The Intermetallic System Cu-Ni-Sn

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Outline

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Why working on Cu-Ni-Sn

Technical applications

- Cu-Ni alloys (Ni-bronzes) with additions of Sn as deformable alloys and conducting materials in electric devices, automobiles and household.
- Solder alloys and Ni as contact material or as a component in lead-free solder applications.

Basic research

- Occurrence of a very special solidification behavior in the (Cu,Ni)-rich corner of the diagram

Ag-Cu-Ni-Sn is currently the most important system for lead-free soldering!

Cu and Ni show total mutual solubility and the TM's solve significant amounts of tin. Beyond that there is practically no mutual solid solubility: ⇒ **Extended ternary solubility of the binary IMC's exists only in Cu-Ni-Sn!**

From a huge amount of diffusion couple studies it turned out that the formation of ternary solid solutions of the types

$Cu_{6-x}Ni_xSn_5$, $Cu_{3-x}Ni_xSn$, $Ni_{3-x}Cu_xSn_4$, and $Ni_{3-x}Cu_xSn$

have tremendous influence on the operation and performance of solder joints.

Literature information

Earlier work was mainly concerned with the (Cu,Ni)-rich part whereas more recent publications are focused on the Sn-rich part.

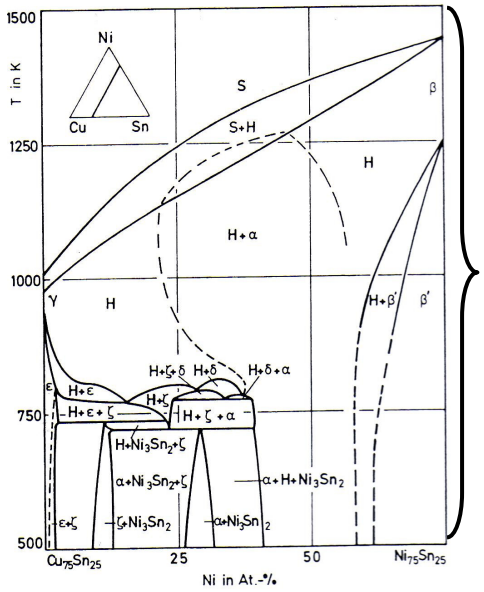
Key papers

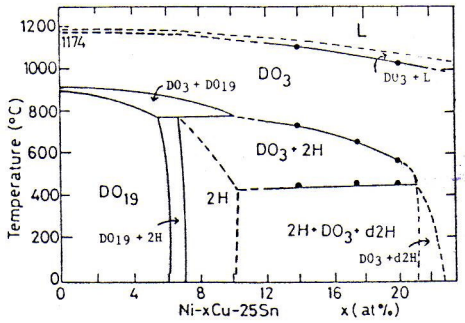
- ***E. Wachtel and E. Bayer, Z. Metallkde., 75, (1984)***
  Isotherm at 647 °C, Isopleth at 25 at.% Sn, part. liquidus projection

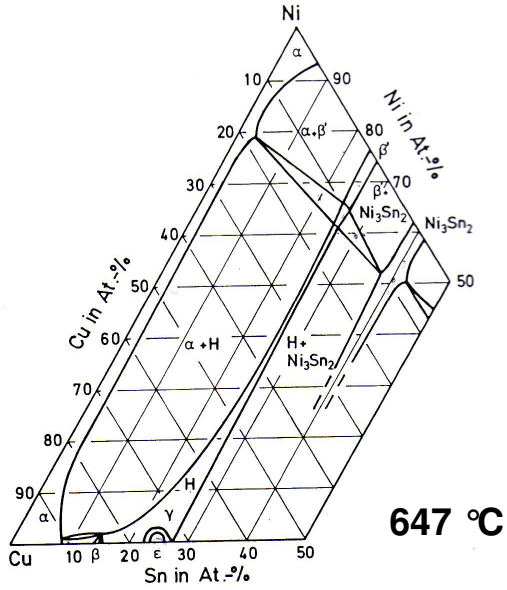
- ***J.S. Lee Pak and K. Mukherjee, O.T. Tinal and H.-R. Pak, Mat. Sci. Eng., A117, (1989) and A130, (1990).***
  part. isopleth at 25 at.% Sn, two ternary phases (2H and d2H)

- ***G. Ghosh, Landolt-Börnstein, New Series IV, Vol. 11C3; MSIT®***
  Comprehensive compilation and assessment of experimental and calculated data to structure, phase relations and thermodynamics
  129 references from 1928 to 2006, 70 describe experimental work!

The vertical section at 25 at.% Sn







647 °C

- Low ternary solubility of the ε-Cu_3Sn phase
- Stabilization of phases to lower T by additions of the second TM
- Complex phase equilibria below ~ 500 °C at the Cu-rich side
- Martensitic phase transformations at the Ni-rich part
- Stable ternary phases 2H (β-Cu_3Ti type) and dH_2 (distorted β-Cu_3Ti type)

Isothermal sections

Many isothermal sections have been published in recent years:

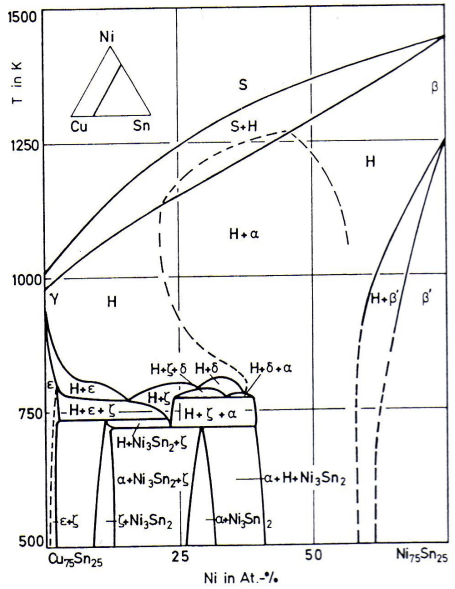
- Most of them are based on experimental data (XRD and EPMA) and calculations at low temperatures (approx. 240 °C).

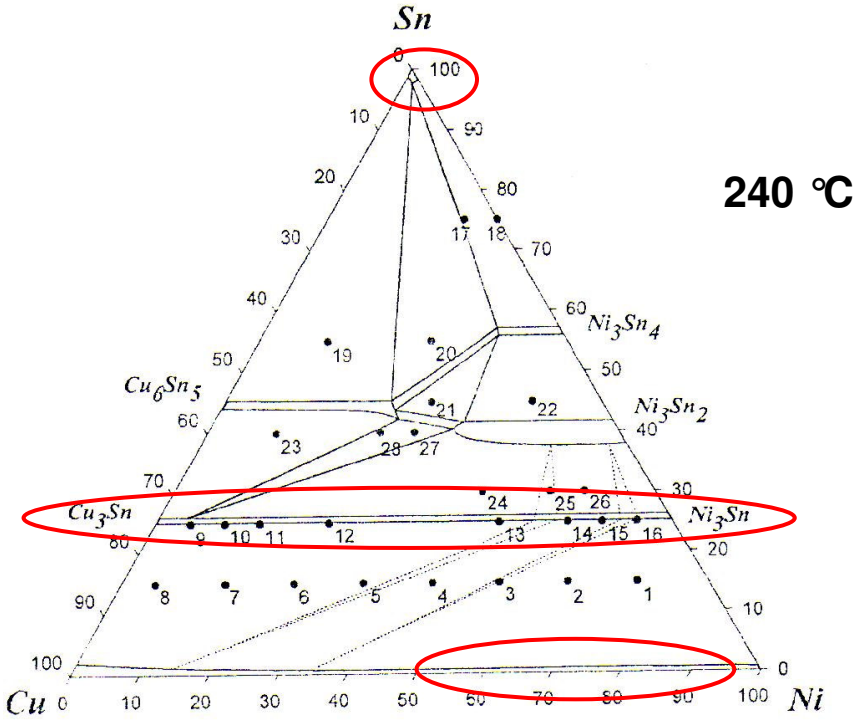
- Conventional equilibration and quenching techniques are not suitable to describe phase relations below ~ 40 at.% Sn at these temperatures.

- Because of complex phase transformations, possible metastable phase transformations, coring effects, etc., the experimental investigation of the (Cu,Ni)-rich part is very difficult.

- Some of the published sections are erroneous simply from a theoretical point of view and neglect well accepted literature data published long time before.

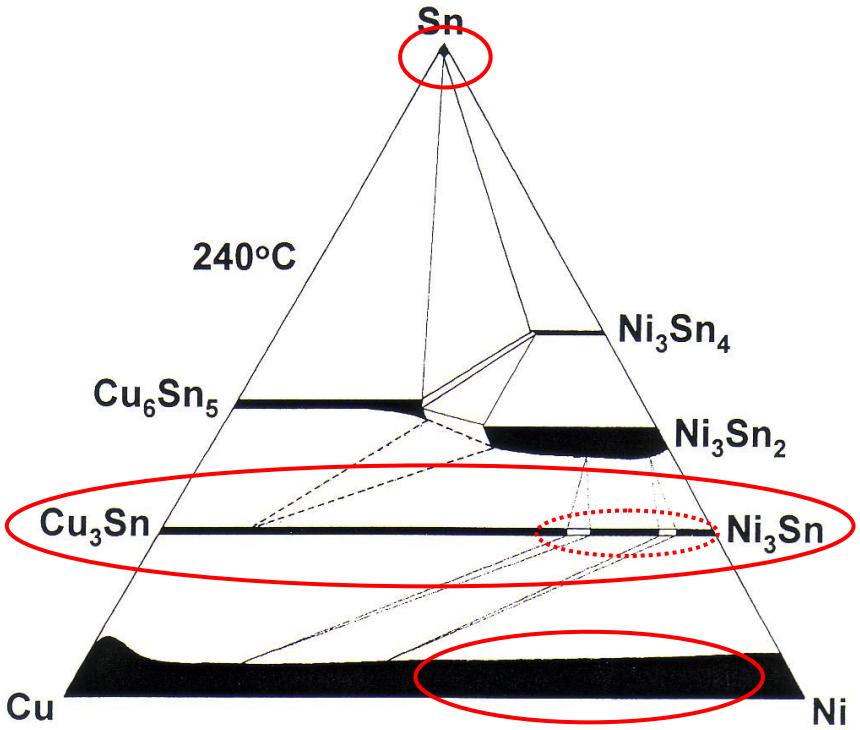
Isothermal sections

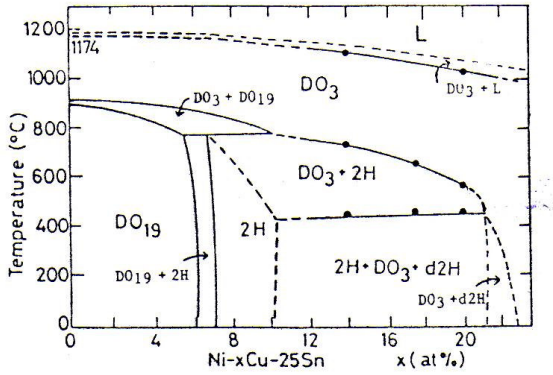




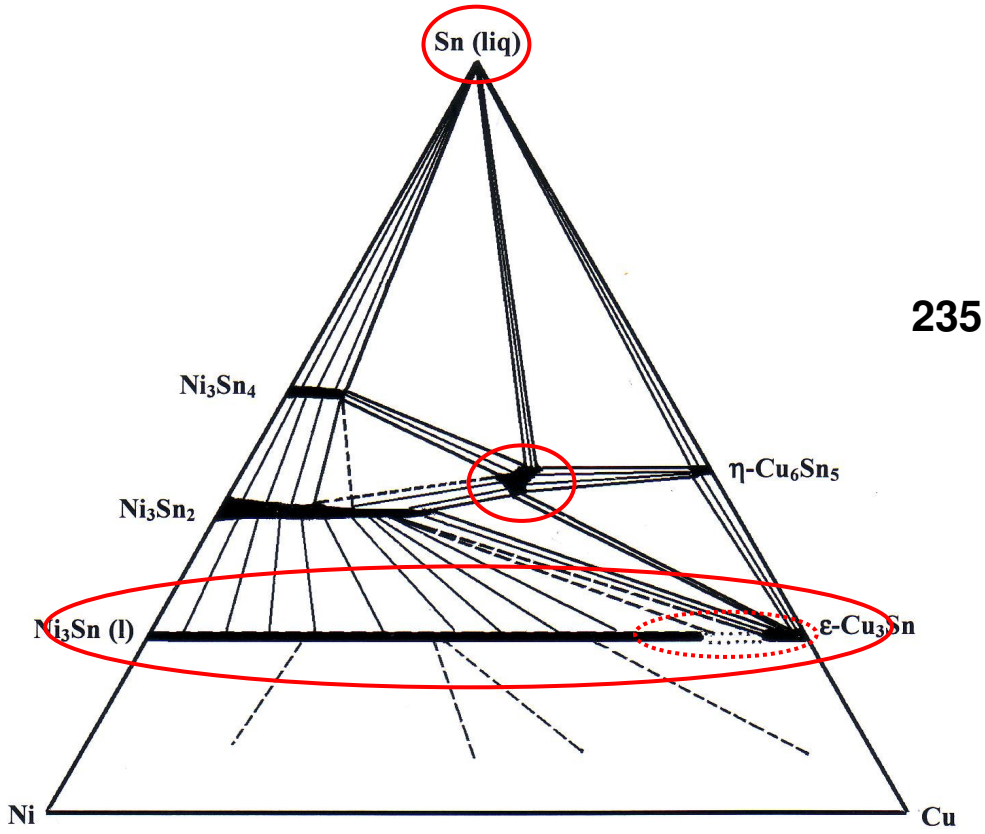
240 °C

Isothermal sections





Isothermal sections



235 °C

Ternary compounds

Are there sepa

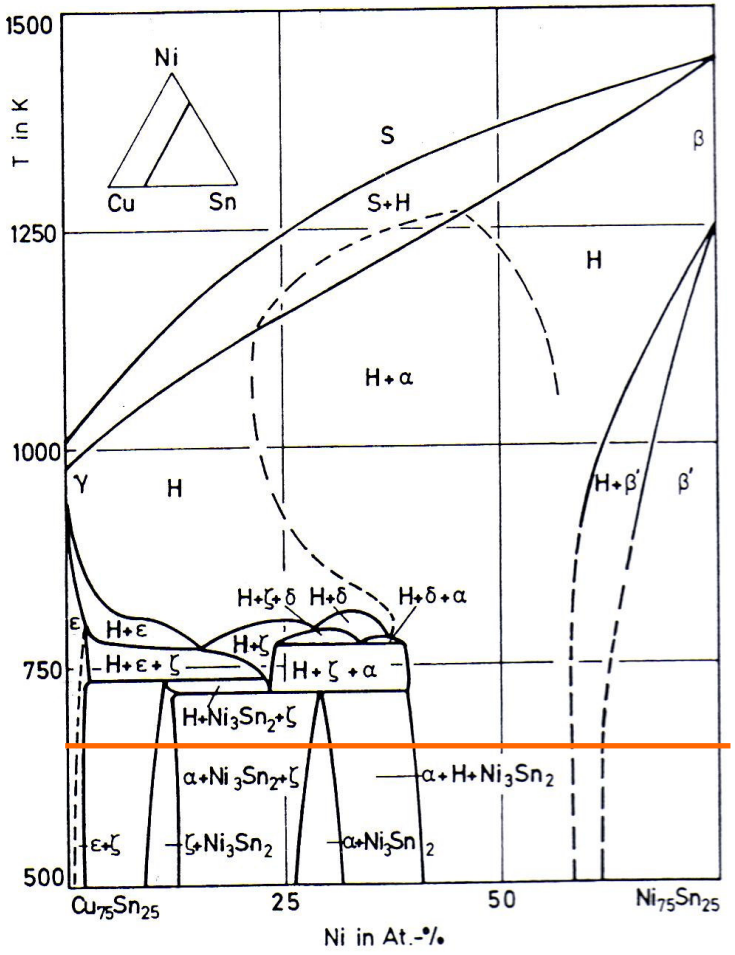
Three ternary p mentioned in literature:

- Cu_2NiS $_2$ $_1$
- $CuNi_5S$ rom TEM and ED
- $CuNi_2S$ Ti type, triclinic

Two ternary pha entioned in literature:

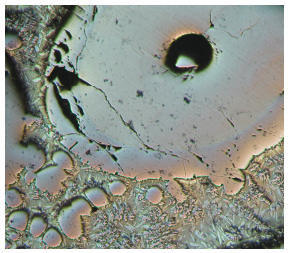
- $Cu_{27}Ni_2$ t 235 °C (2 month)?
- Cu_4Ni_2S stabilities along the section NiAs-type phase. No expe nation mechanism!

According to assessments the existence of a nost likely!



Experimental challenges

- The large difference of m.p. of Cu, Ni and in particular Sn
- The very slow dissolution of Ni in the matrix of Cu and Sn ⇒ difficult homogenization

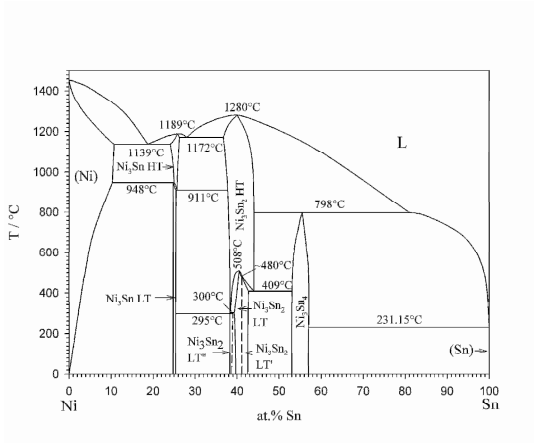


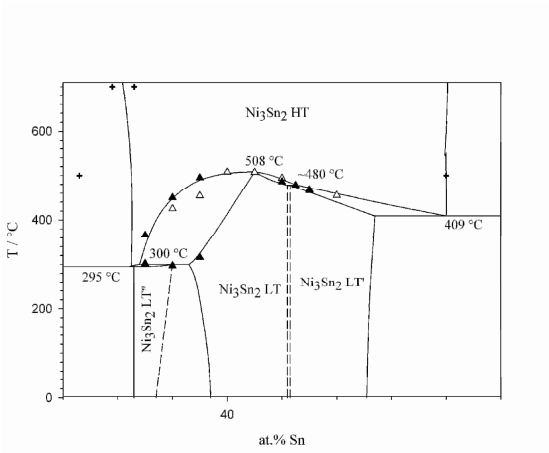
- The small difference in the atomic number of Cu and Ni ⇒ limited distinction of different phases and structures in SEM and XRD
- Many phase transformation in a narrow concentrational region with closely related structures

Experimental efforts

- Cross-check of Cu-Sn with 10 samples
- New investigation of Ni-Sn:

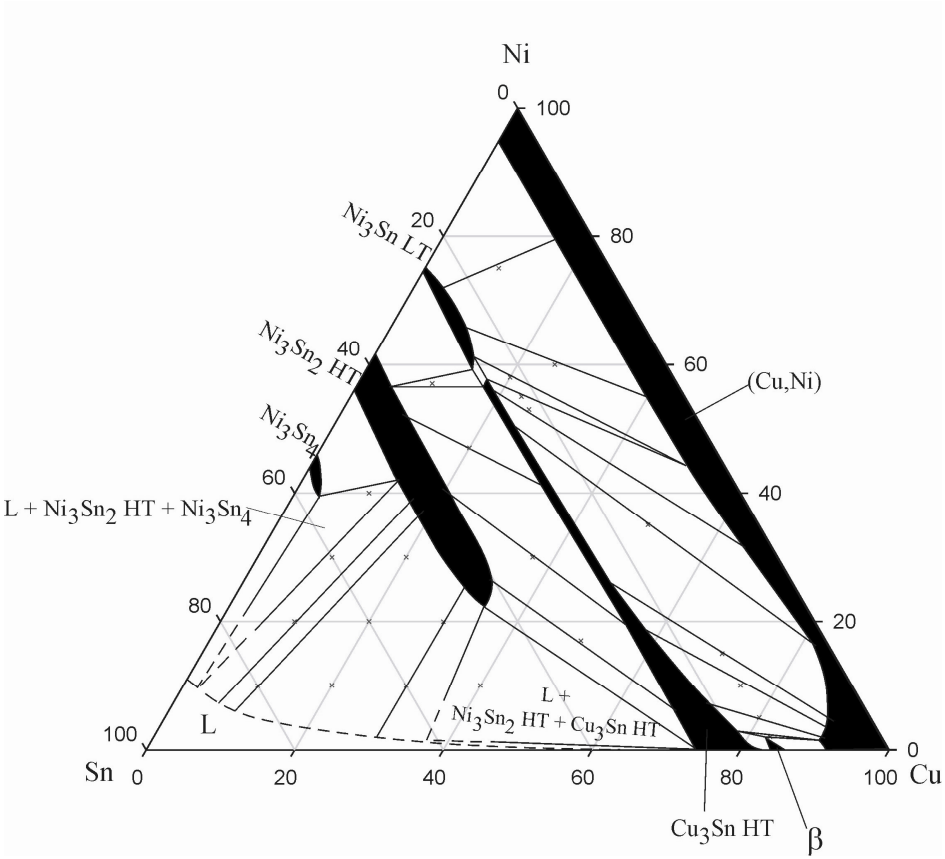
C. Schmetterer, H. Flandorfer*, K. W. Richter, U. Saeed, M. Kauffman, P. Roussel, H. Ipser, Intermetallics, 15, (2007), 869.



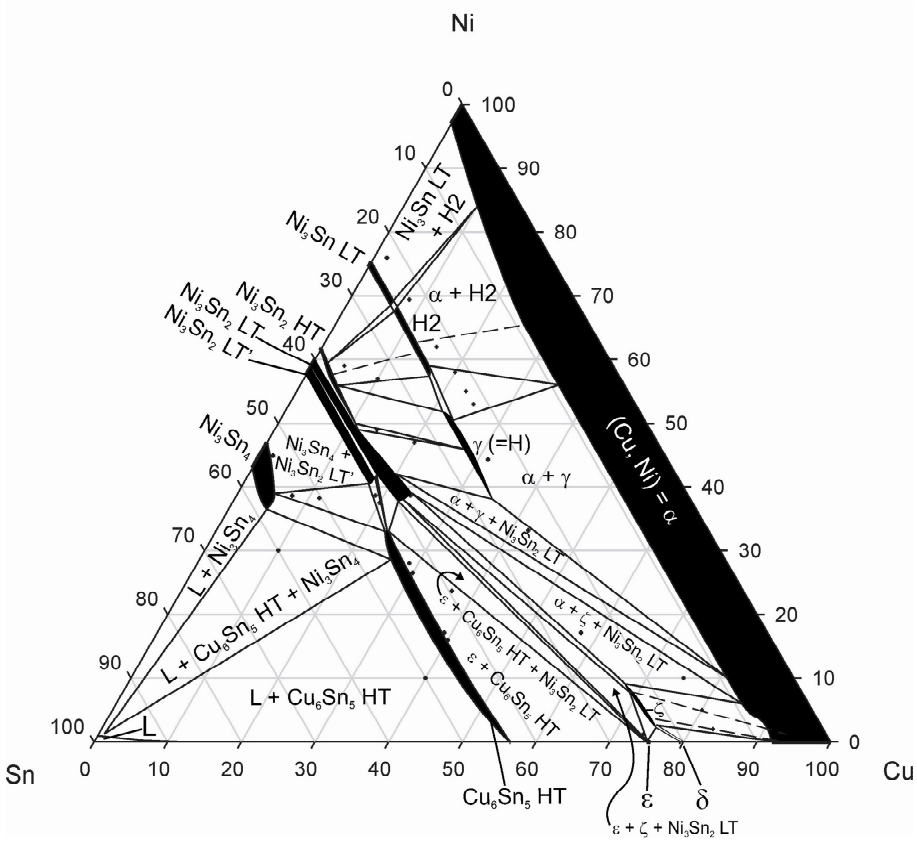


- Preparation of approx. 100 ternary samples, annealing at different temperatures ⇒ XRD, SEM, EPMA

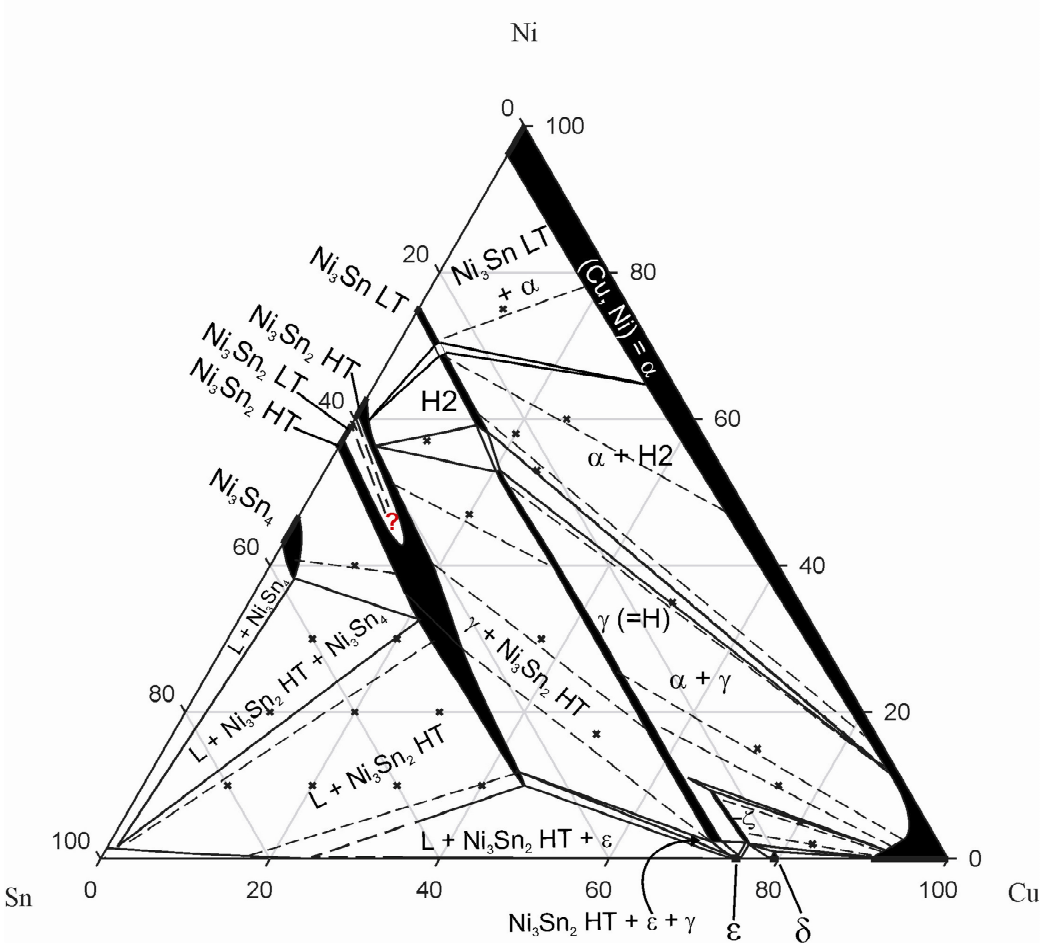
Isothermal Section at 700 °C



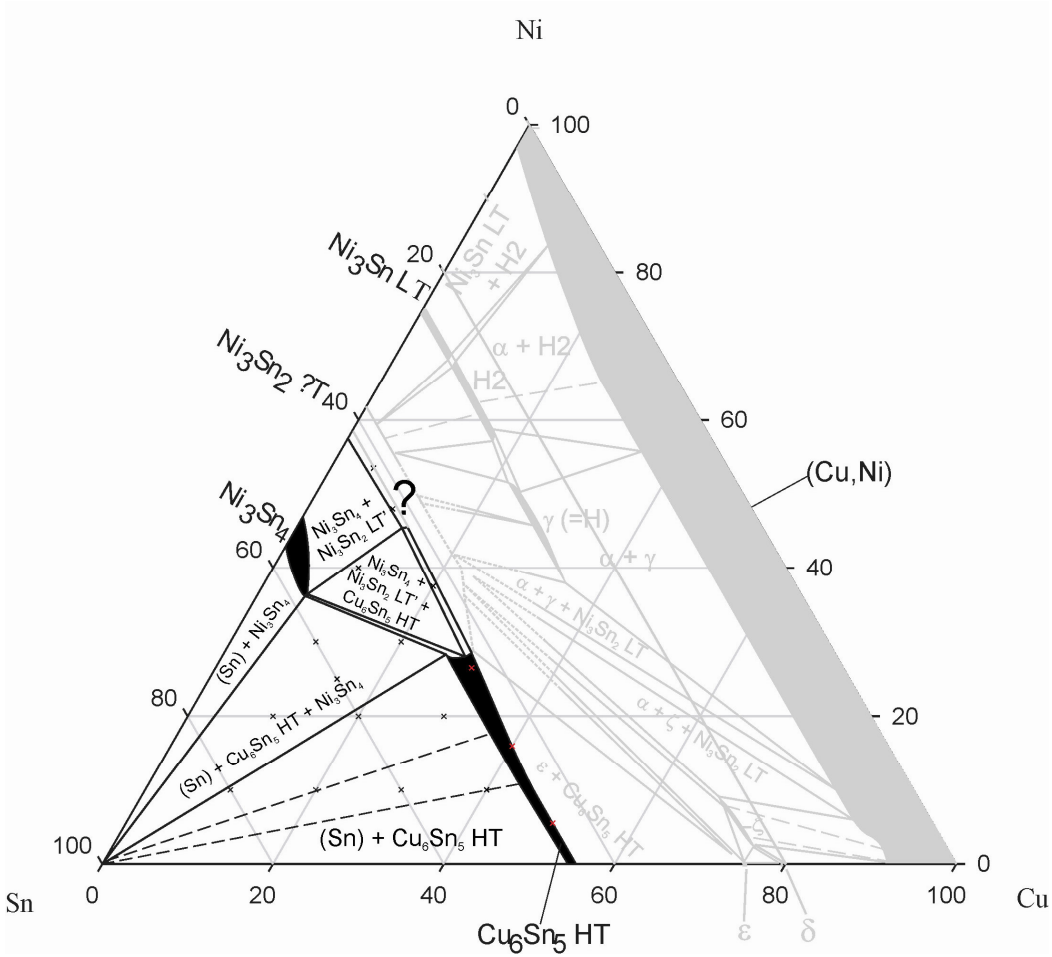
Isothermal Section at 400 °C



Isothermal Section at 500 °C



Isothermal Section at 220 °C



Acknowledgements

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Thank You for Your attention!