water by **Syneresis** – expression of water from the surface of impression (if contains Na_2SO_4 – decreased quality of stone surface)

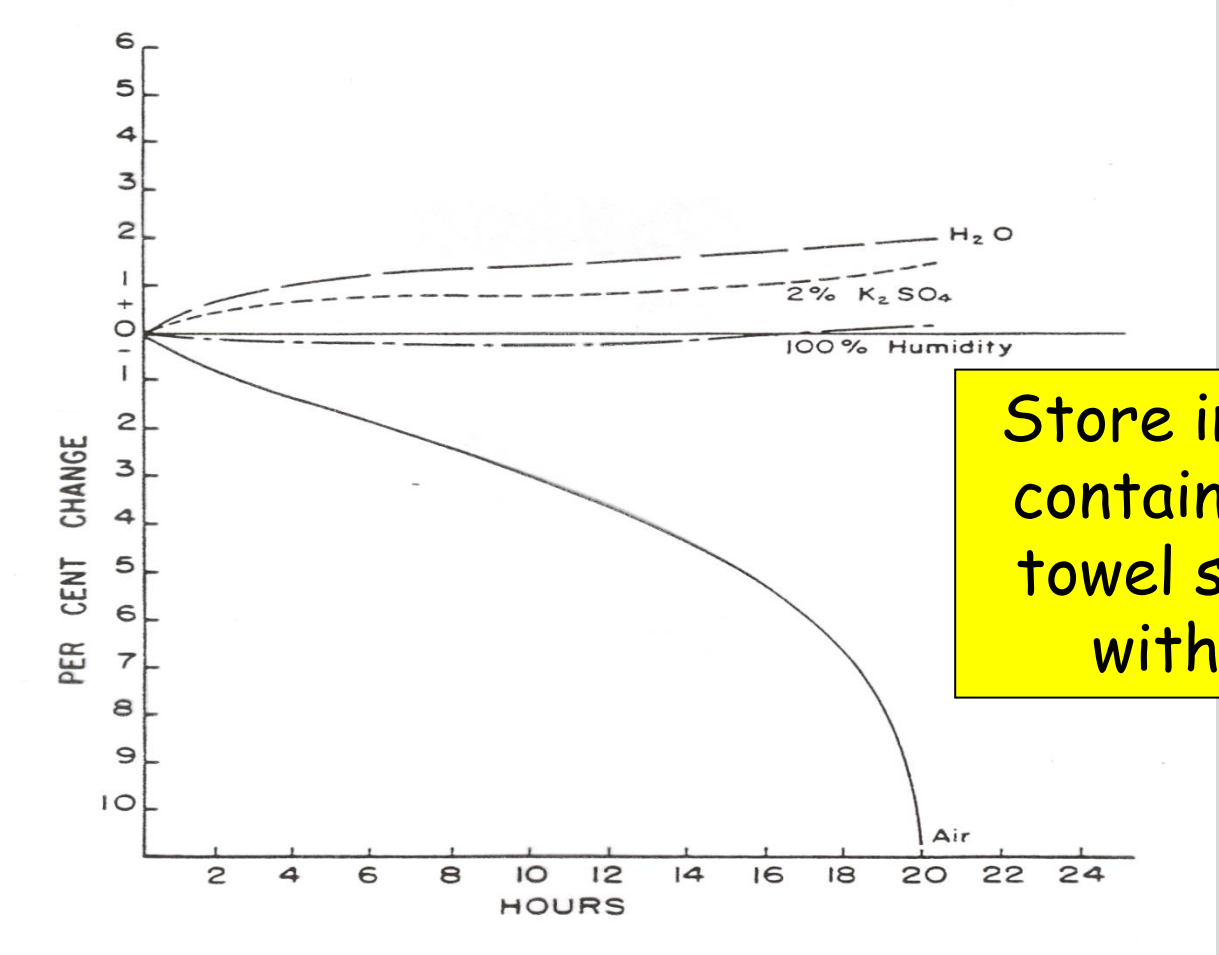
   by **Evaporation** –of water from the surface
3. **Imbibition** – sorption of water causing a dimensional change
4. **Chromatic phase** indicator may be incorporated to signal the impression setting


5 sec


35 sec


1 min 30 sec


2 min



Store in a closed container with a towel saturated with water

Dimensional changes of a cast prepared from alginate impression stored in various environments

Advantages:

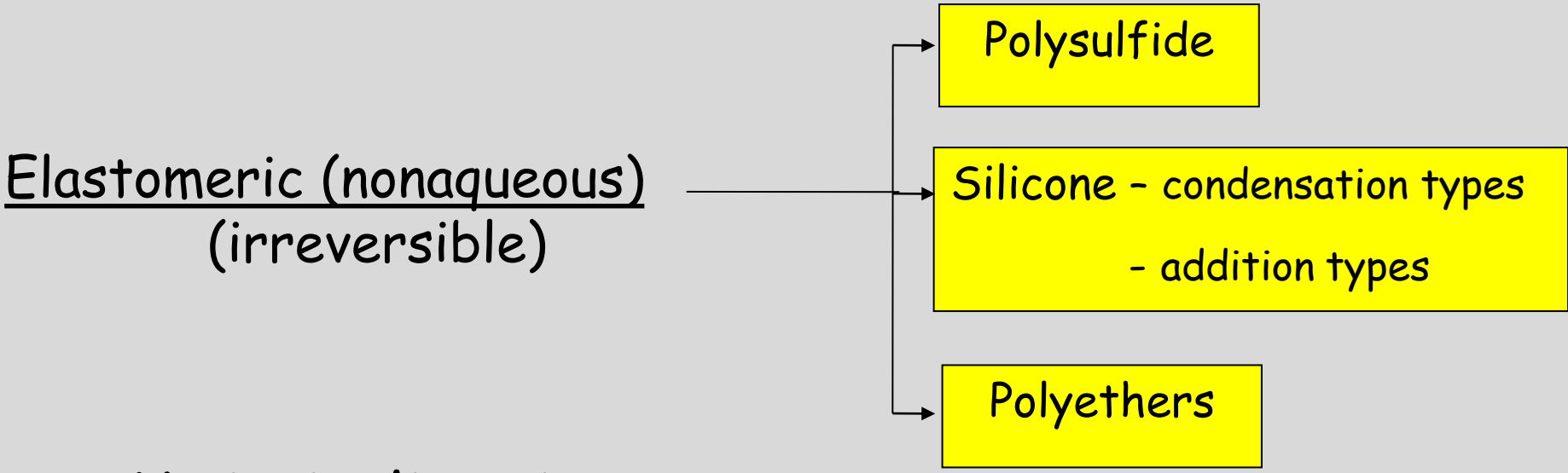
1. Very good biological tolerance
2. Ease of use and mix
3. Fast setting
4. Low price

Disadvantages:

1. Poor dimensional stability
2. Setting dependent on water temperature and water hardness
3. Although 100 h pouring time is also recommended they should be poured as soon as possible
4. Sometimes problems with a model stone compatibility

B. Elastomeric (nonaqueous) impression materials

Synthetic polymers with rubber properties after setting



Main indications

- impressions for partial prostheses (removable)
- impressions for crowns and bridges (fixed)
- impressions for implantology

Main characteristics:

1. Based on synthetic polymers
2. Crosslinked with covalent bonds
3. Stretchable and rapidly recovers to the original dimension
4. Dimensionally stable
5. Delivered as a two-component system: base and catalyst

Shrinkage during setting is usually compensated by using a combination

1. Highly filled-viscous material „**Putty**" for preliminary impression (low polymer content - low shrinkage)

2. Low filled-low **viscosity** „**wash**"/„**light**" impression material (high polymer content - higher elasticity but higher shrinkage)

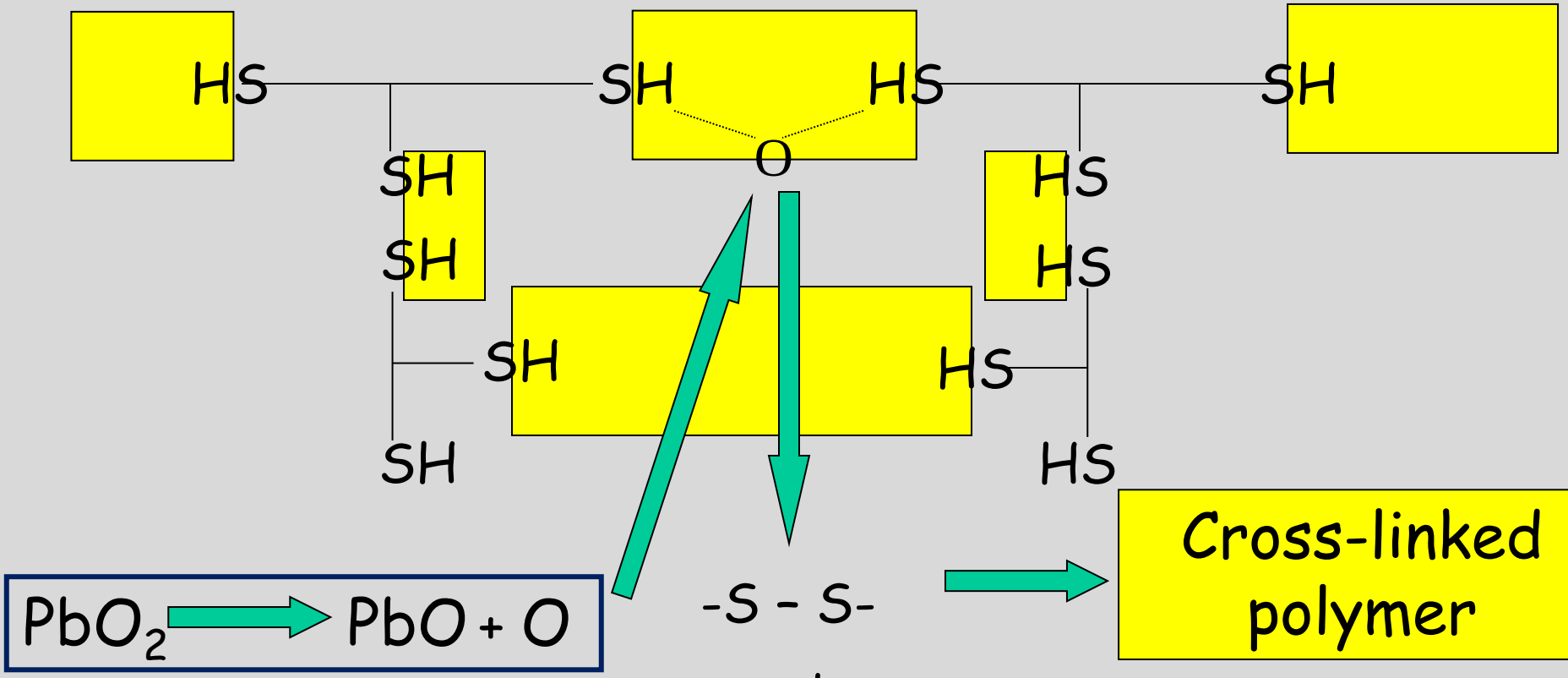
1. Polysulfide impression materials

(Thiokol rubbers, mercaptan rubbers)
The very first elastomeric impression material

Based on reaction between polymer with free mercaptan (-SH) groups and oxidizing agent PbO_2 which cross-links chains via reaction of terminal and pendat -SH groups

Setting reaction:

Linear polysulfide polymer



Catalyst strong oxidizing agent

Composition:

Supplied as a two-paste system

Base paste:

polysulfide polymer, filler, plasticizer (e.g. dibutyl phtalate)

Catalyst paste:

lead dioxide, Cu-hydroxide based catalyst in lead free materials, plasticizer (e.g. dibutyl phtalate)

Volume mixing ratio 1:1

Advantages:

1. Low price
2. Long working time

Disadvantages:

1. Should be poured within 0.5 – 1 hour
2. Lead oxide may cause toxic effects
3. Unpleasant mercaptane smell
4. Long setting time app. to 10 min
5. Poor elastic recovery – prone to plastic deformation

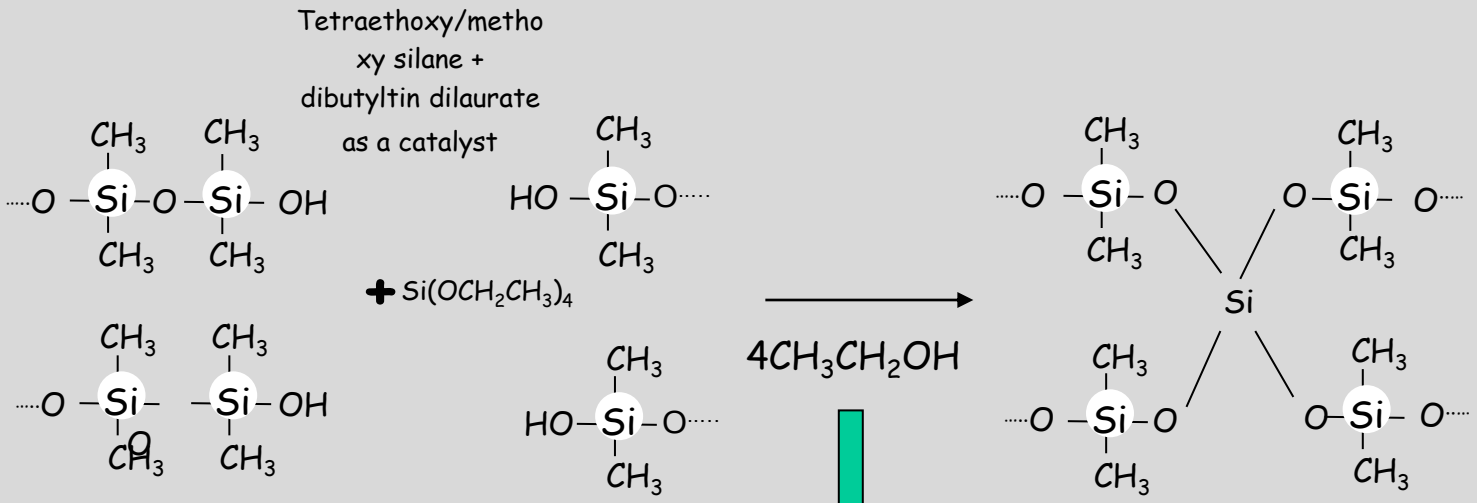
Old fashioned – not frequently used

2. Silicone impression materials

2. 1. C-silicone impression materials (condensation silicones)

Based on cross-linking polycondensatin reaction of hydroxy terminated polydimethylsiloxane polymer with tetraalcoxy silanes catalysed by dibutyltin dilaurate (DBTD)

Polycondensation cross-linking



Hydroxyterminated polydimethylsiloxane

Linear polymer – plastic properties

Cross-linked polymer – elastic properties

Alcohols released contributes to the contraction/shrinkage of the impression

Composition:

Supplied as a two-component system

Base paste:

1. Hydroxyterminated polydimethylsiloxane
2. Filler (cristobalite, talc, starch, calcium carbonate)

Catalyst:

Liquid catalyst:

- Crosslinking agent (e.g tetraethoxy silane, TEOS) + dibutyltin dilaurate, DBTD

Paste catalyst:

- Cross-linking agent, activator, inert oil
- Filler

Advantages:

1. Accurate impressions when poured soon
2. Good elastic recovery
3. Lower price

Disadvantages:

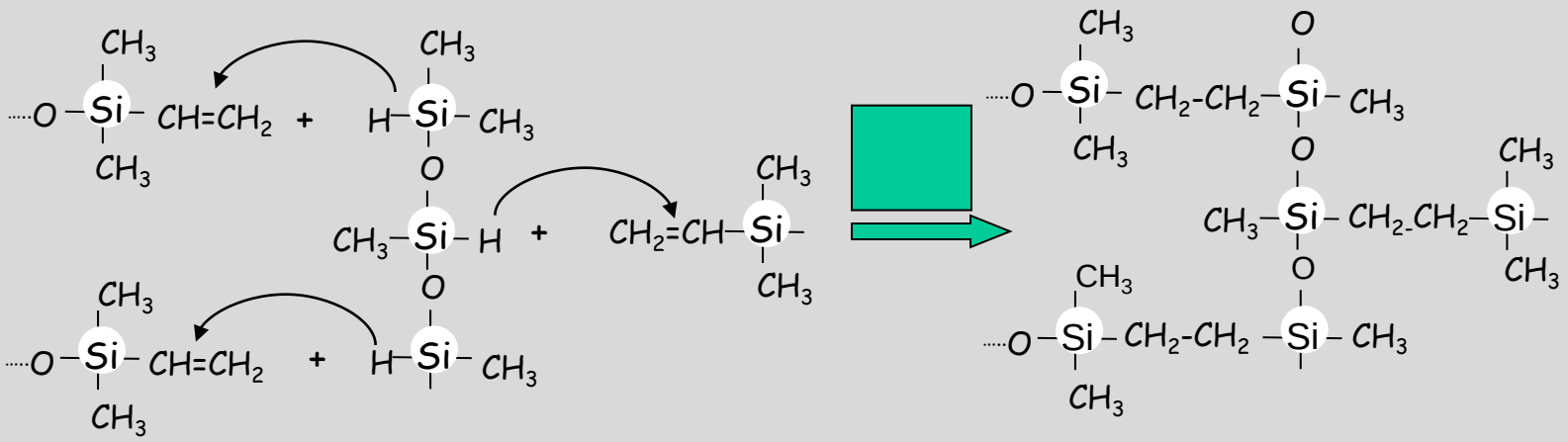
1. Hydrophobic
2. Shrinking of impression over time, pouring time till 4 h
3. Catalyst may cause allergic reaction
4. Difficult to dispense proper volumes of both components
5. Usually only hand-mix versions

2. 2. A-silicone impression materials
(addition silicones, vinyl siloxane, poly(vinyl siloxane))

Impression material, duplicating material, relining material, bite registration material, root canal sealer

Setting reaction - based on cross-linking reaction (polyaddition) of vinyl terminated polydimethylsiloxane polymer with methylhydrogen silicone cross-linking agent in the presence of platinium catalyst

Setting reaction - polyaddition



Linear polymer

Cross-linking agent

Cross-linked polymer

In the presence of Pt catalyst H_2 may be released from water or –OH groups from the reaction mixture causing bubbles on a gypsum model

Composition:

Supplied as a two-component 1:1 system

Base paste:

1. Vinyl terminated polydimethylsiloxane
2. Pt catalyst
3. Filler (cristobalite, talc, starch…)
4. Surfactant (hydrophilic agent)

Catalyst:

1. Vinyl terminated polydimethylsiloxane
2. Cross-linking agent
3. Filler, silicone oil (to adjust viscosity)

Advantages:

1. Accurate impressions, very low shrinkage
2. Very good surface detail
3. Highly elastic
4. Perfect elastic recovery
5. Dimensionally stable
6. Non toxic and non irritant

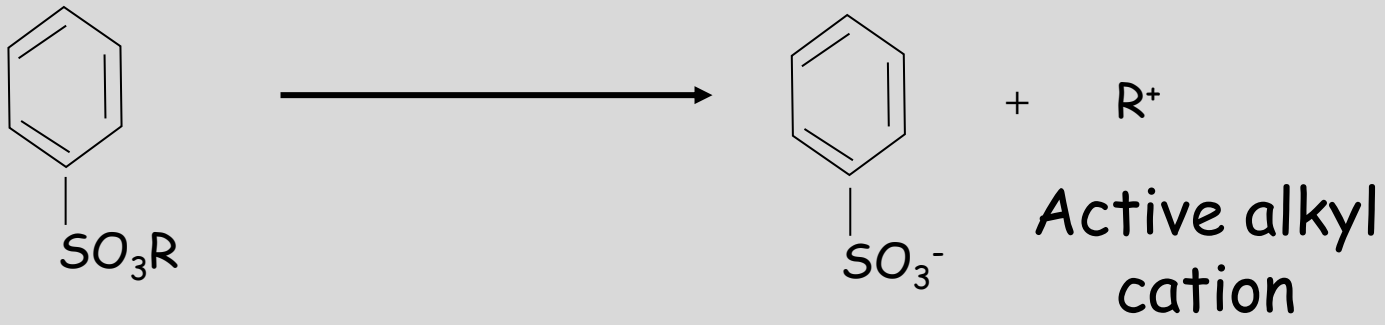
Disadvantages:

1. Hydrophilic – due to surfactants addition
2. **Setting inhibited by latex gloves or some adstringents (sulfur, heavy metals)**
3. Hydrogen release – surface bubbles – pouring time 1 h after removal from the mouth
4. High price

3. Polyether impression materials

Based on cross-linking of polyether chains via cationic polymerization of aziridine rings using aromatic sulfonate ester as an initiator

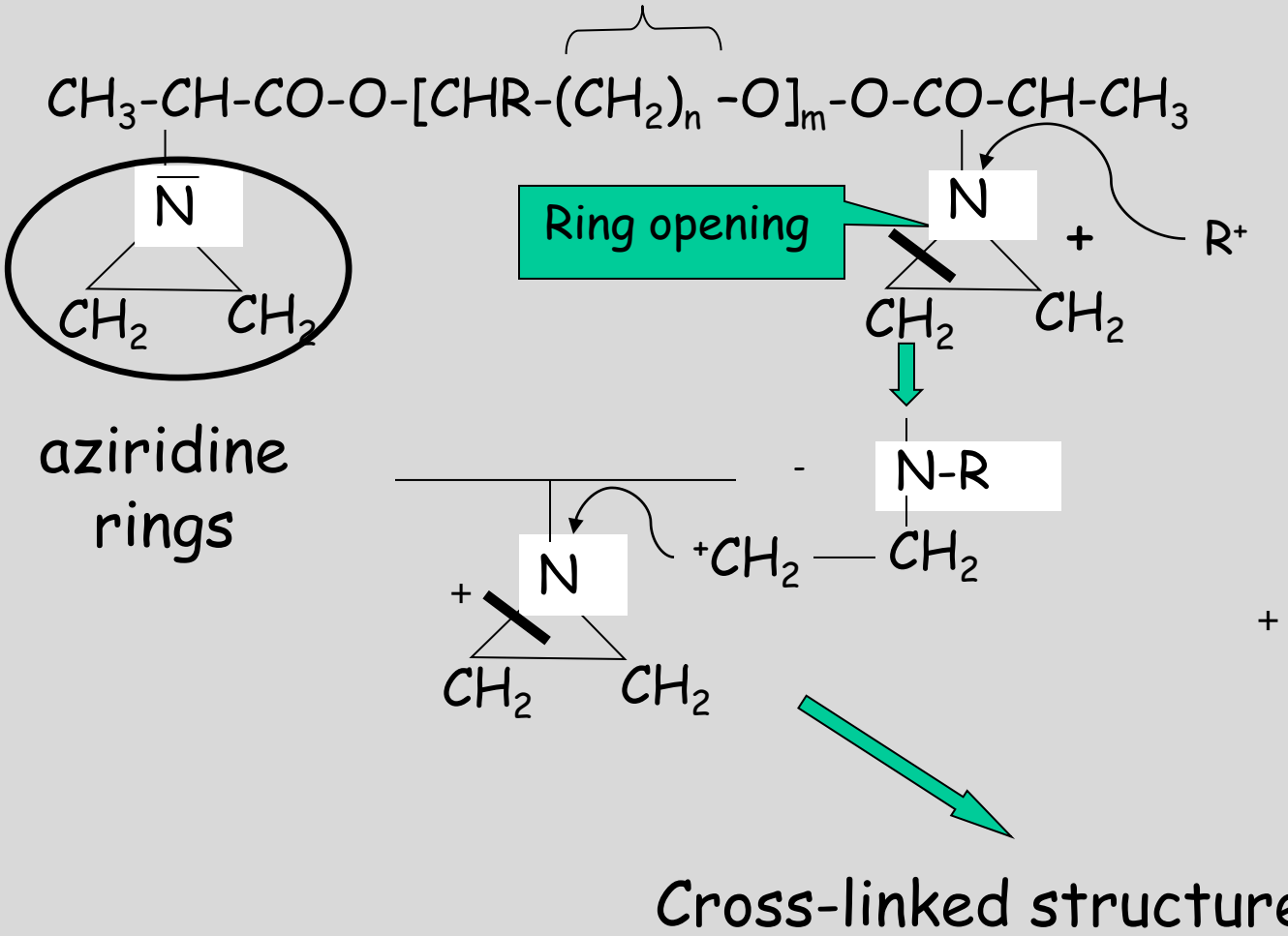
Initiation reaction



Propagation

Linear prepolymer

Ethylene oxide units - hydrophilic part of a polymer molecule



Composition:

Supplied as a two-paste system

Base paste:

1. Polyether
2. Filler, plasticizer

Catalyst paste:

1. Sulfonic acid ester
2. Inert oil
3. Filler

Advantages:

1. „Naturally" hydrophillic
2. Accurate and high dimensional stability
3. Good elastic recovery
4. Low setting contraction
5. Excellent surface detail reproduction

Disadvantages:

1. Rather stiff when set (difficult to remove from mouth)
2. Very expensive
3. May cause allergic reaction due to the sulphonic acid ester

Typical properties of elastic impression materials

Property	Alginate	Agar	Polysulfide	Polyether	C-silicone	A-silicone
No of components	1	1	2 pastes	2 pastes	2 pastes or paste/liquid	2 pastes
Working time [min]	1.5	-	4-7	2-3	2-4	2-4
Setting time [min]	3-4	3-5	7-10	5-6	5-8	4-7
Contraction [lin %] after 24 h	0.5	0.01	0.4-0.5	0.2-0.3	0.2-1.0	0.01-0.2
Recovery from deformation [%]	96	98.8	94.5-96.9	98.3-99.0	97.2-99.6	99.0-99.9
Detail reproduction [μm]	50	25	25	25	25	25
Hydrogen release	N	N	N	N	N	Y
Contact angle [°]	Very low	Very low	82	50-60	98	30*-80
Relative cost	Very low	high	low	Very high	lower	high

*Hydrophilic types