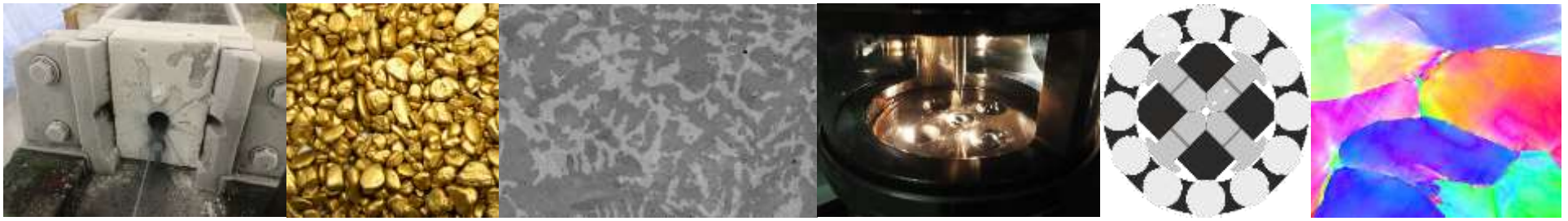

Strength and deformation of precious high-entropy alloys

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Member of the Leibniz Association

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High entropy alloys ⟺ Compositional complex alloys

- 5 principal elements
- homogeneous solid solution
- single phase
- simple crystal structure

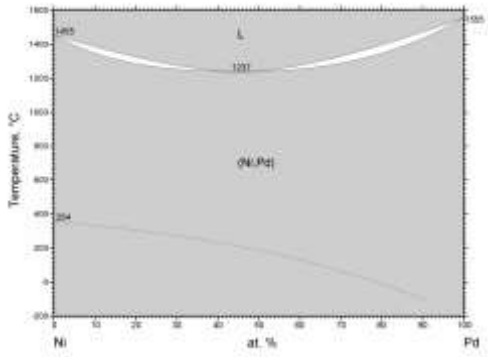
- 5 principal elements
- multi-phase microstructure

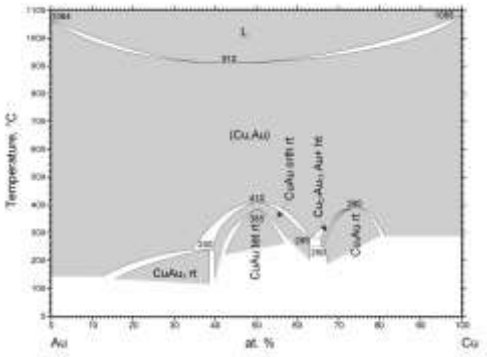
→ benchmarking alloy for all HEAs
cleanly separation from conventional single phase alloys

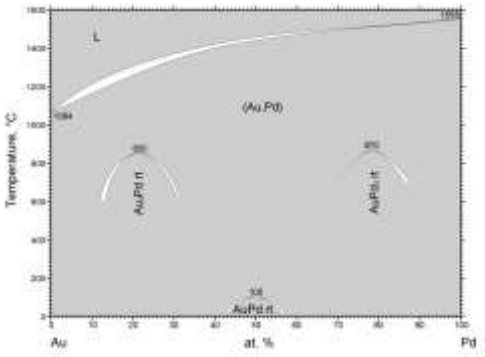
Binary phase diagrams in the Au-Cu-Ni-Pd-Pt system

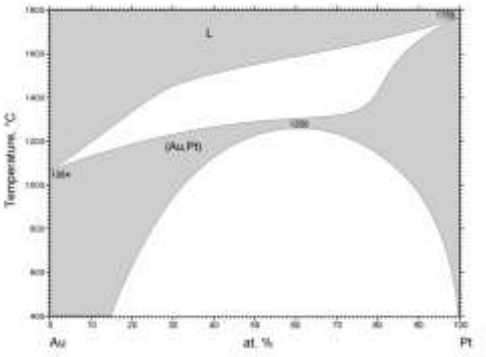
- all show a homogeneous solid solution at high T
- all elements are fcc and do not show allotrope modifications
- no intermetallic phases form out of the melt
- homogeneity covers hole concentration range at high T

→ However: miscibility gabs and phase decompositions at low T



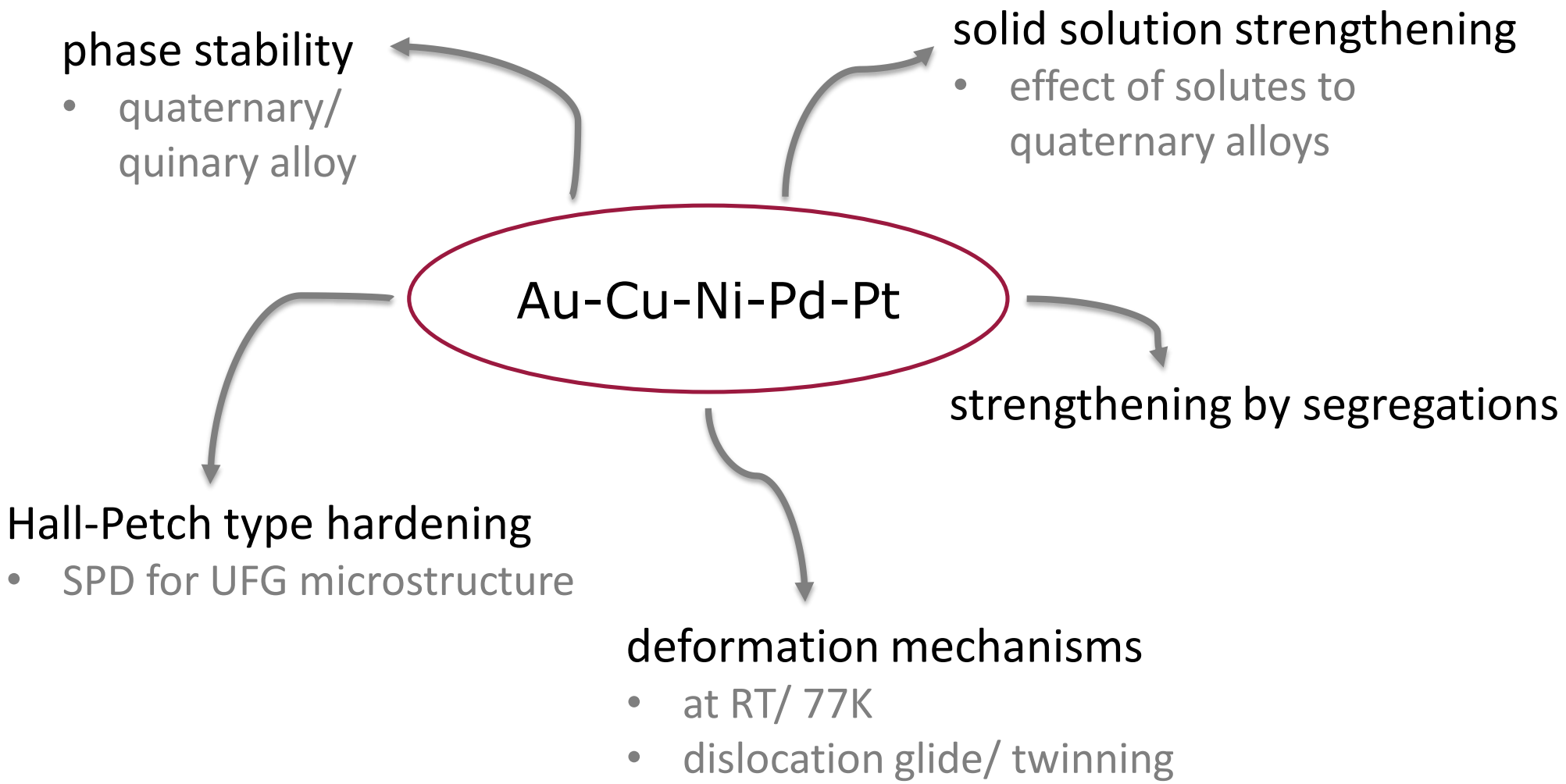






Okamoto H., and Massalski T.B.: Binary Alloy Phase Diagrams, II Ed. (1990)

Research issues



Alloy processing

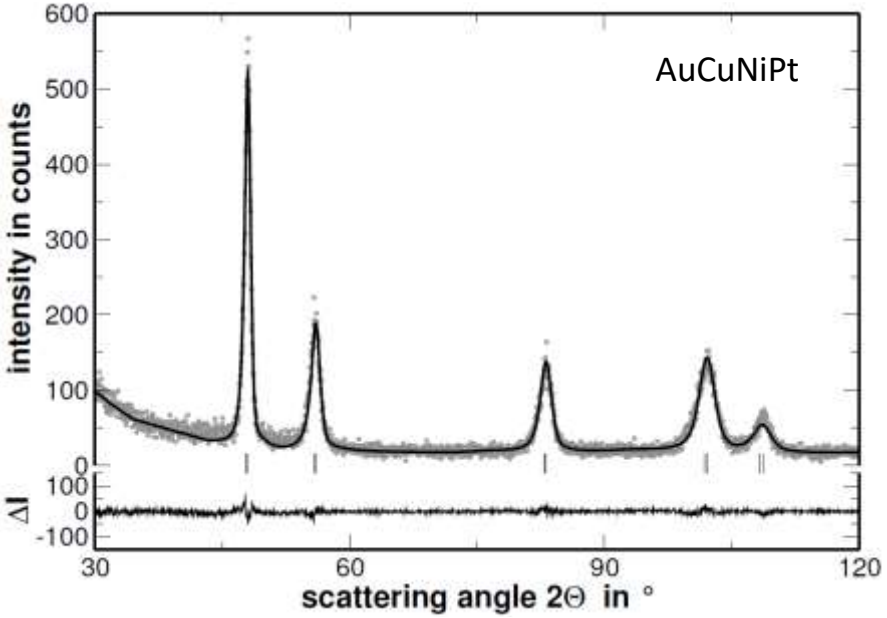
- alloying
- arc melting

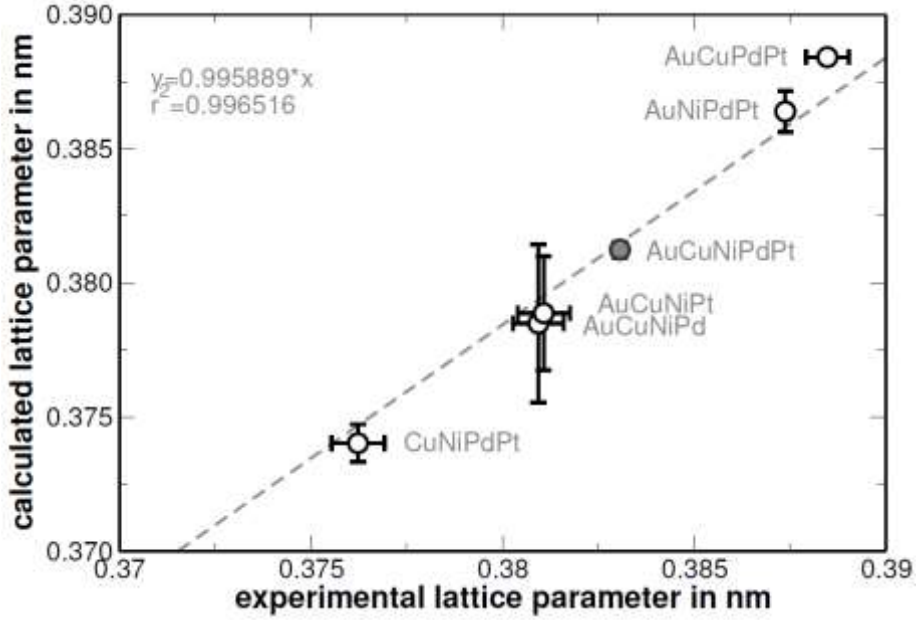
- homogenization
- recrystallization

- cold working

Vegard's rule of mixture

- solution treatment 1000°C/ 24h
- fcc structure
- single phase





$$a = \sum_{i=1}^{5} x_i a_i$$

- linear dependency of calculated and experimental lattice parameter

→ homogeneous solid solution covers the whole concentration range

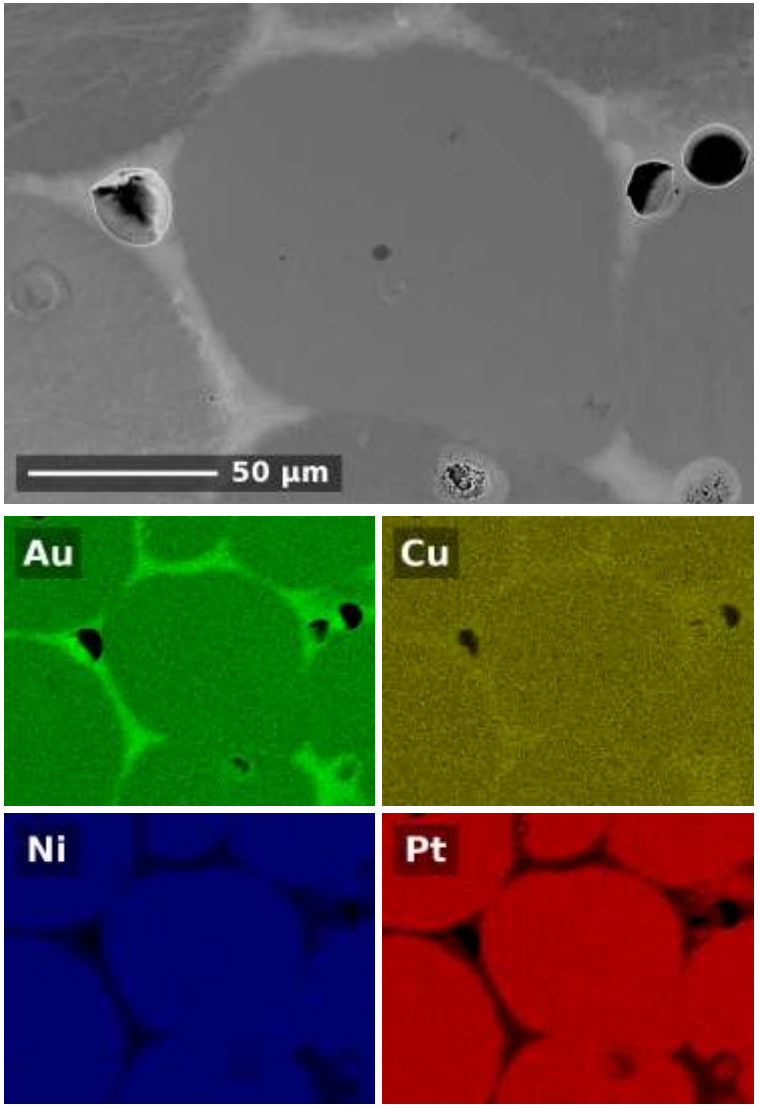
Freudenberger, J et al.: Metals 135 (2017), p. 7

Segregations in AuCuNiPt

- second heat treatment in liquid/ solid state 1100°C/ 17h
- Au & Cu at grain boundaries

  → low elemental melting point

  → pair mixing enthalpy



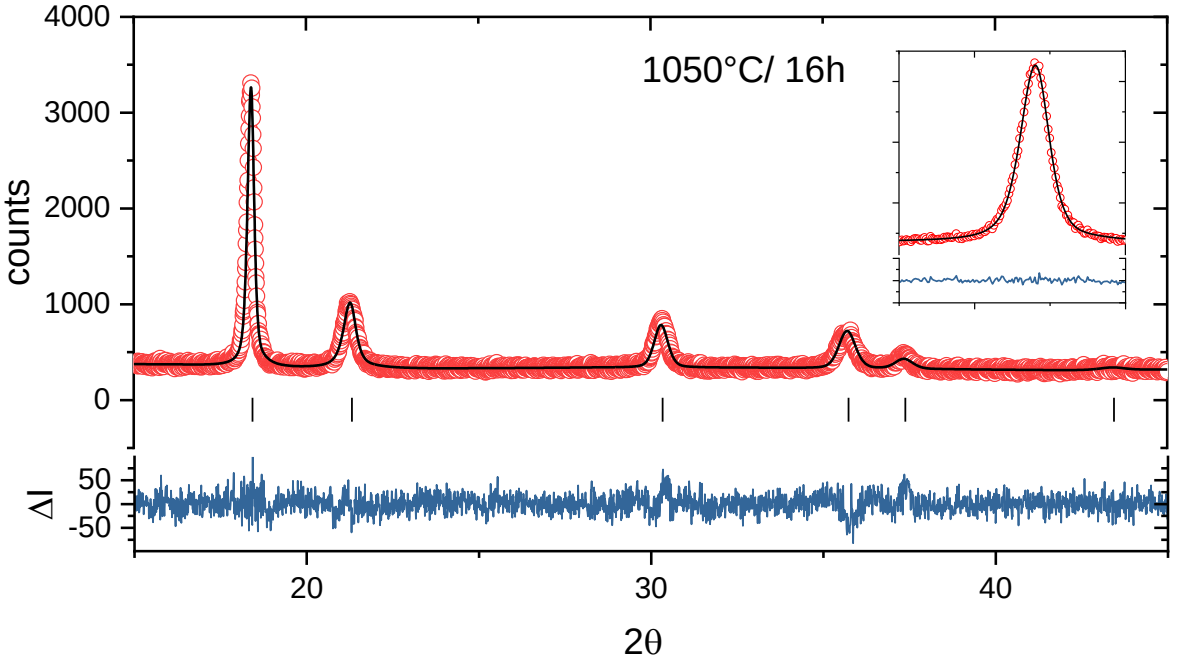
	r_{met} pm	T_m °C
Au	144	1064
Cu	128	1085
Ni	125	1455
Pd	137	1555
Pt	139	1768

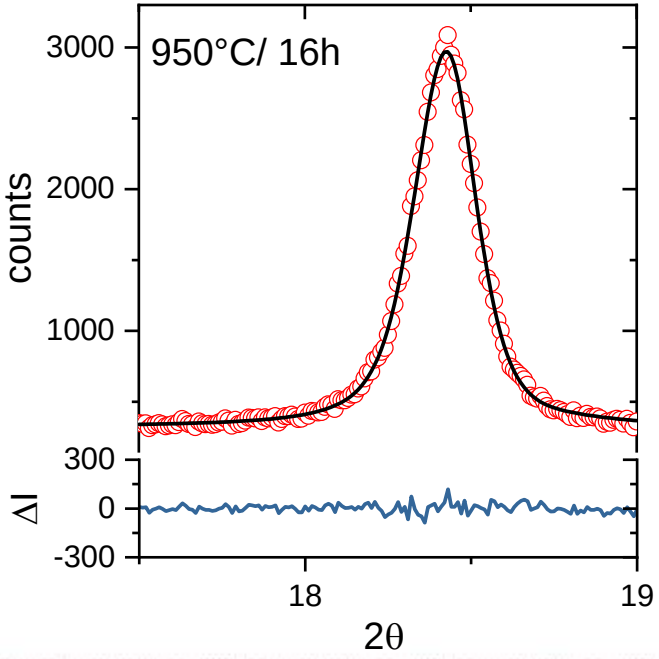
Pair mixing enthalpy			
	Cu	Ni	Pt
Au	-5.2	7.6	0.5
Cu		2.3	-11.4
Ni			-9.3

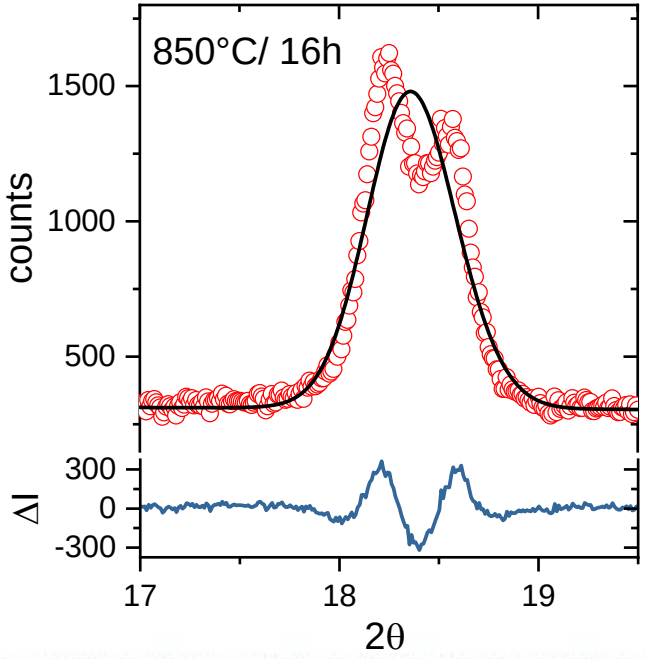
Freudenberger, J et al.: Metals 135 (2017), p. 7

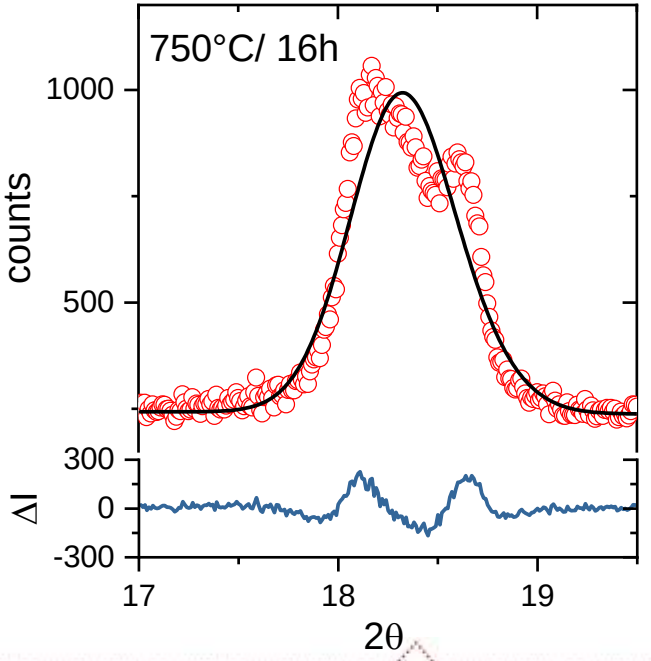
Solution treatment

- single phase at T>950°C
- decomposition at T<900°C into two fcc phases





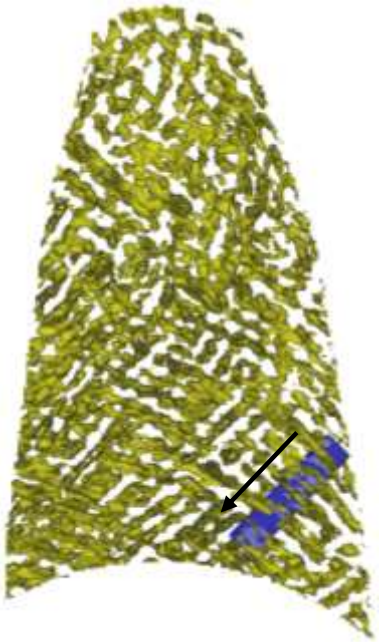


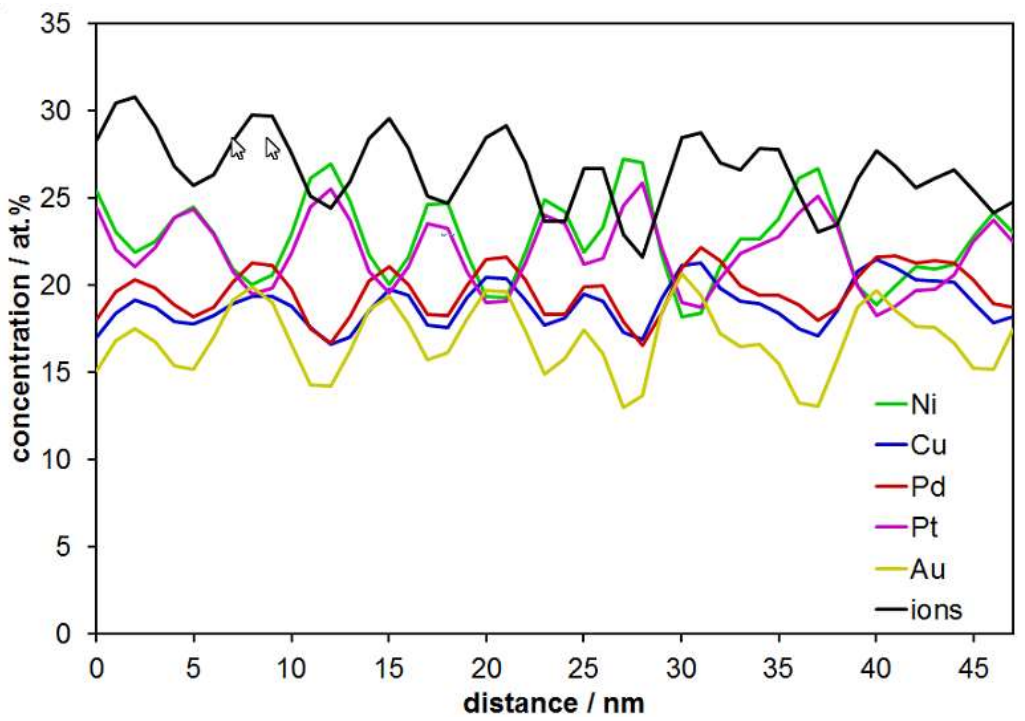


Homogeneity of AuCuNiPdPt

- atom probe tomography of a solution treated AuCuNiPdPt sample
- decomposition of Au-Cu-Pd and Ni-Pt
  phase separations of binary systems Cu-Ni, Pd-Pt & Au-Ni at low T

  → improved solution treatment (possible?)





Conclusions

- single phase at high T, phase decomposition at T < 900°C
- heat treatment in liquid/ solid area leads to segregations at grain boundaries
- APT shows elemental variations on atomic scale in homogenized state

Thank you for your attention!

Sven Donath, Lars Giebeler, David Geissler, Martin Heilmaier, Alexander Kauffmann, Christiane Mix, David Rafaja, Juliane Scheiter, Dirk Seifert, Sascha Seils, Christiane Ullrich

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