Strength and deformation of precious high-entropy alloys

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High entropy alloys

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

Compositional complex alloys

- 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 gaps and phase decompositions at low T
Research issues

- **phase stability**
  - quaternary/quinary alloy

- **solid solution strengthening**
  - effect of solutes to quaternary alloys

- **Au-Cu-Ni-Pd-Pt**

- **strengthening by segregations**

- **Hall-Petch type hardening**
  - SPD for UFG microstructure

- **deformation mechanisms**
  - at RT/77K
  - dislocation glide/twinning
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
  \( \rightarrow \) homogeneous solid solution covers the whole concentration range
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

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<th>( r_{\text{met}} ) pm</th>
<th>( T_m ) °C</th>
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<td>1064</td>
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<td>Ni</td>
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<td>Pt</td>
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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!

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