Thermo-Calc Software
Release News
Version 2024b

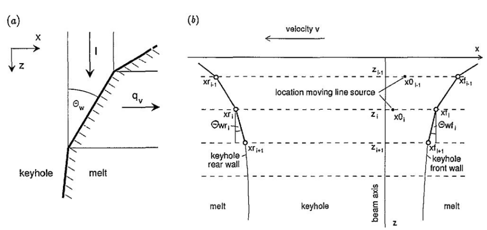
2024b Thermo-Calc

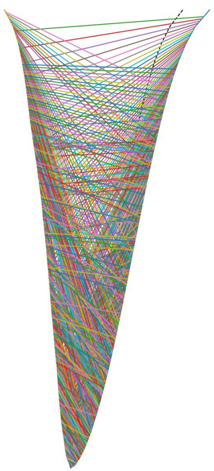
Release Highlights

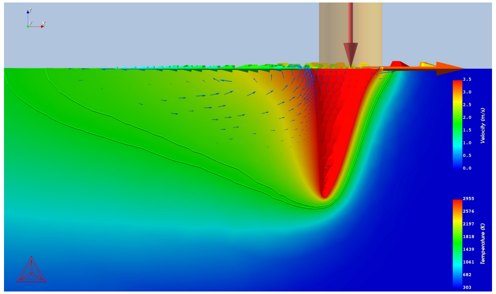
- **Additive Manufacturing Module**
  - ✓ Improves Keyhole Model with Fluid Flow
  - ✓ Adds Batch and Grid Calculation Types
  - ✓ Adds Printability Maps
- **New Titanium Model Library**
- **Elastic Properties Introduced**
- **Significant Speed Improvements in Property Calculations**
- **Improved Martensitic Steel Strength Property Model**
- **First ever databases for Molybdenum-based and Niobium-based refractory alloys**
- **Five other new databases**

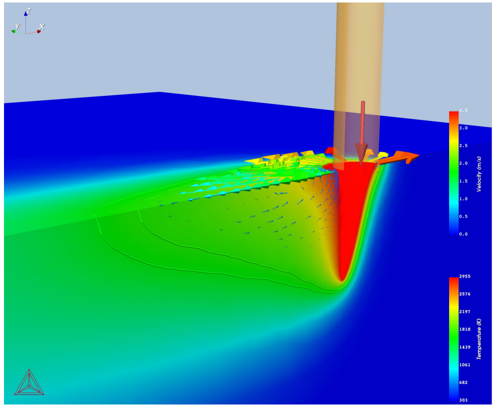
Keyhole Model

- Gaussian heat source at surface
- Geometry of keyhole calculated as a pre-step and cut out from mesh
- Steady-state simulation performed on mesh
- Secondary reflections implemented
- Now with fluid flow!





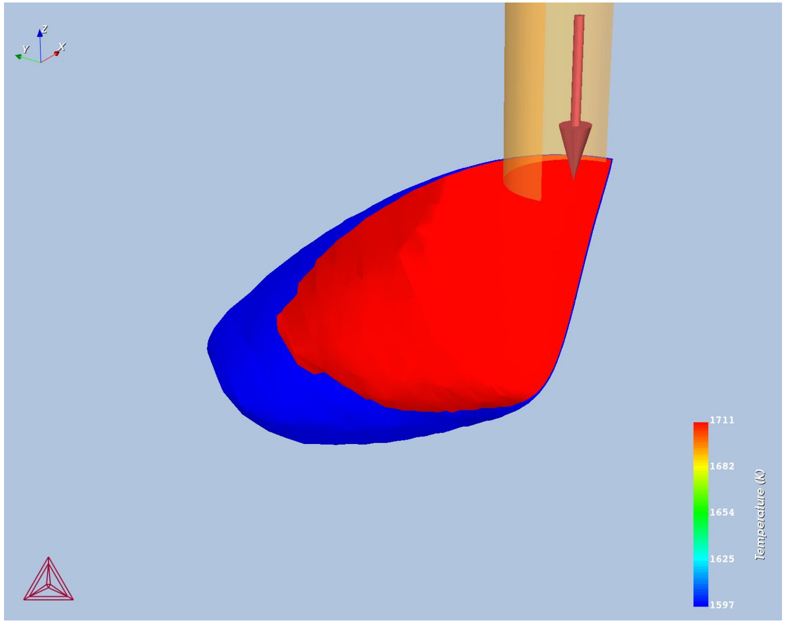


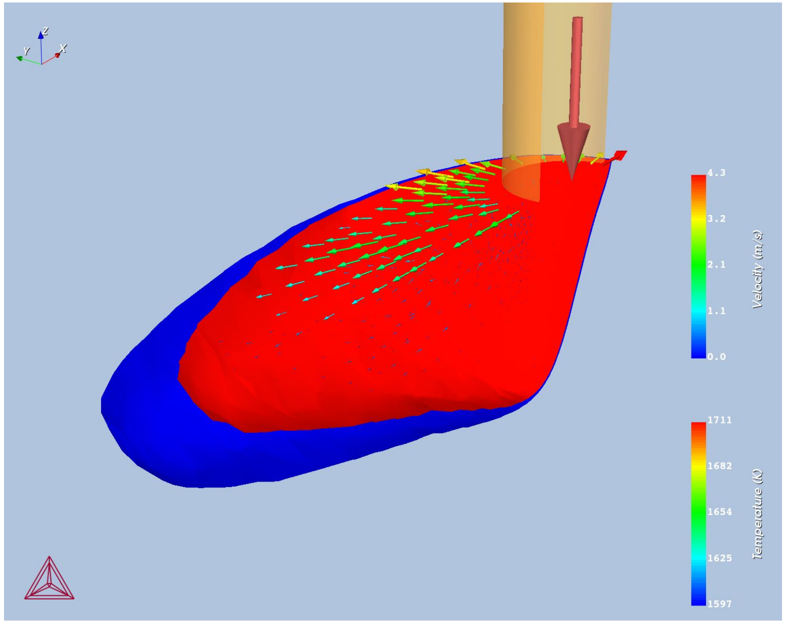


A Kaplan 1994 *J. Phys. D: Appl. Phys* ***27*** *1805*

Fluid Flow Can Make the Melt Pool Wider and Longer

316L: P50W v=400mm/s

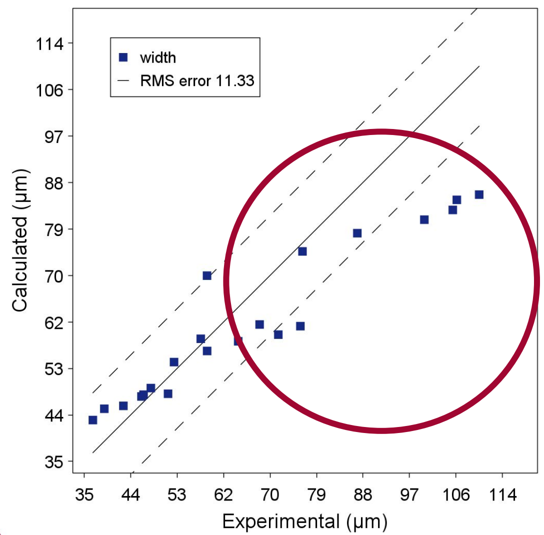




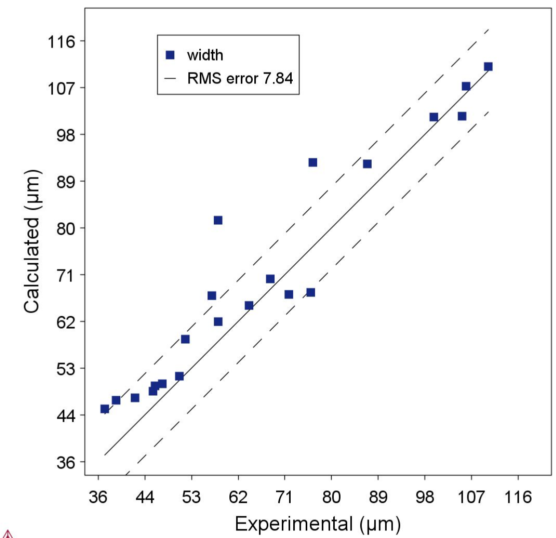
Effect of Fluid Flow - SS316L Hu et al. 2019*

- Gaussian beam radius 22 µm
- Absorptivity 30%

Without fluid flow

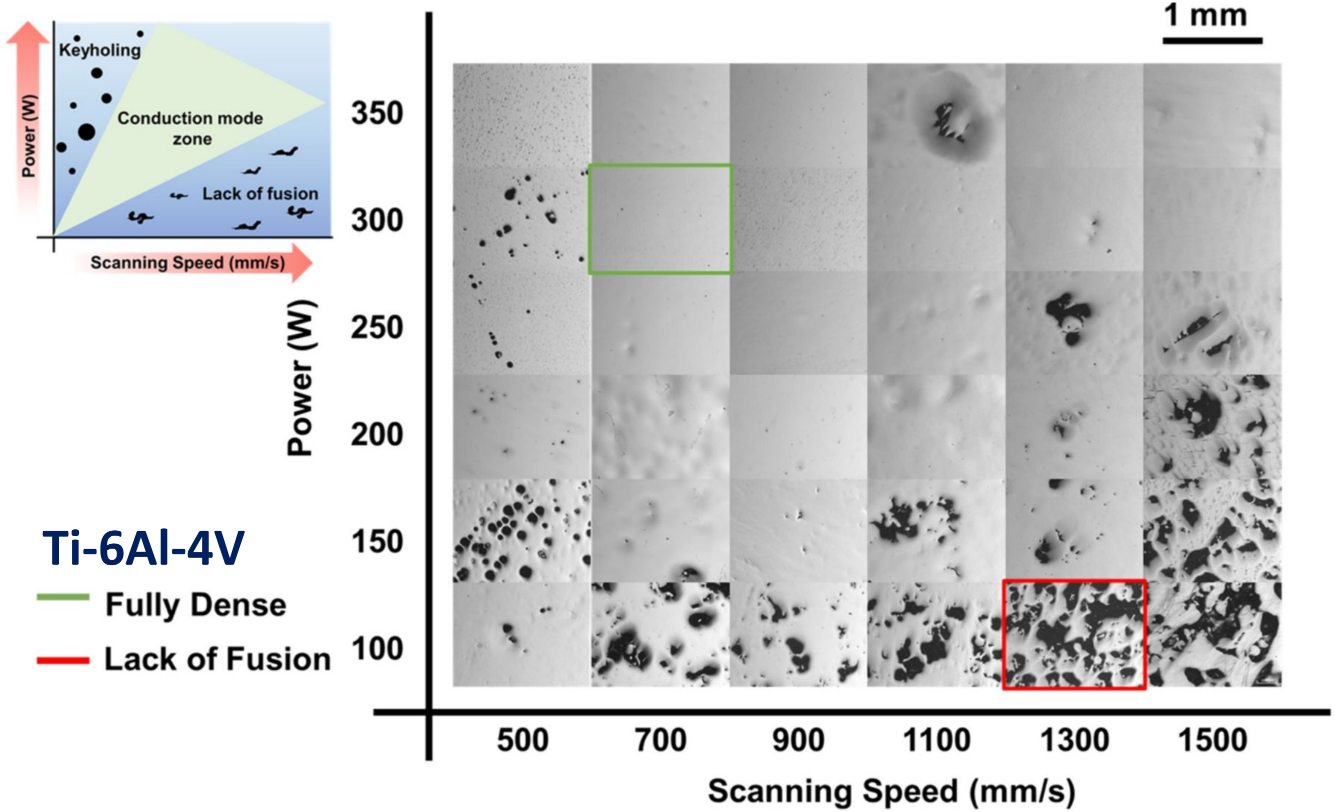


With fluid flow



*Hu et. al Advances in Mat. Sci. and Eng. Vol. 2019

Printability Maps (aka Process Maps)



Bustillos, J., Kim, J., & Moridi, A. (2021). Exploiting lack of fusion defects for microstructural engineering in additive manufacturing. *Add. Man. 48*

Convergence of Steady-state Models Improved

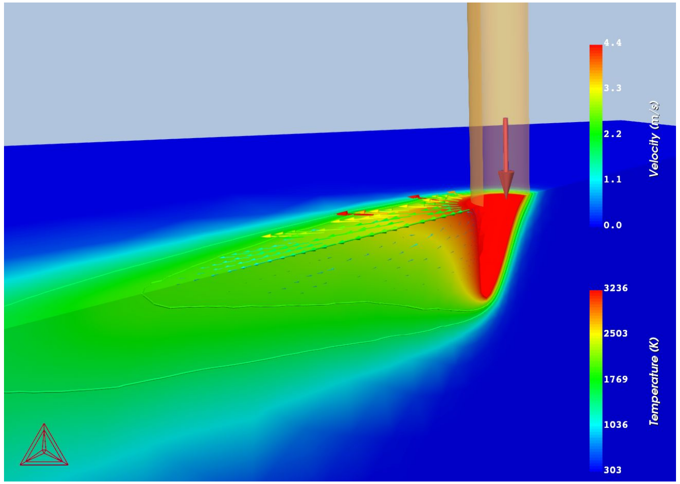
- A new adaptive mesh criterion refines the mesh based on the temperature gradient.
- Improvements in the Streamline upwind Petrov - Galerkin (SUPG) stabilization scheme.

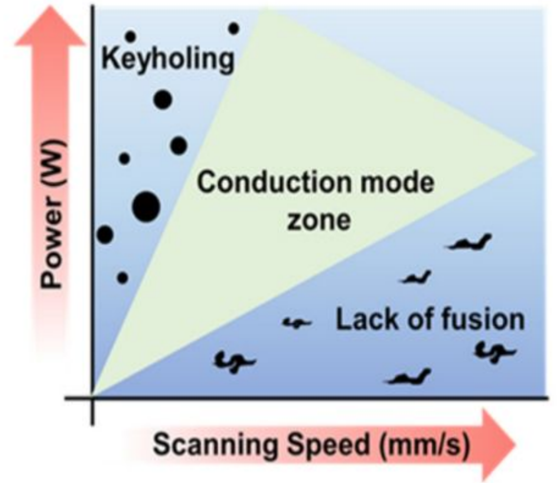
Fluid Flow Model Improved for Turbulent Conditions

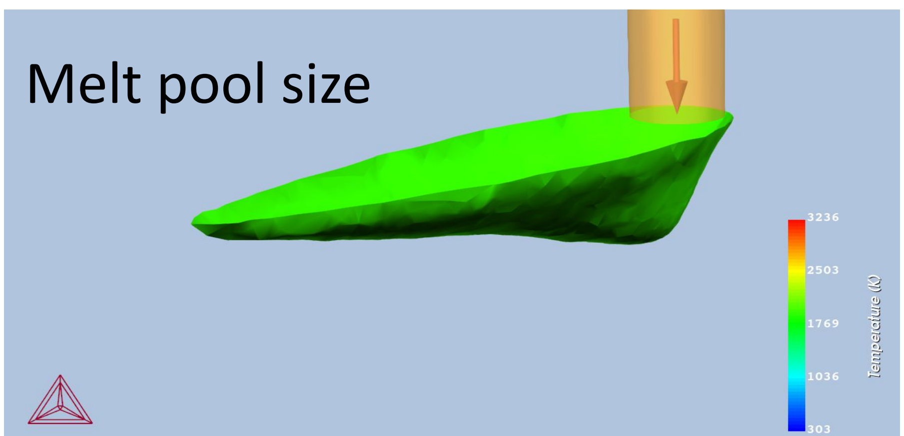
- A new subgrid model that relies on the eddy-viscosity assumption is applied to account for unresolved turbulent motions that cannot be directly simulated due to computational limitations.
- The Smagorinsky model is now applied as default, and it provides a simple way to estimate *Subgrid-scale (SGS)* viscosity in a large eddy simulation

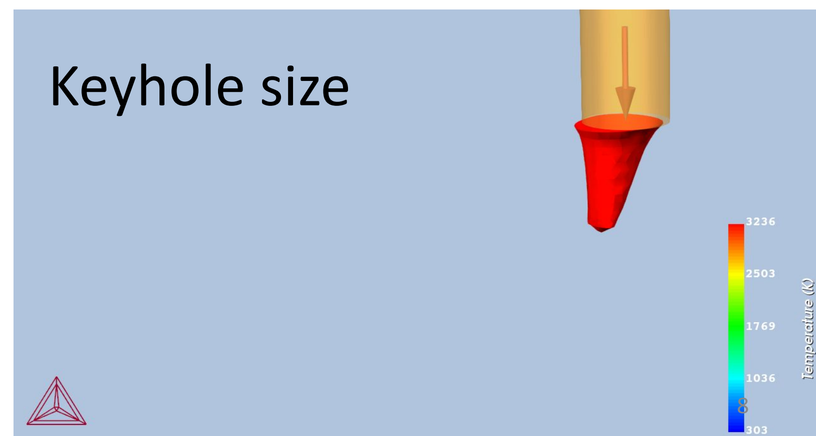
2024b **Additive Manufacturing (AM) Module**

Printability Maps







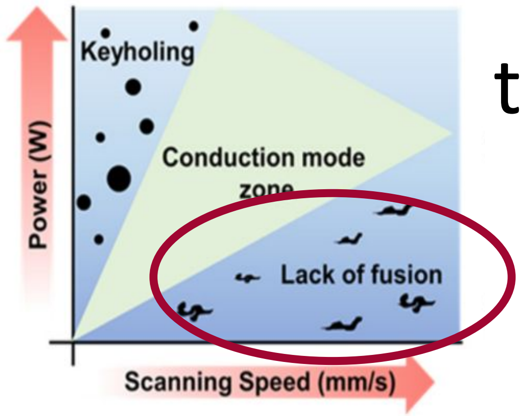


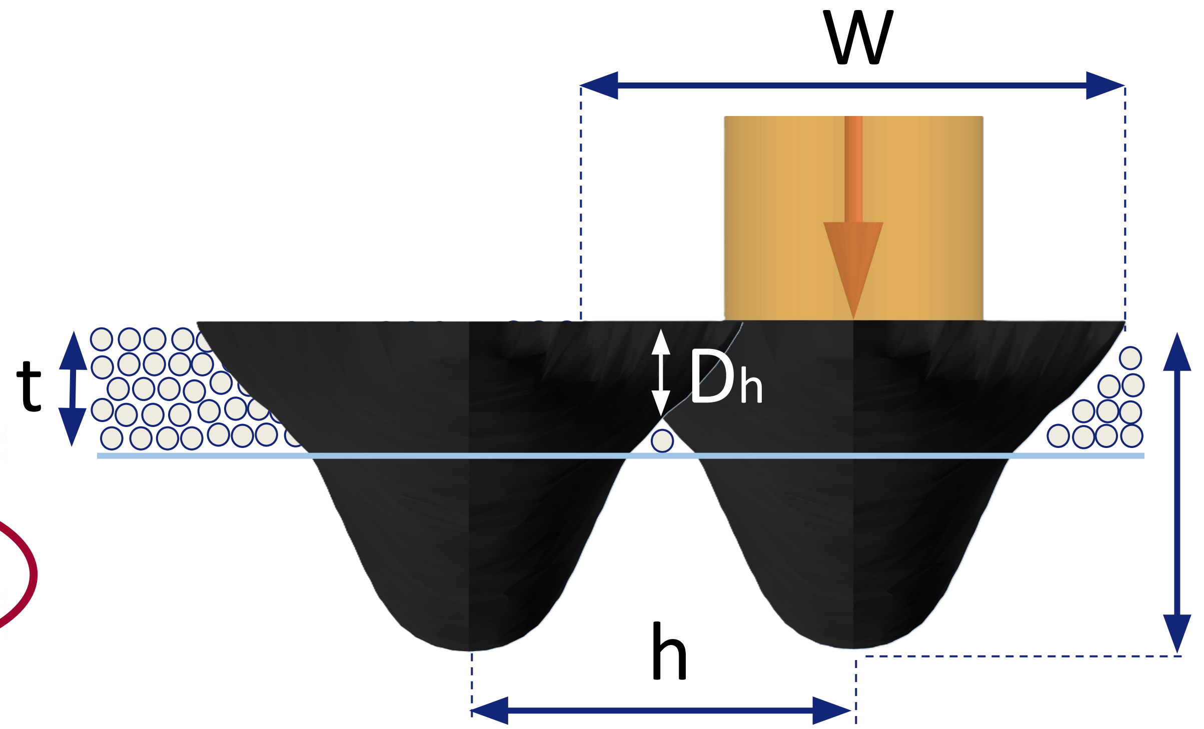
Printability Maps: Lack of Fusion Porosity

Lack of fusion criteria:

- D/t
- Dh/t

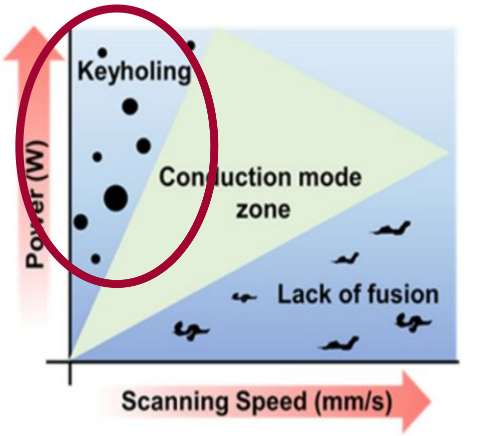
Uneven porosity

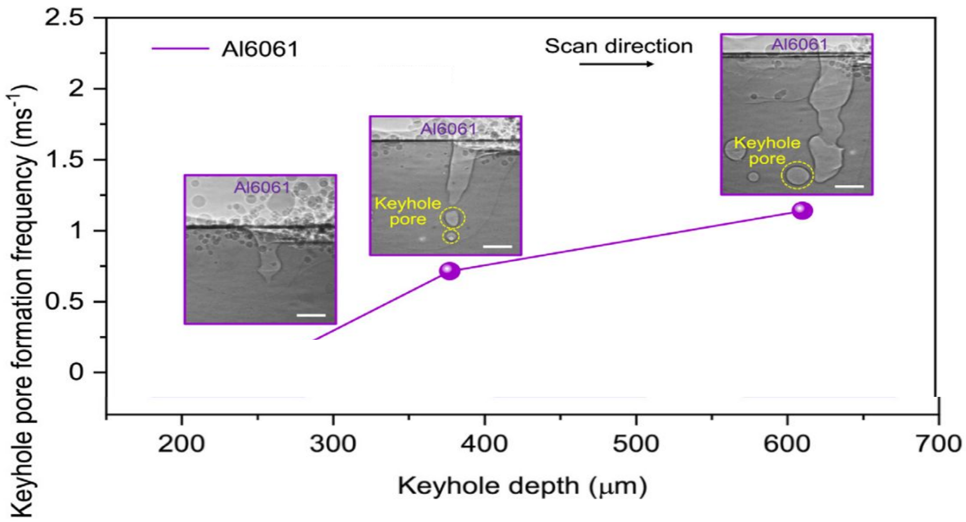




Printability Maps: Keyhole Porosity

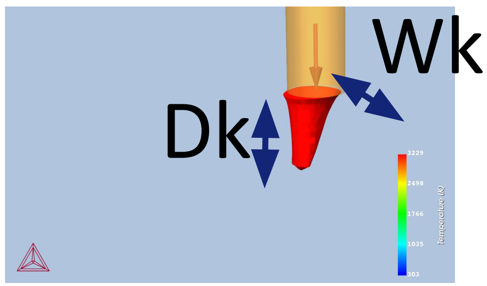
Round porosity

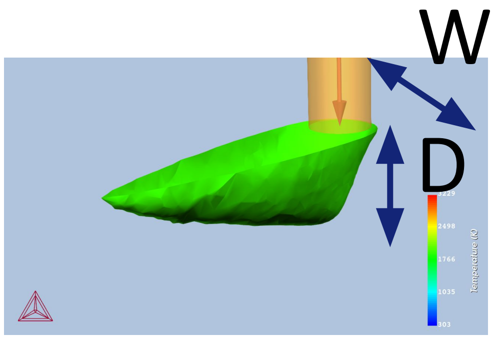




Keyhole criteria:

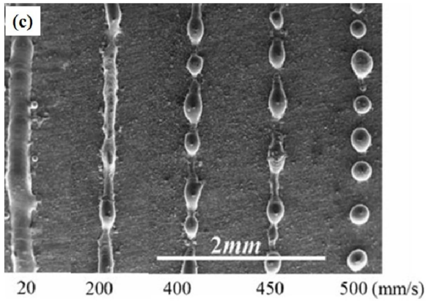
- Wk/Dk
- W/D

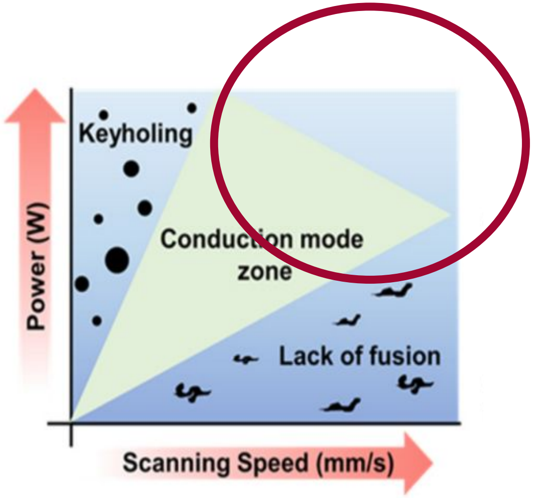




Printability Maps: Balling

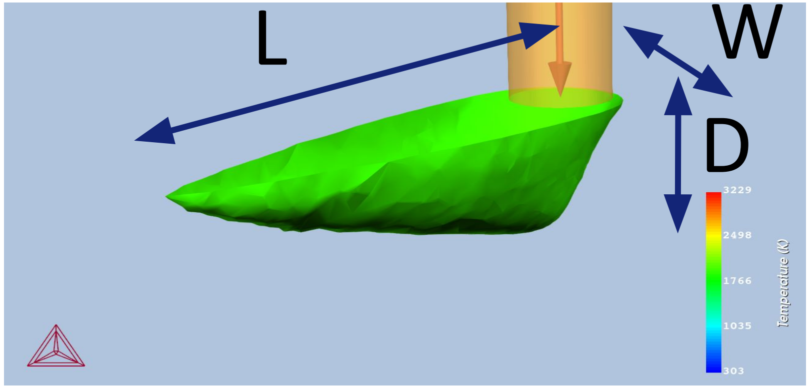
Balling defects





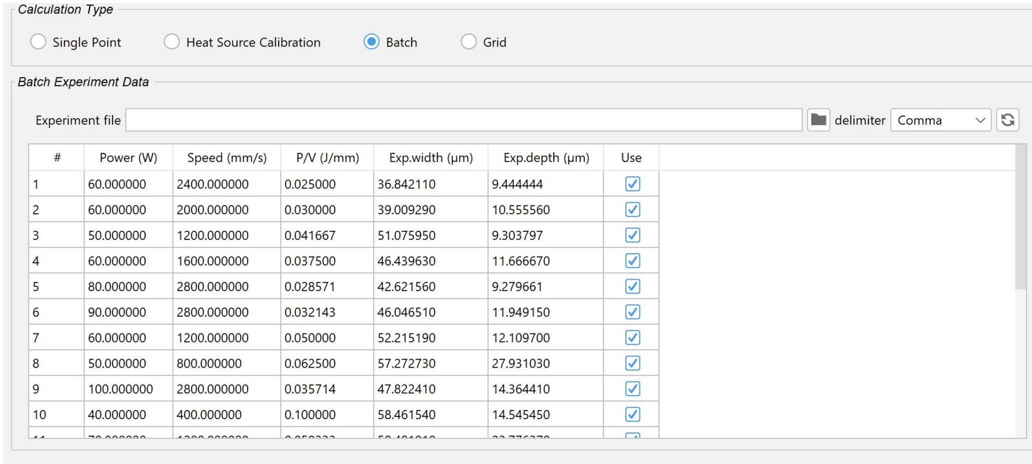
Balling criteria:

- W/L
- D/L



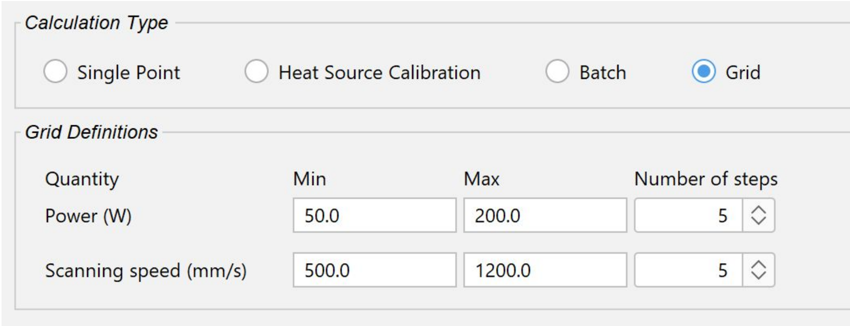
Batch and Grid Calculations: Run Many Steady-state Calculations

- Batch



#	Power (W)	Speed (mm/s)	P/V (J/mm)	Exp.width (μm)	Exp.depth (μm)	Use
1	60.000000	2400.000000	0.025000	36.842110	9.444444	☑
2	60.000000	2000.000000	0.030000	39.009290	10.555560	☑
3	50.000000	1200.000000	0.041667	51.075950	9.303797	☑
4	60.000000	1600.000000	0.037500	46.439630	11.666670	☑
5	80.000000	2800.000000	0.028571	42.621560	9.279661	☑
6	90.000000	2800.000000	0.032143	46.046510	11.949150	☑
7	60.000000	1200.000000	0.050000	52.215190	12.109700	☑
8	50.000000	800.000000	0.062500	57.272730	27.931030	☑
9	100.000000	2800.000000	0.035714	47.822410	14.364410	☑
10	40.000000	400.000000	0.100000	58.461540	14.545450	☑

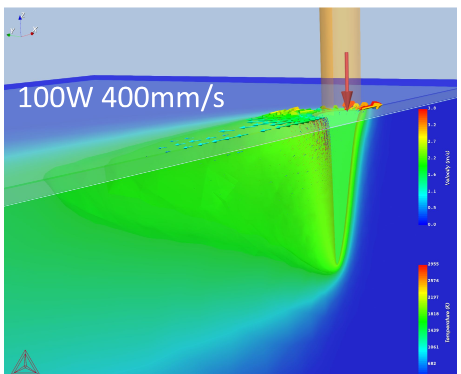
- Grid

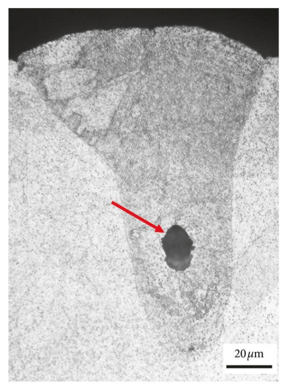


SS316L Hu et al. 2019*

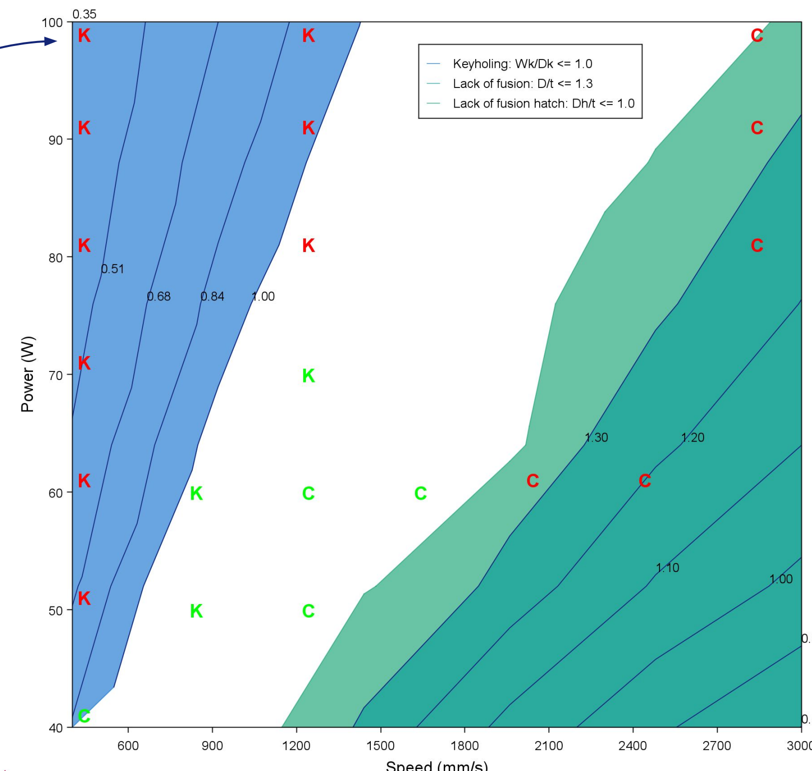
Ex. AM_09a_Printability_Map_316L

- Gaussian beam radius 22 µm
- Powder layer thickness 10µm
- Absorptivity 30%





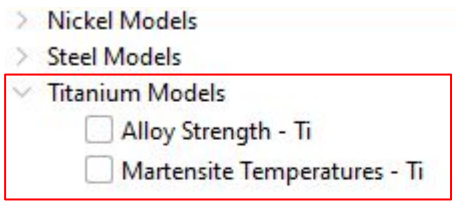
(a)

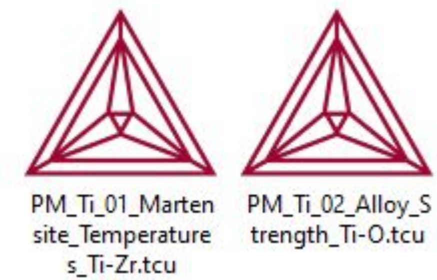


*Hu et. al Advances in Mat. Sci. and Eng. Vol. 2019

New Titanium Property Model Library

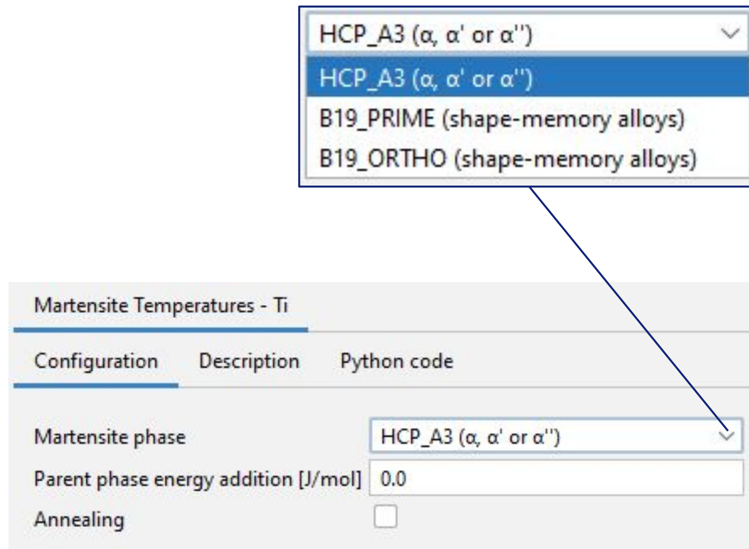
- Together with the update to TCTI6 we focus on a new Property Model Library for Titanium alloys.





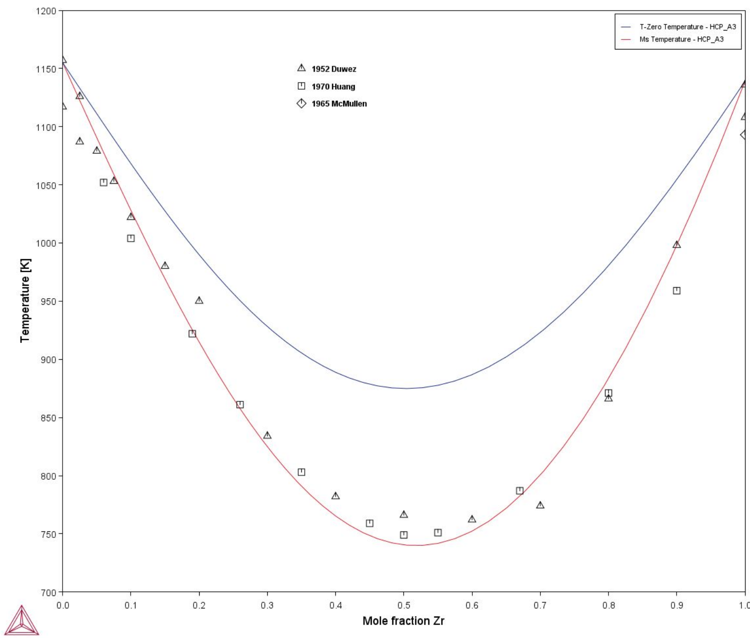
Titanium Model Library: Martensite Temperatures - Ti

- New Property Model for calculating the Ms temperature for Titanium alloys.
  - Developed for structural and shape-memory alloys.
  - Considers three different martensitic phases.
  - Based on the T-Zero Temperature and a composition-dependent correction.
  - Parent phase stability can be displaced by a value or function input.
  - The annealing checkbox allows for evaluating the composition of the parent phase, in case of multi-phase alloy compositions.

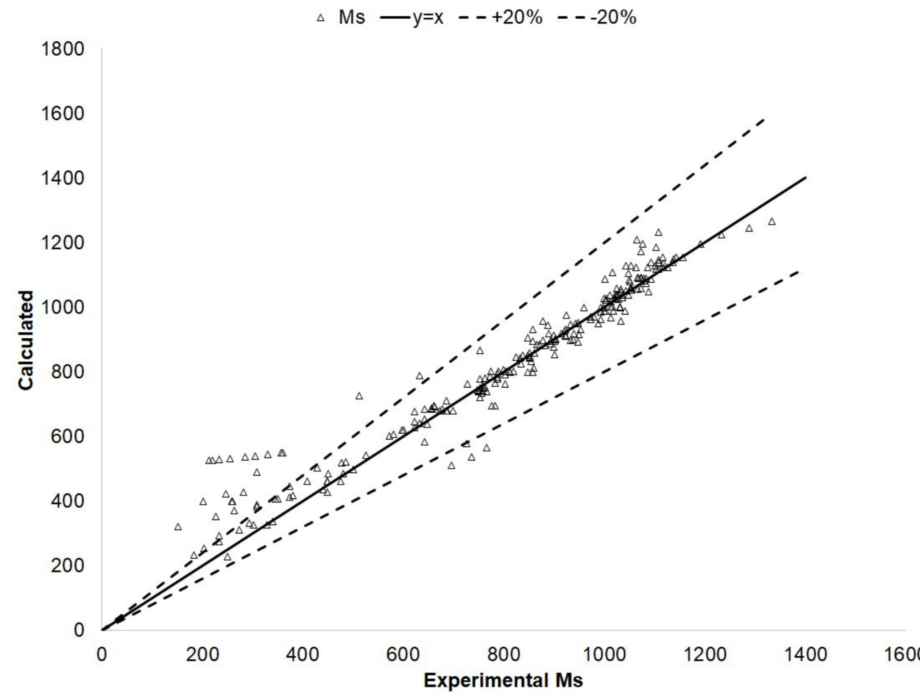


Titanium Model Library: Martensite Temperatures - Ti

- Example: PM_Ti_01

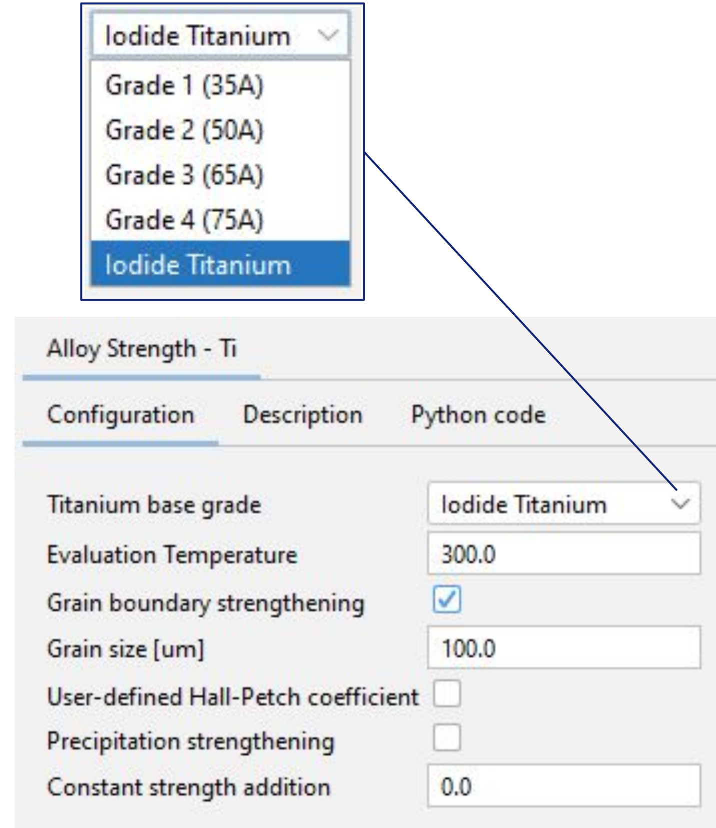


- Benchmark for alpha martensite.



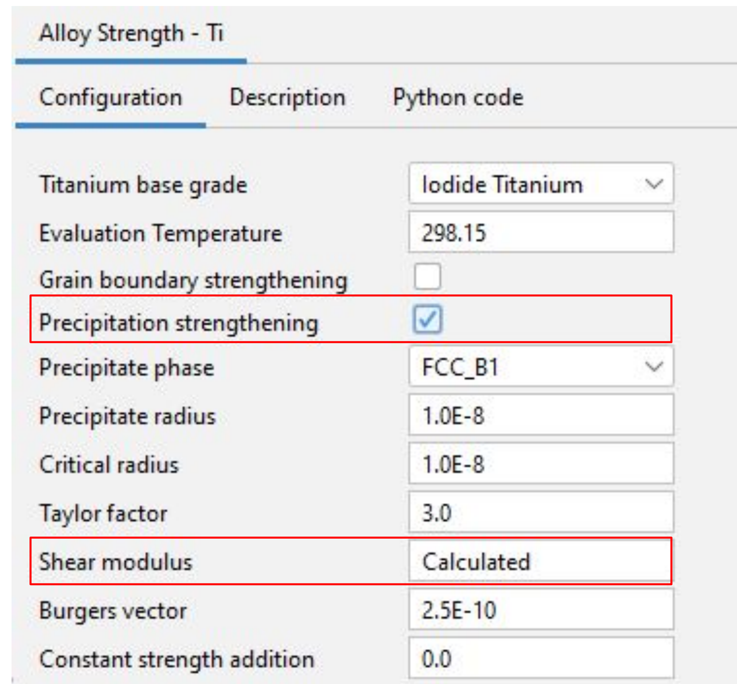
Titanium Model Library: Alloy Strength - Ti

- New strength Property Model.
  - Developed using a large dataset.
  - Impurity contents are of high importance! Select appropriate base grade!
  - All binary Ti-X contributions to solid solution strengthening are parameterized.
  - Also considers grain boundary and precipitation strengthening.
  - Effect of temperature on dislocation mobility (softening) is considered.



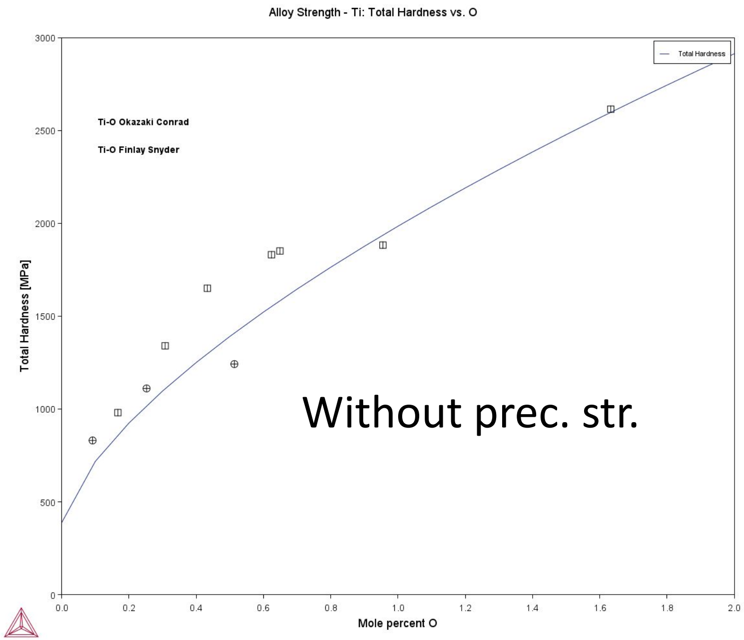
Titanium Model Library: Alloy Strength - Ti

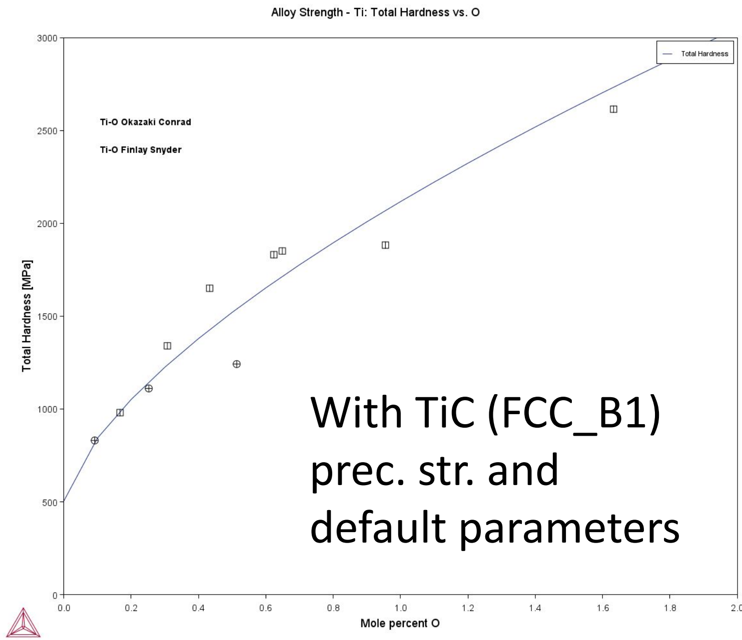
- Making use of modeled elastic properties in the thermodynamic database TCTI6:



Titanium Model Library: Alloy Strength - Ti

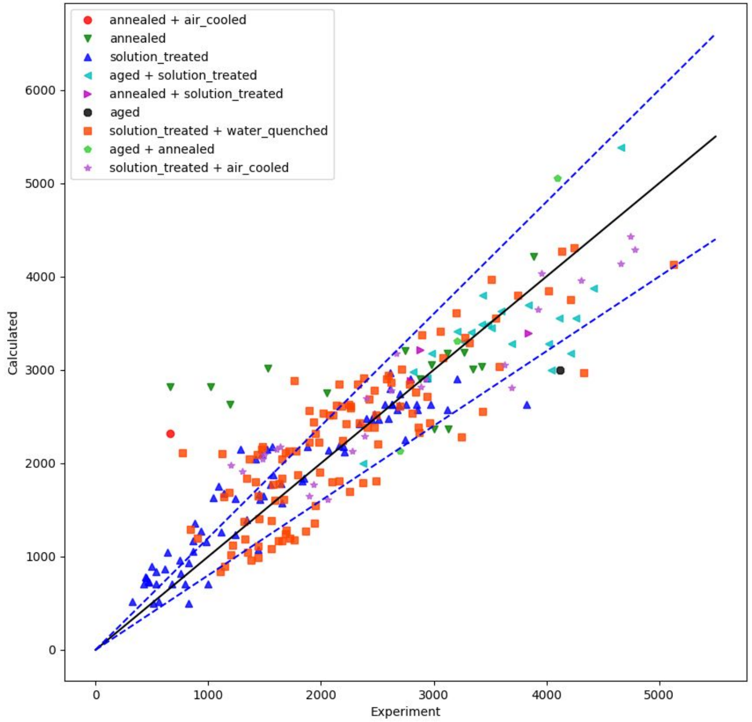
- Example: PM_Ti_02





Titanium Model Library: Alloy Strength - Ti

- Benchmark versus a multitude of alloys (Hardness in MPa).
- Some scatter due to:
  - Complex heat treatments.
  - Unknown or ill-determined impurity levels.
  - Non negligible dislocation density due to martensite or deformed grains.
- Trends with respect to all elements have been thoroughly checked and look good!

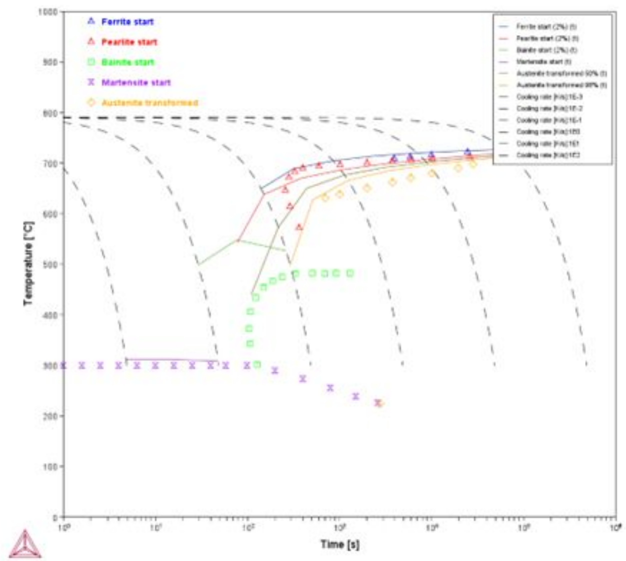


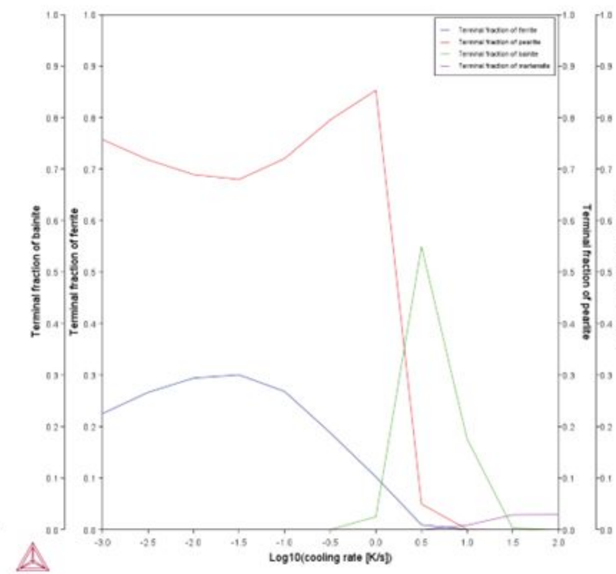
Parallelization of Property Models

Windows 10 Pro
i9-7920X @ 2.9Ghz, 12 cores
64 GB RAM

PM_Fe_08 CCT

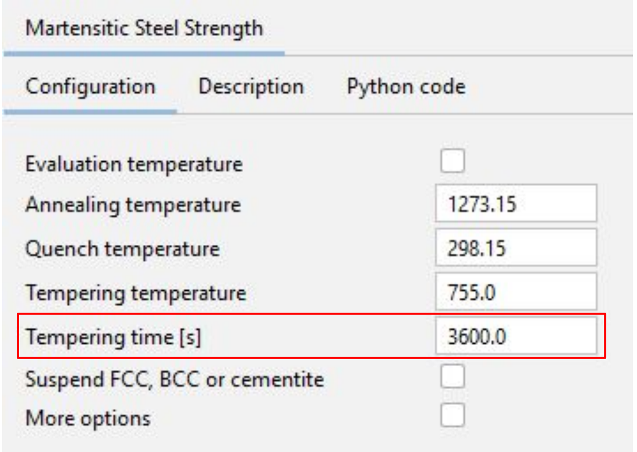
- 33 mins total calculation time with parallellization, 10 workers
- > 10 hours without





Steel Model Library: Improved Martensitic Steel Strength Model

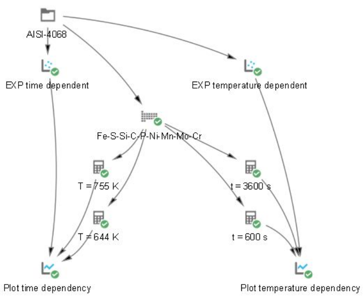
- A large number of datapoints has been collected and curated.
- The tempering behavior has been deduced in detail using machine learning.
- Tempering time is now a parameter.
  - If a tempering time of 0 is given, the model will ignore the machine learning correction.
- Example is updated.

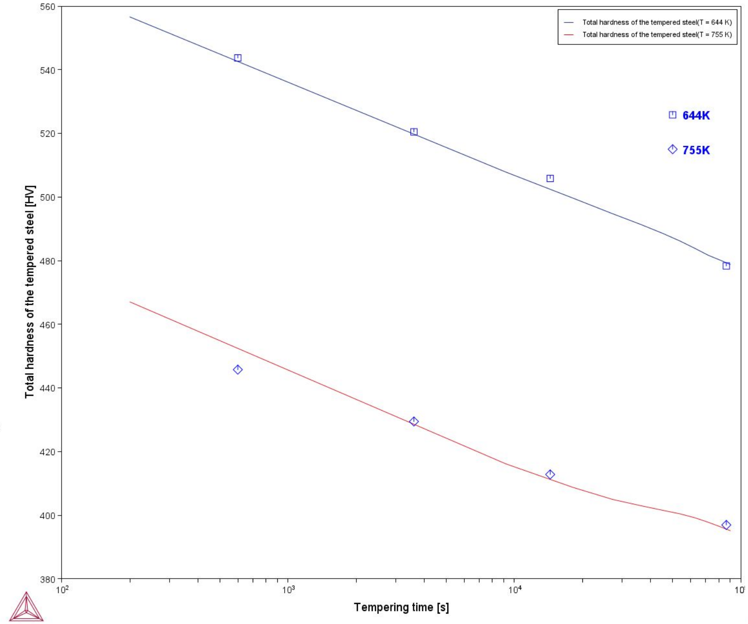


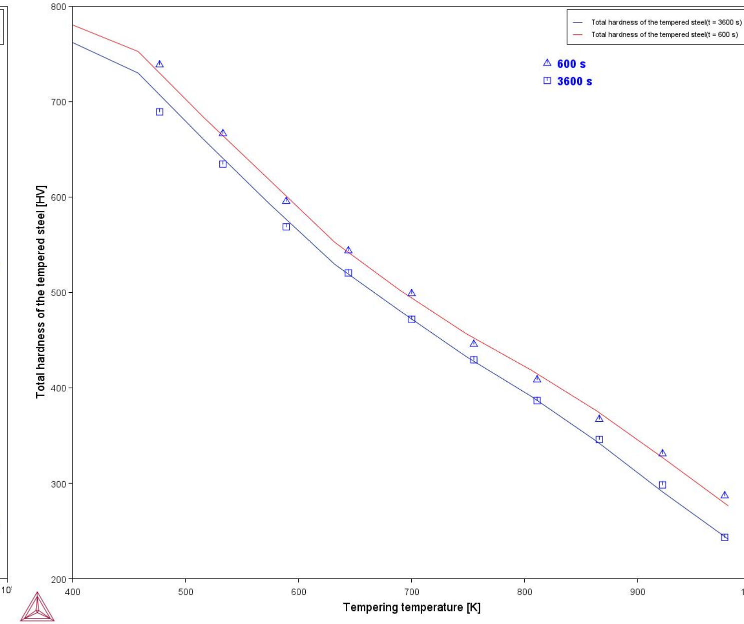
2024b Thermo-Calc Property Models

Steel Model Library: Improved Martensitic Steel Strength Model

- Example: PM_Fe_10







Highlights

New Thermodynamic and Kinetic Databases

- 2 New! TCS Mo-based Alloys Databases (TCMO1 and MOBMO1)
- 2 New! TCS Nb-based Alloys Databases (TCNB1 and MOBNB1)

New Versions of Thermodynamic and Kinetic Databases

- TCS Ultra-high Temperature Materials Database (TCUHTM2)
- TCS Ti/TiAl-based Alloys Database (TCTI6)
- TCS Ti-alloys Mobility Database (MOBTI5)
- TCS Solder Alloy Solutions Database (TCSLD5)
- TCS Solder Alloy Solutions Mobility Database (MOBSLD2)

Other Updates:

- TCS Aluminum-based Alloys Database (TCAL9 to version 9.1)
- DEMO Solders Database SLDEMO

TCS Mo-based Alloys Database (TCMO1)

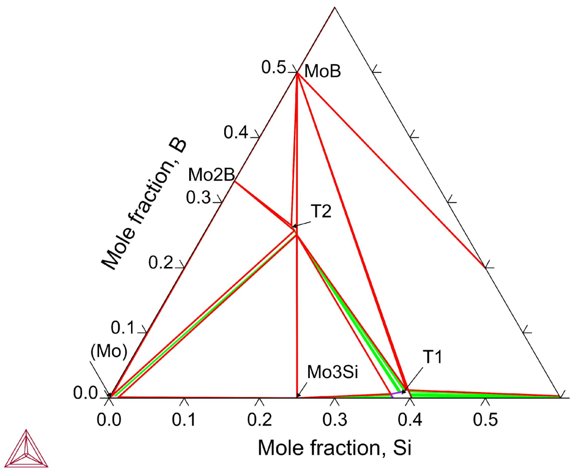
- 12 elements

Al	B	C	Cr	Fe	Hf	Mn	Mo	Re	Si	Ti	Zr

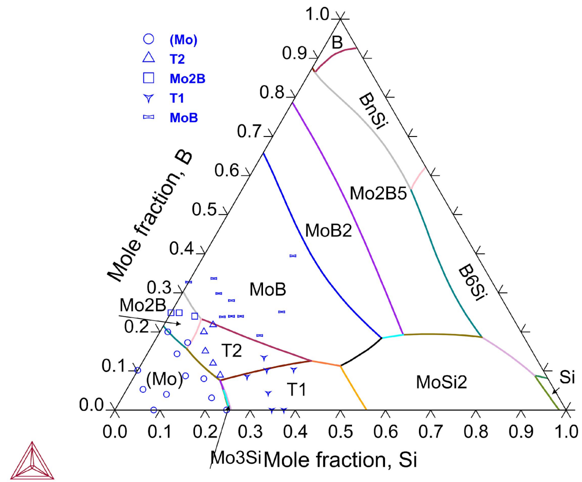
- 66 binary systems
- 46 ternary systems
  - 10 B-Mo-X ternary systems
  - 9 C-Mo-X ternary systems
  - 7 Mo-Si-X ternary systems
  - 20 other critical ternary systems
- 3 quaternary systems
  - B-Hf-Mo-Si, B-Mo-Si-Ti, B-Mo-Si-Zr
- 167 phases

TCS Mo-based Alloys Database (TCMO1)

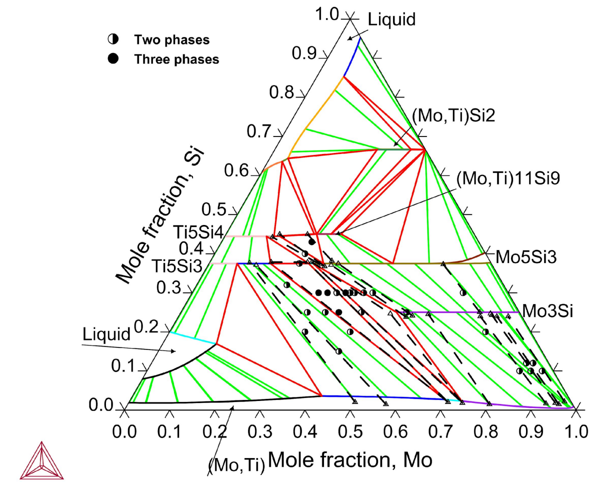
Ternary Phase Diagrams



B-Mo-Si: Isothermal section at 1600 ^{o}C



B-Mo-Si: Liquidus projection[1]



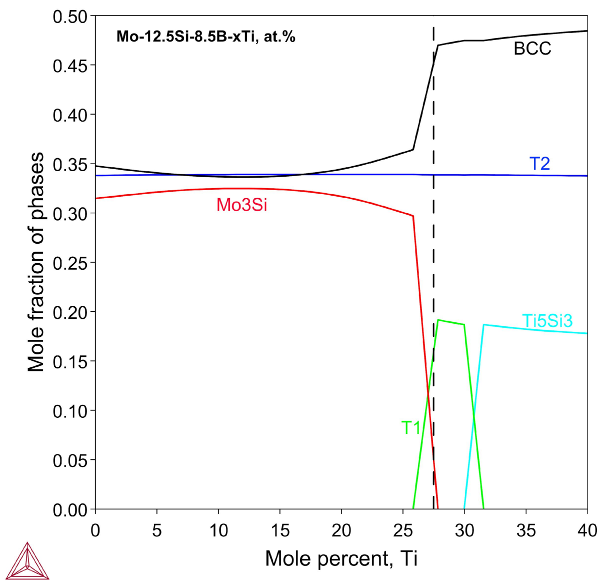
Mo-Si-Ti: Isothermal section at 1600 ^{o}C[2]

[1] Y. Yang, Y.A. Chang. Thermodynamic modeling of the Mo–Si–B system. Intermetallics 13 (2005) 121-128.
[2] Y. Yang, et al. Experimental investigation and thermodynamic descriptions of the Mo–Si–Ti system. Materials Science and Engineering: A 361 (2003) 281-293.

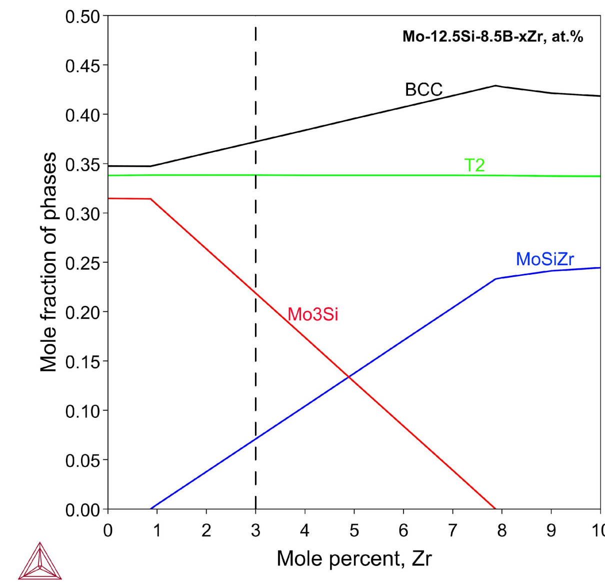
TCS Mo-based Alloys Database (TCMO1)

Example: Mo-Si-B based Alloys

Phase fractions of Mo-12.5Si-8.5B-*x*Ti(Zr) alloys and phase compositions of Mo-12.5Si-8.5B-27.5Ti alloy at 1600 ^{o}C



		Exp.	Calc. [TCMO1]
BCC	x(Mo)	0.695	0.735
	x(Ti)	0.245	0.241
	x(Si)	0.023	0.023
	x(B)	0.037	0
Mo3Si	x(Mo)	0.477	0.478
	x(Ti)	0.299	0.272
	x(Si)	0.224	0.25
	x(B)	~0	0
T2	x(Mo)	0.35	0.361
	x(Ti)	0.29	0.264
	x(Si)	0.135	0.125
	x(B)	0.225	0.25
T1	x(Mo)	0.246	0.231
	x(Ti)	0.387	0.394
	x(Si)	0.367	0.375
	x(B)	~0	0



[1] Y. Yang, H. Bei, S.L. Chen, E.P. George, J. Tiley, Y.A. Chang. Effects of Ti, Zr, and Hf on the phase stability of Mo_ss+Mo3Si+Mo5SiB2 alloys at 1600°C. Acta Materialia 58 (2010) 541-548.

TCS Nb-based Alloys Database (TCNB1)

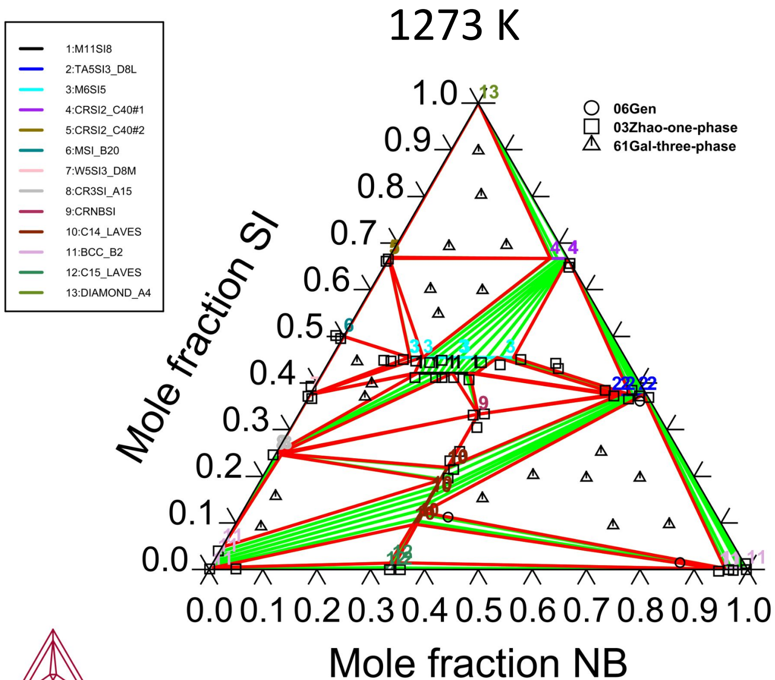
- 12 elements: Al-C-Cr-Hf-Mo-**Nb**-Si-Ta-Ti-V-W-Zr
- All (66) binaries assessed within the framework.
- 76 ternary systems (36 Nb-related) assessed.

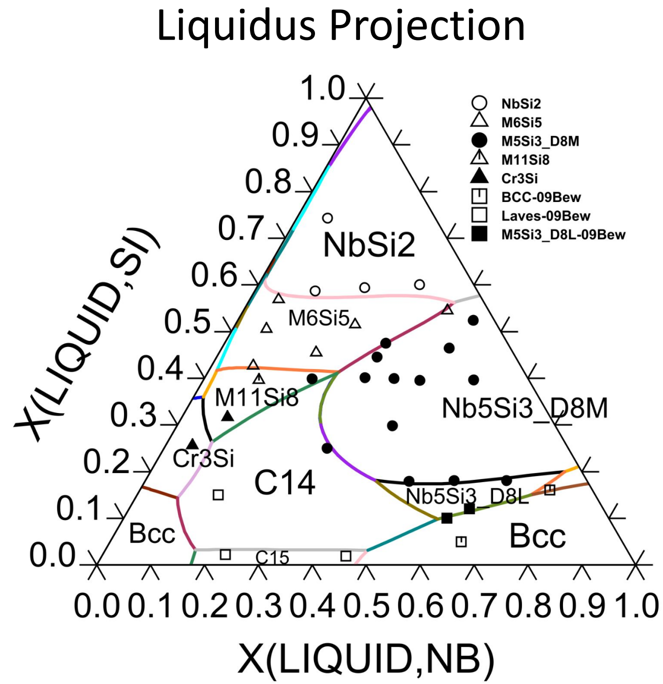
Nb-Al-Cr	Nb-Al-Mo	Nb-Al-Si	Nb-Al-Ti	Nb-Al-V	Nb-Al-W	Nb-C-Cr	Nb-C-Hf
Nb-C-Mo	Nb-C-Ta	Nb-C-Ti	Nb-C-V	Nb-C-W	Nb-C-Zr	Nb-Cr-Hf	Nb-Cr-Mo
Nb-Cr-Si	Nb-Cr-Ta	Nb-Cr-Ti	Nb-Cr-V	Nb-Cr-W	Nb-Cr-Zr	Nb-Hf-Si	Nb-Hf-Ti
Nb-Mo-Si	Nb-Mo-Ta	Nb-Mo-V	Nb-Si-Zr	Nb-Si-Ta	Nb-Si-Ti	Nb-Si-V	Nb-Si-W
Nb-Si-Zr	Nb-Ta-Ti	Nb-Ti-V	Nb-V-Zr				

- 101 phases included

TCS Nb-based Alloys Database (TCNB1)

Cr-Nb-Si

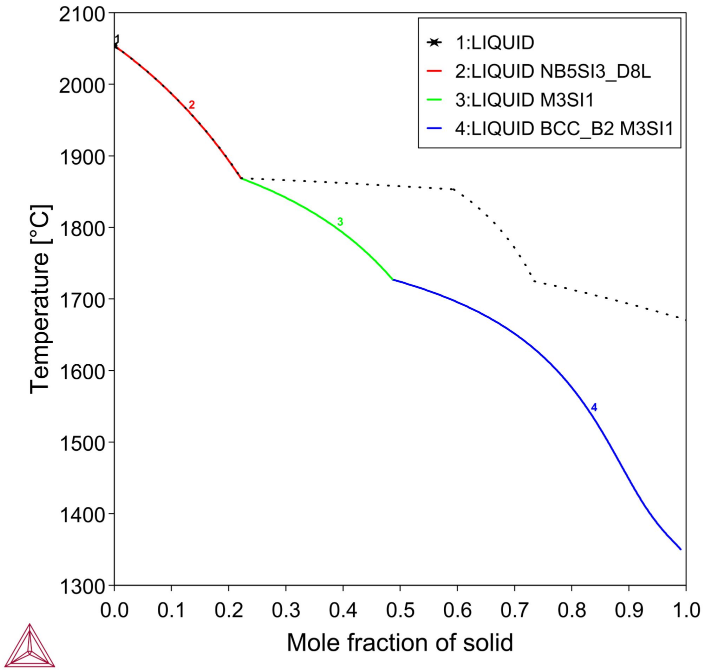




TCS Nb-based Alloys Database (TCNB1)

Comparison between the phases observed from as-cast Nb-Hf-Si-Ti alloys [2007Yang] and those predicted from Scheil simulation.

Alloy Composition	Phases Observed From As-cast Alloys	Phases Predicted From Scheil Simulation
Nb-7.5Hf-21Ti-16Si	Bcc, M3Si	Bcc, M3Si
Nb-12.5Hf-21Ti-16Si	Bcc, M3Si	Bcc, M3Si
Nb-10Hf-33Ti-16Si	Bcc, M3Si, M5Si3	Bcc, M3Si, M5Si3
Nb-8Hf-25Ti-22Si	Bcc, M3Si, Nb5Si3	Bcc, M3Si, Nb5Si3

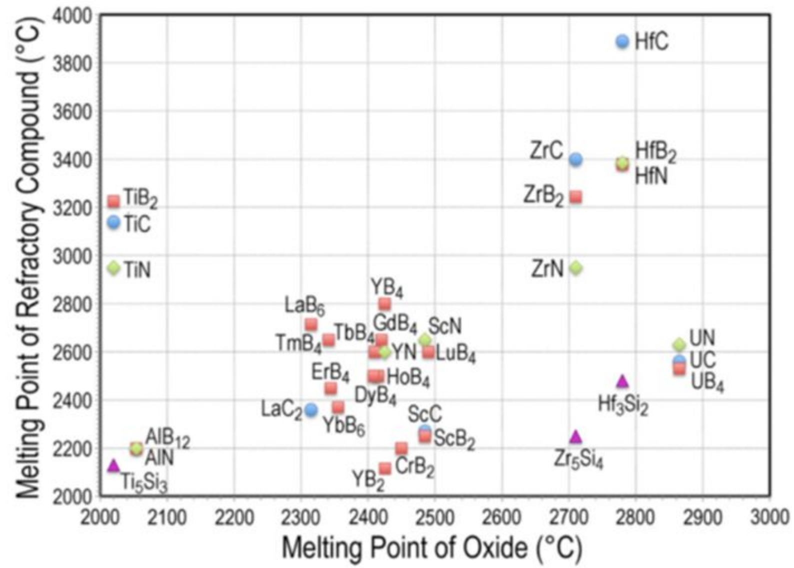


Y. Yang et al., J. Phase Equilibria and Diffusion, 28 (2007) 107-114

Calculated solidification path of Nb-8Hf-25Ti-22Si using the Scheil and equilibrium model

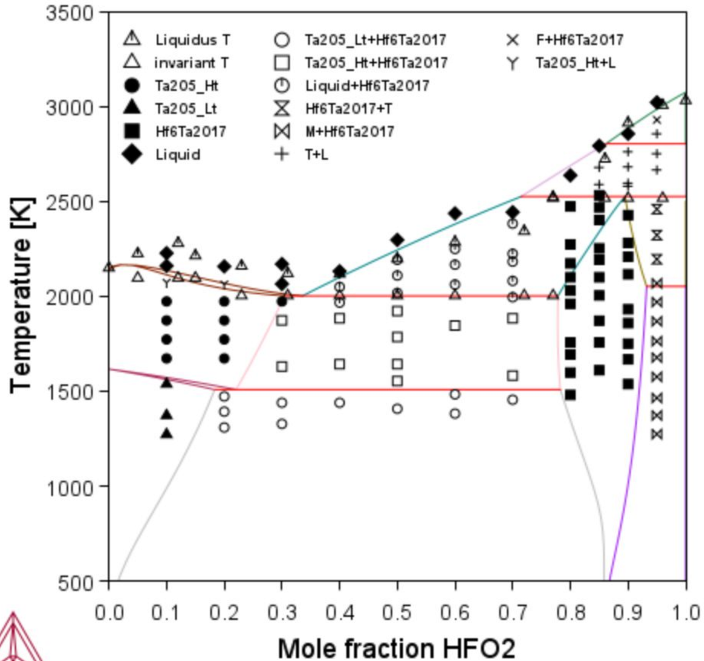
TCS Ultra-high Temperature Materials Database (TCUHTM2)

- Add one new element, O. Now it is an 8 elements framework: B-C-Hf-N-O-Si-Ta-Zr.
- 47 phases are included. Ionic liquid model was used for the liquid solution phase.
- 28 binary systems are included. 7 O-X binary systems are assessed.
- 41 ternary system are included. 15 oxygen related ternary systems were assessed and added: **B-Hf-O (T), B-N-O (T), B-O-Si, B-O-Zr, C-Hf-O (T), C-O-Zr, Hf-O-Si, Hf-O-Zr, O-N-Si, O-Si-Zr, Hf-N-O, Hf-O-Ta, N-O-Zr, O-Si-Ta, and O-Ta-Zr**

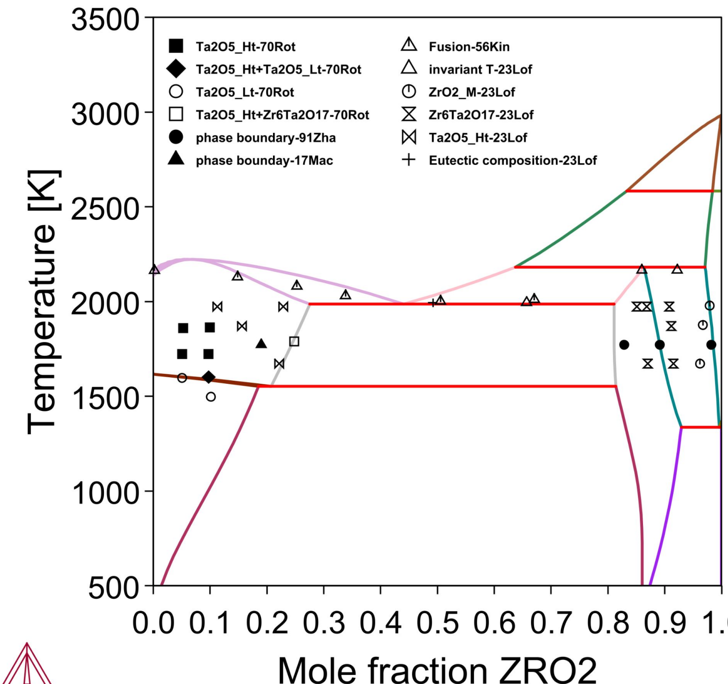


Thermo-Calc Software

TCS Ultra-high Temperature Materials Database (TCUHTM2)



Ta_2O_5-HfO_2



Ta_2O_5-ZrO_2

TCS Ti/TiAl-based Alloys Database (TCTI6)

Thermo-Calc Software

Thermodynamic Assessments

- **Ti-Ni** improved with the modelling of metastable phases, B19_PRIME, B19_ORTHO, R_MARTE, Ti2Ni3, Ti3Ni4
- **8 ternaries** (Ti-Al-Ni, Ti-Al-Ta, Ti-B-Ni, Ti-Cr-Fe, Ti-Cu-Ni, Ti-H-Ni, Ti-Ni-Pd, Ti-Ni-Sn), **2 binaries** (Mn-W, O-Sn) updated
- Full gas descriptions updated

Elastic Properties for Ti-based Alloys Available

- Elastic constants (C11, C12, C13, C33, C44) for HCP, BCC, FCC phases
- Elastic moduli (bulk/shear/Young's modulus)

Other Updates

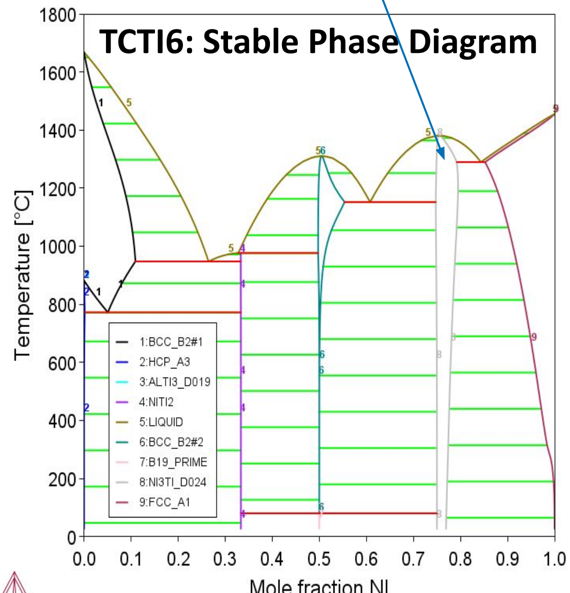
- Surface tension of Fe-Ni
- Molar volume of Bcc_A2 in Al-V, Nb-Ti, Ta-Ti, Al-Ti-V, Ti-V-Zr

TCS Ti/TiAl-based Alloys Database (TCTI6)

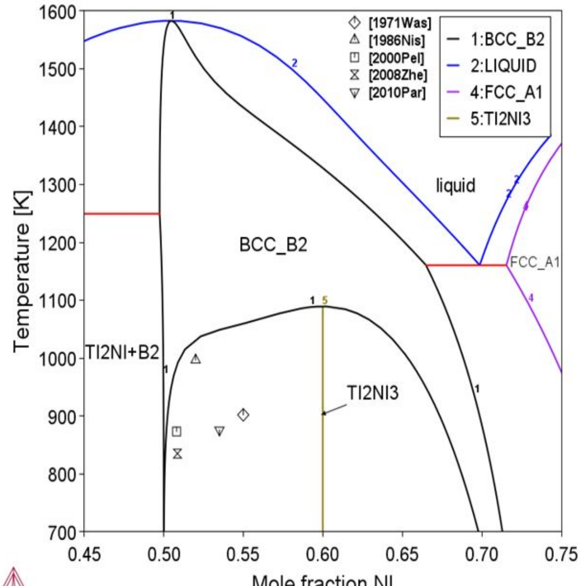
Ti-Ni: Metastable Phases Ti_2Ni_3, Ti_3Ni_4

Experimental studies on Ti-52Ni alloy found Ti3Ni4, Ti2Ni3, TiNi3 phases. Phase transformations occur in the following order with increasing aging temperature and time,

Ti3Ni4→Ti2Ni3→TiNi3

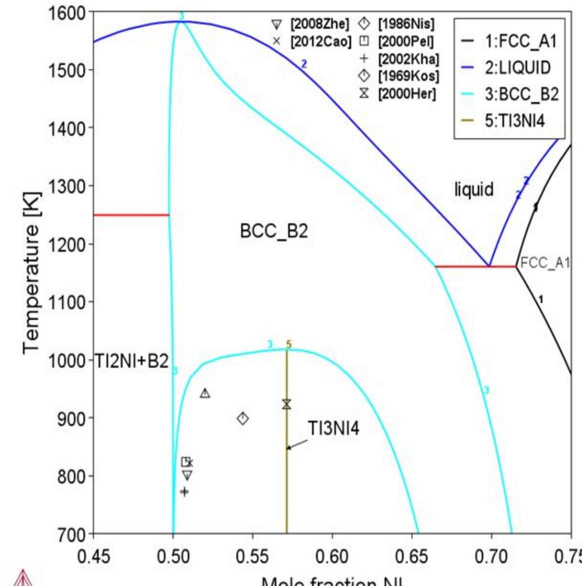


Metastable Phase Diagram



Symbols denote conditions of experimentally observed B2+Ti2Ni3

Metastable Phase Diagram



Symbols denote conditions of experimentally observed B2+Ti3Ni4

Thermo-Calc Software

TCS Ti/TiAl-based Alloys Database (TCTI6): Elastic Properties

- Elastic constants of TCTI6 elements and systems have been assessed and are available for FCC, BCC and HCP phases.
  - For cubic (FCC, BCC) phases the independent elastic constants are C11, C12 and C44.
  - For hexagonal (HCP) phase the independent elastic constants are C11, C12, C13, C33 and C44.
- The assessed elastic constants are used to derive the polycrystalline elastic moduli (bulk, shear and Young's) using the Voigt-Reuss-Hill averaging method. They are expressed in terms of the Voigt (upper limit) and Reuss (lower limit) estimates of the elastic moduli:

Bulk modulus

$$B = \frac{1}{2}(B_V + B_R)$$

Shear modulus

$$G = \frac{1}{2}(G_V + G_R)$$

Young's modulus

$$E = \frac{9BG}{3B + G}$$

- The Voigt and Reuss estimates depend on crystal symmetry. For cubic (FCC, BCC) solids they are:

$$B_V = B_R = \frac{1}{3}(C_{11} + 2C_{12})$$

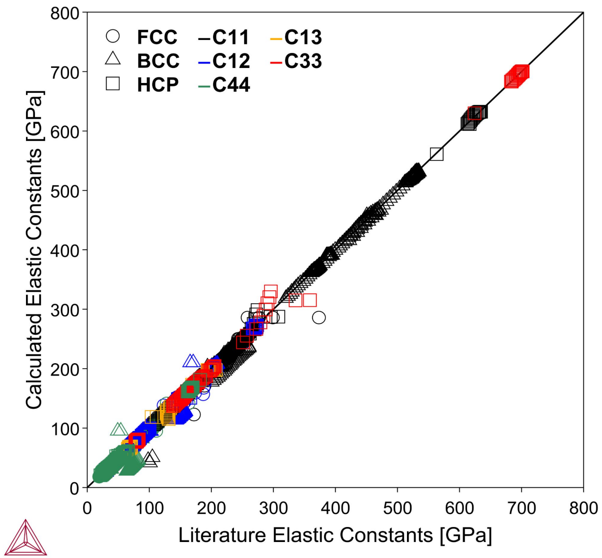
$$G_V = \frac{1}{5}(C_{11} - C_{12} + 3C_{44})$$

$$G_R = \frac{5(C_{11} - C_{12})C_{44}}{3(C_{11} - C_{12}) + 4C_{44}}$$

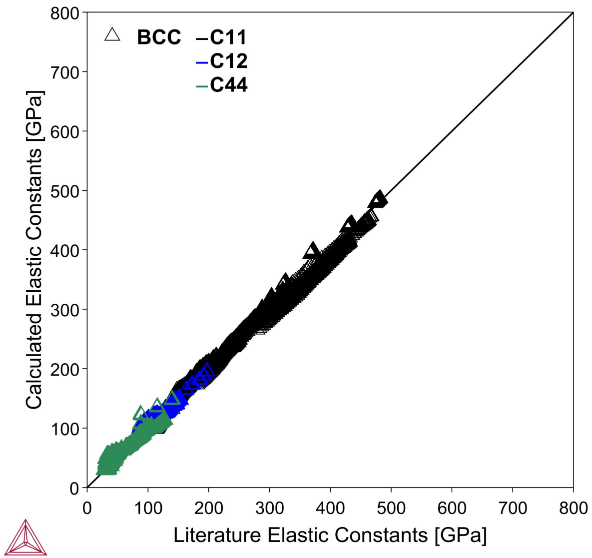
TCS Ti/TiAl-based Alloys Database (TCTI6): Elastic Properties

Example: Literature vs Calculated Elastic Constants

TCTI unaries in different phases at different temperatures.



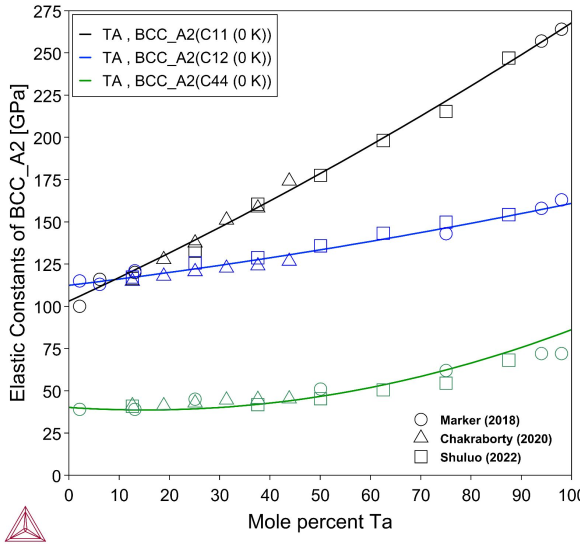
TCTI titanium binaries and other important binary systems for titanium alloys in BCC phase at different temperatures and compositions



TCS Ti/TiAl-based Alloys Database (TCTI6): Elastic Properties

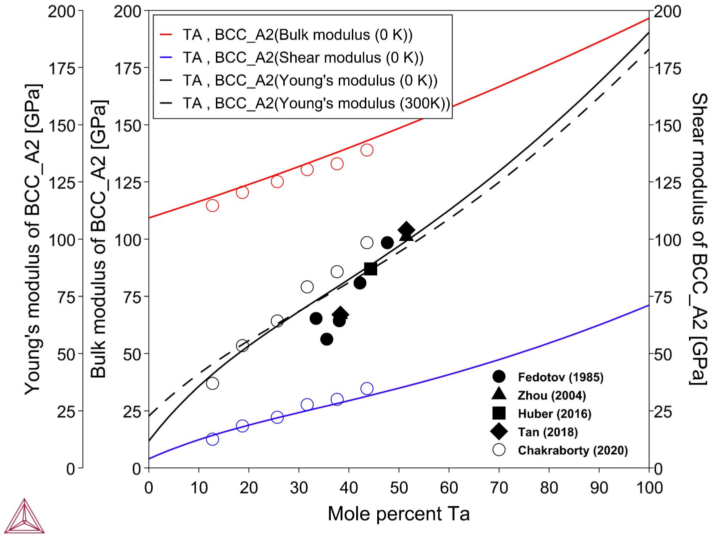
Example: Elastic Moduli of BCC Ti-Ta Alloys

C11
C12
C44



DFT calculations (open symbols)

Bulk
Young's
Shear



DFT calculations (open symbols)
Room temperature experiments (filled symbols)

TCS Solder Alloy Solutions Database (TCSLD5)

- Focused on **brazing alloys**
- 24 elements (new elements are in green):

Ag	Al	Au	Bi	Ca	Cd	Co	Cu	Ga	Ge	Hf	In
Mg	Mn	Ni	Pb	Pd	Pt	Sb	Si	Sn	Ti	Zn	Zr

- 161 assessed binary systems:
  - **19 new** binary systems (green) and **3 reassessed** binary systems (blue):

Ag-Hf	Ag-Ti	Ag-Zr	Bi-Mg	Bi-Mn	Cu-Hf	Cu-Ti	Cu-Zr	Ga-Hf	Ga-Ti	Ga-Zr
Hf-Sn	Hf-Ti	Hf-Zr	In-Pb	In-Ti	In-Zr	Mg-Pb	Ni-Pb	Sn-Ti	Sn-Zr	Ti-Zr

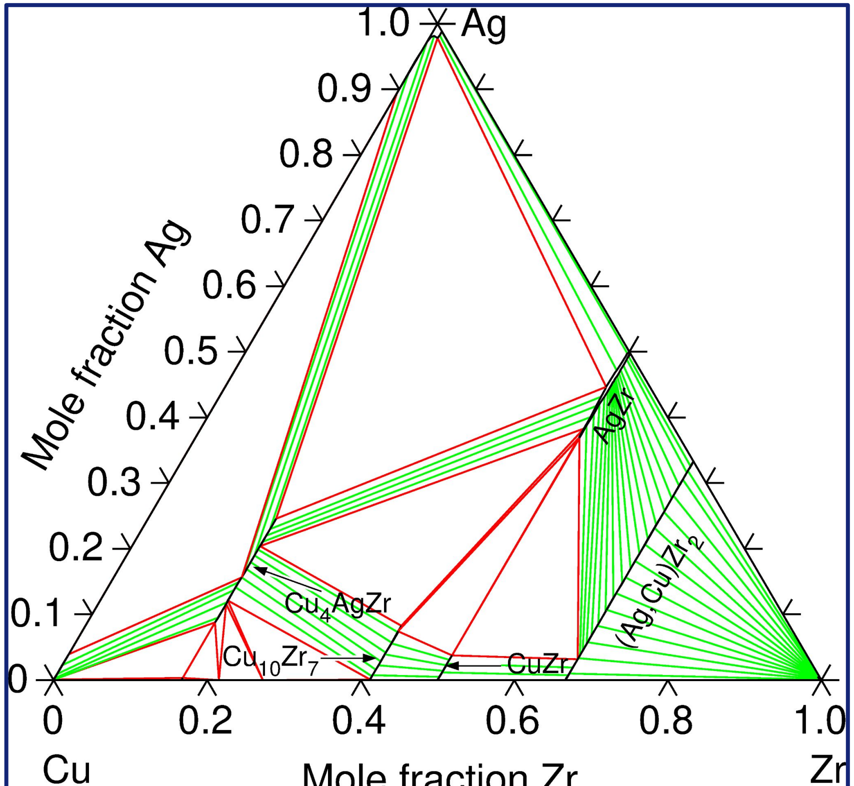
- 77 assessed ternary systems:
  - **5 new** ternary systems (green) and **1 reassessed** ternary system (blue)

Ag-Cu-Ga	Ag-Cu-Ti	Ag-Cu-Zr	Bi-Sb-Sn	Cu-Sn-Ti	Cu-Ti-Zr

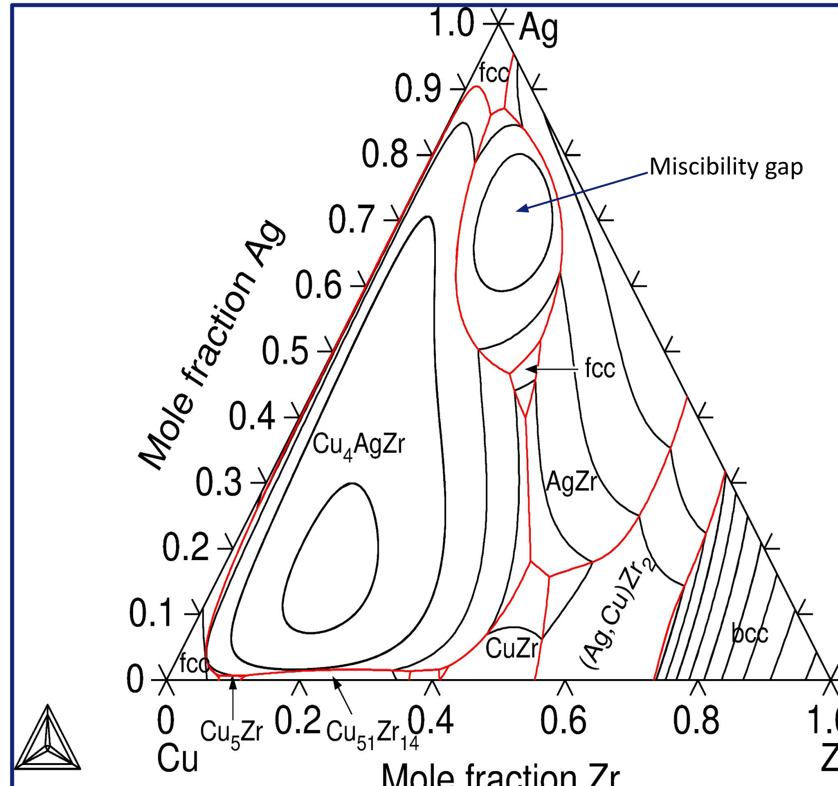
- 328 phases (56 new)
- The HCP_A3 phase restored to describe the lattice stability of Zn (HCP_ZN removed)

TCS Solder Alloy Solutions Database (TCSLD5)

Ag-Cu-Zr: Isothermal Section at 750 °C



Ag-Cu-Zr: Liquidus Surface



Thermo-Calc Software

TCS Mo-based Alloys Mobility Database (MOBMO1)

1 Elements (12)

Al, B, C, Cr, Fe, Hf, Mn, Mo, Re, Si, Ti, Zr

2 Phases (10)

Solution phases (5)

FCC_A1, BCC_A2, BCC_B2, HCP_A3, LIQUID

Compounds (5)

MO5SI3_D8M, MO3SI_A15, MOSI2_C11B, C15_LAVES, M6C

3 Included Systems

27 binary- and 8 ternary- systems for solid phases are assessed.

Parameters for self- and impurity- diffusivity of all the liquid systems are estimated using the Modified Sutherland equation. (66 systems)

Thermo-Calc Software

TCS Mo-based Alloys Mobility Database (MOBMO1)

Assessed systems

(having interaction parameters)

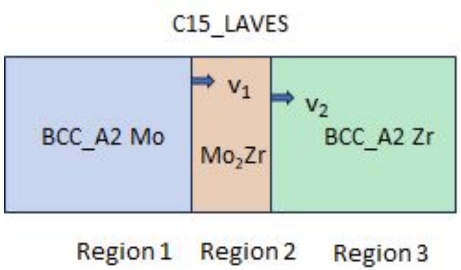
MOBMO1

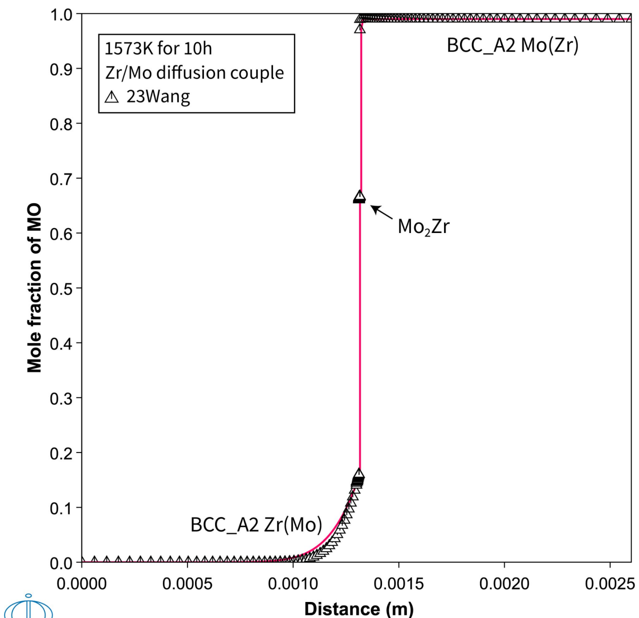
FCC_A1(9)	BCC_A2(23)	HCP_A3(3)	Compounds
Al-Cr, Al-Fe, Al-Si, Al-Ti, Cr-Fe, Fe-Si, Fe-Mn, Fe-Mn-Si, Fe-Cr-C	Al-Fe, Al-Ti, Cr-Fe, Cr-Mo, Cr-Ti, Fe-Mn, Fe-Mo, Fe-Si, Fe-Ti, Hf-Mo, Hf-Ti, Hf-Zr, Mn-Ti, Mn-Zr, Mo-Ti, Mo-Zr, Zr-Ti, Fe-Cr-Mo, Fe-Mn-Si, Ti-Al-Cr, Ti-Al-Fe, Ti-Al-Mo, Ti-Al-Zr	C-Mo, Cr-Fe, Fe-Zr	MO5SI3_D8M: Mo_5Si_3 C15_LAVES: $ZrMo_2$ M6C: Fe_3Mo_2C

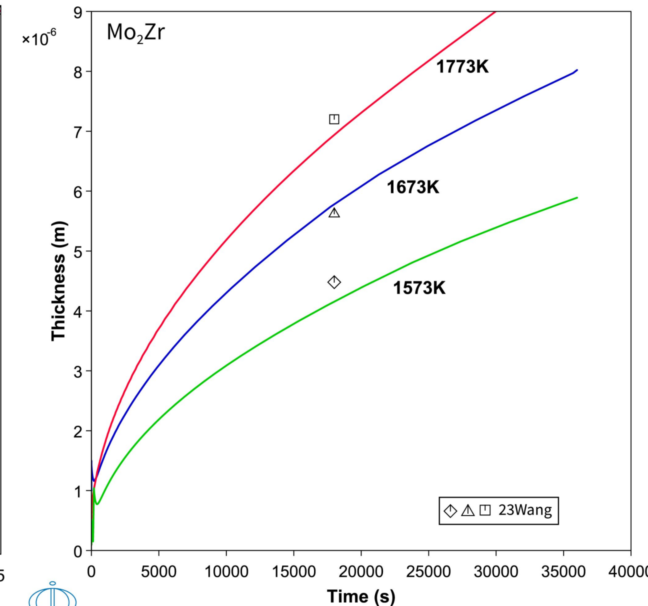
Thermo-Calc Software

TCS Mo-based Alloys Mobility Database (MOBMO1)

Moving boundary problems:
(Diffusion in multi-phases)







Diffusion couple:
Mo/Mo$_2$Zr/Zr

Temperature: 1573-1773K

Annealing time: 36000s

K. Wang, X. Liu, T. Liu, C. He, J. Liu, Interdiffusion in Zr-Mo/W Intermetallics. Appl. Sci. 13, 6375 (2023).

TCS Nb-based Alloys Mobility Database (MOBNB1)

Introduction

MOBNB1 is a kinetic database containing atomic mobility data for Nb-based refractory alloys for diffusion-controlled phenomena using the Diffusion Module (DICTRA) and/or Precipitation Module (TC-PRISMA).

MOBNB1 is compatible and primarily recommended for use with TCNB1 thermodynamic database.

1 Elements (12)

Al, C, Cr, Hf, Mo, Nb, Si, Ta, Ti, V, W, Zr

2 Phases (6)

Solution Phases (4)

BCC_A2 FCC_A1 HCP_A3 LIQUID

Compounds (2)

CRSI2_C40, NB5SI3_D8L

Thermo-Calc Software

TCS Nb-based Alloys Mobility Database (MOBNB1)

Assessed systems

(having interaction parameters)

MOBNB1

BCC_A2 (38)	FCC_A1	HCP_A3 (2)	Compounds (2)
Al-Nb, Al-Ti, Al-V, Cr-Nb, Cr-Ta, Cr-Ti, Hf-Nb, Hf-Ta, Hf-Ti, Mo-Cr, Mo-Hf, Mo-Nb, Mo-Ta, Mo-Ti, Mo-W, Nb-Ta, Nb-Ti, Nb-V, Nb-W, Ta-Ti, Ta-W, Ti-V, Zr-Hf, Zr-Mo, Zr-Nb, Zr-Ta, Zr-Ti, Zr-V, Ti-Al-Nb, Ti-Cr-Nb, Ti-Nb-Ta, Ti-Nb-V, Zr-Ta-Nb, Zr-Ti-Nb, Ti-Nb-Ta-Zr, Ti-Nb-Hf-Zr, Ti-Nb-Zr-W, Ti-Cr-Nb-Zr	Al-Si, C-Nb	C-Mo, C-Nb	CRSI2_C40: $NbSi_2$ NB5SI3_D8L: Nb_5Si_3

TCS Ti-alloys Mobility Database (MOBTI5)

1 Elements (28)

Ag, Al, B, C, Co, Cr, Cu, Fe, H, Hf, Mn, Mo, N, Nb, Ni, O, Pd, Pt, Re, Ru, Si, Sn, Ta, Ti, V, W, Y, Zr

2 Phases (5)

Solution Phases (3)

BCC_A2 HCP_A3 LIQUID

Compounds (2)

Ti3Al (ALTI3_D019), TiAl (ALTI_L10)

3 Included Systems

46 binary- and 28 ternary/quaternary- systems for solid solution phases, 14 elements in ALTI_L10 compound, and 6 elements in the ALTI3_D019 compound are assessed.

Parameters for self- and impurity- diffusivity of all the liquid systems are estimated using the Modified Sutherland equation. (378 binary systems)

TCS Ti-alloys Mobility Database (MOBTI5)

❖ DICTRA simulations

Diffusion-controlled simulations in multi-component systems:

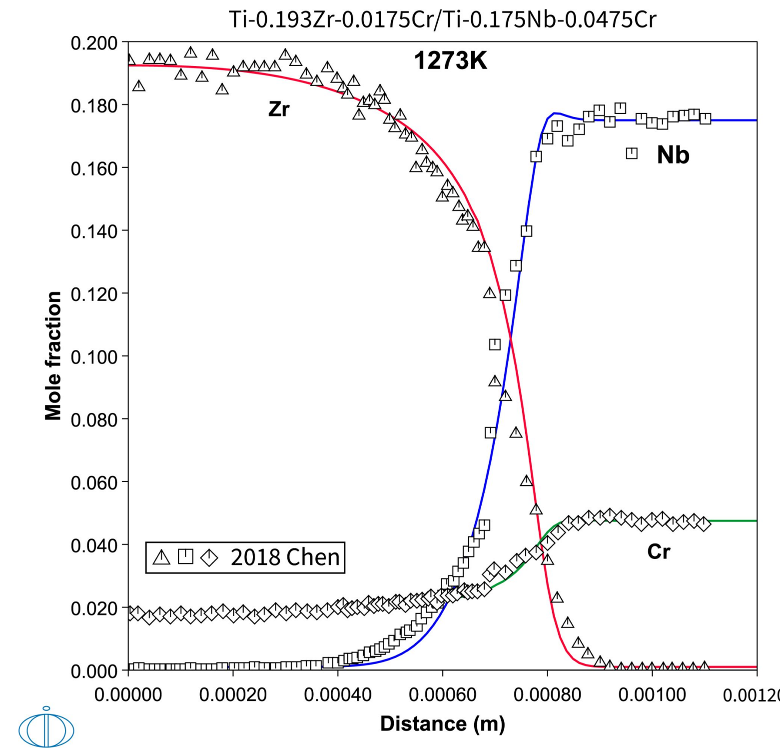
Diffusion in single phase

Diffusion couple: **(mole fraction)**

Temperature: 1273K

Annealing time: 90000s

The plots show the homogenization results from the DICTRA simulations. The simulations were performed by using the MOBTI5 combined with the TCTI6.



TCS Solder Alloy Solutions Mobility Database (MOBSLD2)

Introduction

MOBSLD2 is a kinetic database containing atomic mobility data for solder alloys for diffusion-controlled phenomena using the Diffusion Module (DICTRA) and/or Precipitation Module (TC-PRISMA).

MOBSLD2 is compatible and primarily recommended for use with TCSLD5 thermodynamic database.

1 Elements (24)

Ag, Al, Au, Bi, Ca, Cd, Co, Cu, Ga, Ge, In, Mg, Mn, Ni, Pb, Pd, Pt, Sb, Si, Sn ,Zn, Hf, Ti, Zr (new)

2 Phases (12)

Solution Phases (6)

FCC_A1, HCP_A3, BCT_A5, DIAMOND_A4, RHOMBOHEDRAL_A7, LIQUID

Compounds (Updated: 6)

NI3SN4, CU2IN_LT, CU7IN3, ALCU_ZETA, CU5ZN8_GAMMA, CU3SN

Thermo-Calc Software

TCS Solder Alloy Solutions Mobility Database (MOBSLD2)

Assessed systems

(having interaction parameters)

FCC_A1	HCP_A3	Compounds	Other Phases
Binary: …(29 systems from MOBSLD1)… Updated: Ag-Ge, Ag-Mg, Ag-Mn, Ag-Pd, Al-Pt, Al-Ti, Al-Zr, Au-Pt, Co-Mn, Co-Ti, Cu-Ge, Ni-Pd, Ni-Ti and Pd-Pt Ternary/Quaternary: …(16 systems from MOBSLD1)… Updated: Ag-Cu-Ni, Ag-Sn-Zn, Cu-Sn-Zn, Cu-Ni-Sn, Cu-Al-Ni and Cu-Al-Sn.	Updated: Ag-Mg, Ag-Ti, Cu-Ti, Mg-Ga, Mg-Zn and Mg-Ag-Zn	**NI3SN4:** Cu, Ni, In, Sn **CU2IN_LT:** Cu, In **CU7IN3:** Cu, In, Sn **CU11IN9:** Ag, Cu, Al, In **CU5ZN8:** Au, Ni, Sn, Zn **CU3SN:** other elements	Add self- and impurity-diffusivity data for Hf-X, Ti-X and Zr-X binary systems

TCS Aluminum-based Alloys Database (TCAL9 to Version 9.1)

- Thermal conductivity and electrical resistivity of liquid Al were re-assessed.
- Electrical resistivity of the liquid phase in the Al-Si system was re-assessed.
- Surface tension parameters were updated for the systems Ag-Cu, Bi-Sn, Cu-Sn, and Ag-Cu-Sn.
- Viscosity parameters were updated for the systems Ag-Cu, Al-Sb, Al-Te, B-Bi, B-Mg, B-Pb, B-Sn, B-Sr, B-Zn, Bi-C, Bi-Fe, Bi-Mo, Bi-Nd, C-Ca, C-Pb, C-Sn, Cr-Pb, Mg-Sb, Mg-Sn, Mo-Pb, Mo-Sn, Nb-Pb, Pb-Ti, Pb-V, and Cu-Ti-Zr.
- The FCC_A1 parameters were corrected in the Cu-Hf system.

Thermophysical Properties

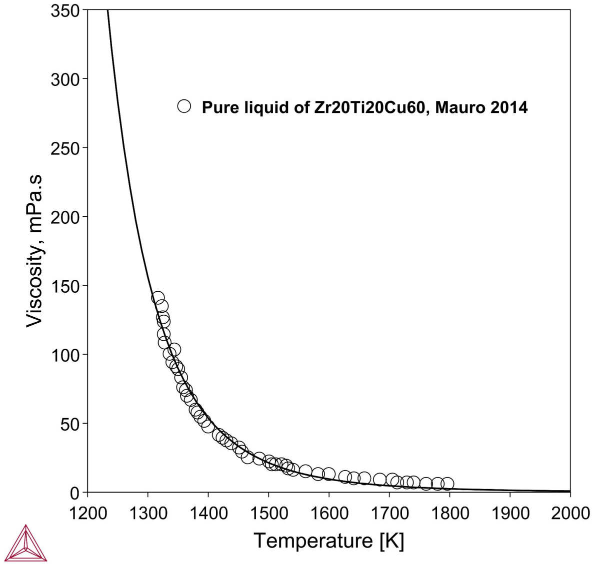
	TCMO1	TCSLD5	TCNB1	TCUHTM2	TCTI6 *	TCAL9.1
Molar Volume	X	X	X	X	X	X
Surface Tension	X	X	X		X	X
Viscosity	X	X	X		X	X
Thermal Conductivity	X	X	X		X	X
Electrical Resistivity	X	X	X		X	X

* TCTI6

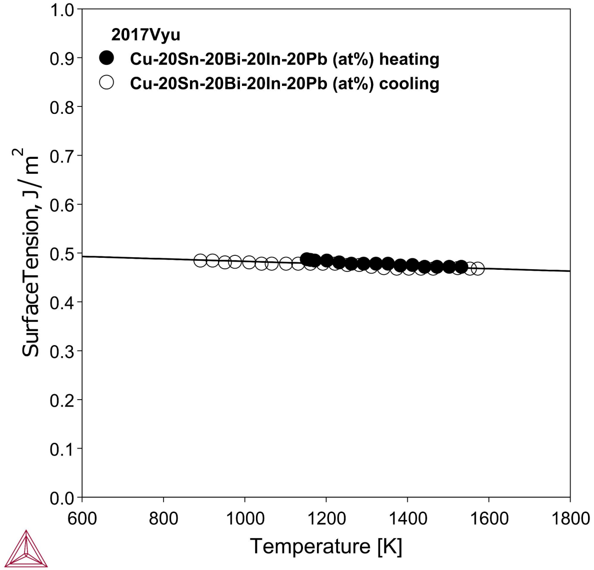
- Improved surface tension of Fe-Ni.
- Molar volumes of BCC_A2 phase are revised for the systems Al-V, Nb-Ti, Ta-Ti, Al-Ti-V, and Ti-V-Zr.

Thermophysical Properties: Examples

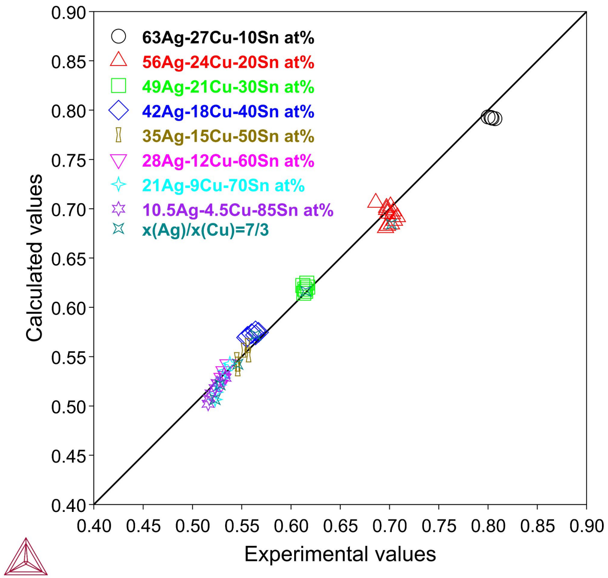
Viscosity Cu-Ti-Zr, TCSLD5



Surface Tension Cu-Sn-Bi-In-Pb, TCSLD5



Surface Tension Ag-Cu-Sn, TCSLD5/TCAL9.1



Thank You for Attending the Webinar!

AM Module Highlights

- ✔ Keyhole model with fluid flow
- ✔ Printability maps in Graphical mode

Property Model Highlights

- ✔ New Titanium Model Library
- ✔ Parallelization of property model calculator
- ✔ Martensitic Steel Strength Property Model improvements

Database Highlights

- ✔ Two new Refractory alloy databases TCMO1 and TCNB1, come paired with kinetic databases
- ✔ Oxygen added to TCUHTM2 Ultra-High Temperature Materials database
- ✔ TCTI6 Titanium alloy database with Elastic constants
- ✔ Brazing elements added to TCSLD5 solder database

Q & A

- Please type questions into the Q&A feature
- Or “raise your hand” to ask to be unmuted

Do you want a free consultation of the software applied to your work?
Contact us at info@thermocalc.com

Or visit our website www.thermocalc.com for more information