TEN HOT METALLURGY QUESTIONS!

A hitlist of the questions most frequently asked by our customers

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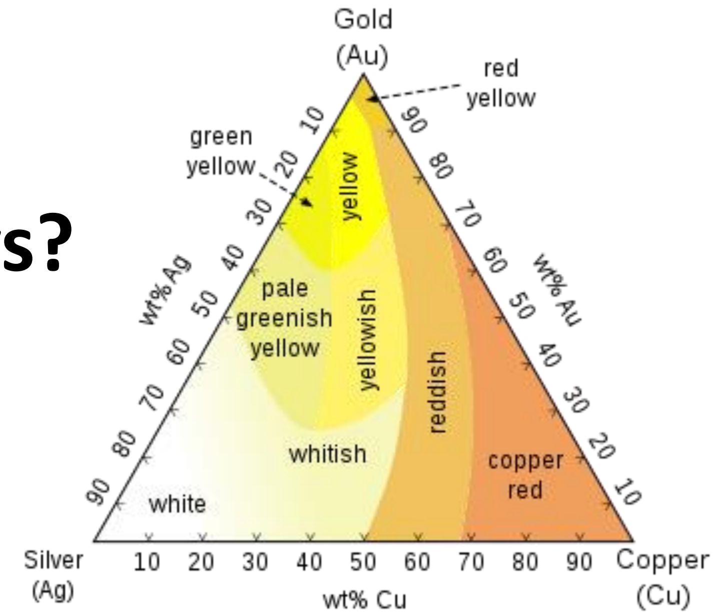
Position ten

Why is silver useful in gold alloys?

Aka: Why do I have to pay an alloy so much?

Why is silver useful in gold alloys?



In yellow gold:

Perfectly miscible, no loss, highly deformable….

Extremely high shininess, intensifies color hue

International standards based on ternary formulas Au-Ag-Cu

Age-hardenable in 585‰

Why is silver useful in gold alloys?

In white gold:

Improves fluidity in Ni-based formulations, in all titles

Protects stones thanks to a lower shrinkage during cooling

Why is silver useful in gold alloys?

Cheaper alternatives:

Zinc, with limits on color, risk of loss, low chemical resistance

Gallium, Indium, tin, but only in small quantities

Position nine

What burnout cycle and why?

First, what is an investment»?

Powdery mixture of:

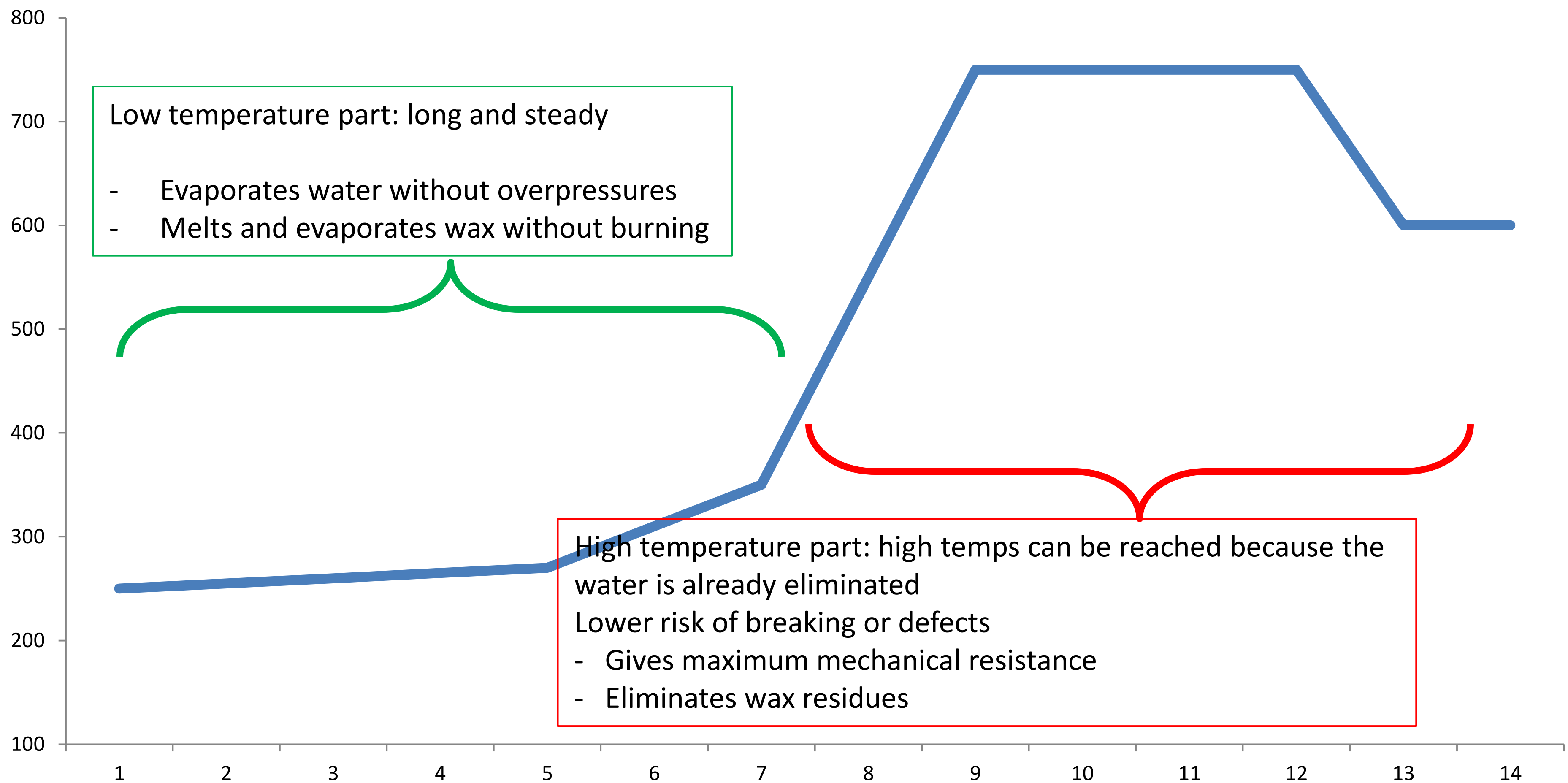
◦ 70-75% Silica (refractory) [SiO_2]
◦ 25-30% emi-hydrate calcium sulphate (binder) ($CaSO_4 \circ ½H_2 0$)
◦ Additives, impurities (borax…)

Reaction with water brings to hydrate calcium sulphate, then reduced to anhydrous calcium sulphate by heating

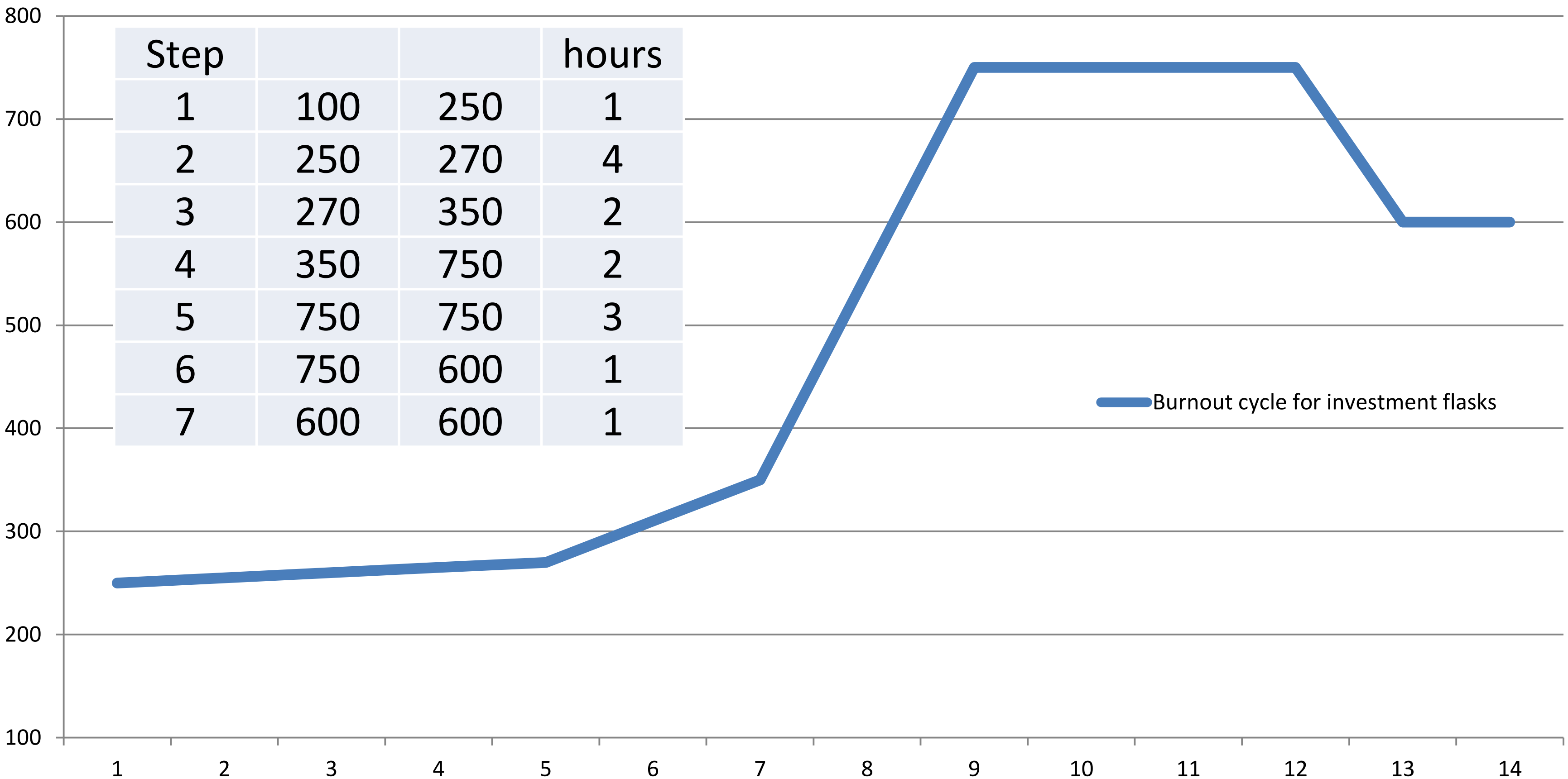
$$CaSO_4 \circ ½H_2 0 + H_2 0 \rightarrow CaSO_4 \circ 2H_2 0 \rightarrow CaSO_4$$

(@25°C) **(@104°C, @246°C)**

What burnout cycle and why?



What burnout cycle and why?



Step			hours
1	100	250	1
2	250	270	4
3	270	350	2
4	350	750	2
5	750	750	3
6	750	600	1
7	600	600	1

Optimizing preparation

Must be used before expiry date!

Remixable to improve homogeneity of components

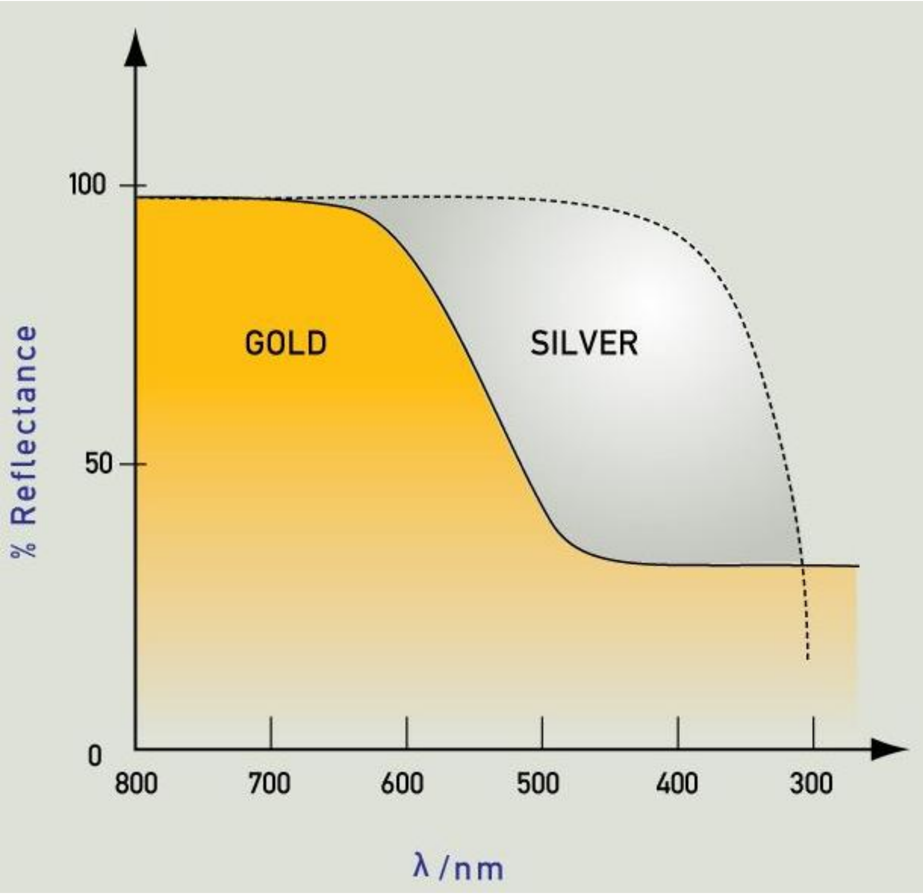
Water powder ratio: 36 – 40%

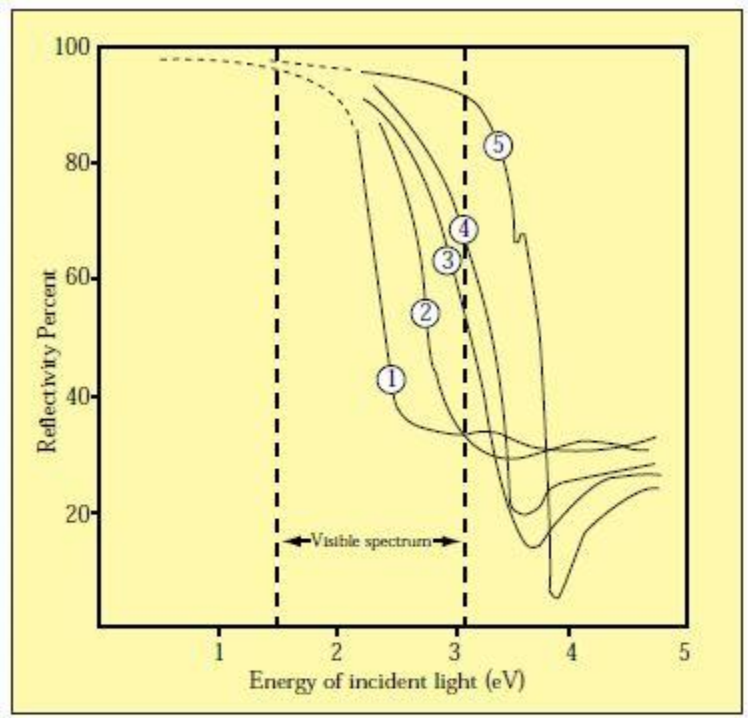
- Changes the hardening time
- Depends on the room temperature
- Impacts the investment mechanical resistance

Position eight

Do you have an alloy at title 375 with 24K color?

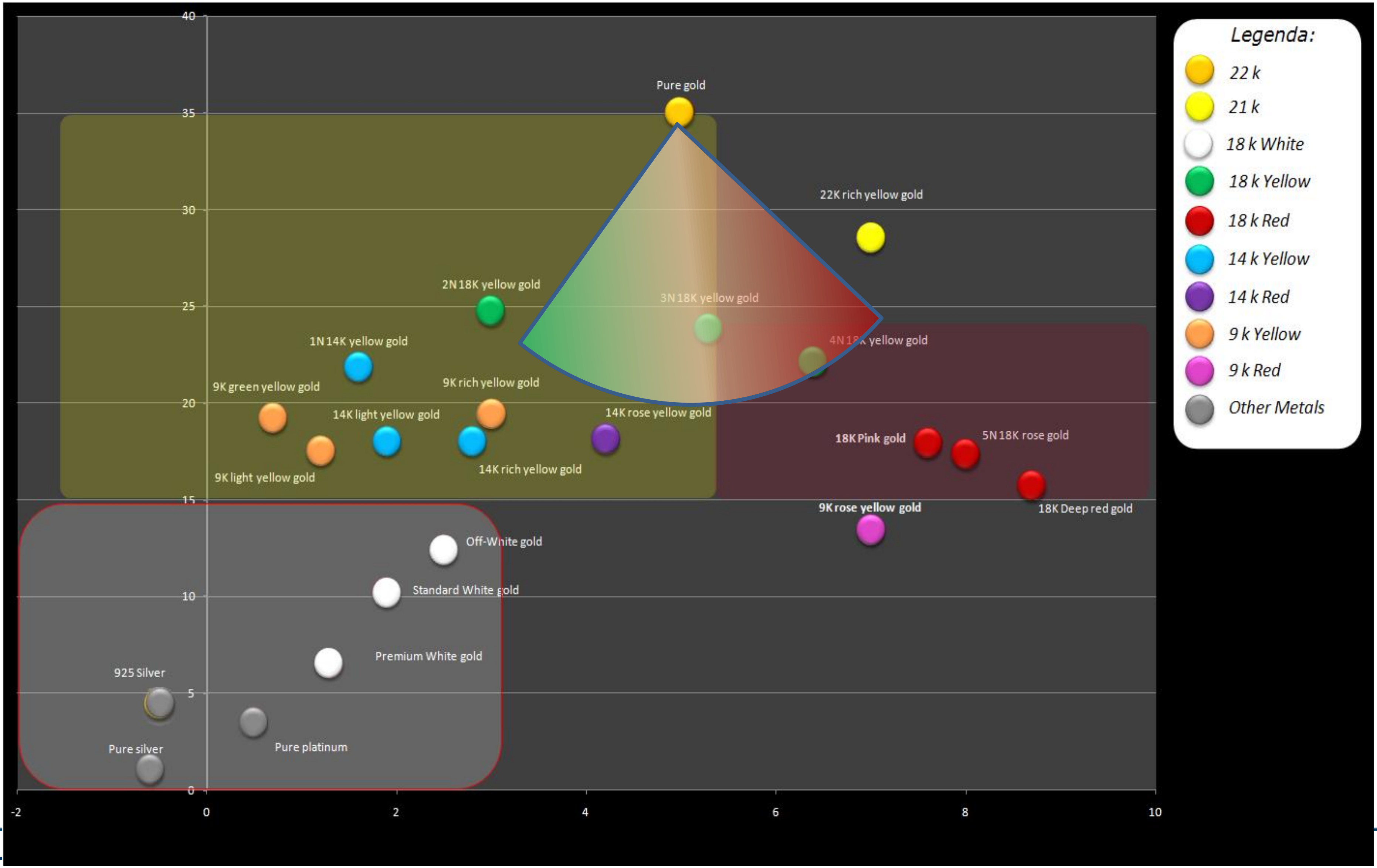
Reflectivity





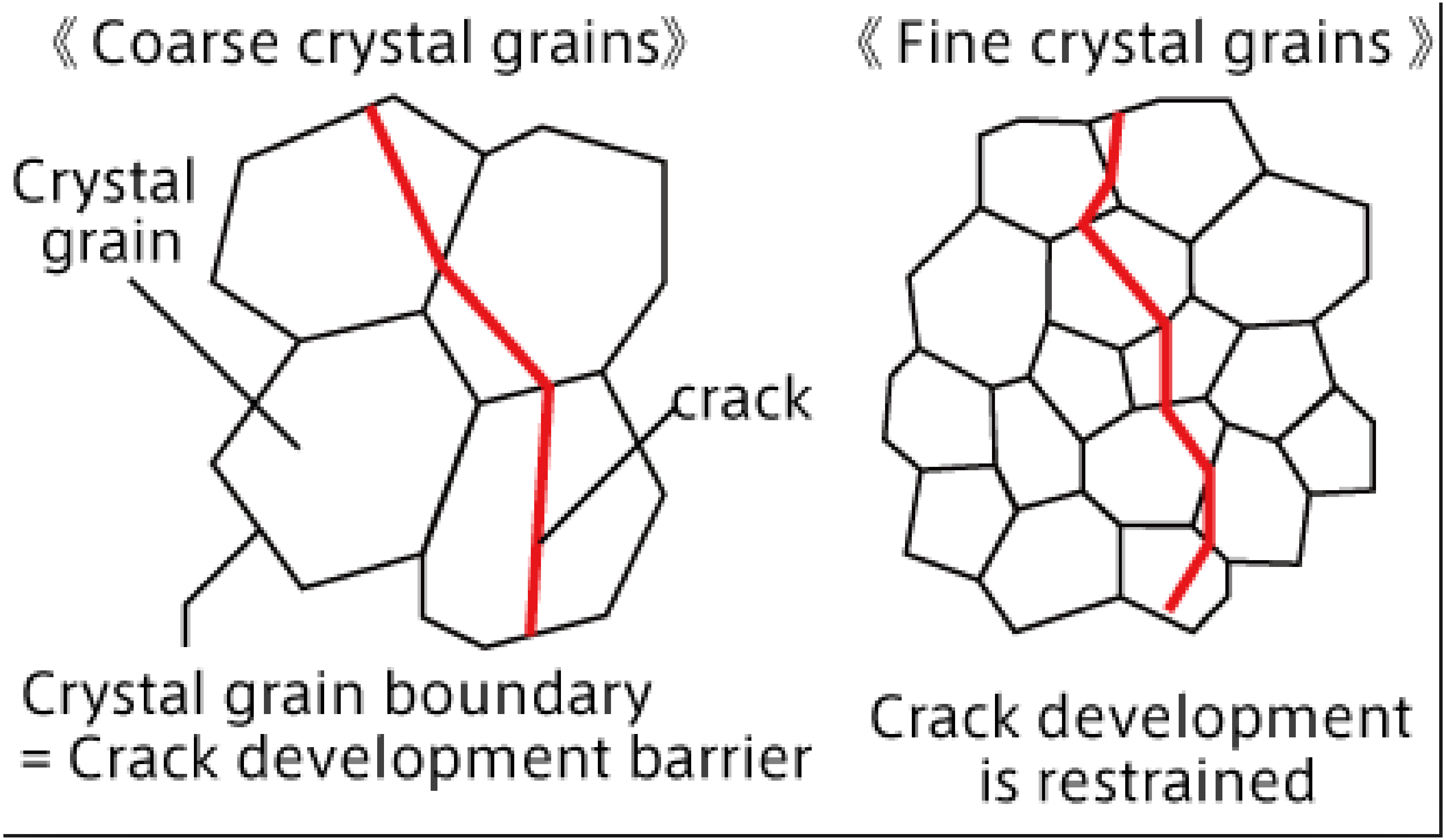
1 – Pure gold
2 – 50% Au – 50% Ag (At.)
3 – 90% Ag – 10% Au (At.)
4 – 95% Ag – 5% Au (At.)
5 – Pure silver

Distance from pure color



Position seven

Why is everything cracked?

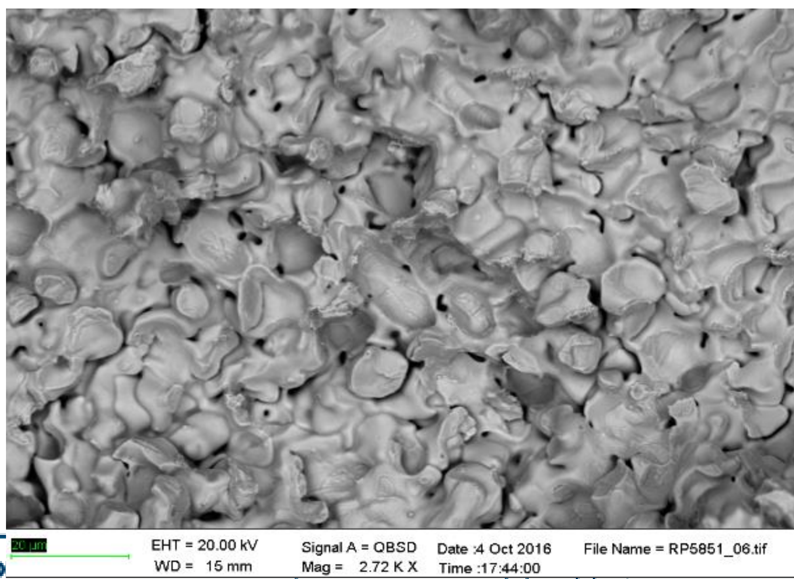

《Coarse crystal grains》
《Fine crystal grains》
Crystal grain
crack
Crystal grain boundary
= Crack development barrier
Crack development
is restrained

Why do pieces crack?

Excessively high process temperatures:

- Excessive overheating (metal or investment) leading to grain growth

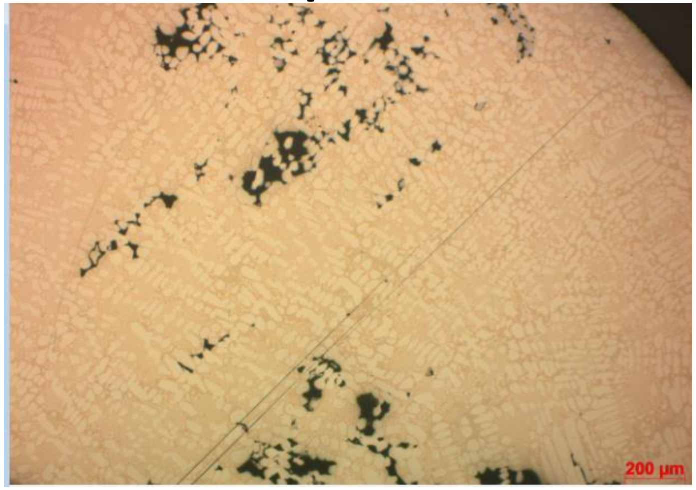
- Alloys oxidation, leaving, on the solidification front, unwanted compounds



Why do pieces crack?

Excessively low temperature

- Voids, internal porosities
- If the item is incomplete, it is also less resistant from the mechanical point of view



Why do pieces crack?

Wrong processing times:

Too long a quenching

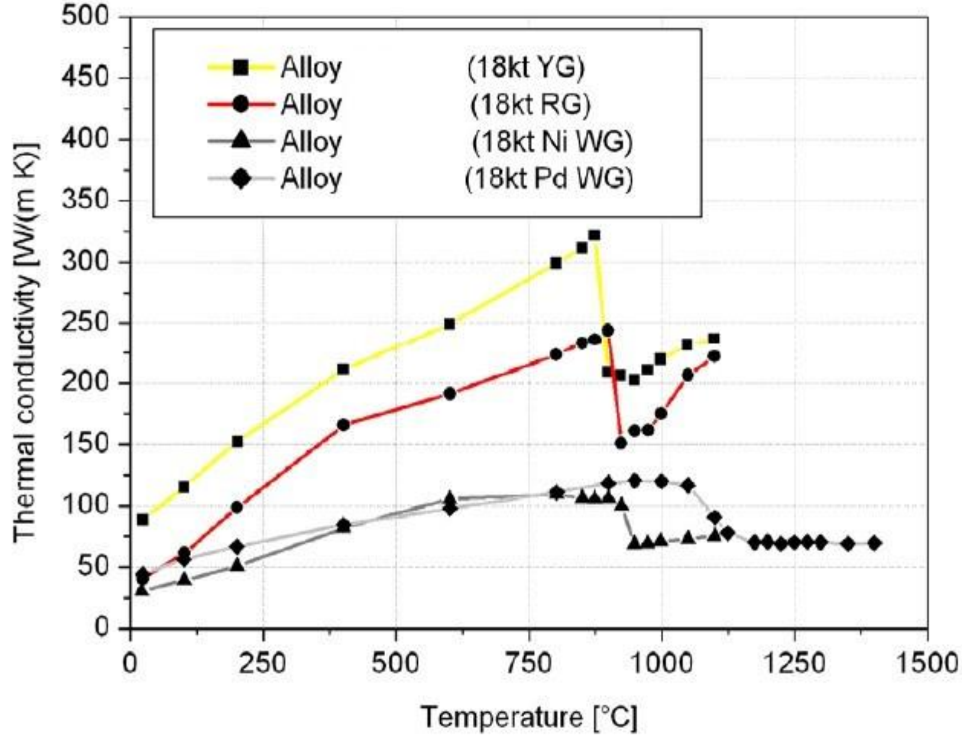
E.g.: 3 hours before quenching
(→ grain growth!)

Why do pieces crack?

Too quick quenching

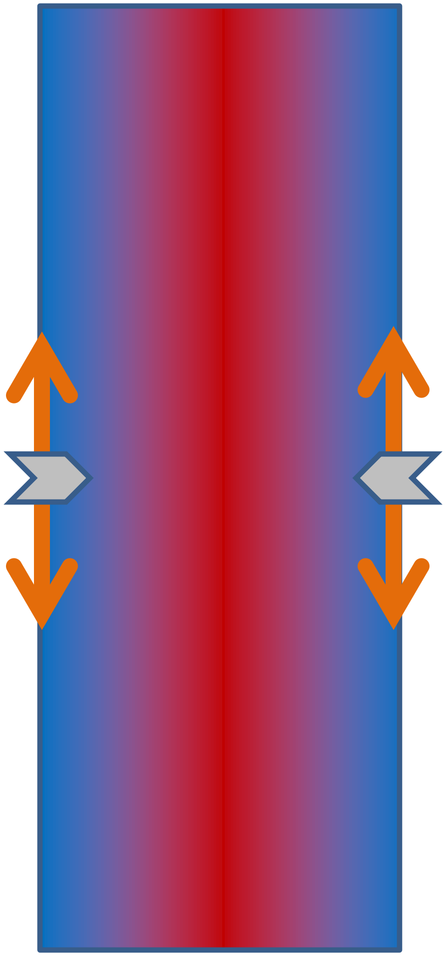
Excessive stress :

Hardness + low thermal conductivity (Ni-based alloys)



Stress during cooling

Excessive thermal gradient,
So much that it generates a stress between **skin** (cold, small specific volume) and **core** (still hot, high specific volume)



Position six

How to improve stone-in-place casting?

Common issues

Stone breakage

Color shift

Stones falling from the item

Fundamental:

Prongs with adequate size and tolerances

Well made mounting

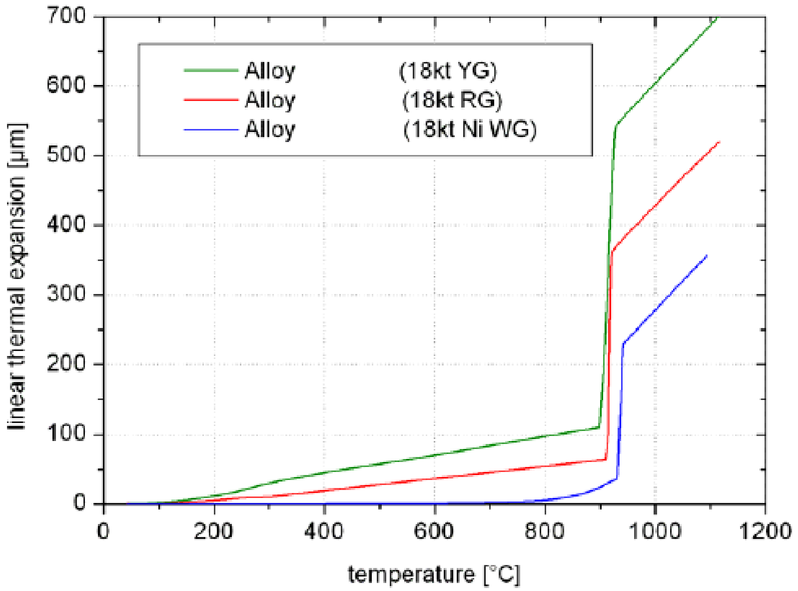
Constant quality stones

Thoughts on the alloy

Thermal expansion varies with the formulation:

Silver/copper ratio (yellow gold):

More silver means:
- Higher shrinkage
- More strength on the stone



If I lose the stones, I need an alloy with more silver
If my stones break, I choose a formula with more copper

Thoughts on the alloy

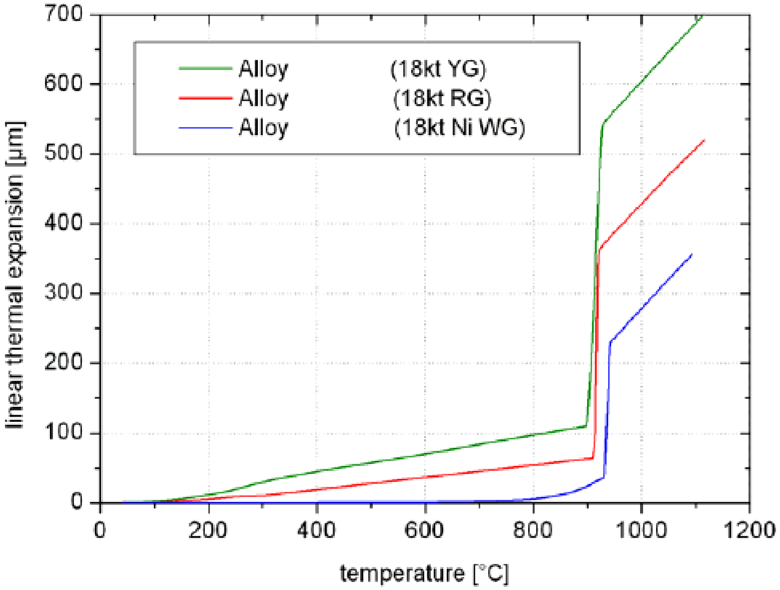
For Ni-based alloys, hardness is the largest risk factor

Less nickel means:

- Less strength on the stone

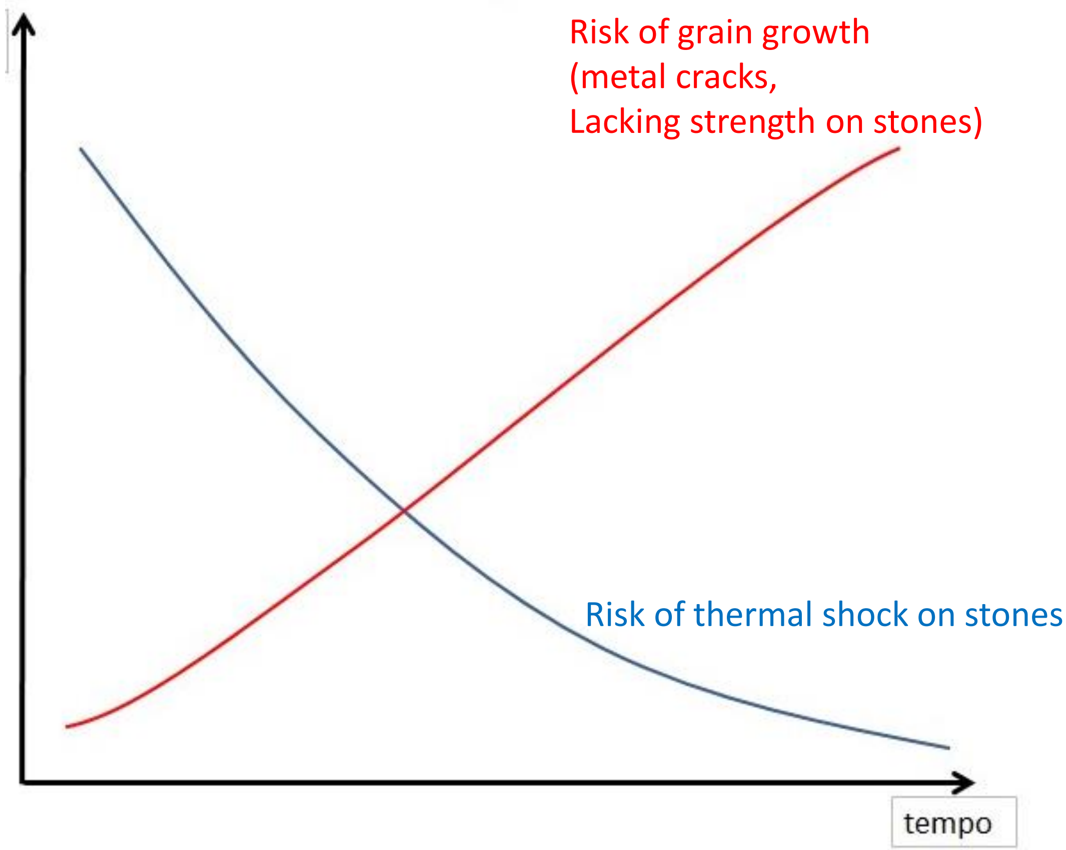
Silver addition in a white alloy (from practical experience):

- Lower shrinkage
- Increasing thermal exchange
- Better heat sink



Thoughts on time

Thermal shock on stones must be avoided…
…and this goes opposite from metal protection



Example on an 18K yellow

2h: 20% loose stones
1 h: 7% loose stones
30’: 0% loose stones
10’: stones crack

Thoughts on cooling

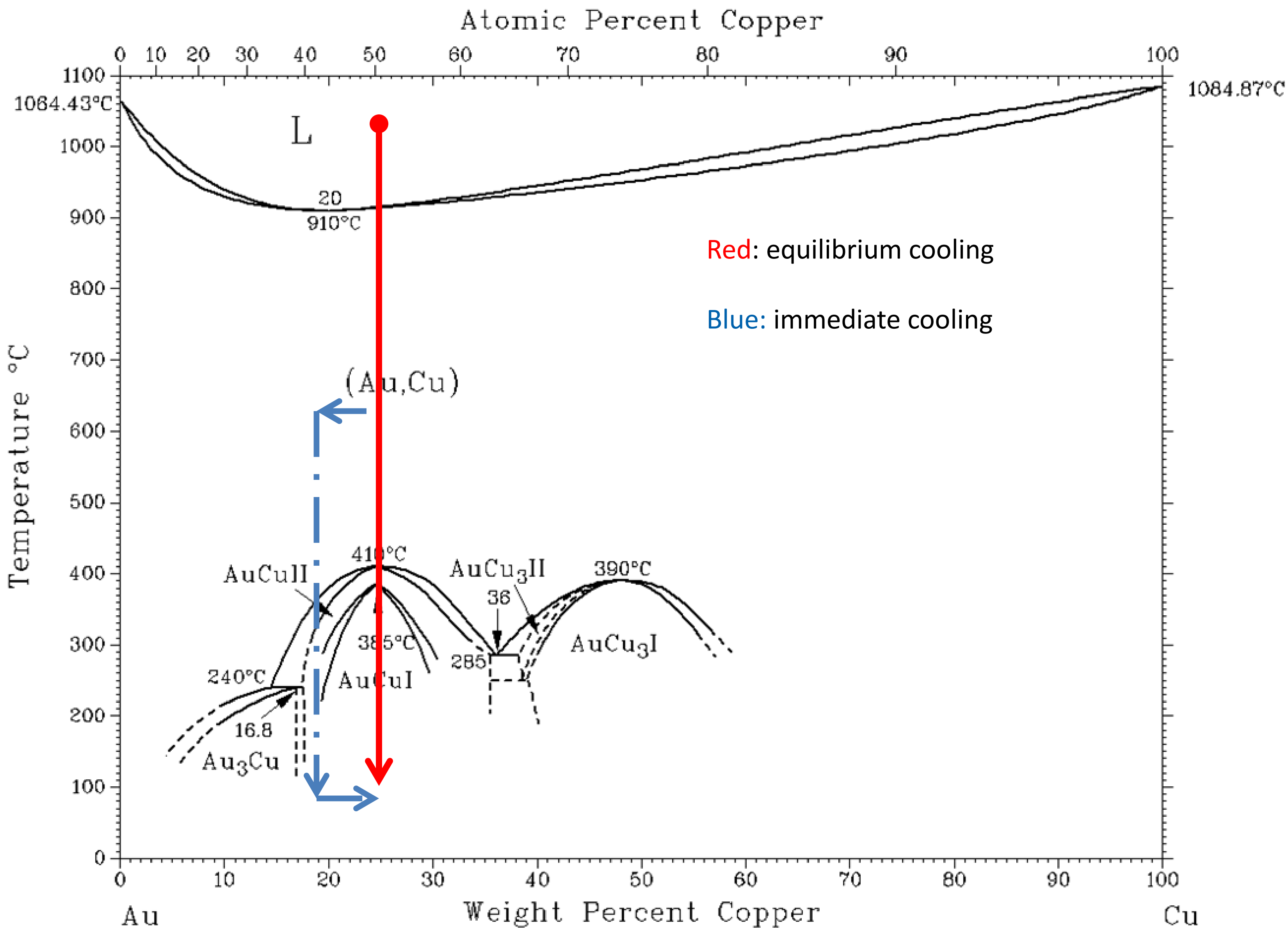
Useful on white gold:

To have a gentler cooling curve the flask can be re-put in the furnace after pouring (10-15 minutes)

In this way the metal can be left to settle at an intermediate temperature

Position five

How to avoid cracks in 750‰ red gold?


Atomic Percent Copper
0 10 20 30 40 50 60 70 80 90 100
1084.43°C
1084.87°C
L
20
910°C
Red: equilibrium cooling
Blue: immediate cooling
(Au,Cu)
410°C
AuCuII
$AuCu_3II$
390°C
36
385°C
285
$AuCu_3I$
240°C
AuCuI
16.8
Au_3Cu
Temperature °C
1100 1000 900 800 700 600 500 400 300 200 100 0
0 10 20 30 40 50 60 70 80 90 100
Au
Weight Percent Copper
Cu

Intermetallic compounds

Order-disorder transformation possible with Cu/Au 1:1 atomic ratio, leading to a face-centered tethraedric super-lattice, with high hardness deriving from atom size difference

Phase	Composition at.% Cu	Pearson symbol prototype	Strukturbericht designation
Au–Cu hT solid solution	0–100	cF4-Cu	A1
Au_3Cu	10–38.5	cP4-$AuCu_3$	$L1_2$
AuCu (I)	42–57	tP4-AuCu	$L1_0$
AuCu (II)	38.5–63	oI40-AuCu (II)	
$AuCu_3$ (I)	67–81	cP4-$AuCu_3$	$L1_2$
$AuCu_3$ (II)	66–?	tP28-$PdCu_3$	

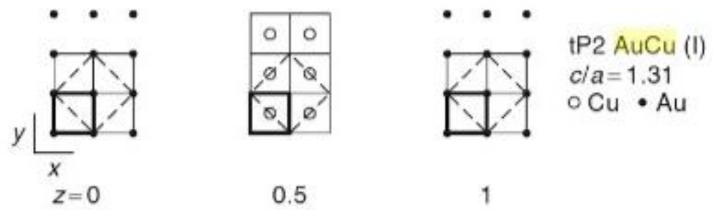


Figure 7.26. Section sequence parallel to the base plane of the tP2-AuCu (I) type structure. A tP4 pseudo-cell is outlined by dotted lines.

How to reduce this problem?

In the alloy:
Elements that modify the Au-Cu ratio

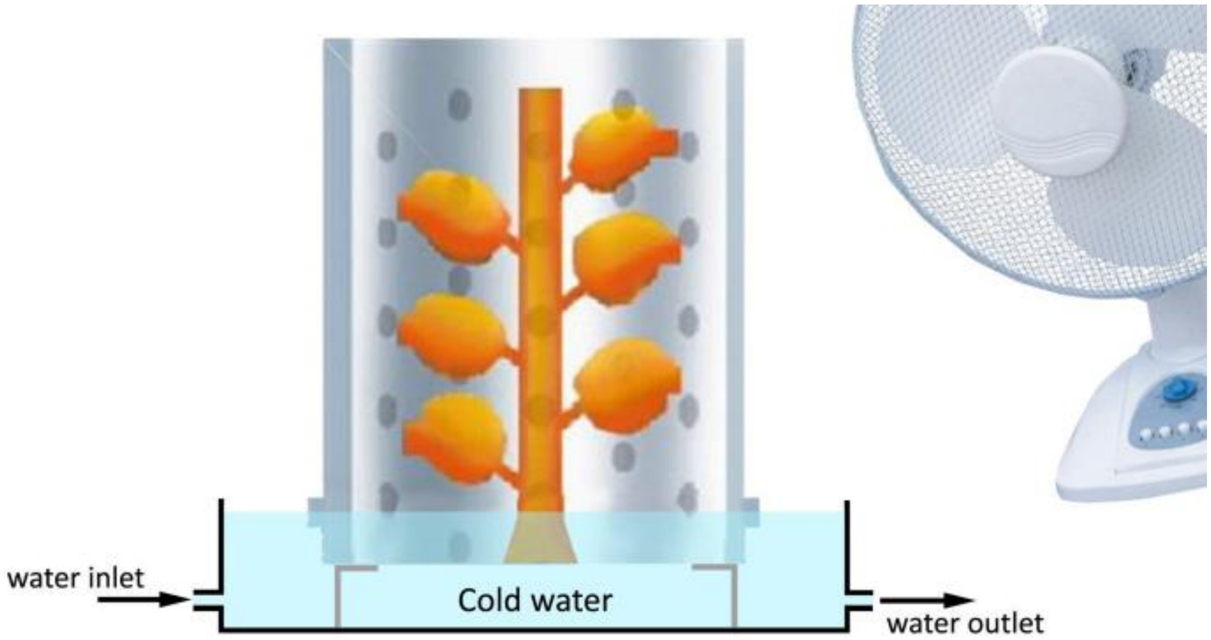
(Silver, zinc)

Elements that reduce the risk for cracks

(grain refiners)

In case of stone-in-place casting:

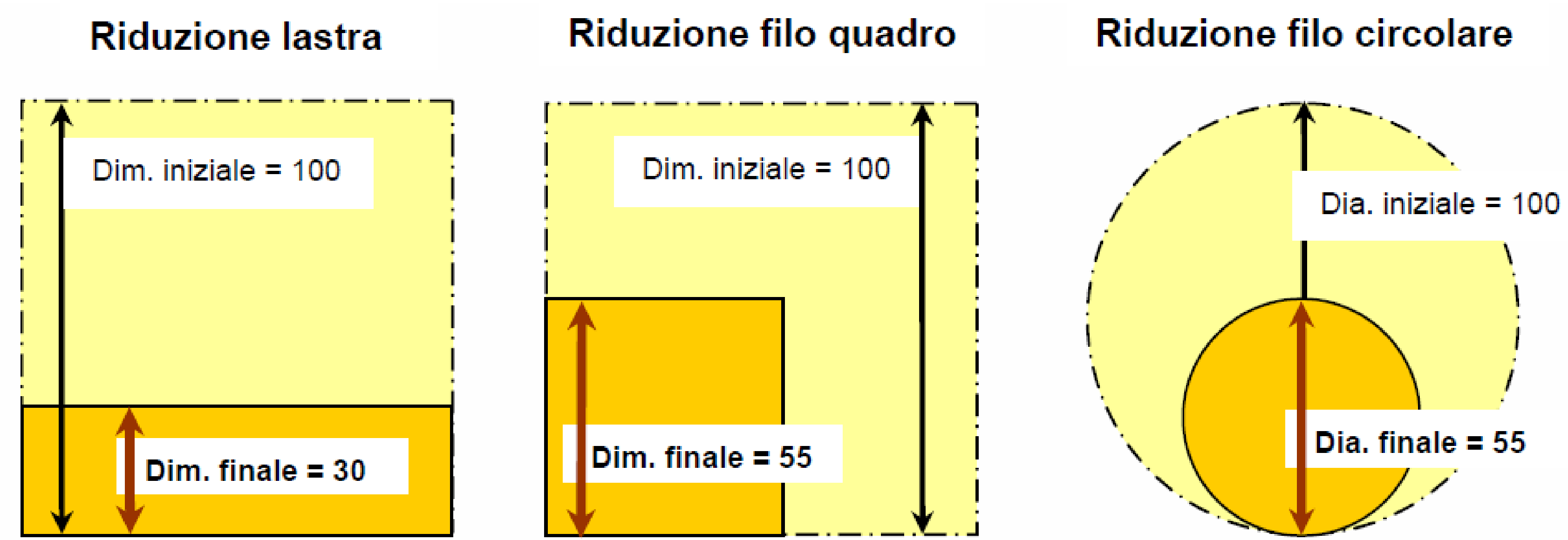
- Put bottom of tree in contact with running cold water
- Cool the flask with a fan
- Wait 10-15 minutes
- Quench in warm water (60-80°C)



Position four

Annealing: one more or one less?

Area reduction calculation



Area iniziale 100x100.
Area finale 100x30.
Rapporto di riduzione =70%

Area iniziale 100x100.
Area finale 55x55.
Rapporto di riduzione =70%

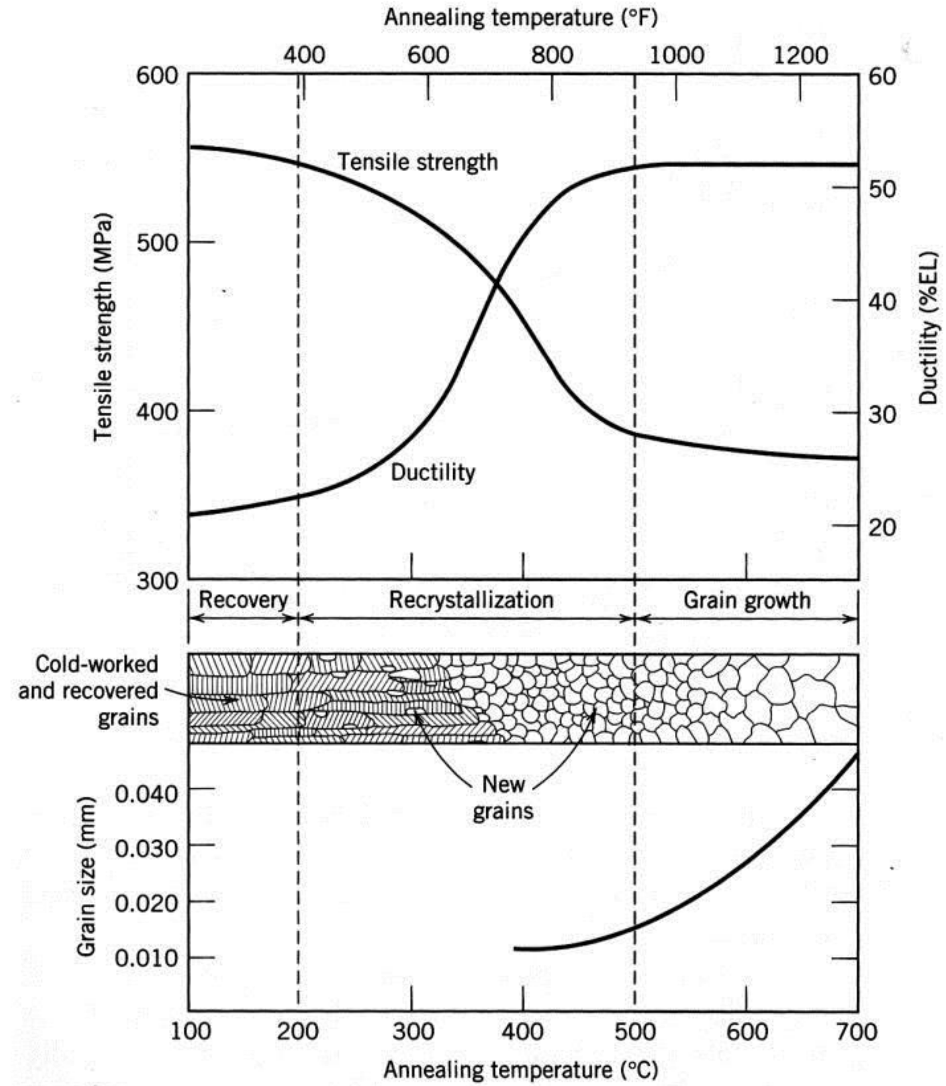
Area iniziale 50x50xπ.
Area finale 28x28xπ.
Rapporto di riduzione =70%

Too heavy plastic deformation:

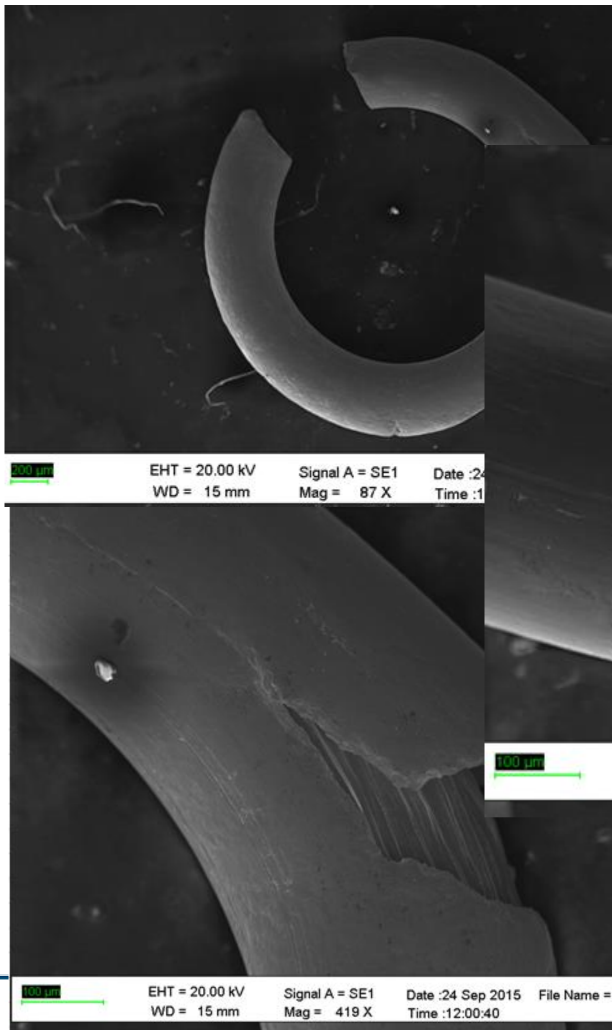
- excessive number of dislocations, damaged microstructure

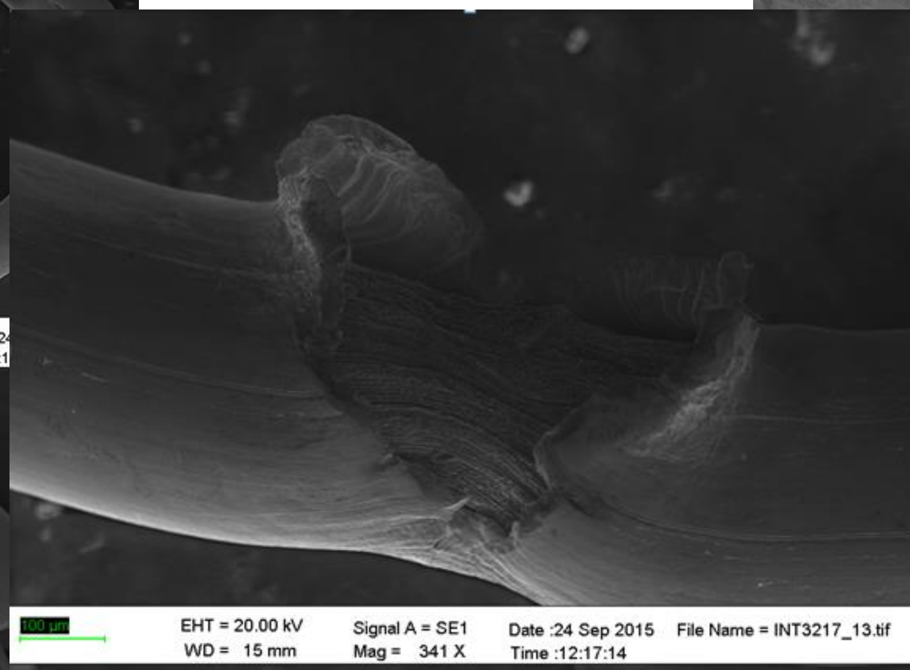
Lacking deformation:

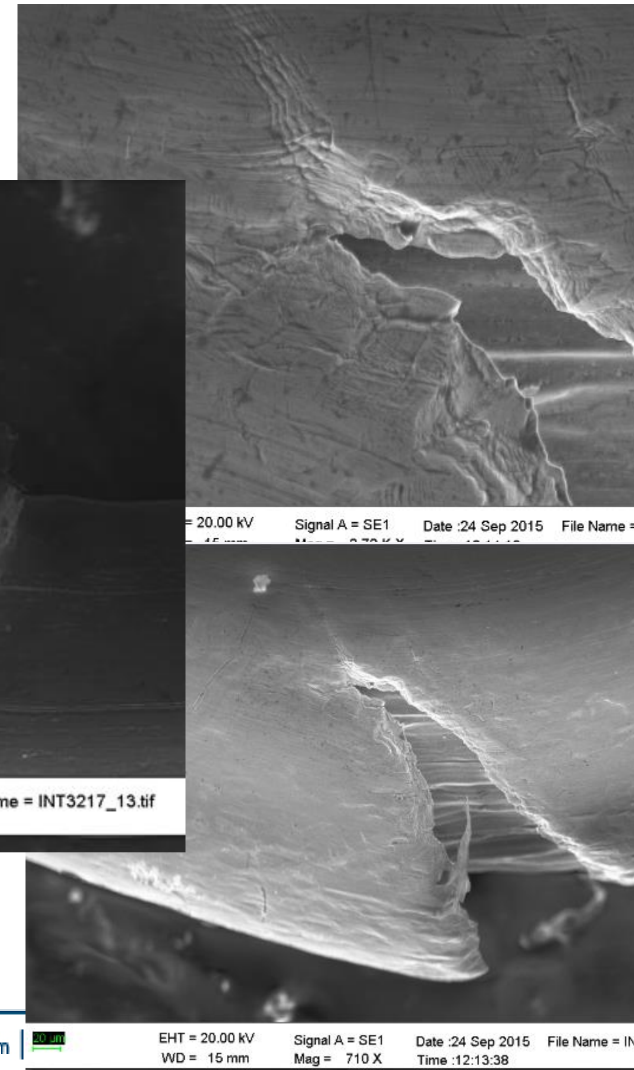
- Lacking or non-homogeneous dislocations: after annealing some zones are having grain growth, others are still in recrystallization



Hollow chain with iron core







Sheet deformation

	Initial process (sheet)				Modified process (sheet)	
1	Melting	Sheet 22,0x5,2 mm		1	Melting	Sheet 22,0x5,2 mm
2	Rolling	Red. 50% → 2,5 mm		2	Rolling	Rid. 65% → 1,8 mm
3	Annealing	660°C, 45 minutes, stat.		3	Annealing	660°C, 45 minutes, stat.
4	Rolling	Red. 70% → 0,8 mm		4	Rolling	Rid. 80% → 0,38 mm
5	Annealing	660°C, 45 minutes, stat.		5	Annealing	660°C, 45 minutes, stat.
6	Rolling	Red. 37% → 0,5 mm		6	Hollow chain shaping (iron)	Ø = 5,80 mm
7	Annealing	660°C, 45 minutes, stat.				
8	Rolling	Red. 24% → 0,38 mm				
9	Annealing	660°C, 45 minutes, stat.				
10	Hollow chain shaping (iron)	Ø = 5,80 mm				

Hollow wire deformation

	Second part (drawing)	
1	Drawing	Ø 5,80 mm → Ø 5,00 mm
2	Annealing	660°C, 45 minutes, stat.
3	Drawing	Ø 5,00 mm → Ø 4,40 mm
4	Annealing	660°C, 45 minutes, stat.
5	Drawing	Ø 4,40 mm → Ø 3,60 mm
6	Annealing	660°C, 45 minutes, stat.
7	Drawing	Ø 3,60 mm → Ø 2,80 mm
8	Annealing	660°C, 45 minutes, stat.
9	Drawing	Ø 2,80 mm → Ø 2,10 mm
10	Annealing	660°C, 45 minutes, stat.
11	Drawing	Ø 2,10 mm → Ø 1,40 mm
12	Annealing	660°C, 45 minutes, stat.
13	Drawing	Ø 1,40 mm → Ø 0,90 mm
14	Annealing	660°C, 45 minutes, stat.
15	Drawing	Ø 0,90 mm → Ø 0,55 mm
16	Annealing	660°C, 45 minutes, stat.

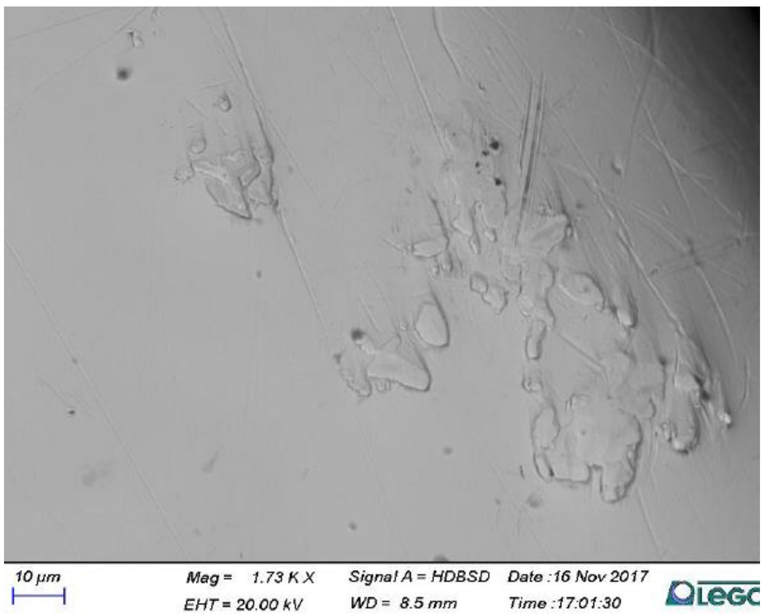
	Modified process (drawing)	
1	Drawing	Ø 5,80 mm → Ø 4,70 mm
2	Annealing	660°C, 45 minutes, stat.
3	Drawing	Ø 4,70 mm → Ø 3,70 mm
4	Annealing	660°C, 45 minutes, stat.
5	Drawing	Ø 3,70 mm → Ø 3,00 mm
6	Annealing	660°C, 45 minutes, stat.
7	Drawing	Ø 3,00 mm → Ø 2,20 mm
8	Annealing	660°C, 45 minutes, stat.
9	Drawing	Ø 2,20 mm → Ø 1,50 mm
10	Annealing	660°C, 45 minutes, stat.
11	Drawing	Ø 1,50 mm → Ø 0,90 mm
12	Annealing	660°C, 45 minutes, stat.
13	Drawing	Ø 0,90 mm → Ø 0,60 mm
14	Annealing	660°C, 45 minutes, stat.

Position three

I got hardspots on an item surface: why?

Which causes for hardspots?

- Very common examples: Contaminations from metals

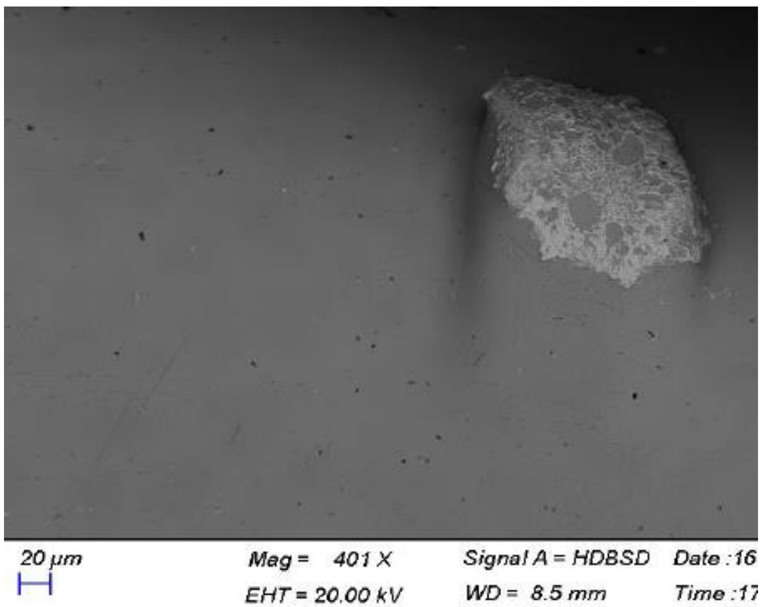


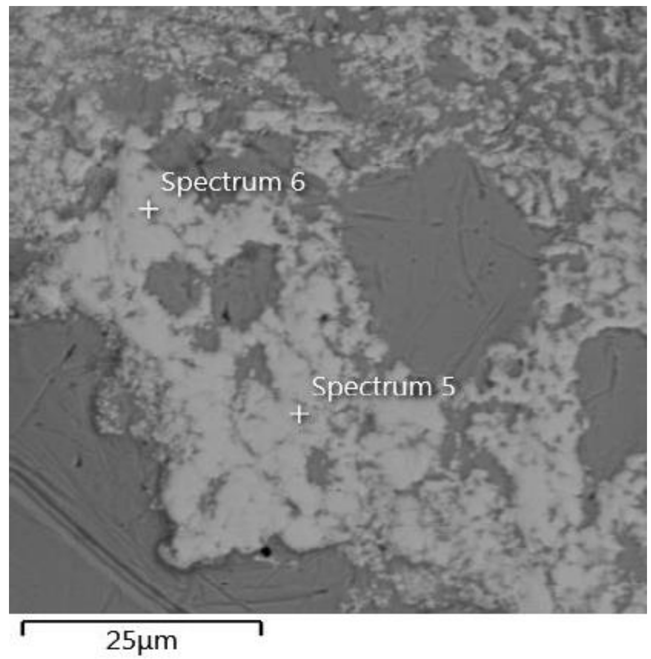
Spectrum 1:
Ruthenium 17,96%
Iridium 82,04%

Spectrum 2:
Ruthenium 22,23%
Iridium 77,77%

Which causes for hardspots?

- Very common examples: Contaminations from metals

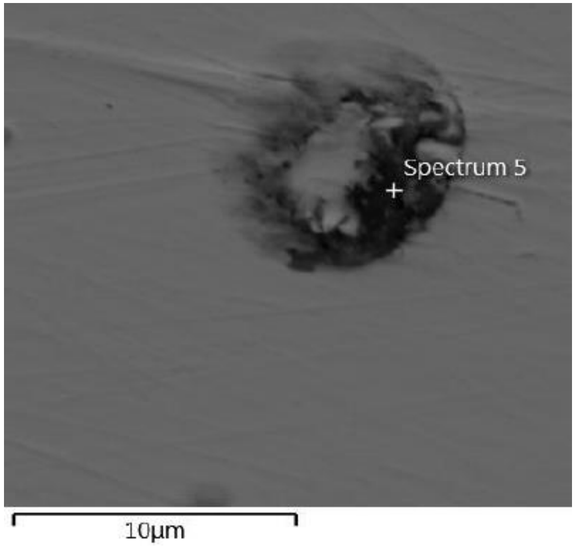


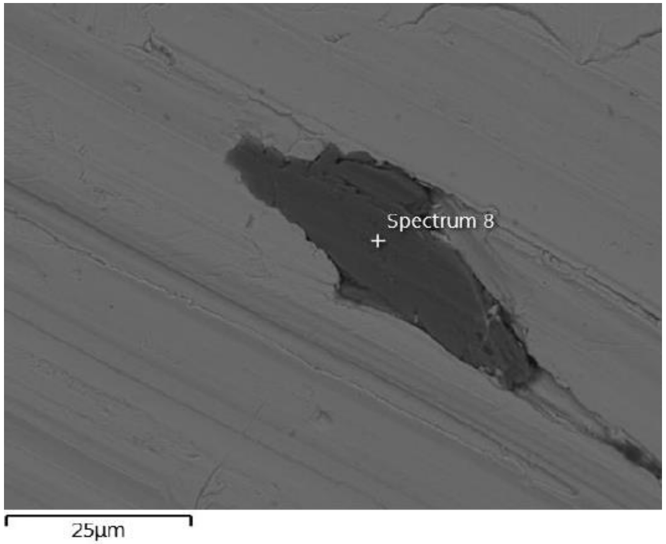


Spectrum 5:
Copper 2,14%
Osmium 97,86%

Spectrum 6:
Copper 2,55%
Osmium 97,45%

Very common examples: Contaminations from non-metallic compounds





Spectrum 5:
Oxygen 48%
Aluminum 52%

Spectrum 8:
Iron 72,5%
Chromium 9,6%
Carbon 7%

Position two

As cast silver is too soft! How to harden it?

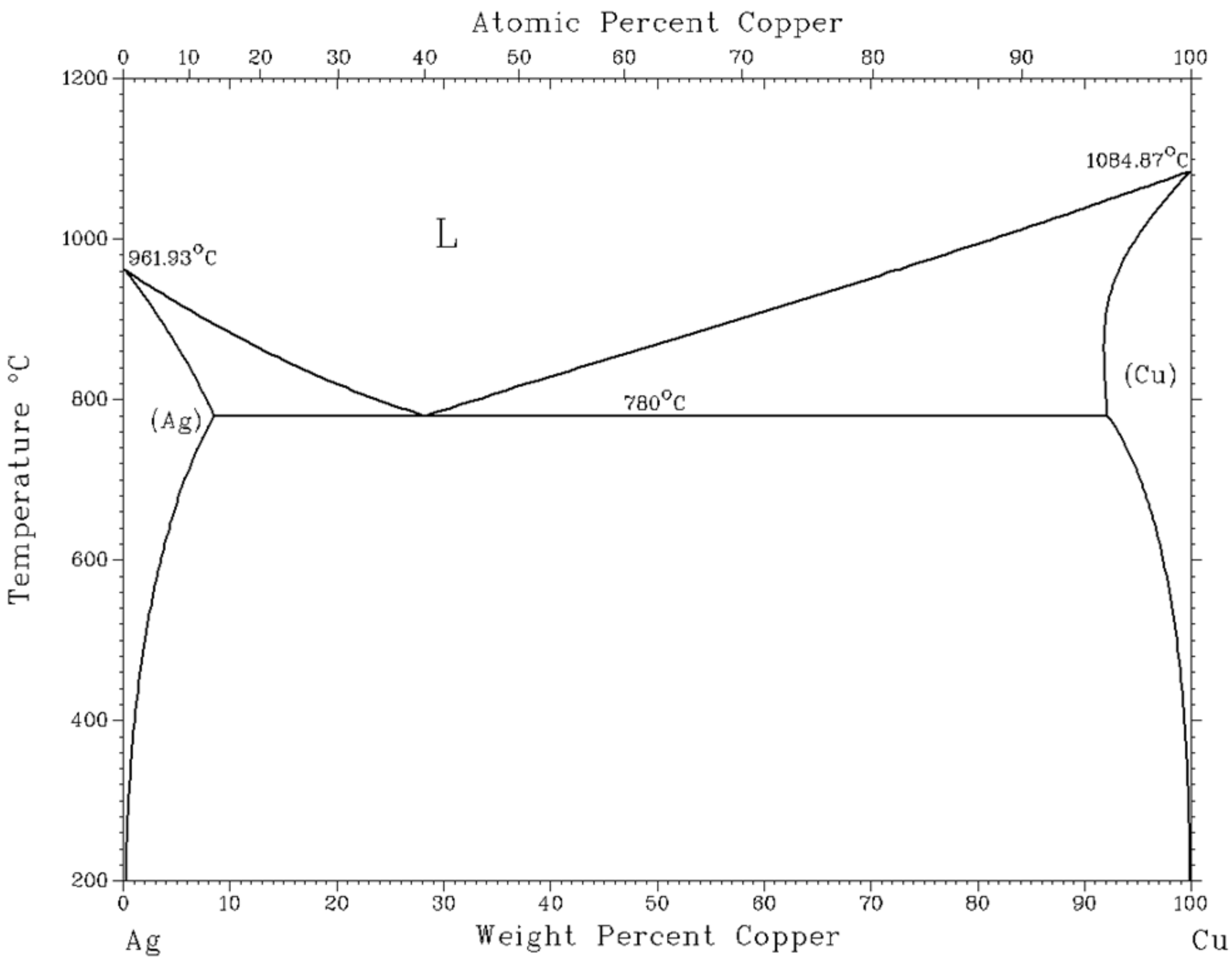
Hardening elements…?

Limited as cast hardness, miscibility problems

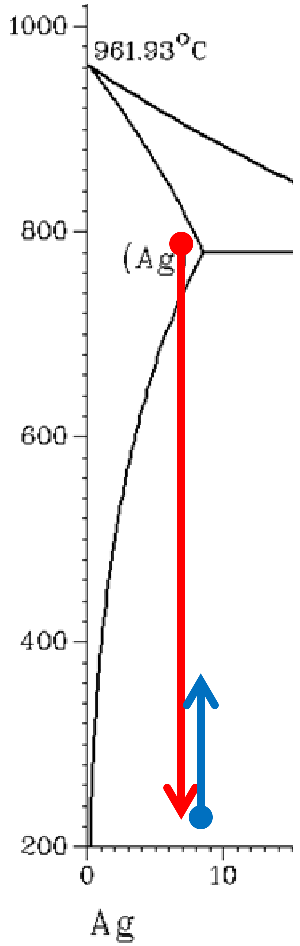
- Nickel (release)
- Manganese (high tarnishing, slag)
- Tin (porosity, quality issues)

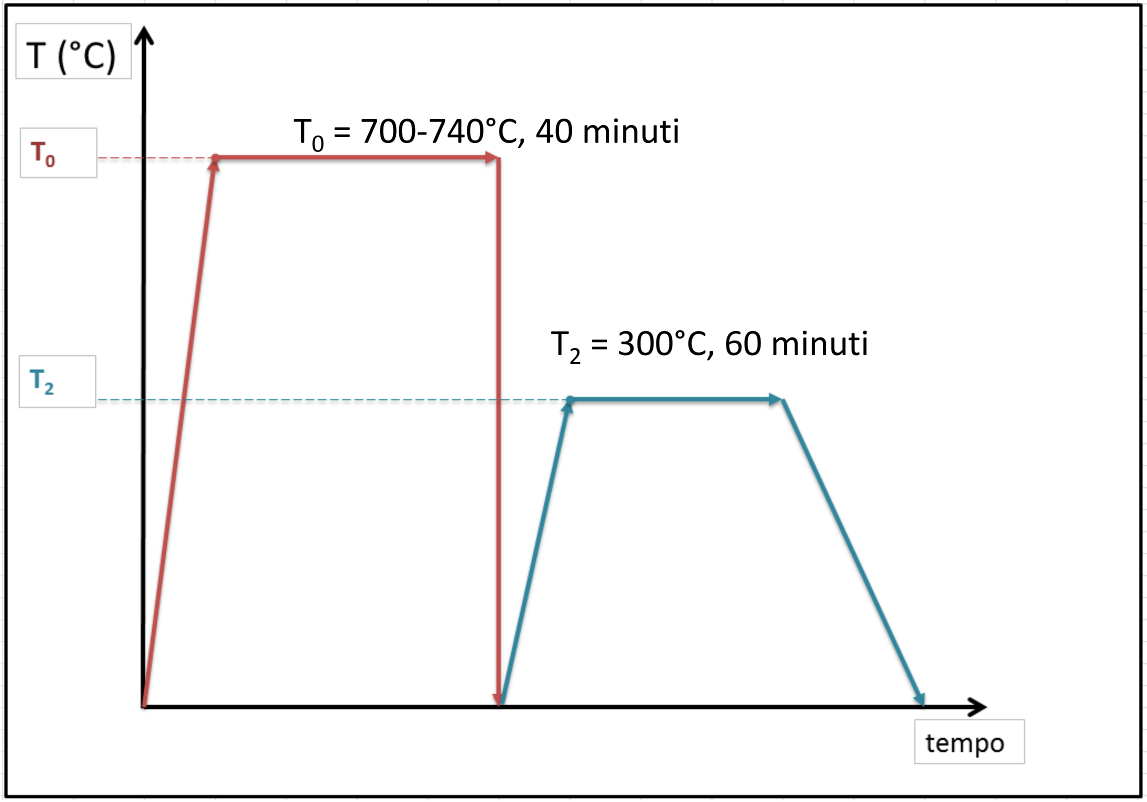
From internal characterization:
- Ni 95 HV
- Mn 75 HV
- Sn 80 HV
- In 45 HV

AgCu alloys are suitable for age-hardening!



Age-hardening: principle of functioning





Inert atmosphere or vacuum in the hardening furnace?

Both work well, but not to harden the item…

There are other metallurgies in which the atmosphere can harden the surface
(nitridization, carbocementing)

Advantage: protection from oxydation and thermal stability

Can I add the plastic deformation hardness to that from age-hardening?

Unfortunately no, hardning is obtained by a limitation to the dislocation mobility, and it’s not an additive property

Position one

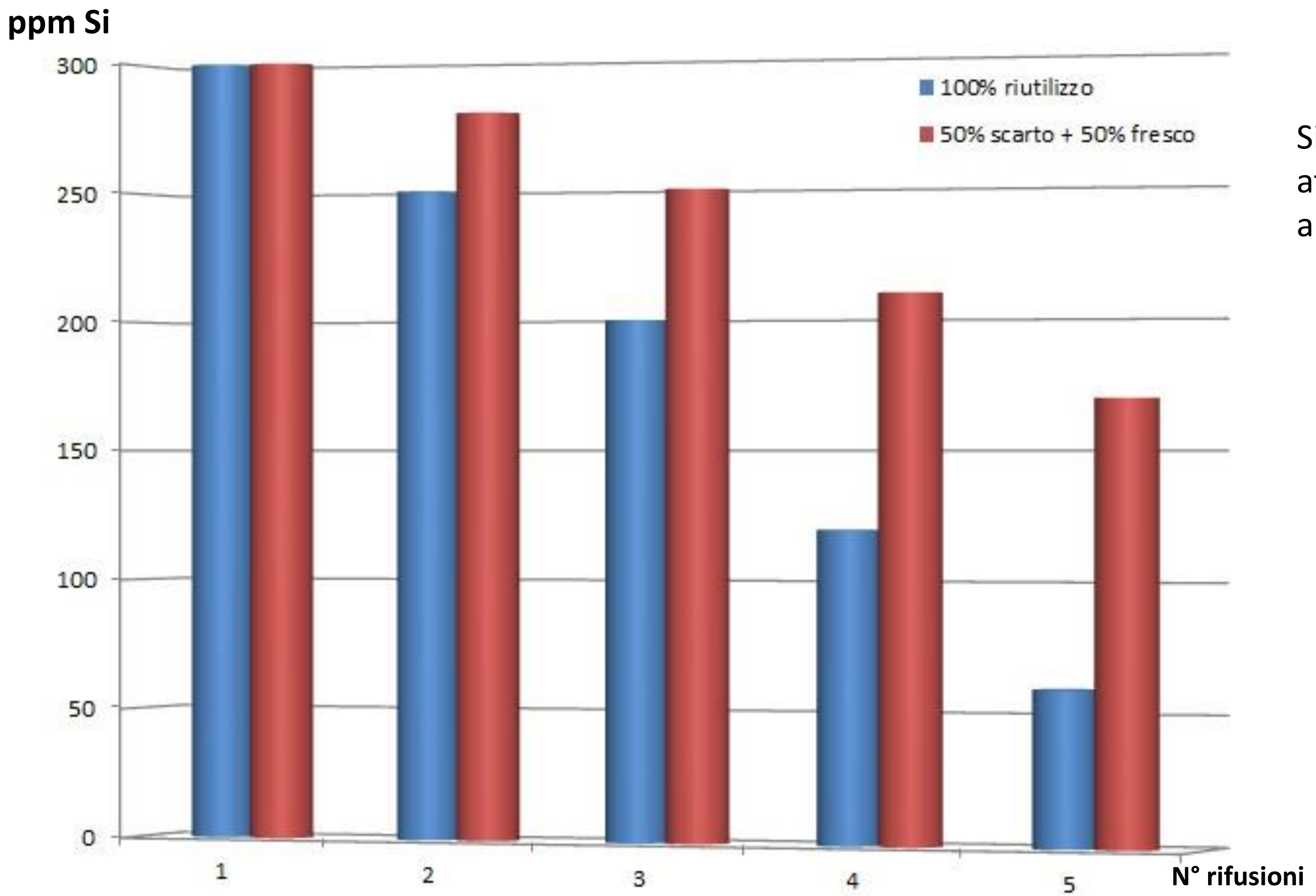
How many times can I re-use an alloy?

It depends….

- Production process
- What does the alloy come in contact with
- Investment reaction
- Alloy overheating
- Refractory residues
- Oxydation / Oxygen intake
- Lubricant residues

Consumption of functional elements in the alloy

Deoxidizers getting lower need to be replenished



Silicon content of a yellow alloy at title 750 after several casting and recasting cycles

In casting it is recommended to use at least 50% of new alloy with each casting

Clean scraps with pickling and magnetic tumbler

Do not exceed with reuse!

- 6 times at max for yellow/red gold
- 4 times for white gold

Aim: a stable process

Acknowledgements

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