

Fe Binary Phase Diagrams, April 21, 2024
Including data from NIMS,
National Institute of Materials Science, Japan
Computational Phase Diagram Database
<https://cpddb.nims.go.jp/>

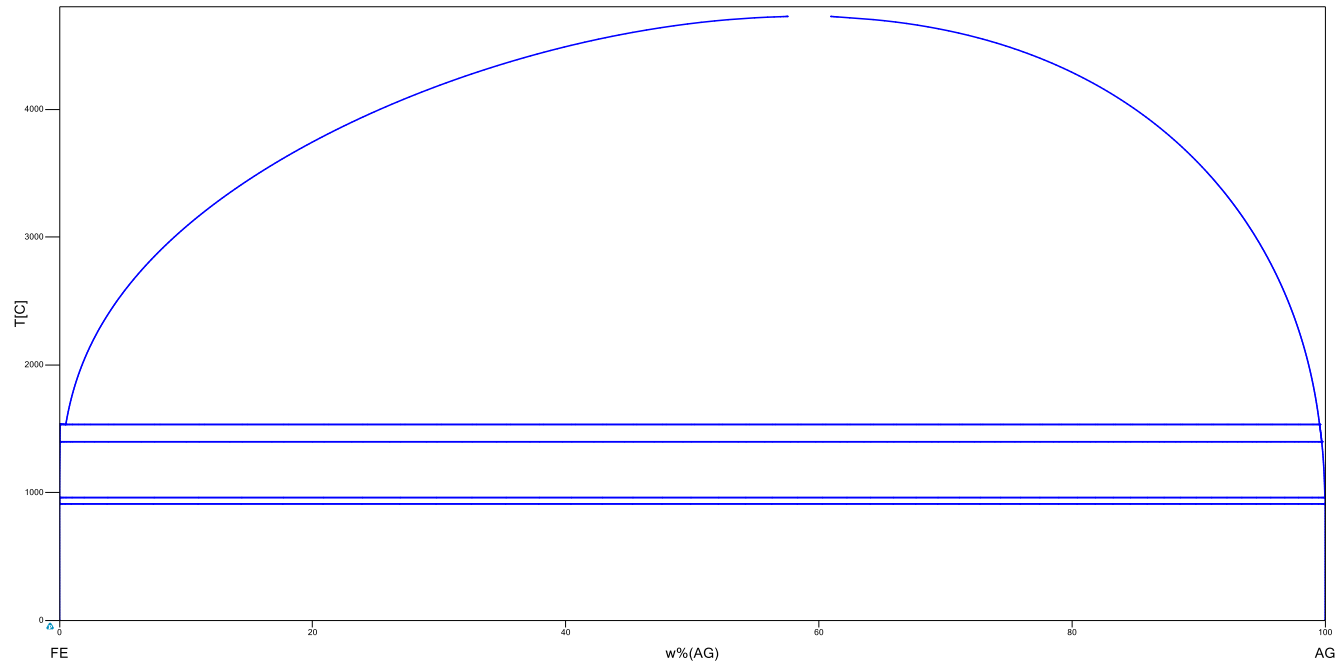
Fabio Miani, University of Udine, Italy;





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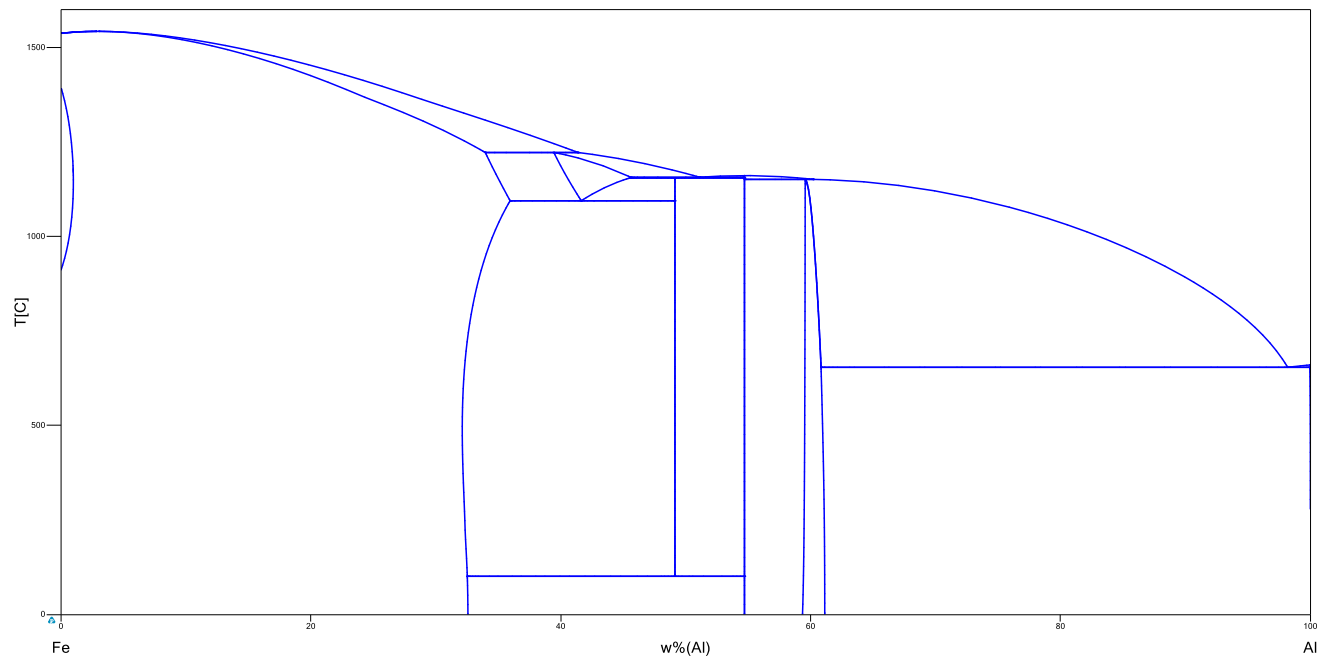
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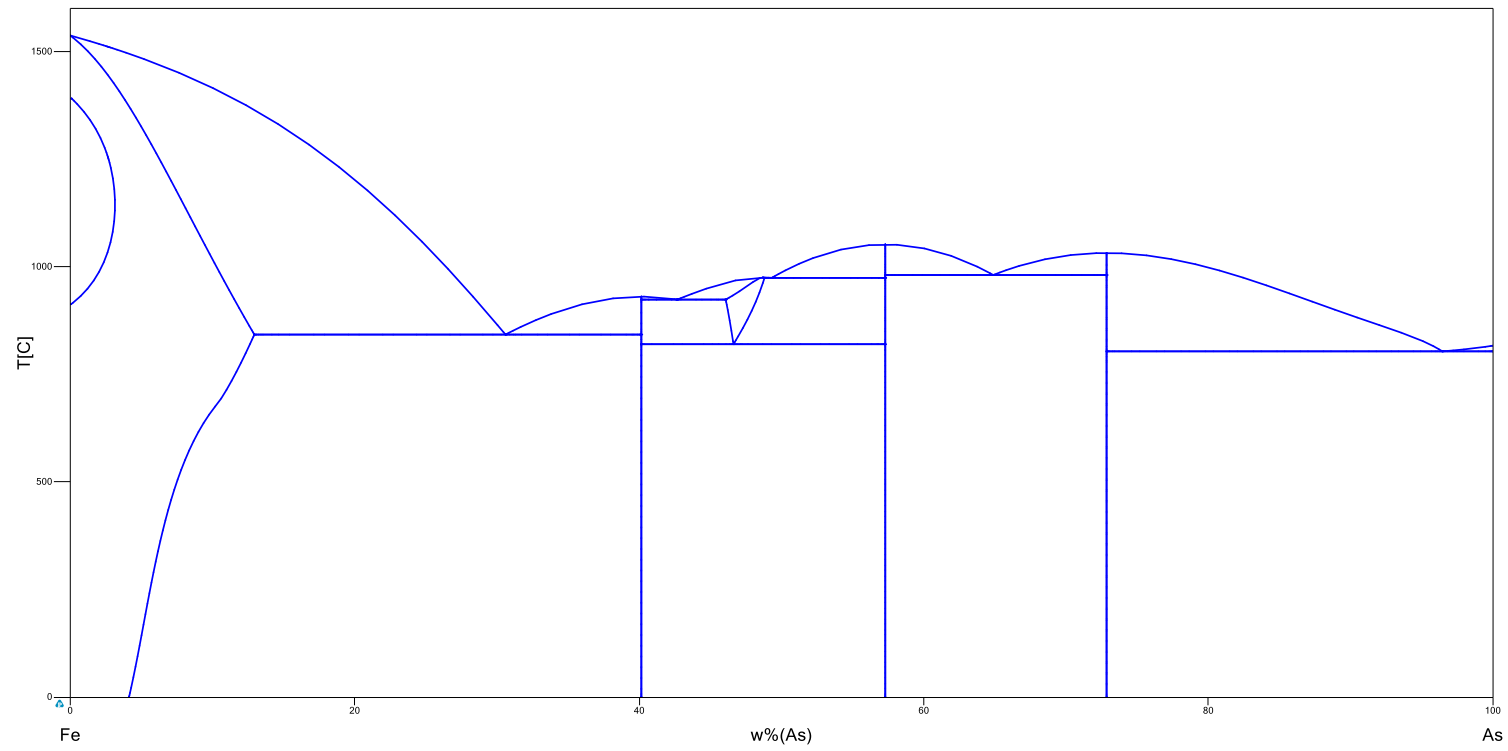
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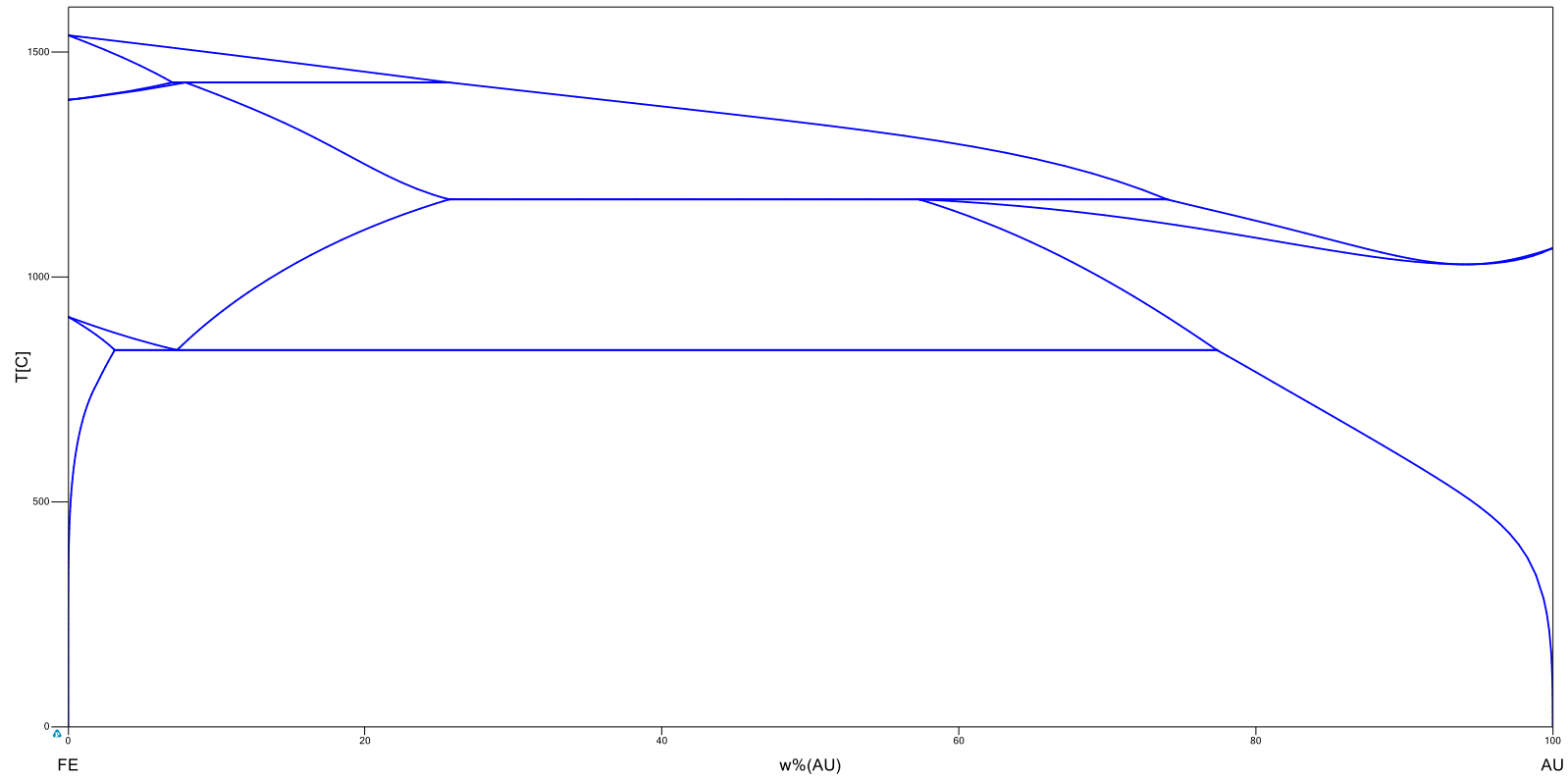
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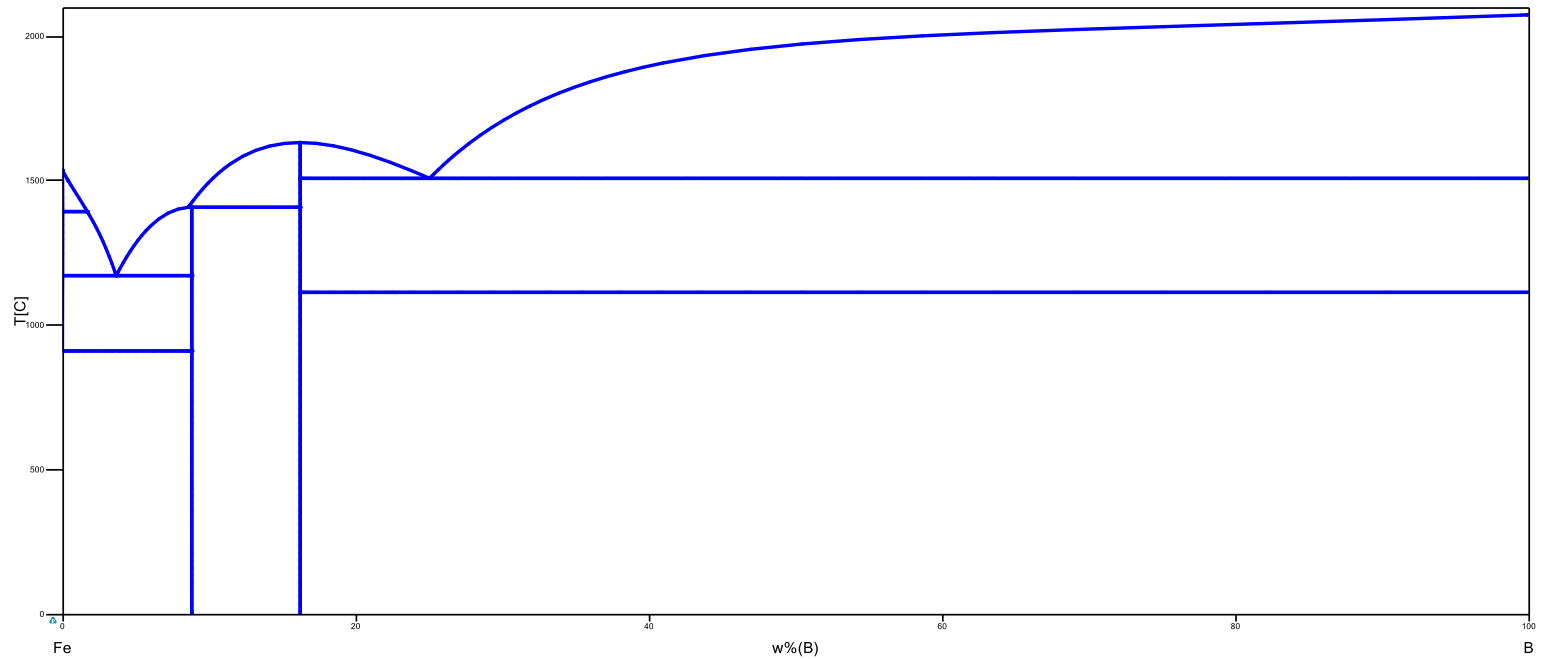
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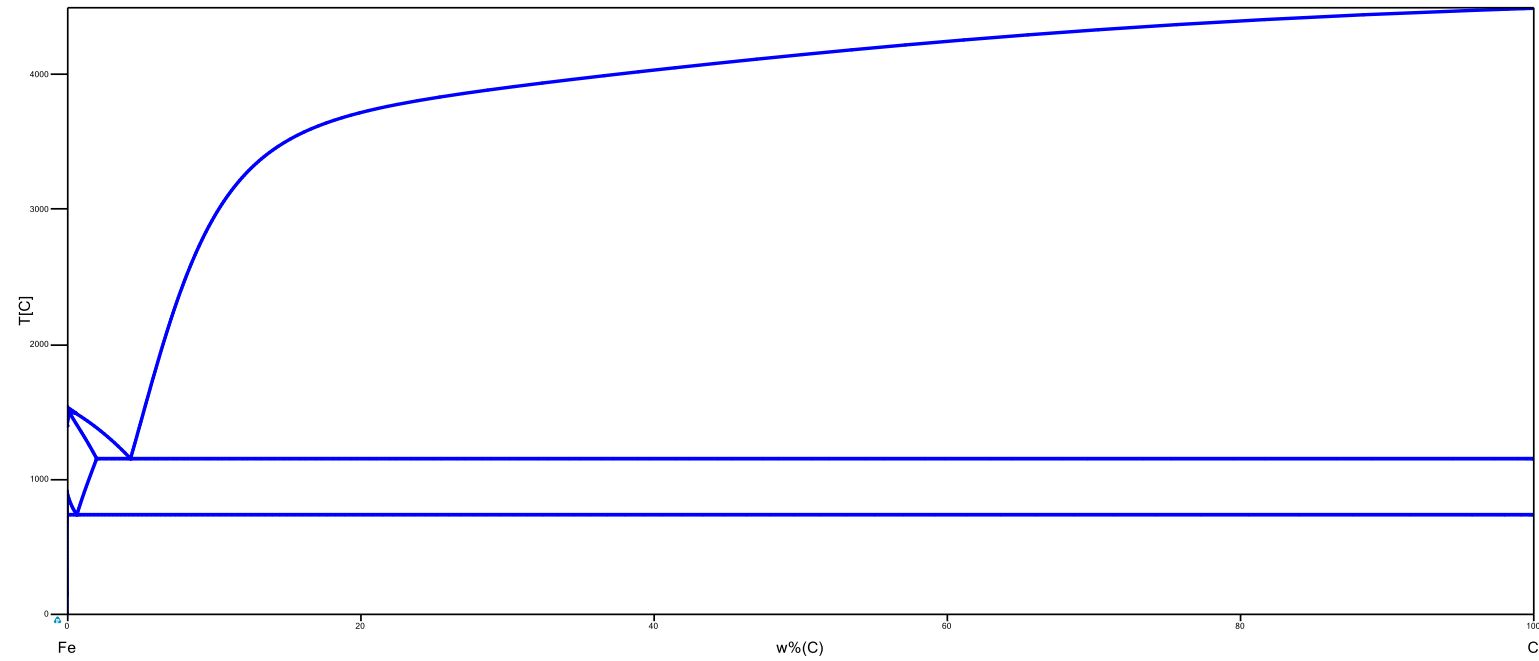


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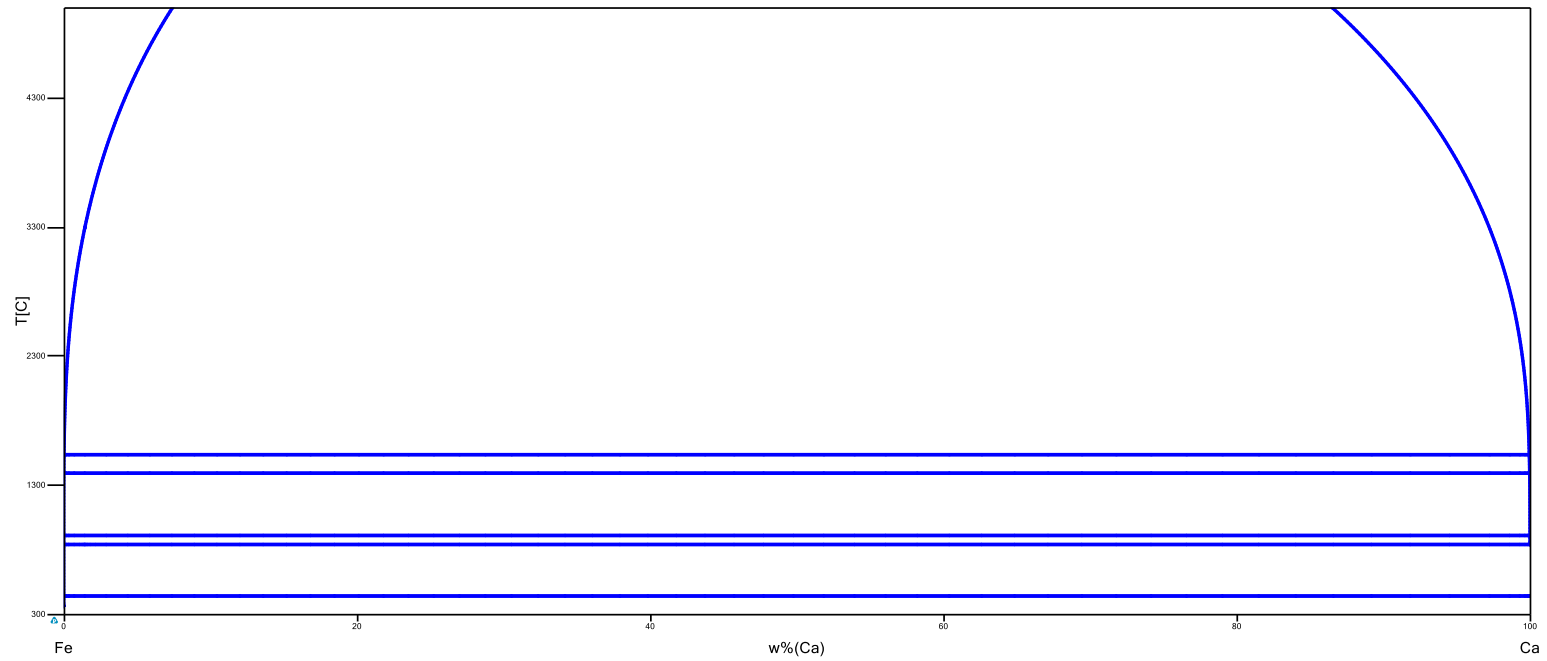
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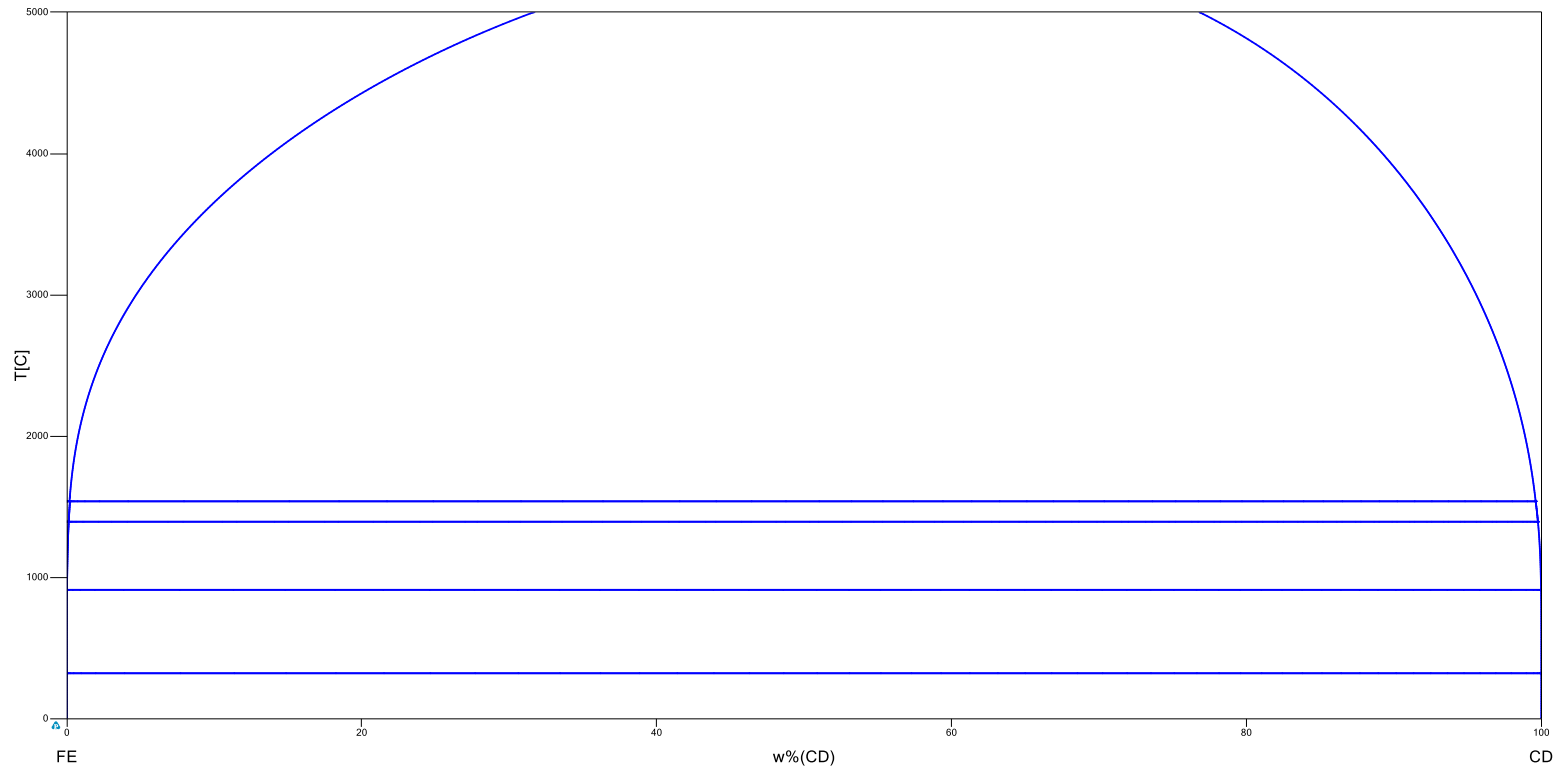
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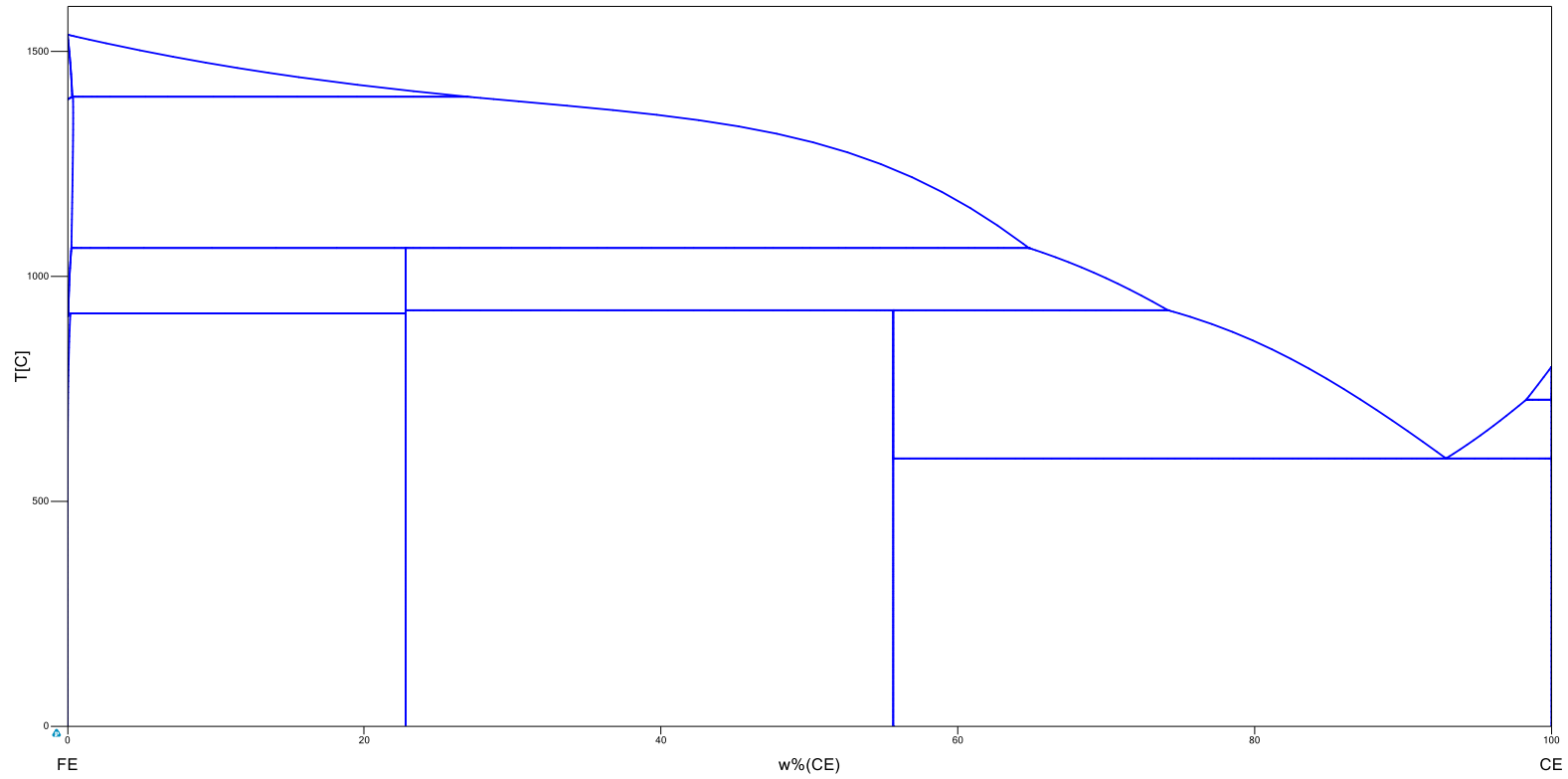
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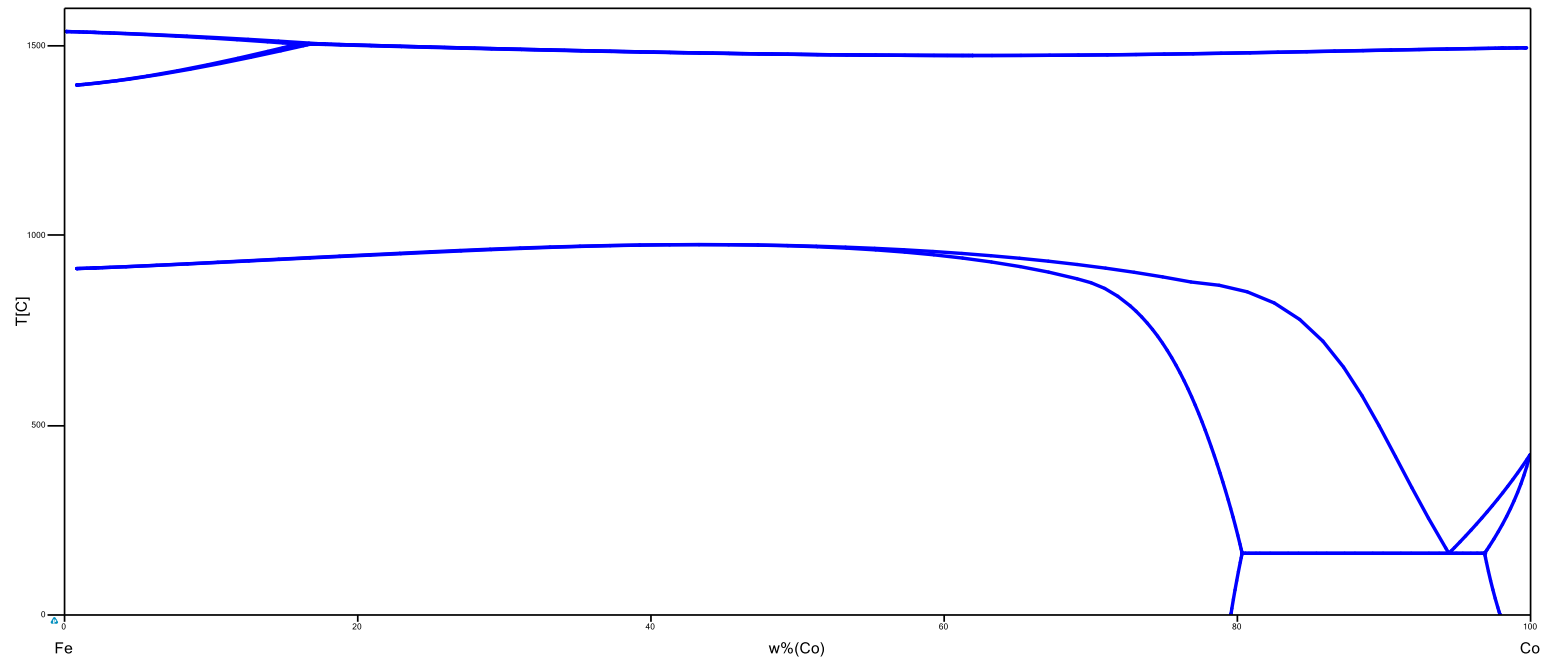
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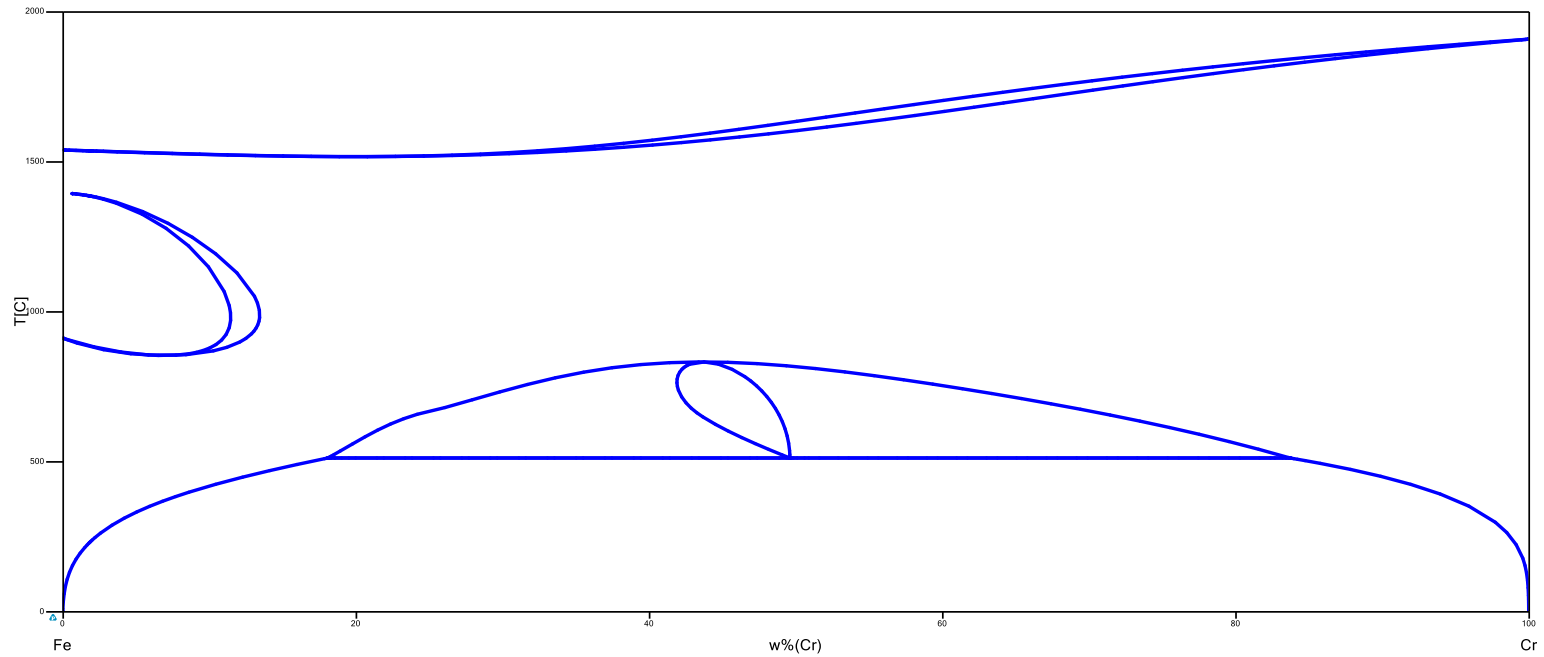


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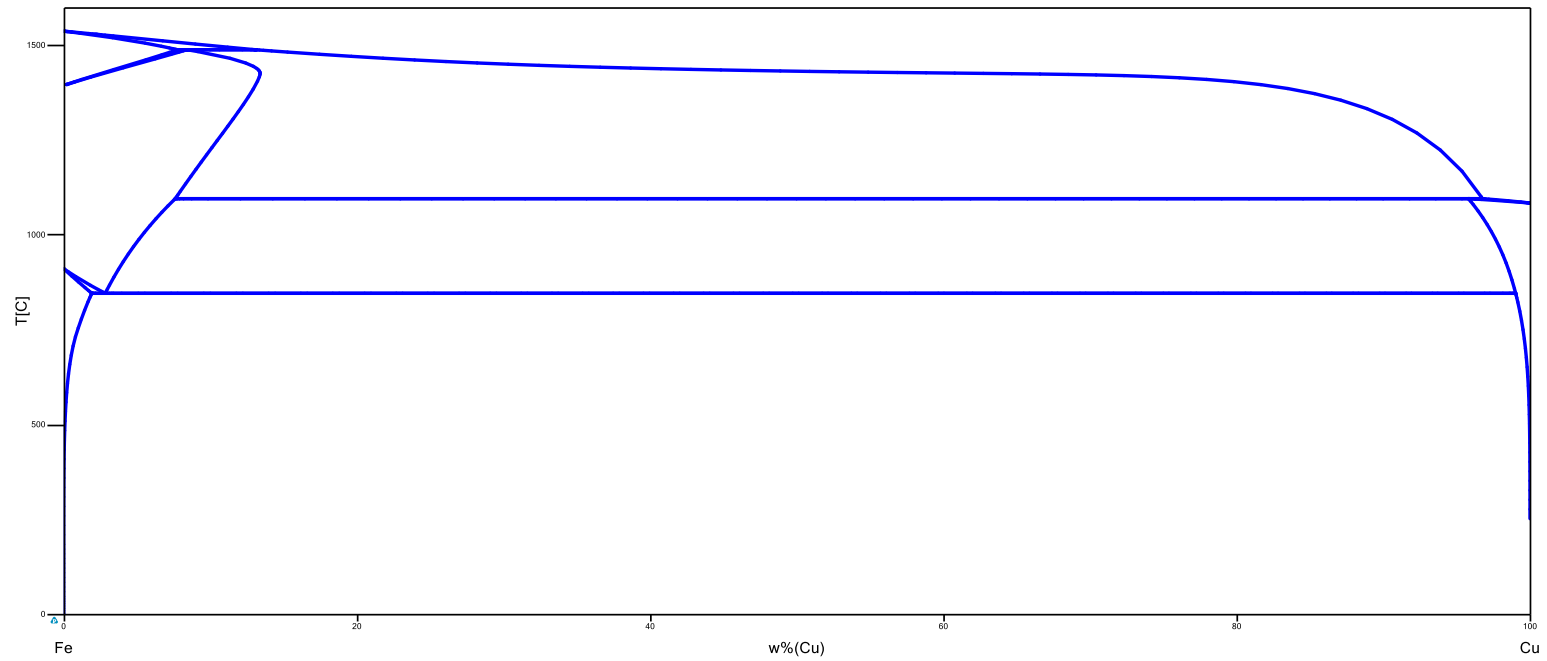


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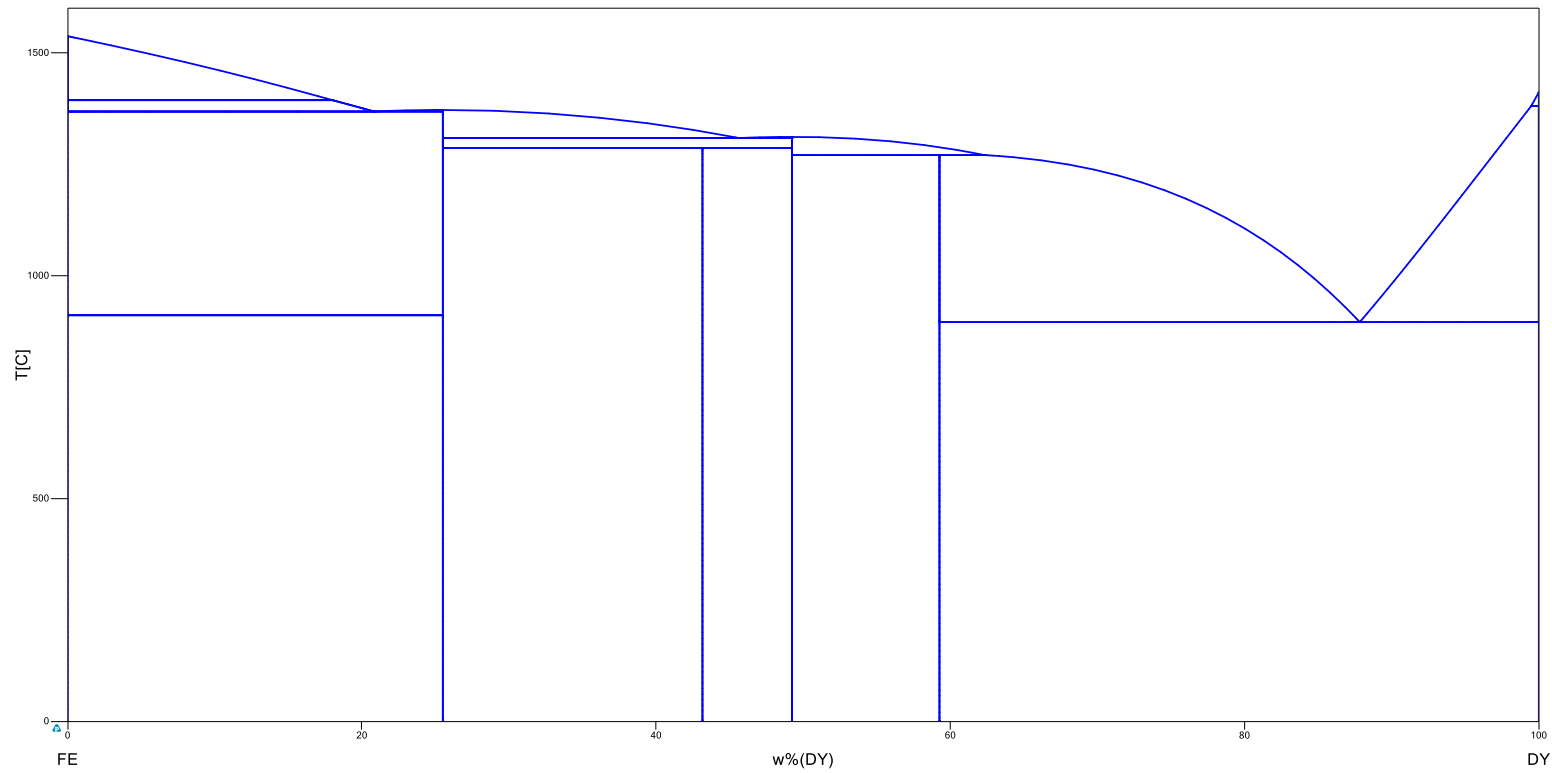
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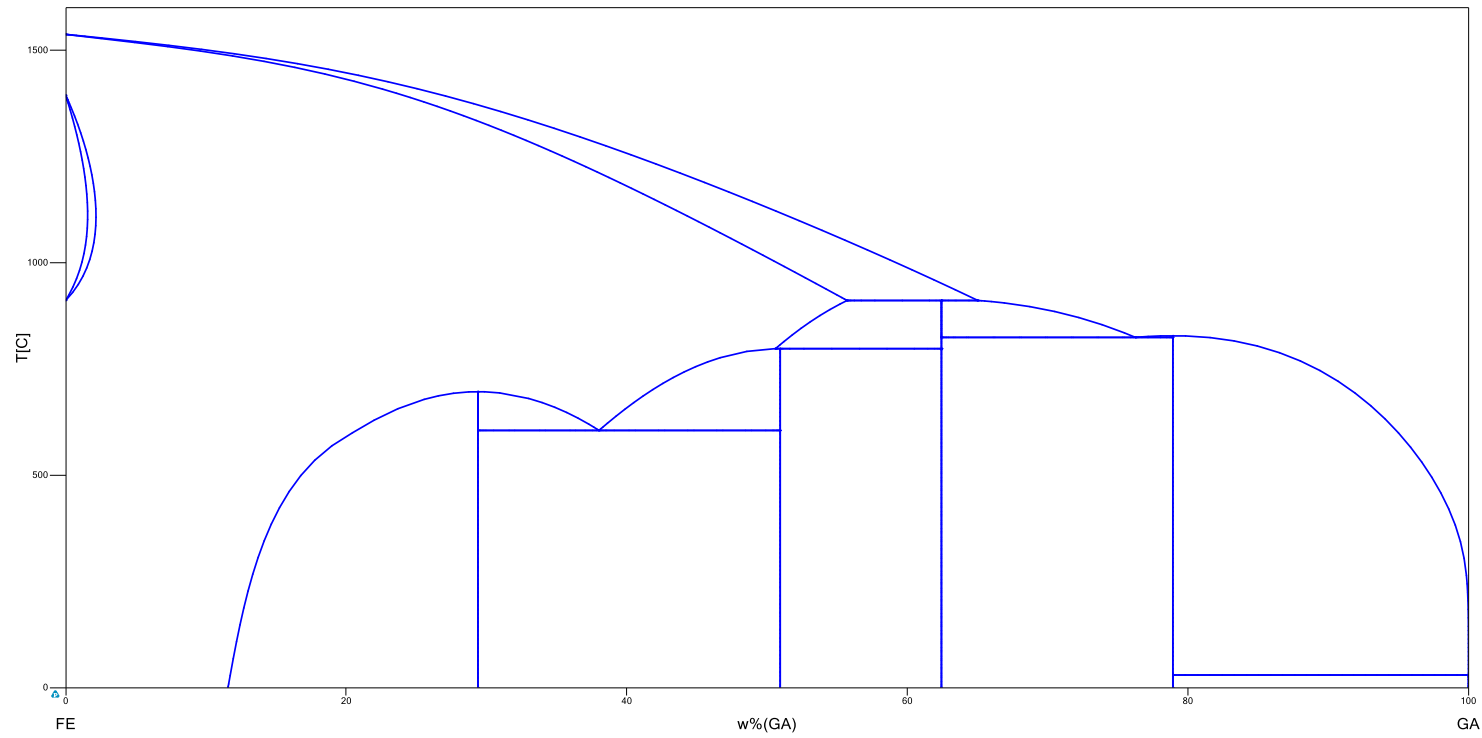
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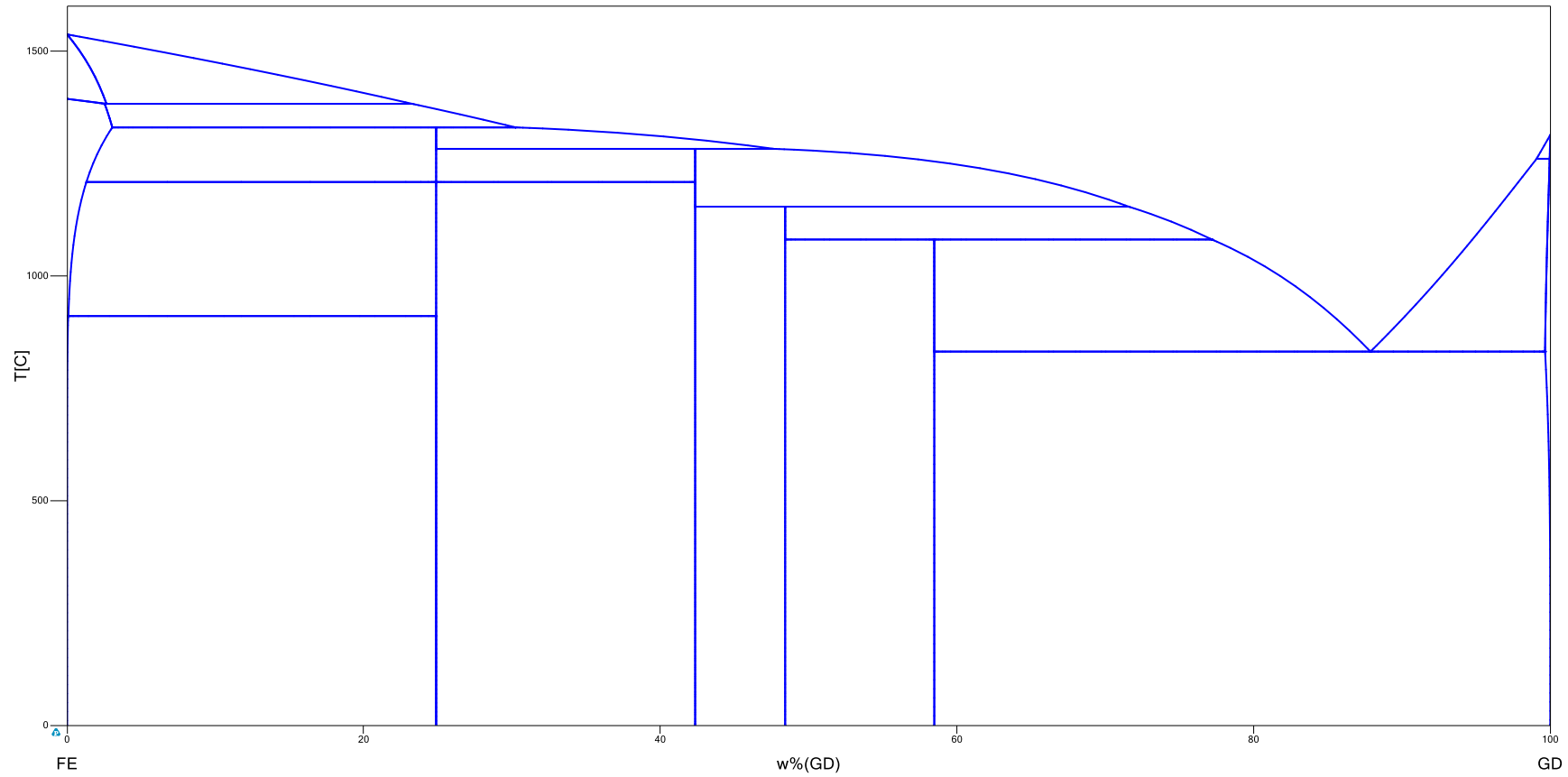
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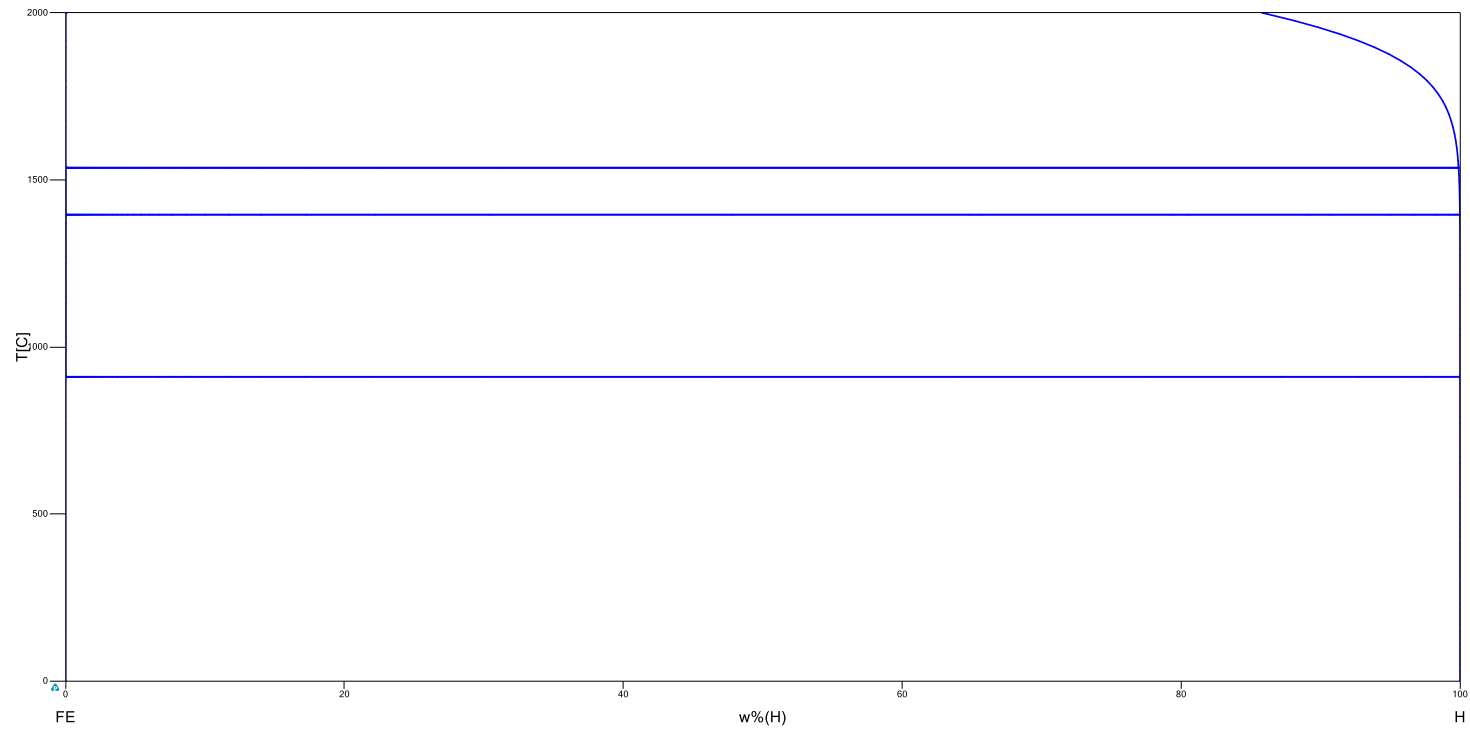
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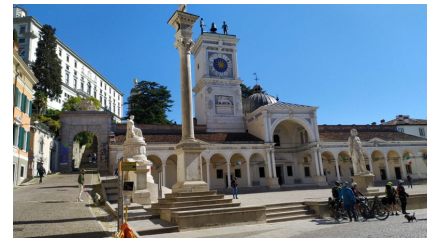
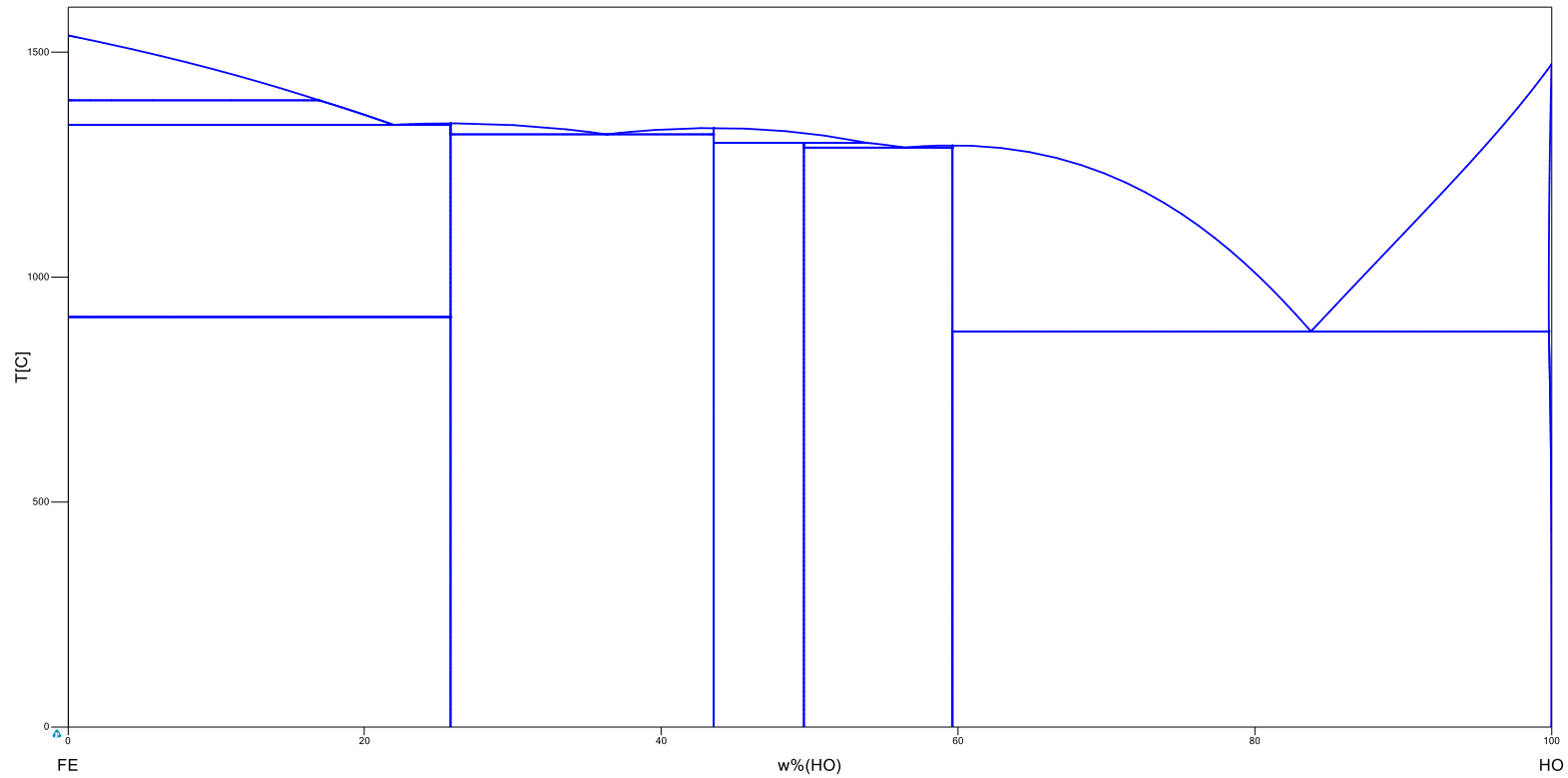
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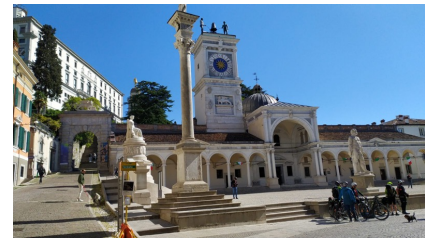
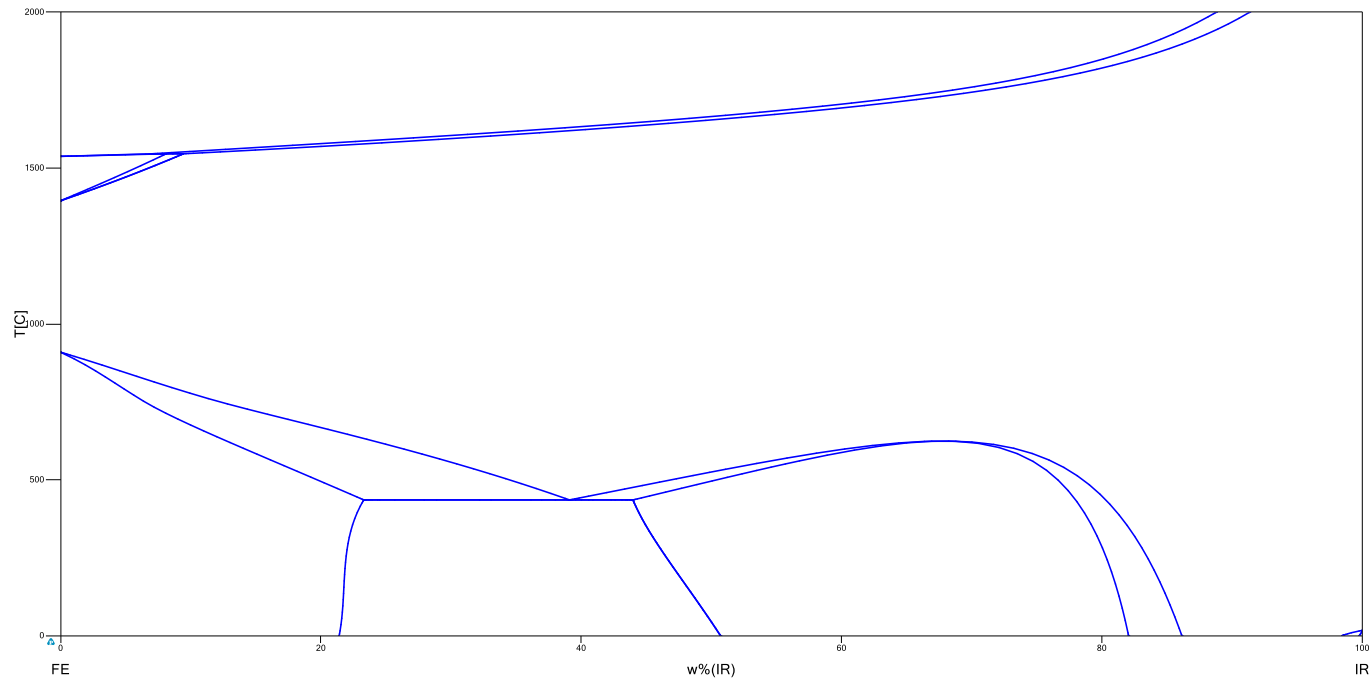
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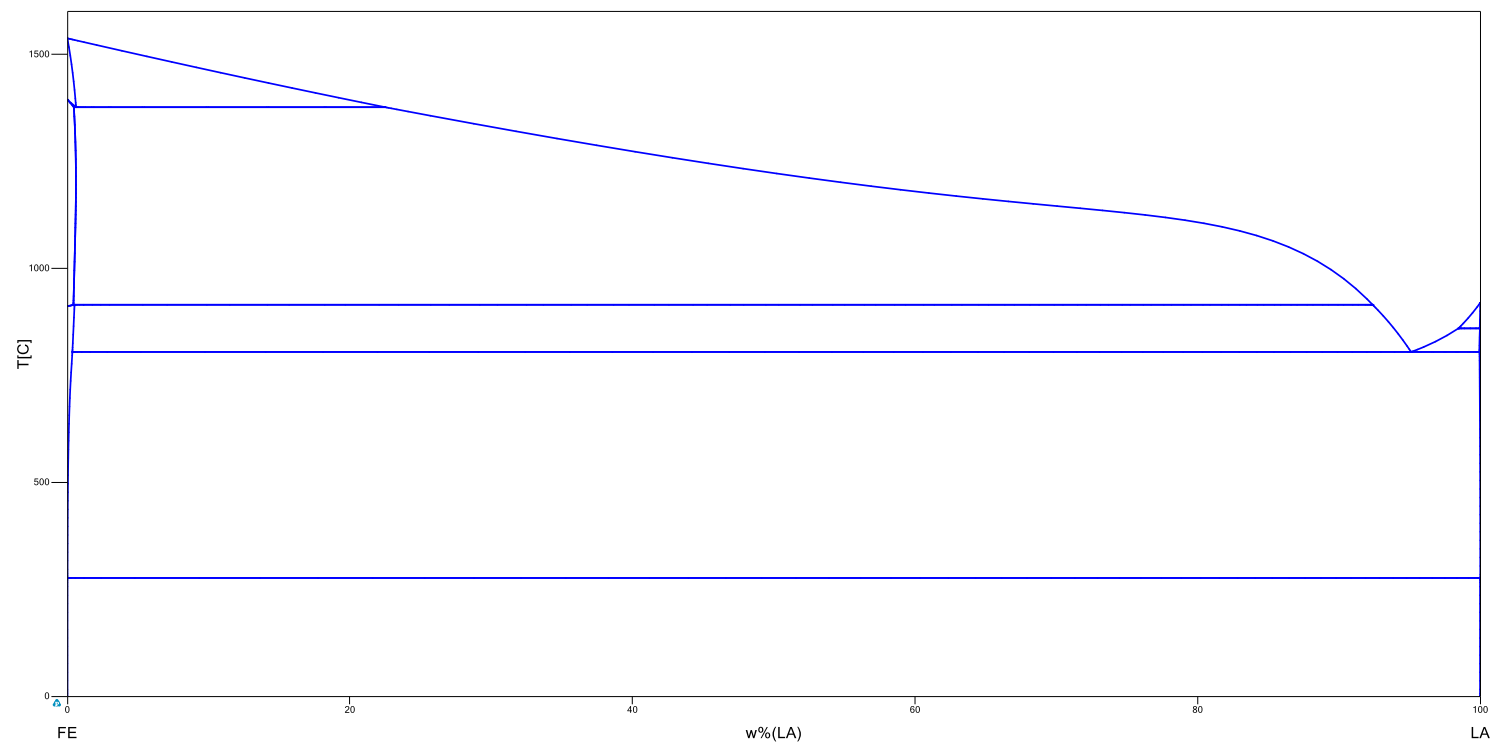
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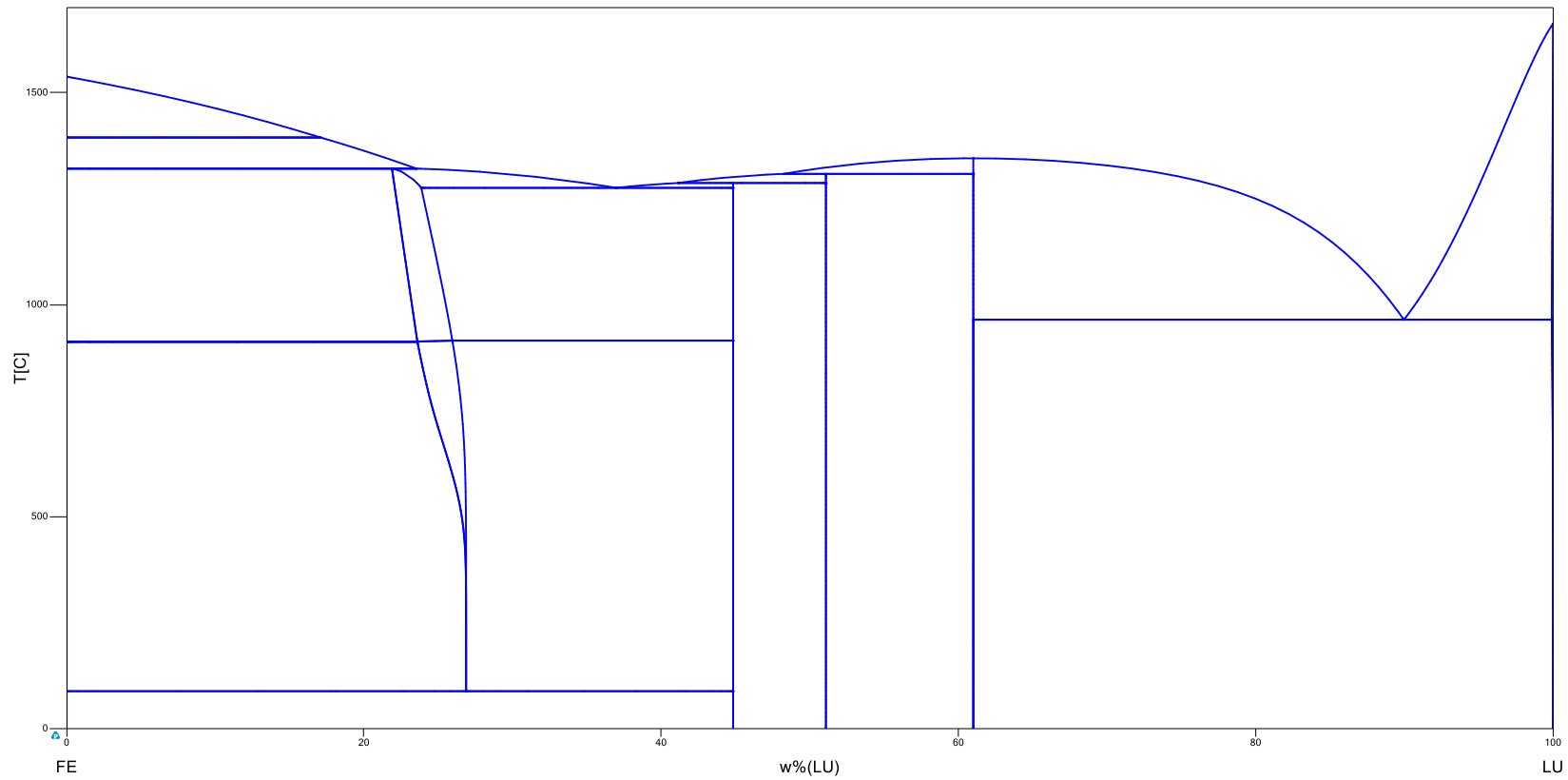
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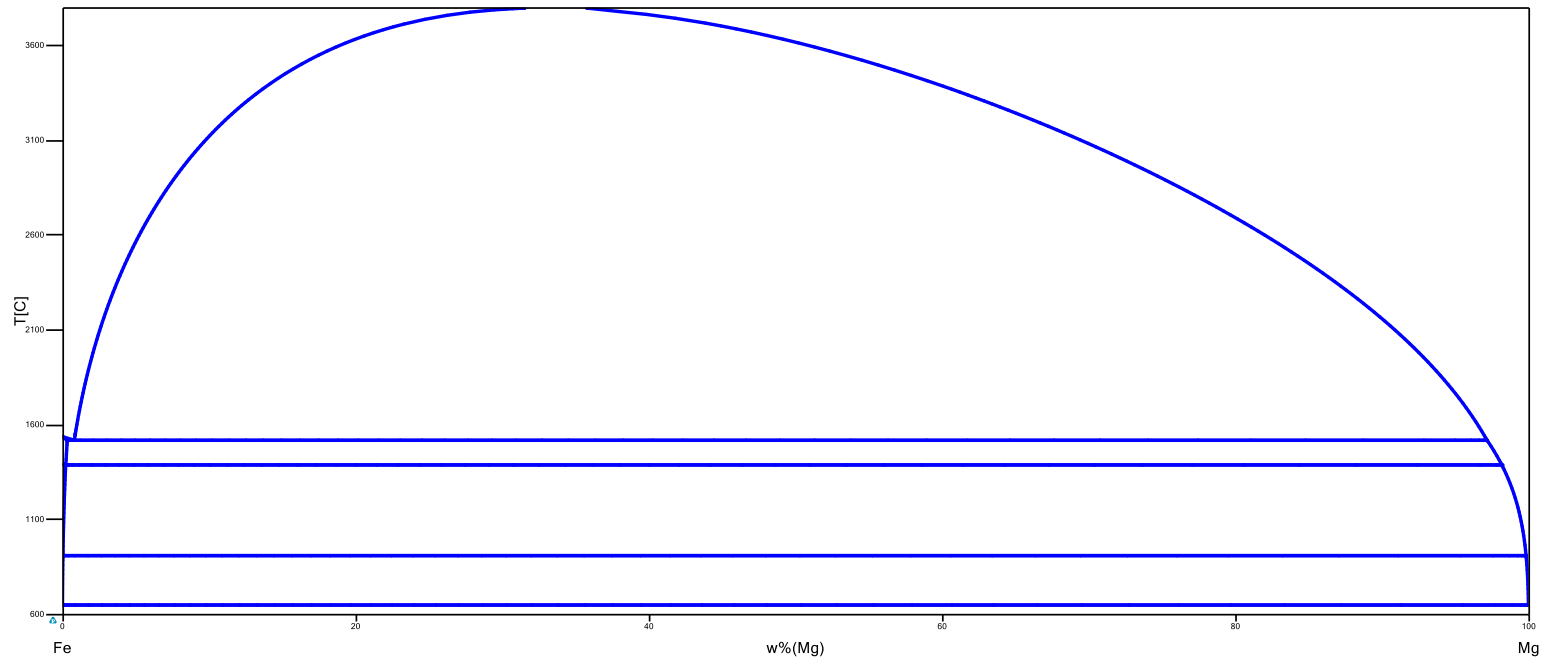
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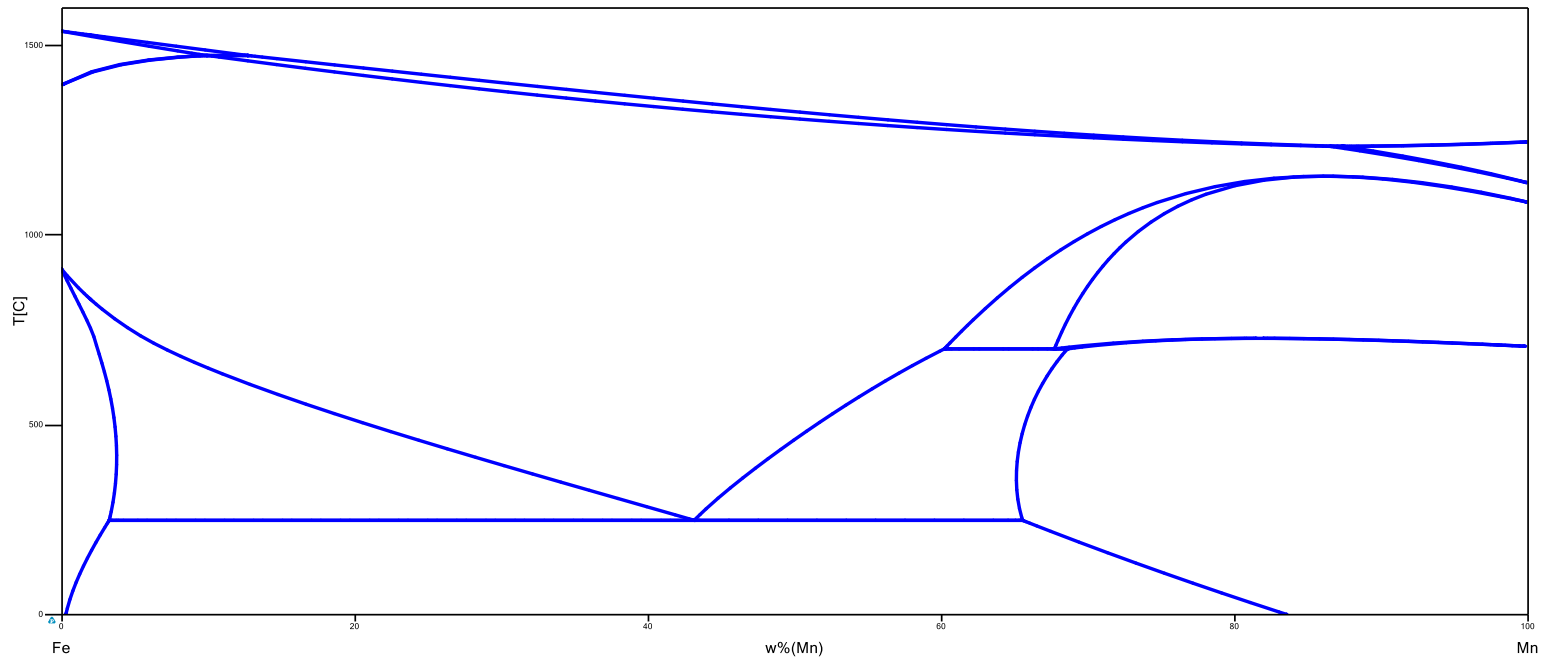
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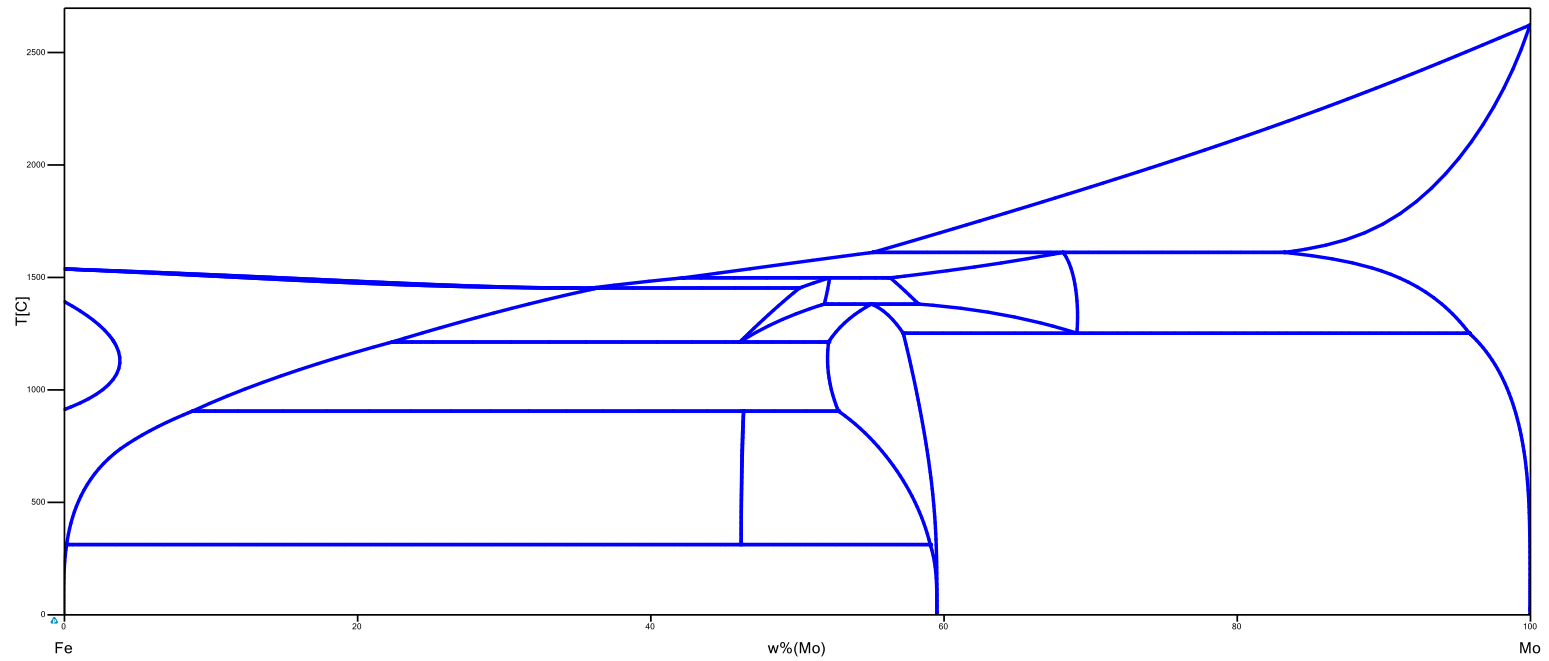


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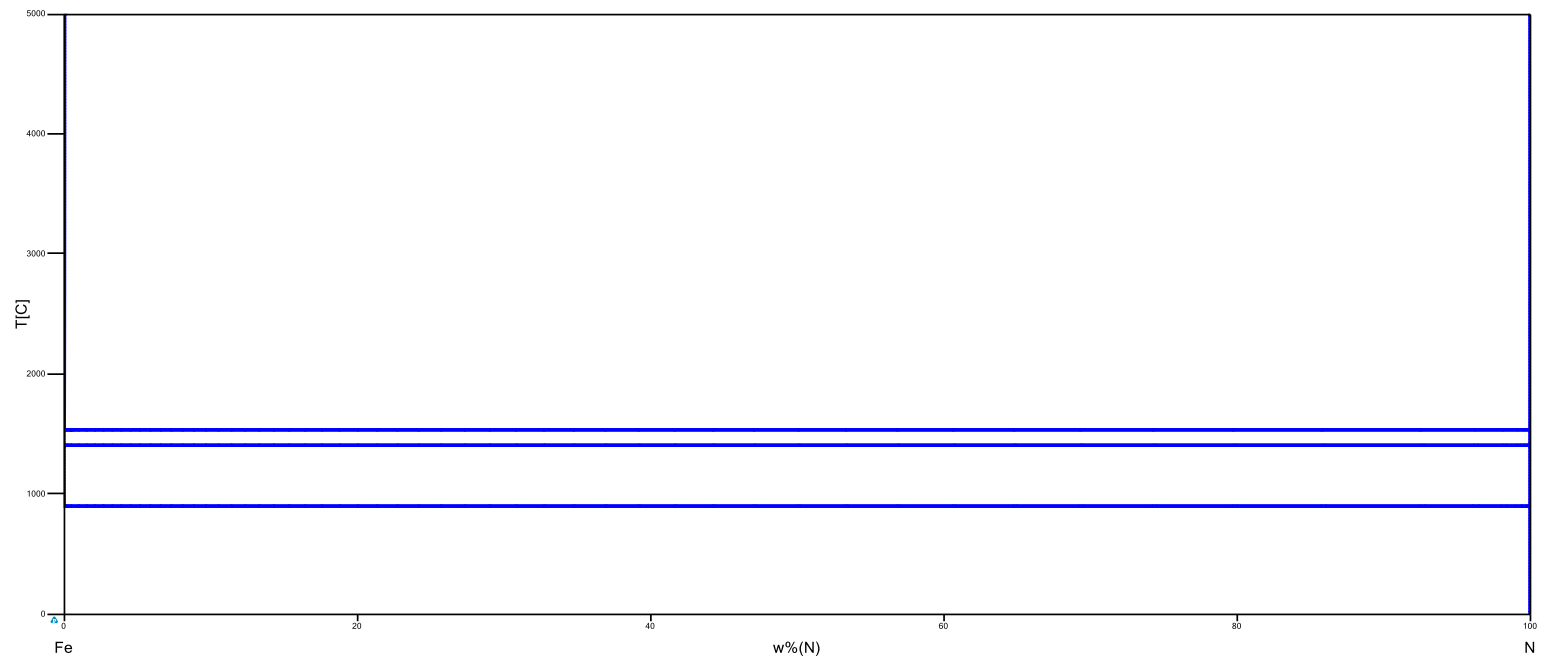
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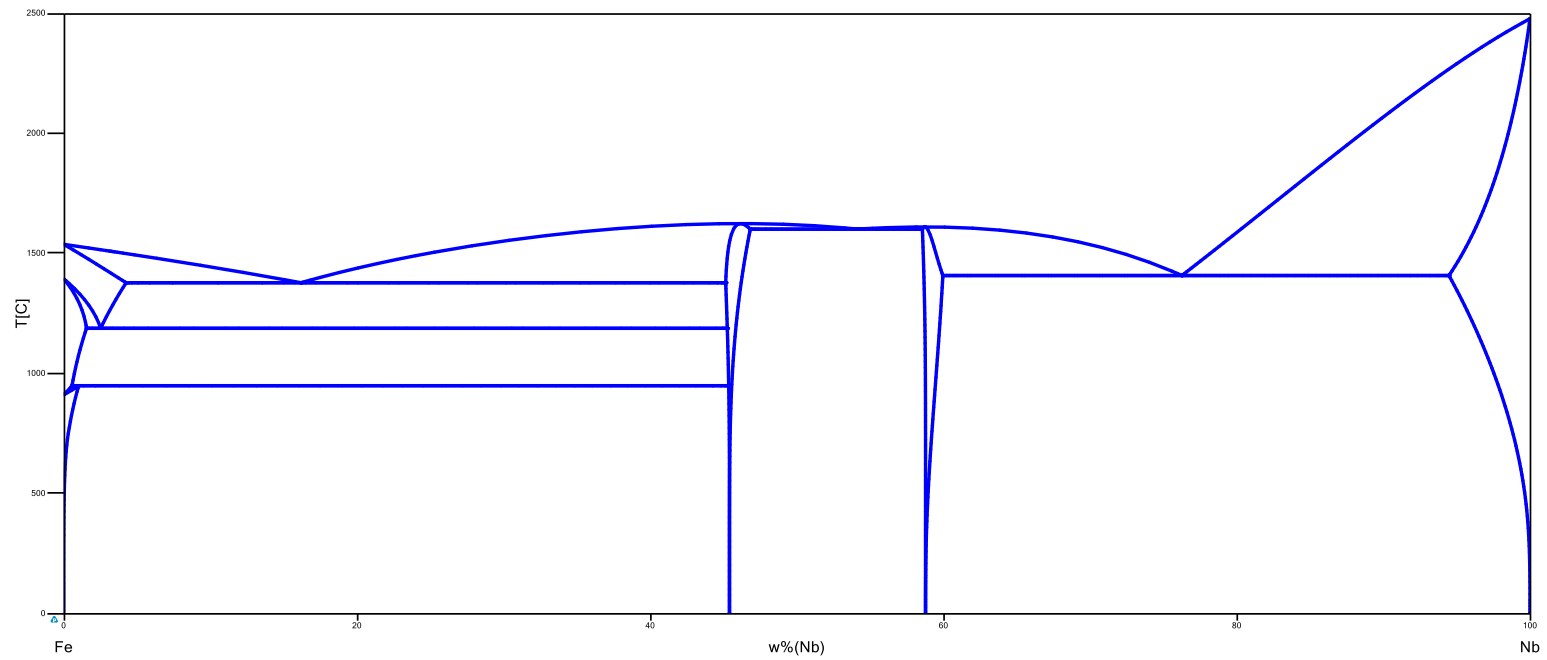
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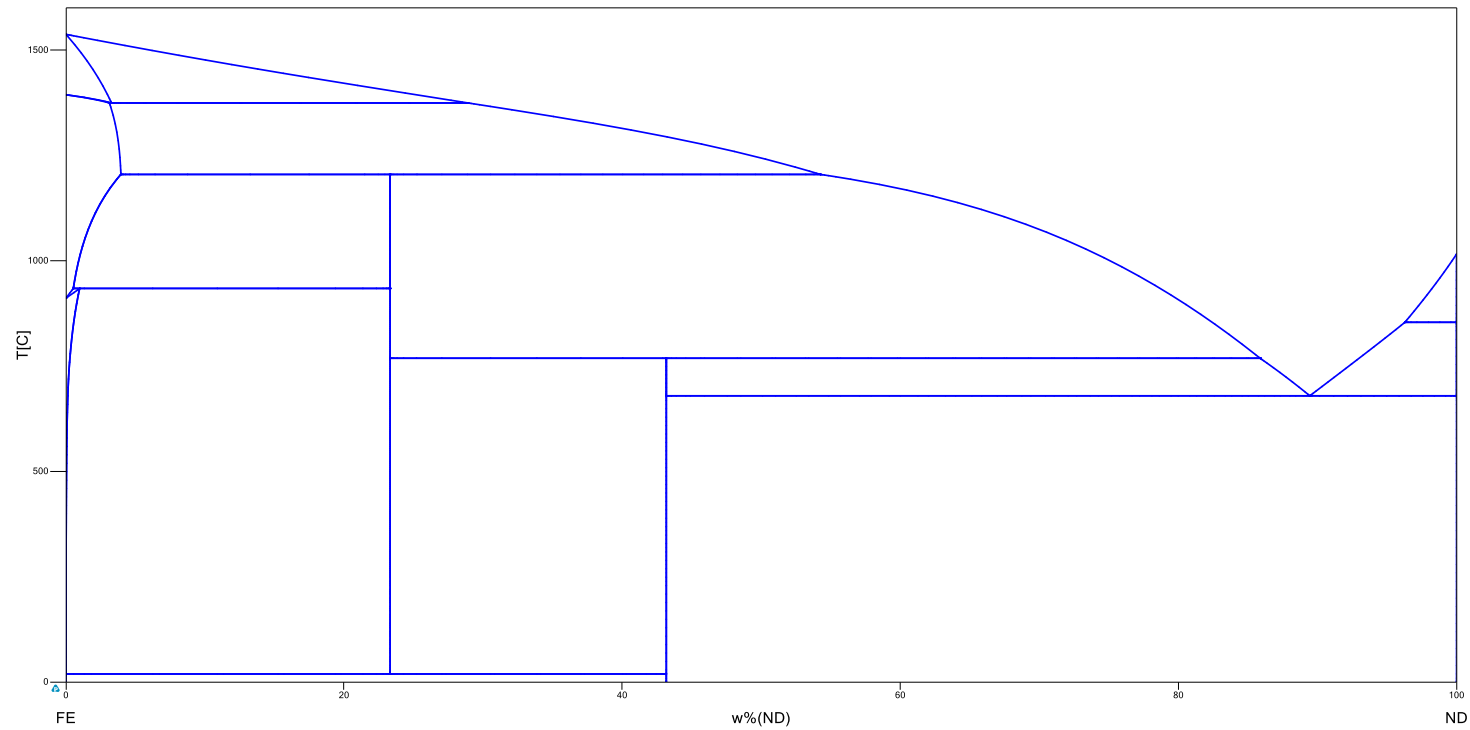
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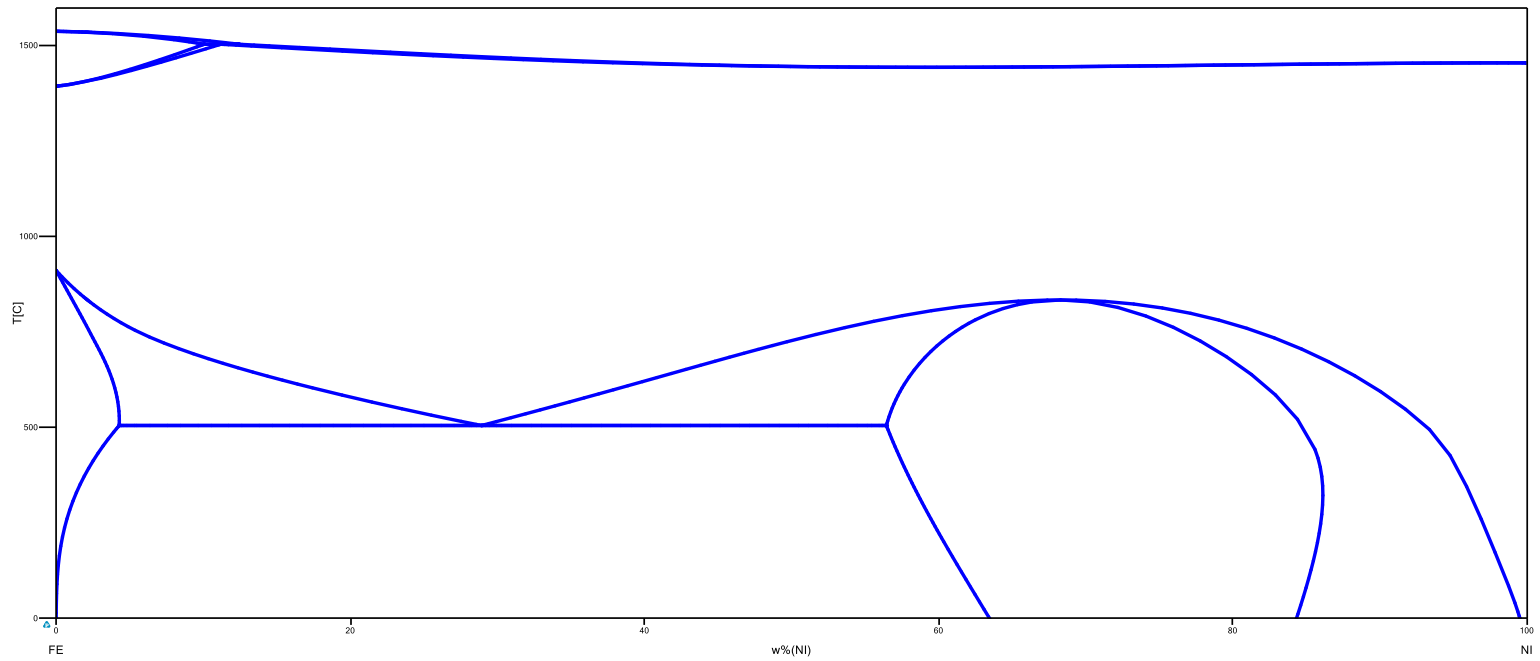
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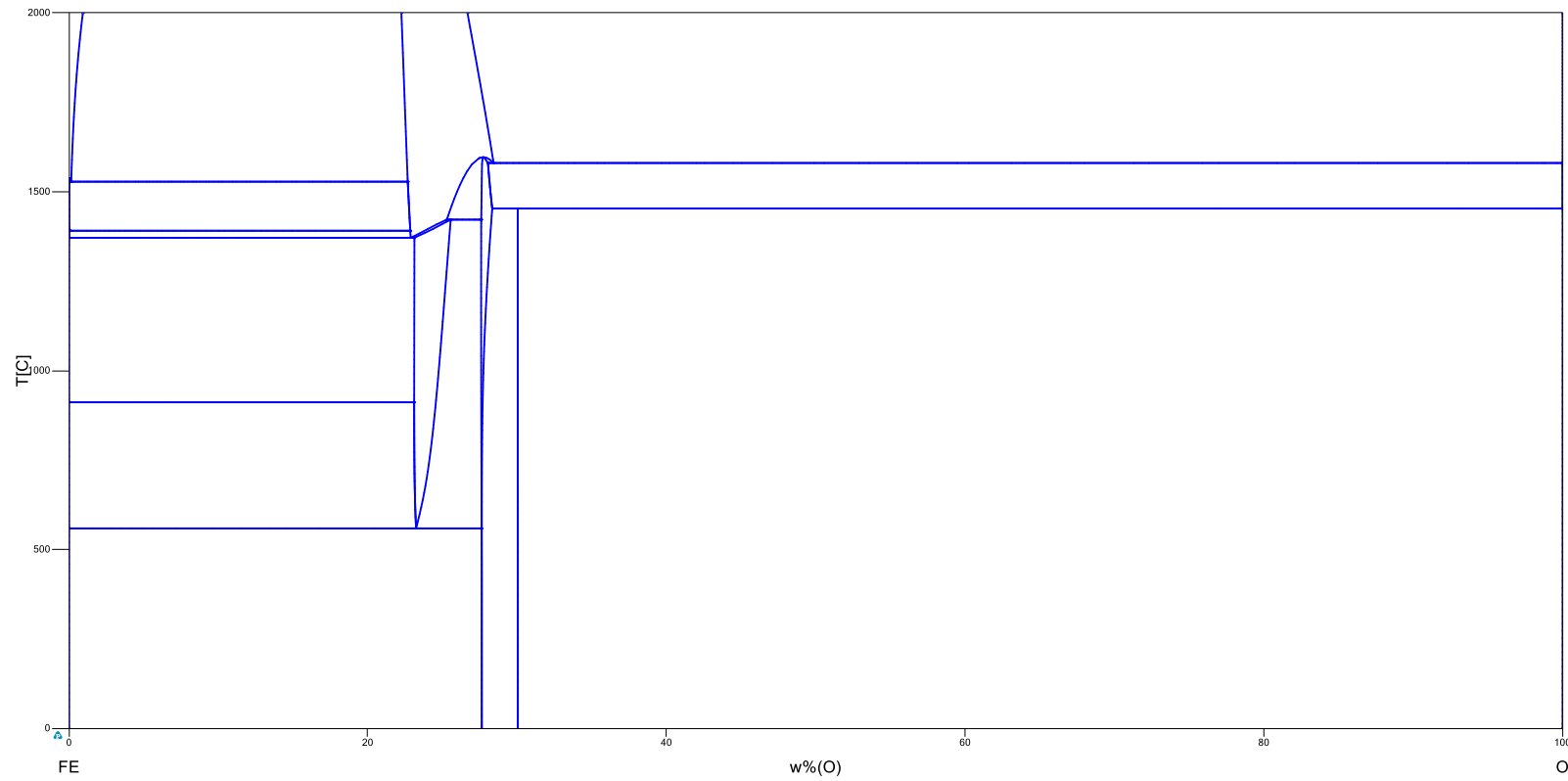
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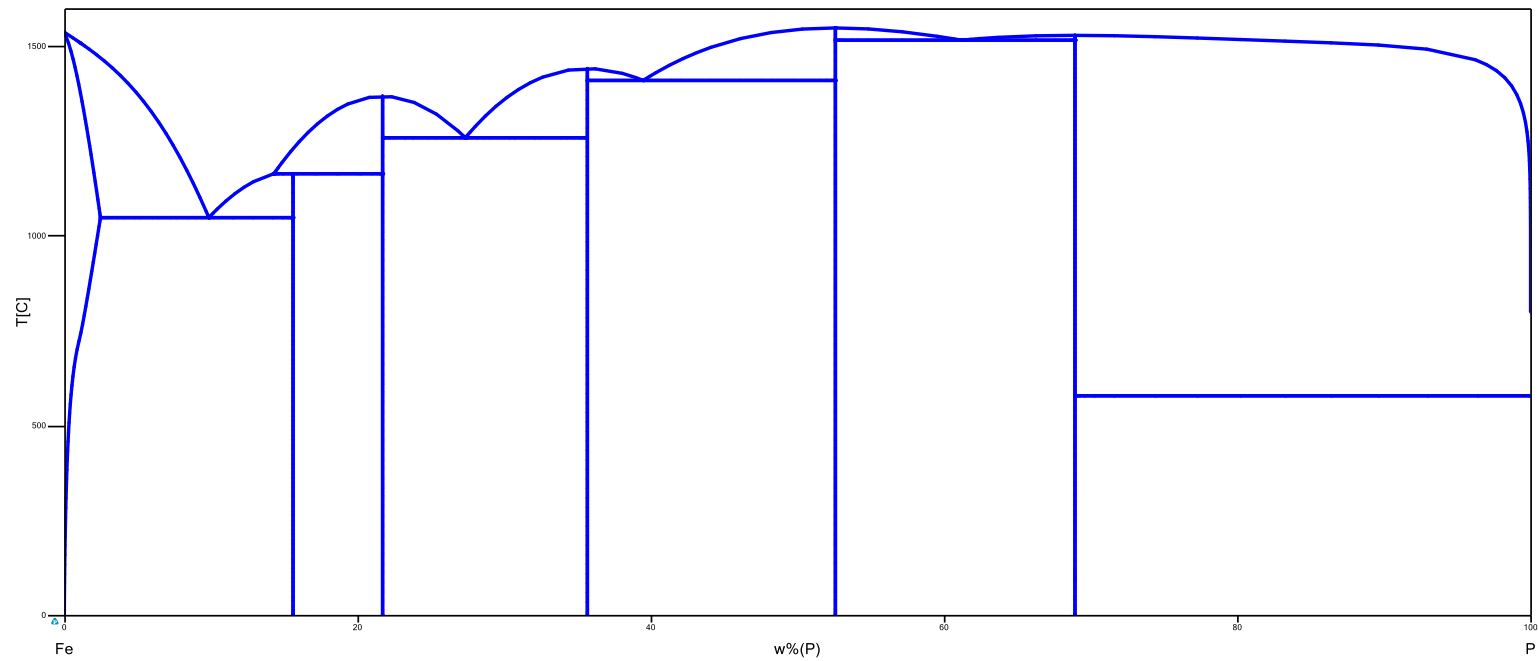
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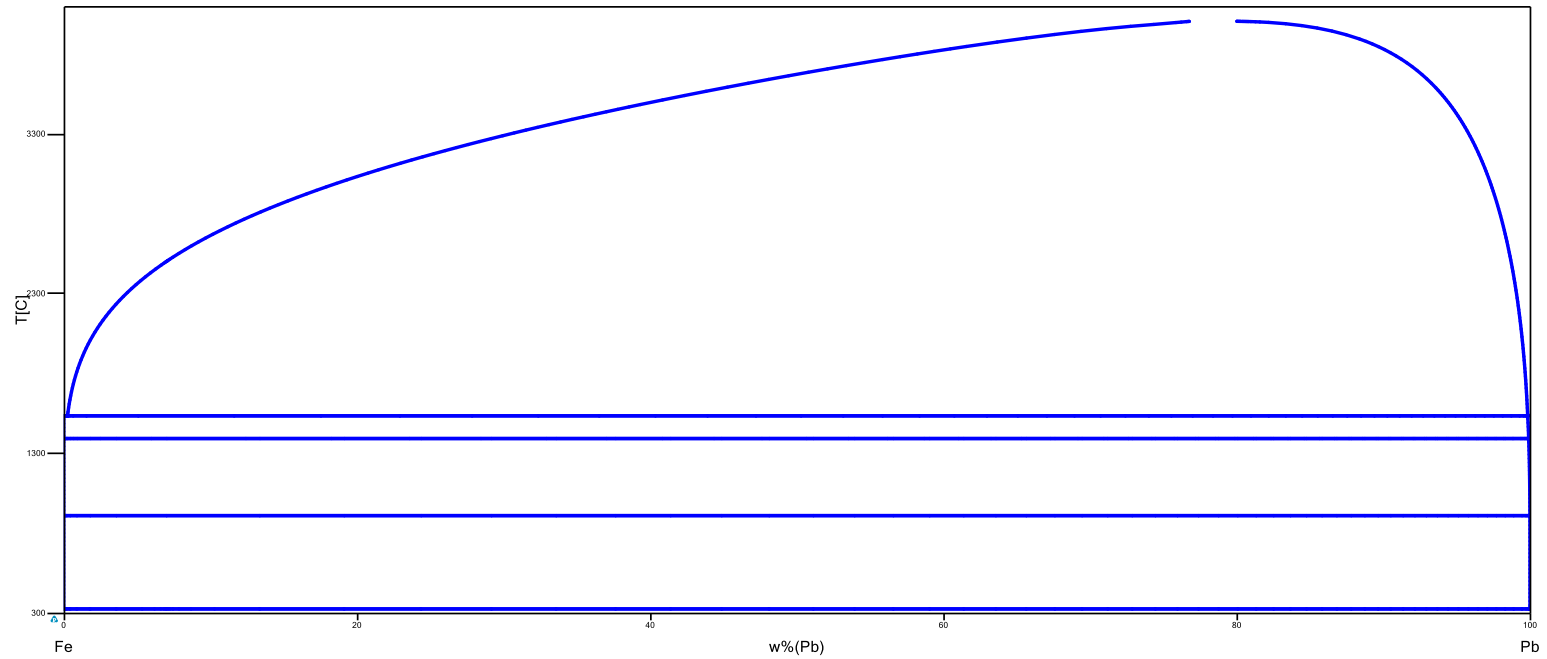


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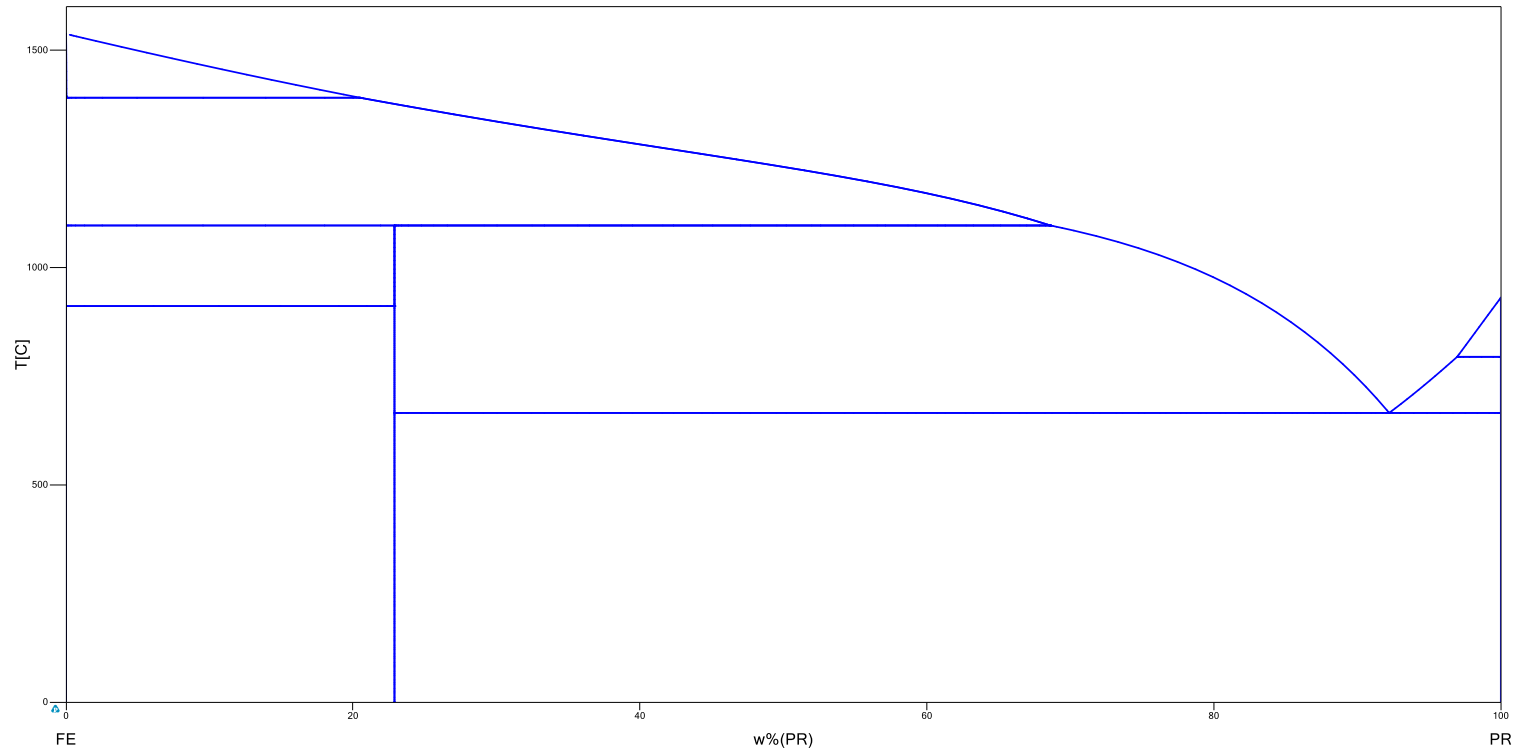
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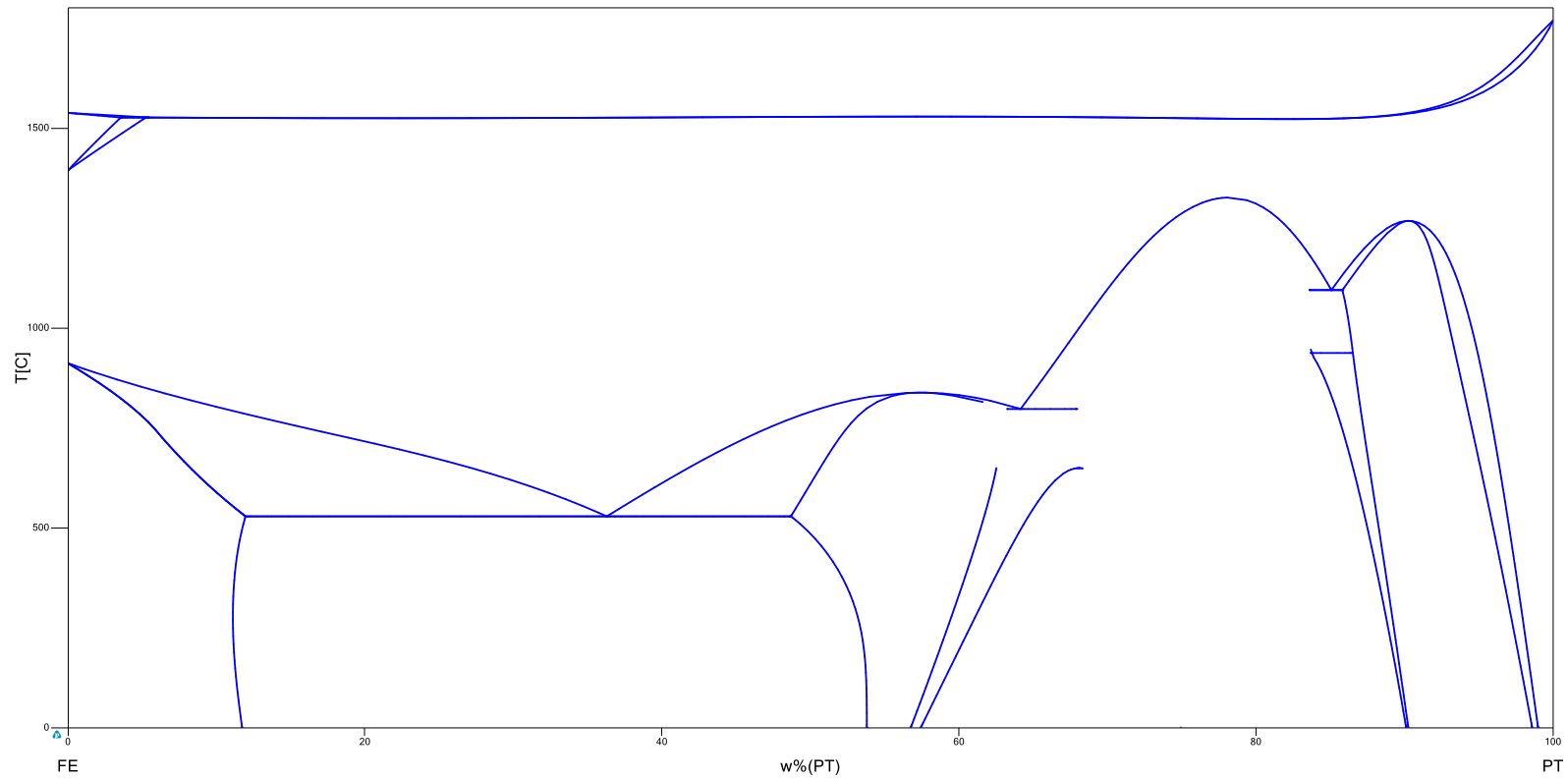
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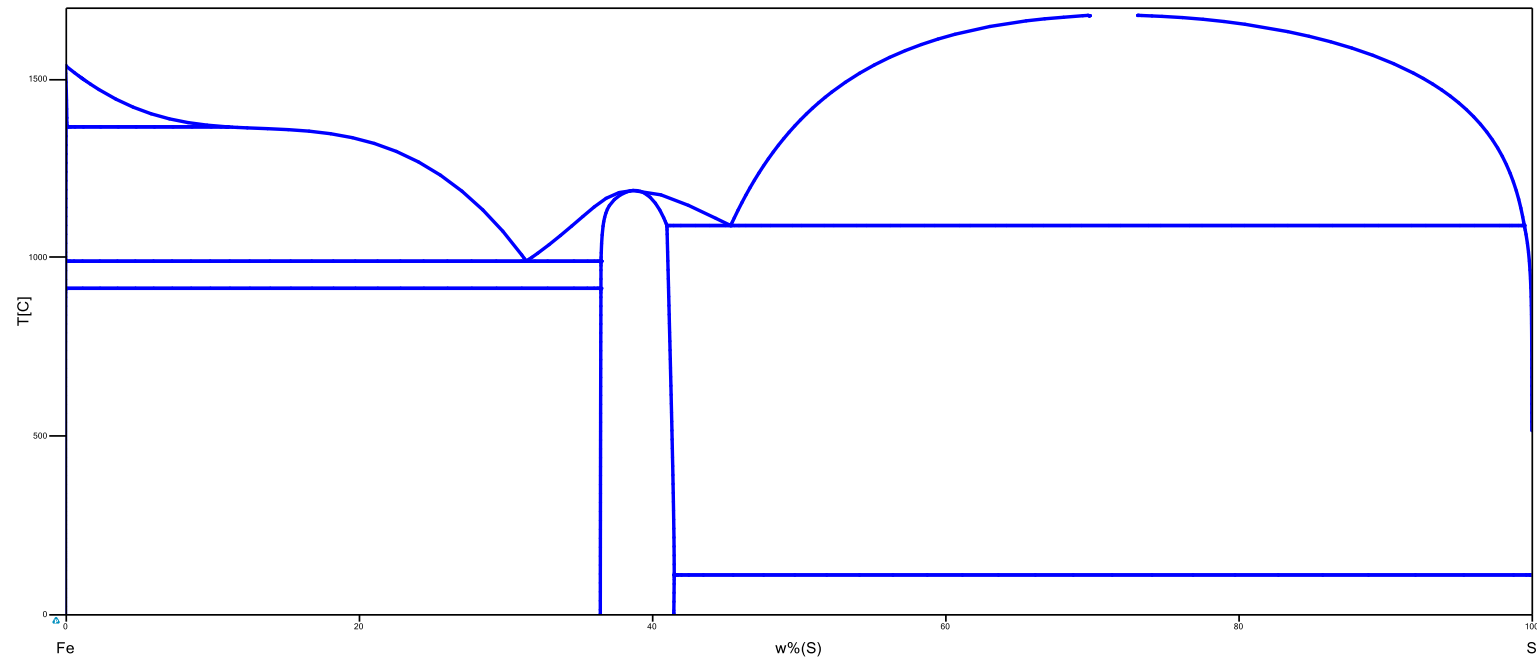
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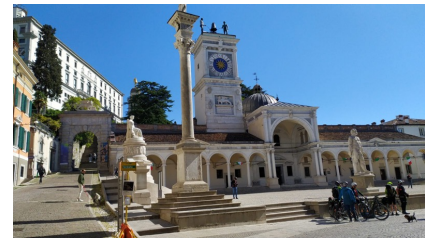
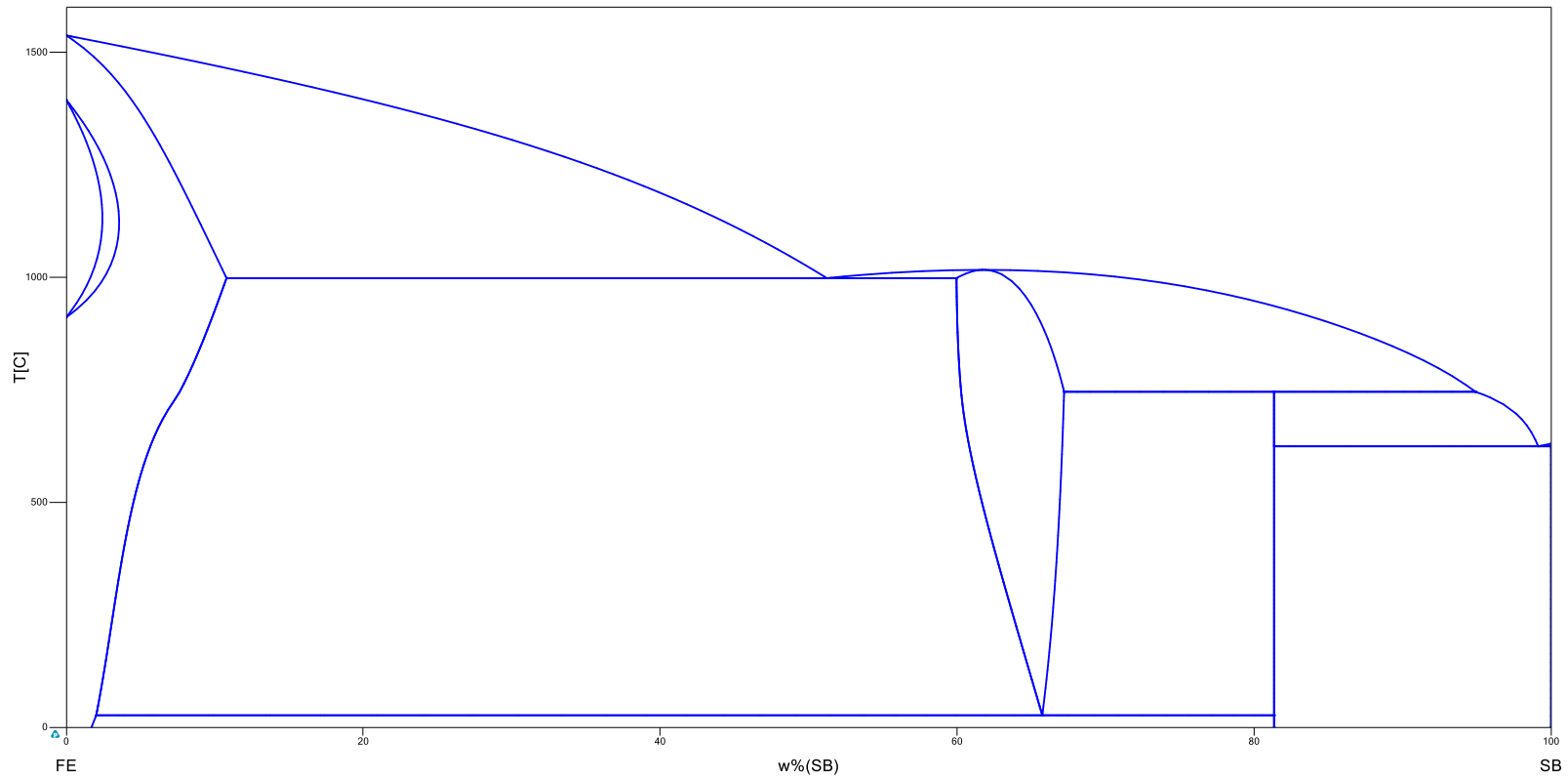
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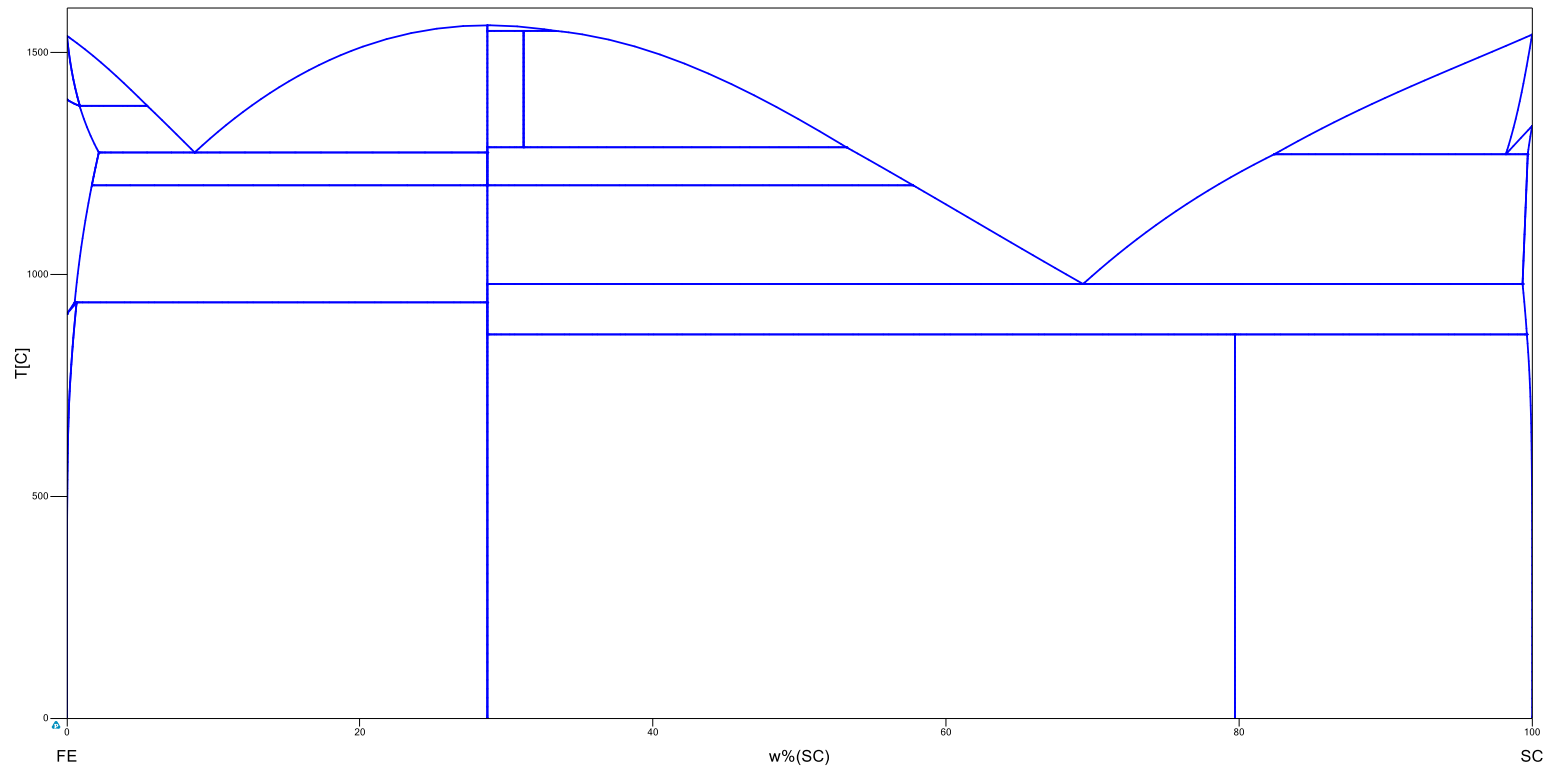
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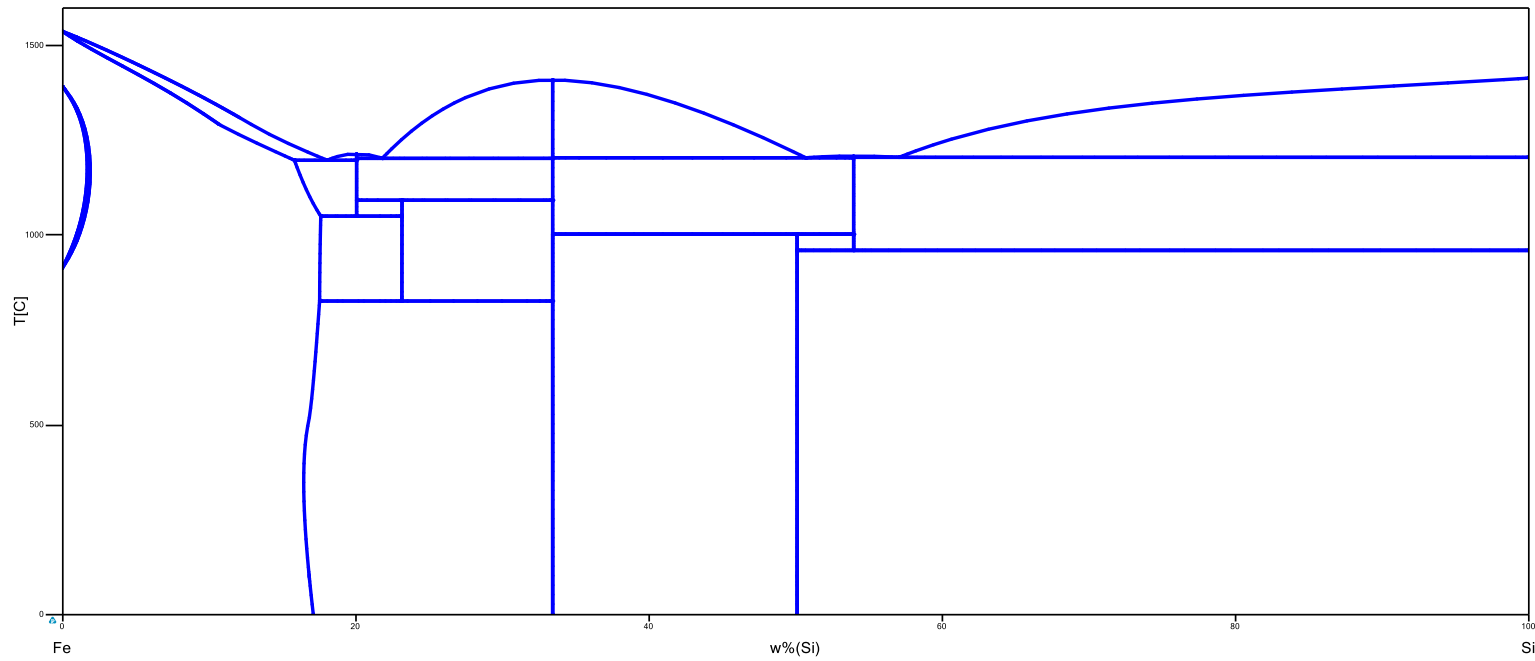
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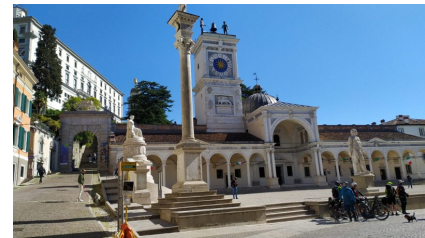
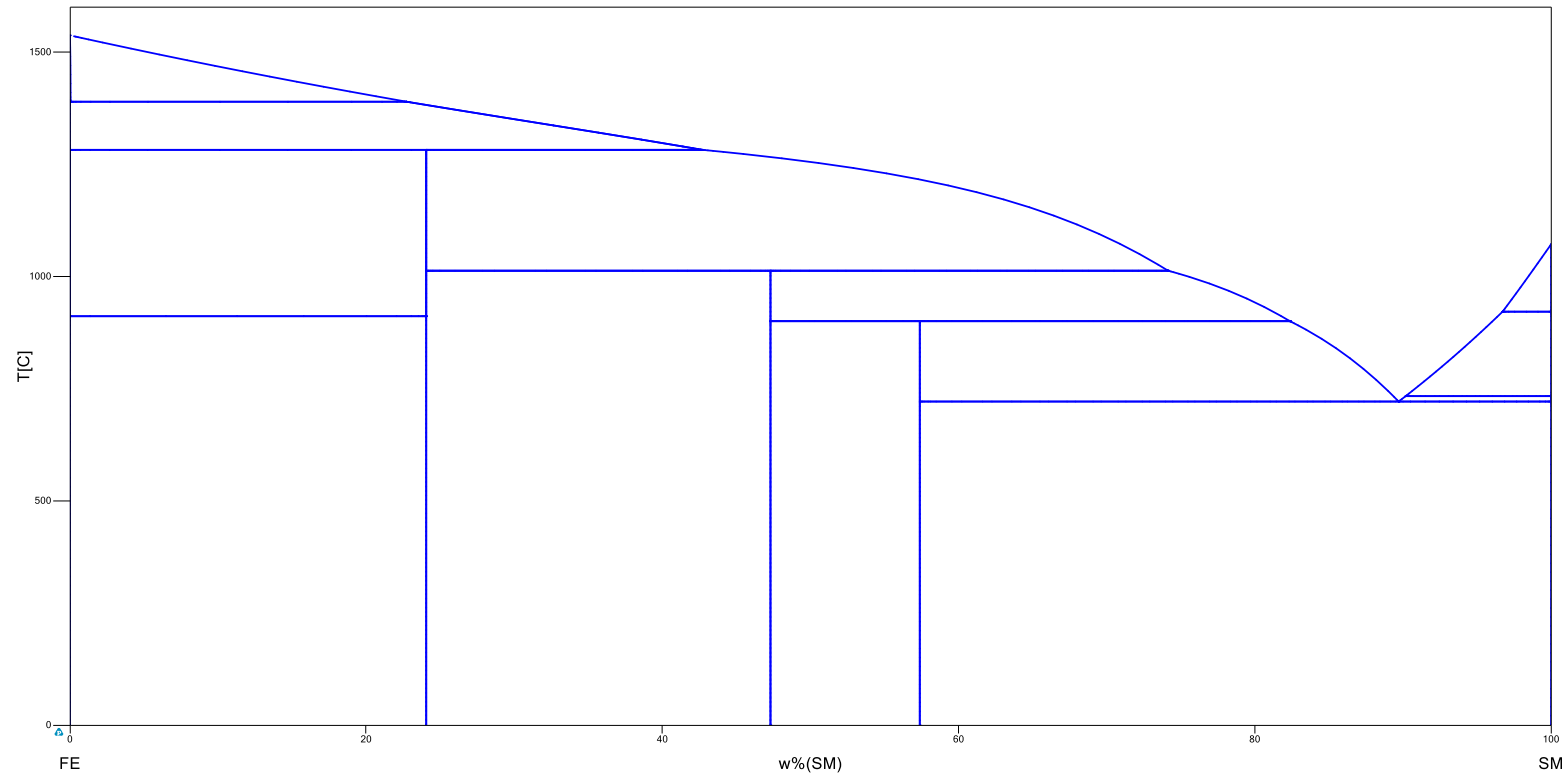
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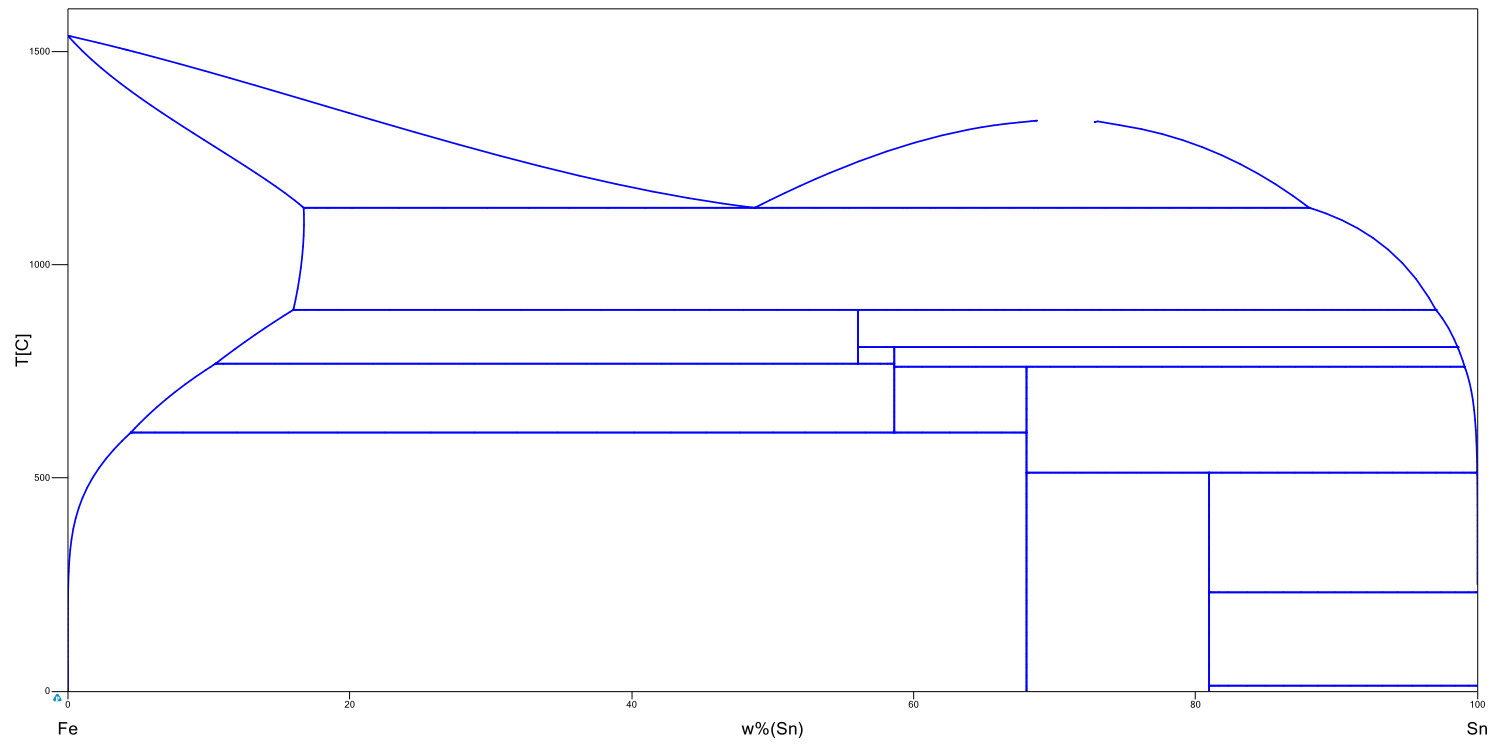
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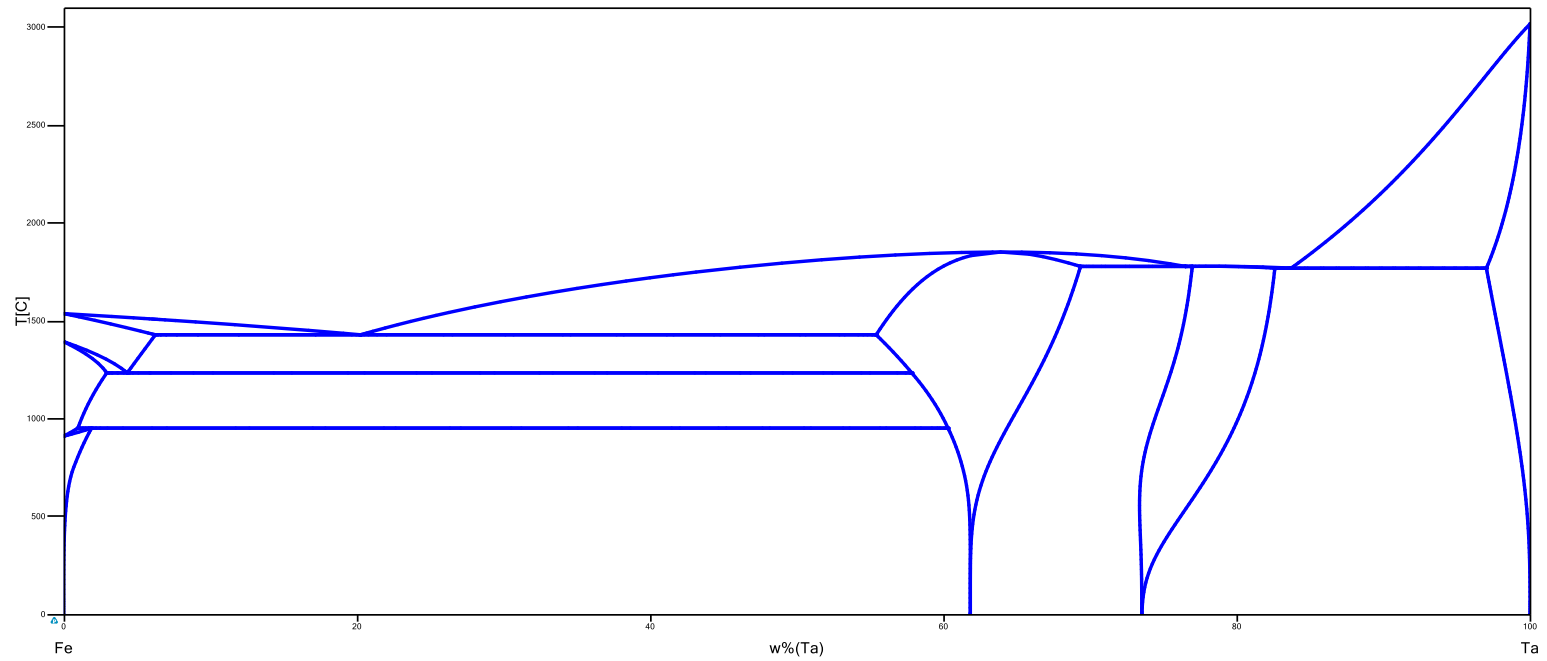


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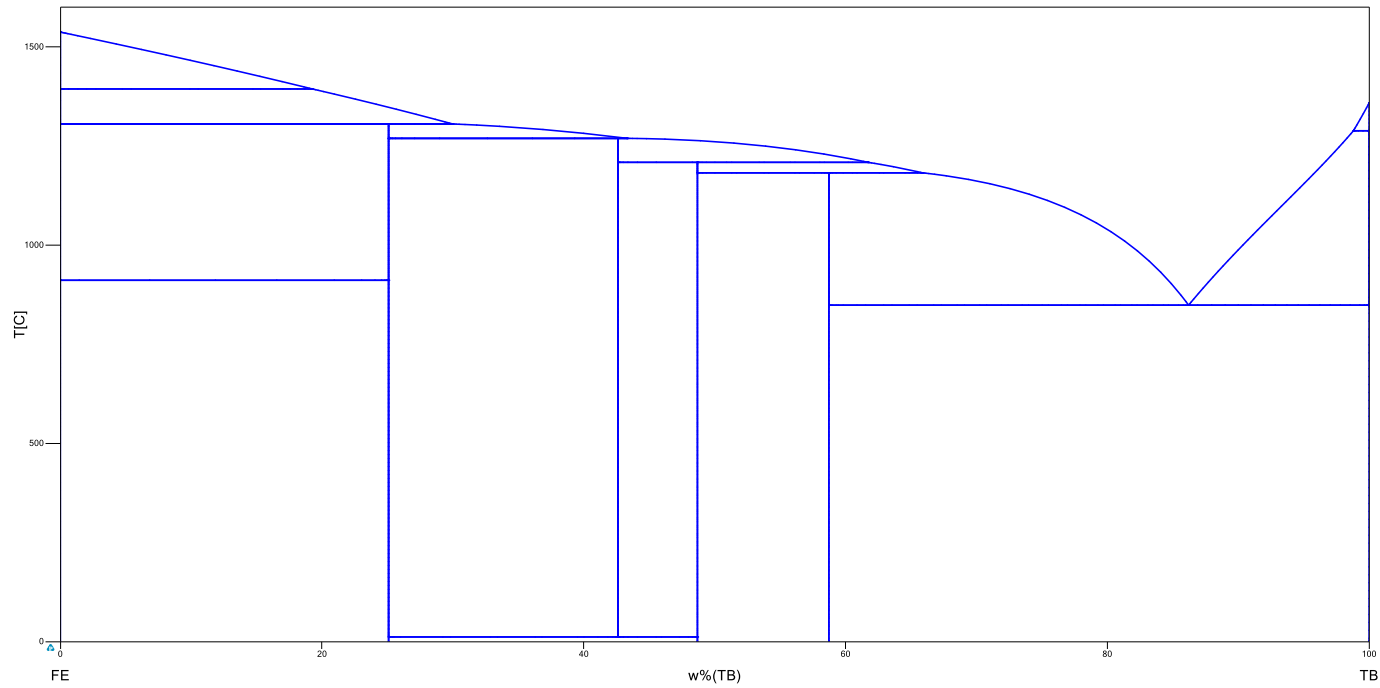
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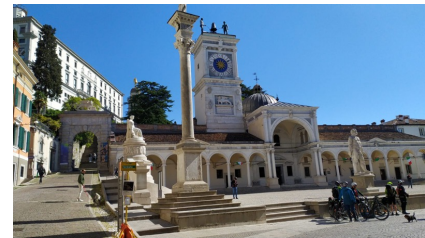
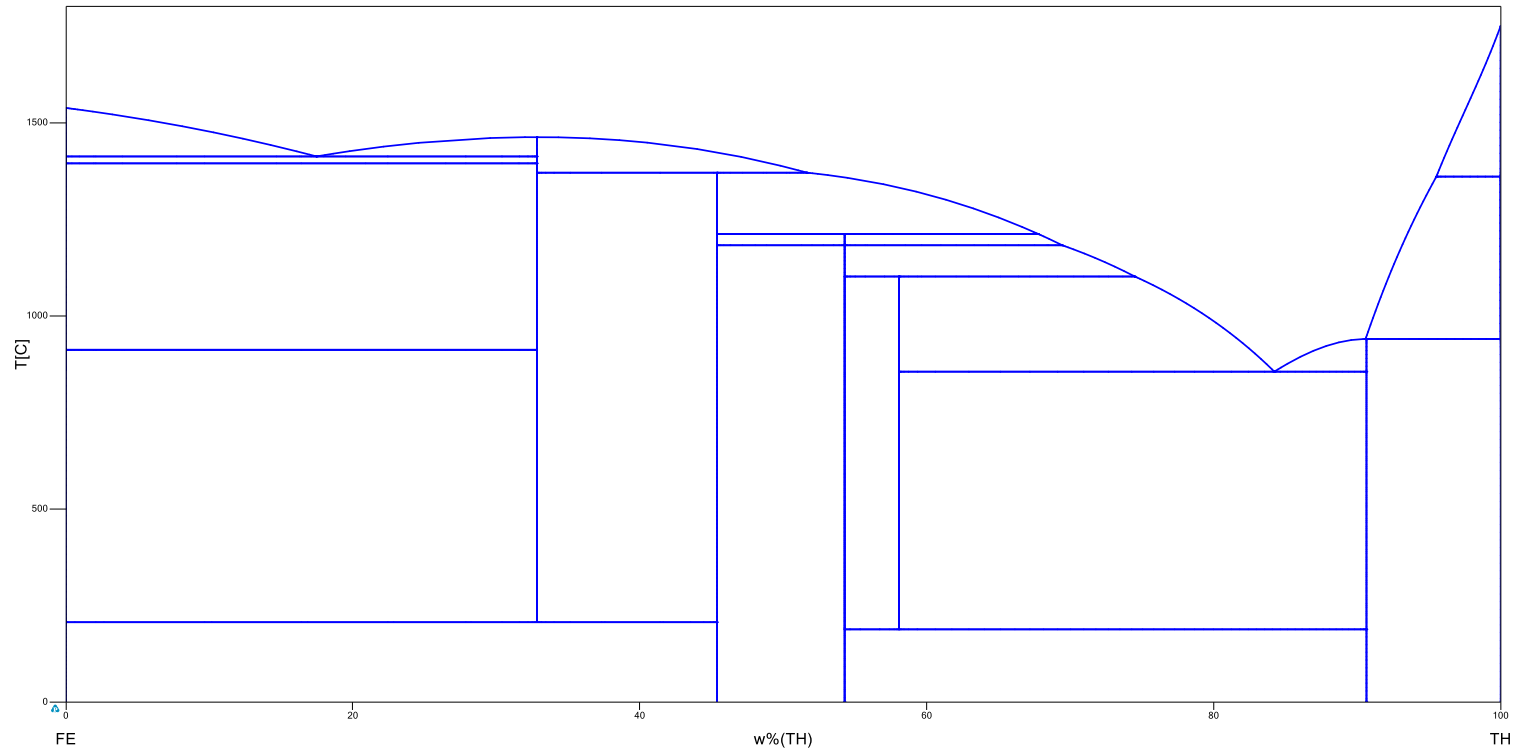
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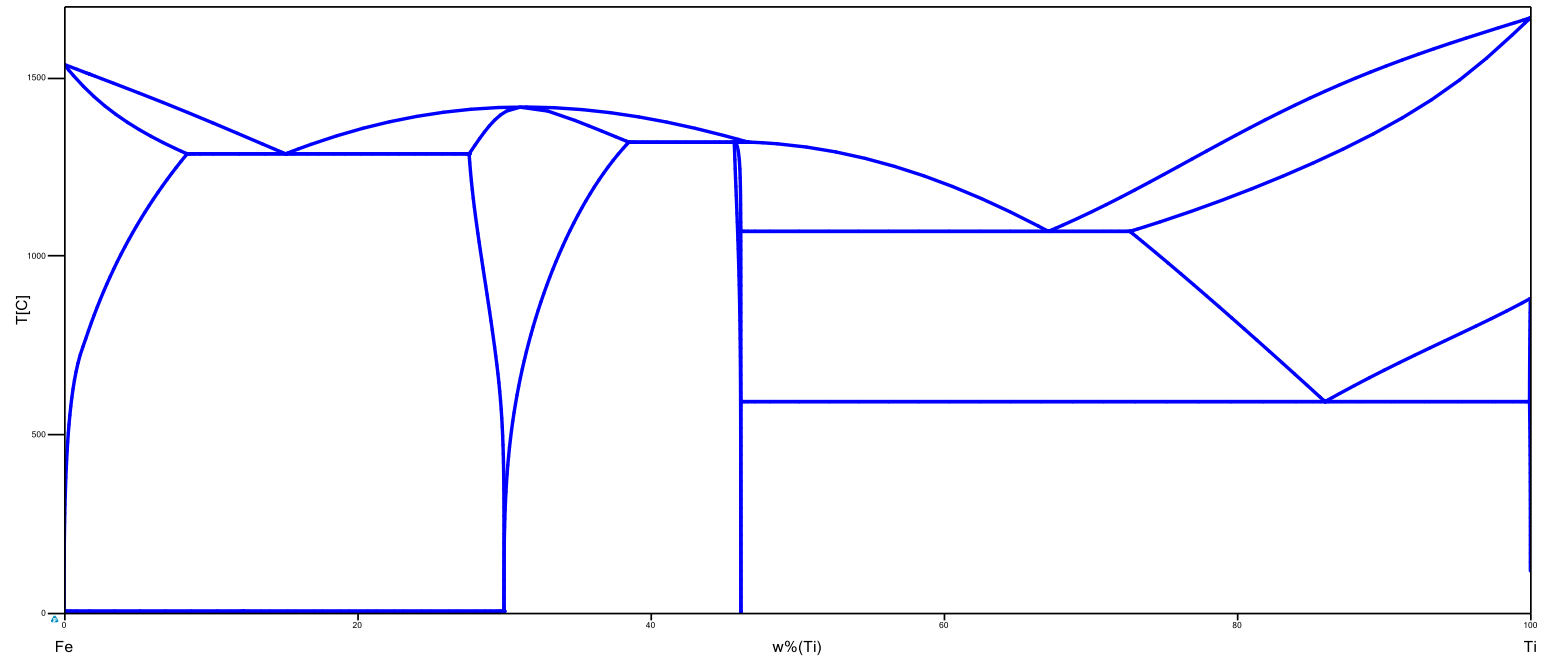
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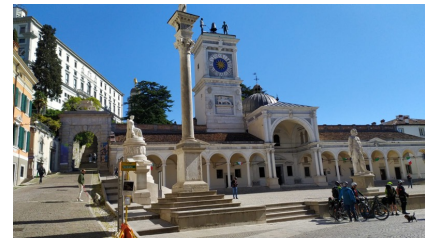
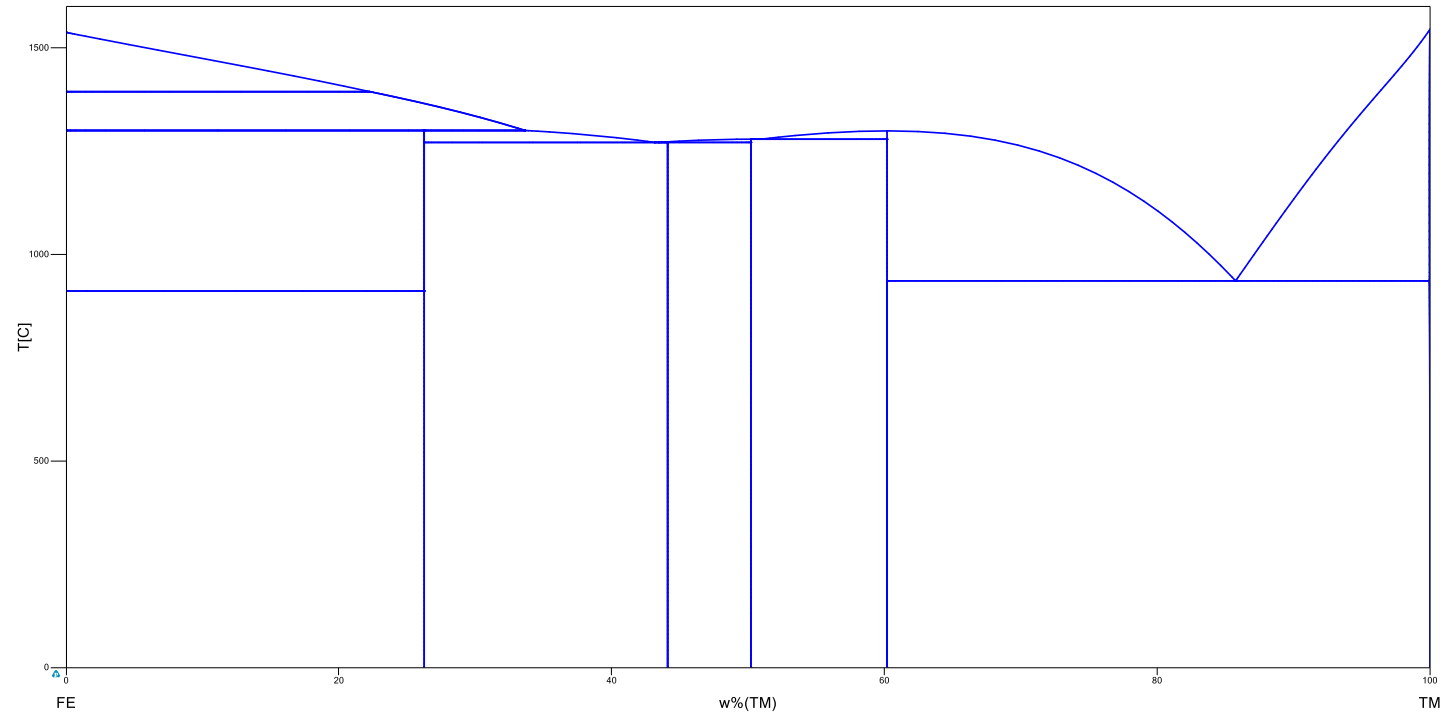
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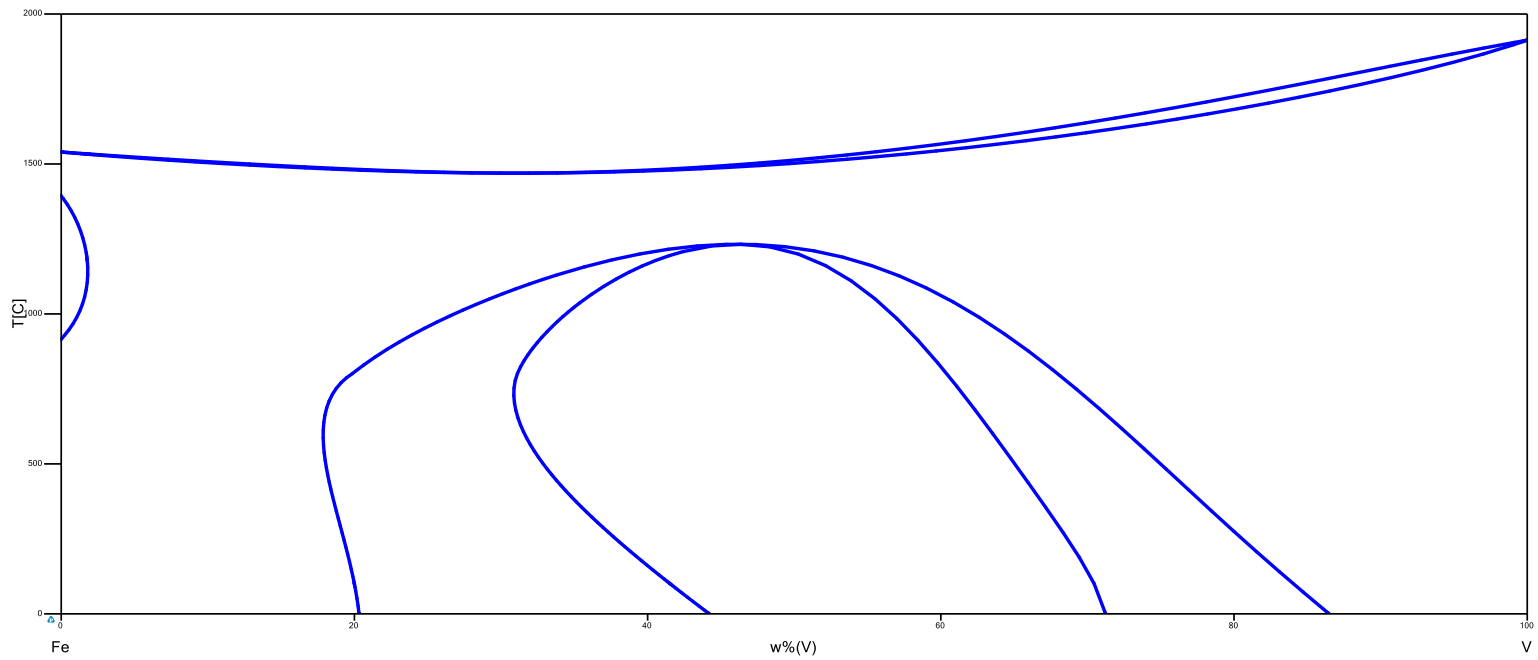
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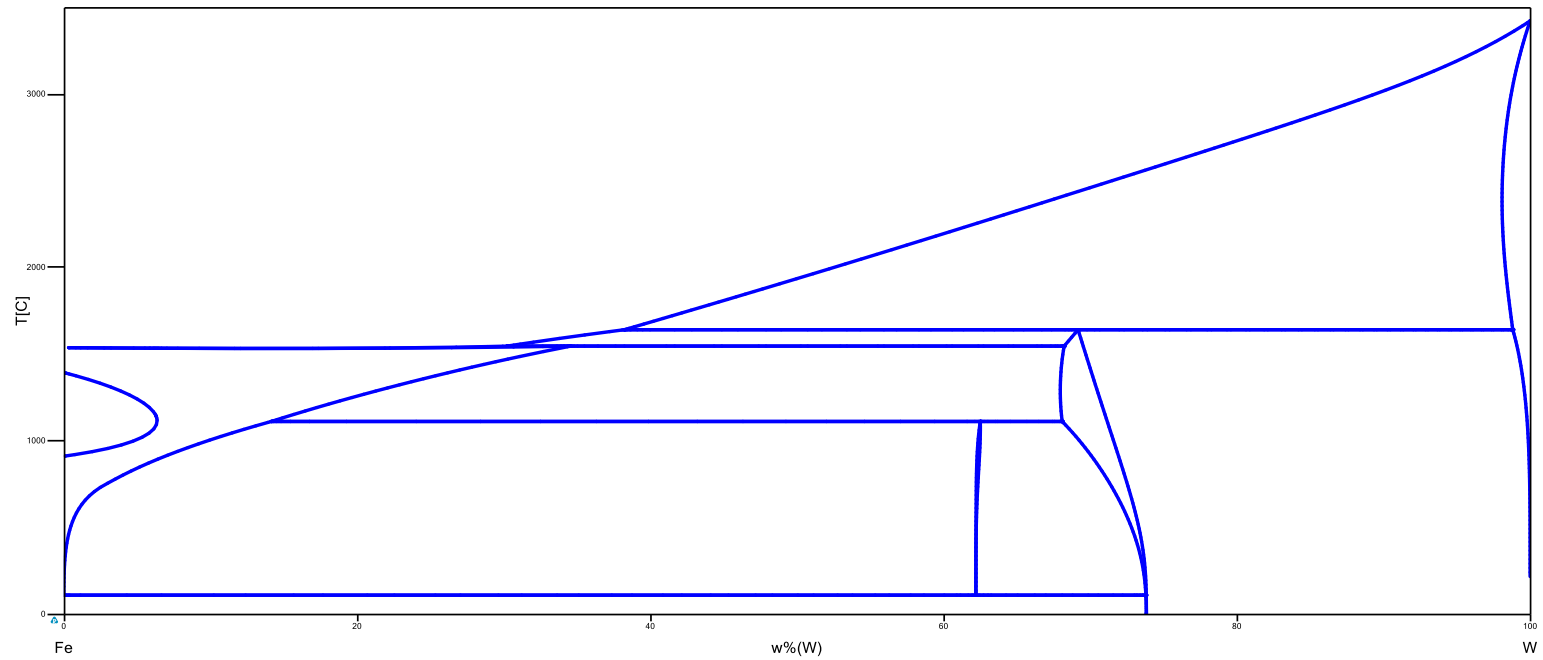


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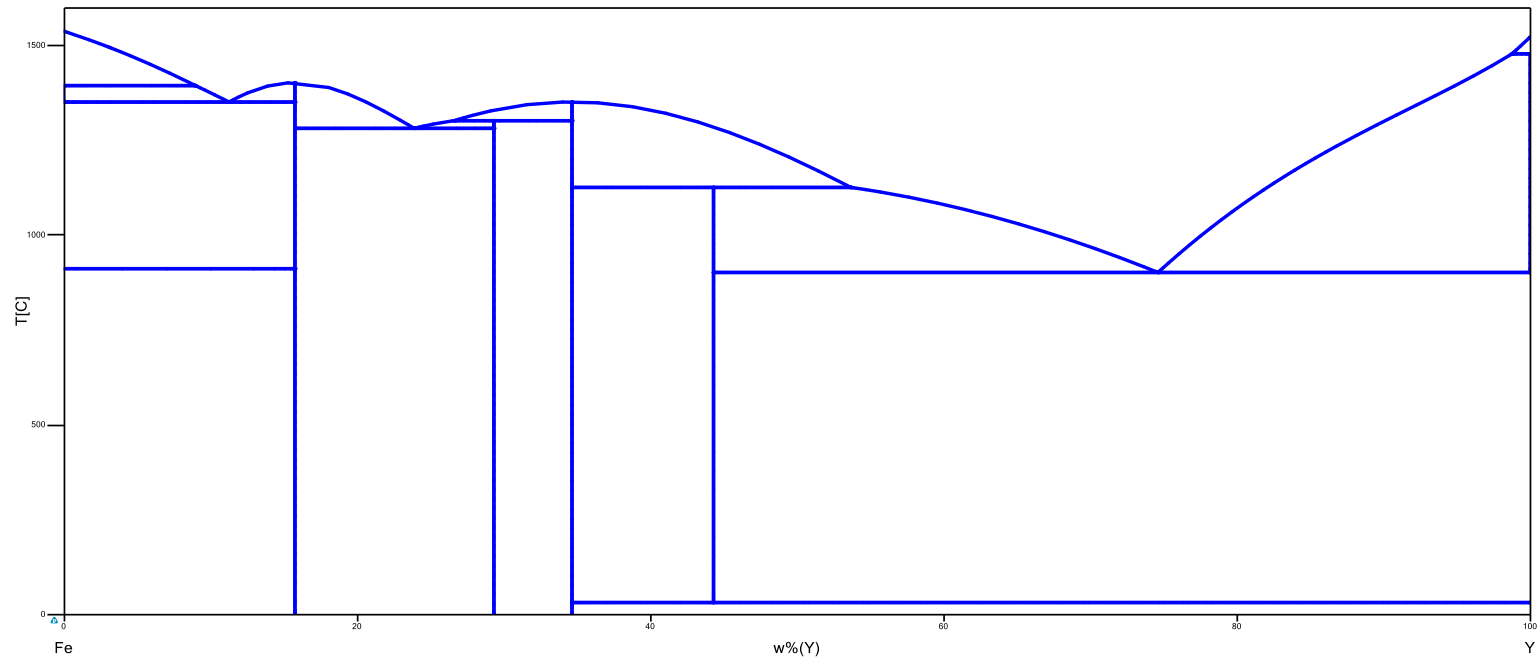


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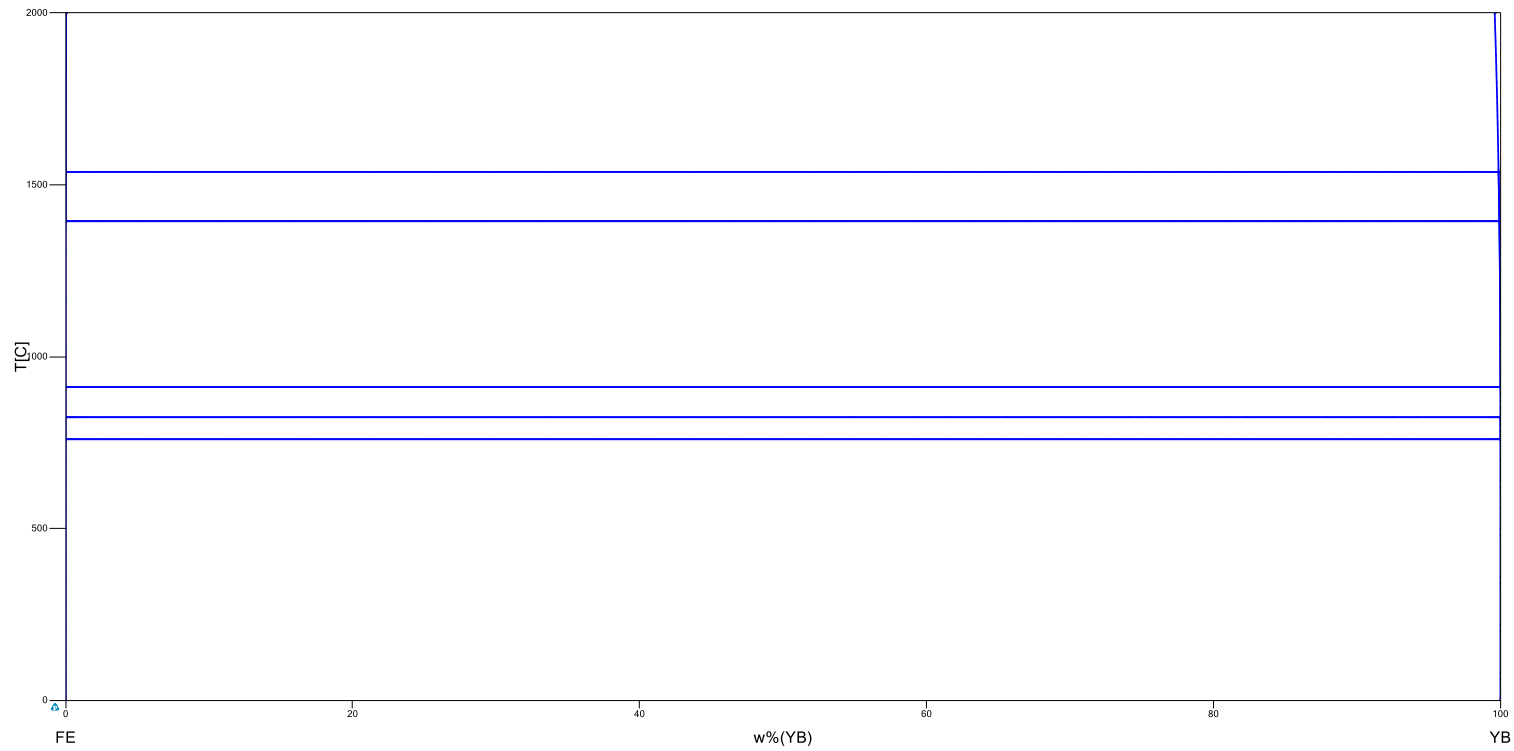
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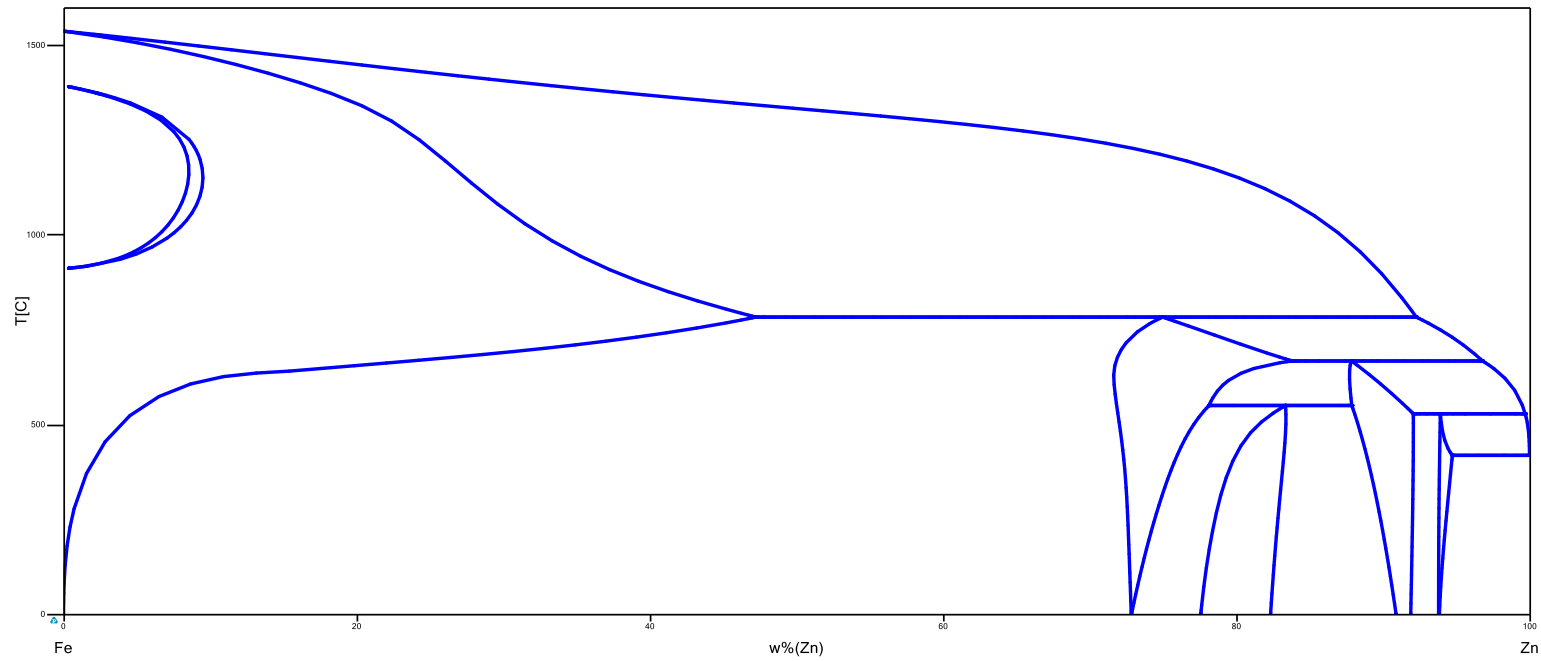
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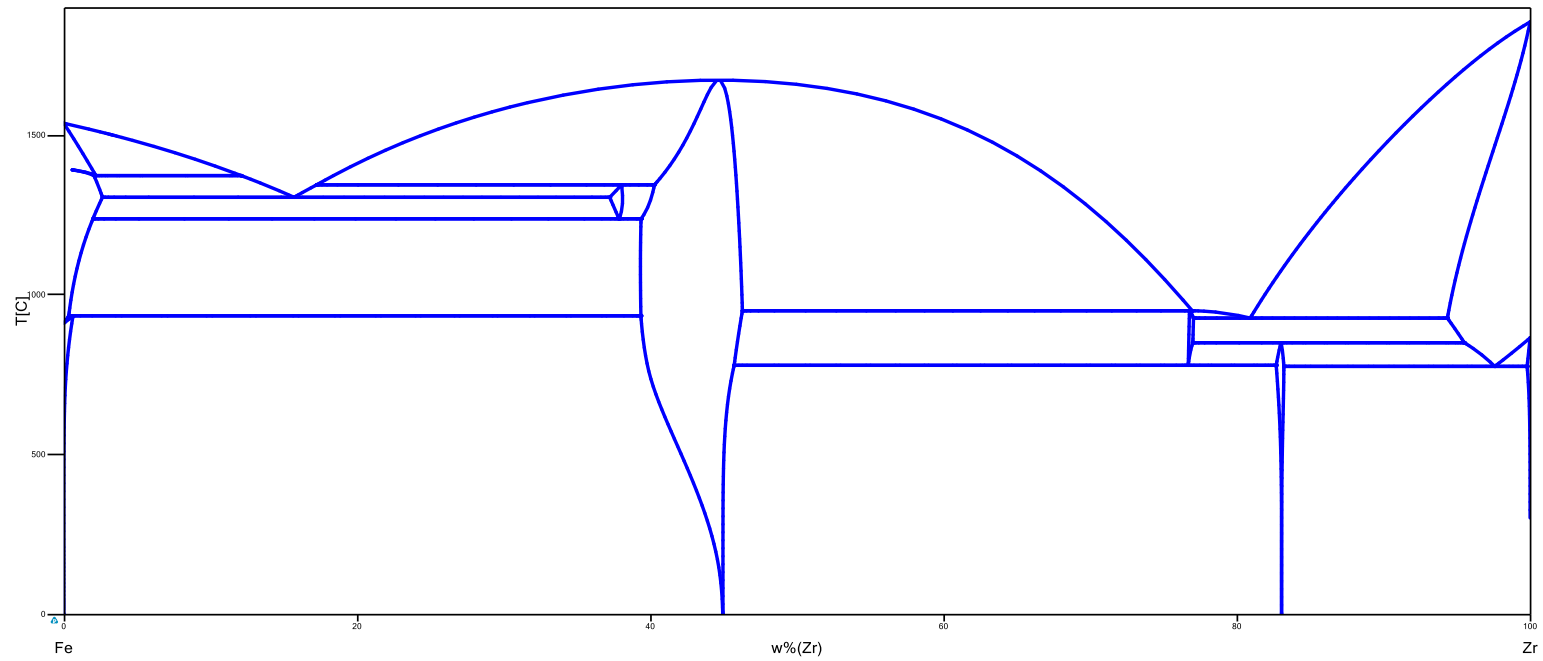
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LPBF and Raboso + Prosecco Tezze di Vazzola, April 19, 2024

My own erratic experience 25 years in LPBF narrative with my personal experience and my current activities

Prehistory 1 – University of Udine, Fiat Research Center Project and other activities

1996: Fabio Miani coordinating R&D Activities for Pometon Metal Powders, Maerne di Martellago (Venice, Italy). Development of Diffusion Bonded Fe powders

1998: A project with CRF Fiat Research Center, University of Udine and Local innovation Agency of an EOS M250

2005: Fabio Miani: paper on Design and optimisation of conformal cooling channels tools currently the one most globally cited in this field

2006: Fabio Miani Collaborating with INGLASS Research Center in Valenzano, Bari for developing injection moulding inserts with an EOS M270

2010: Fabio Miani collaborating with Sisma-Trumpf to design of a new LPBF machine

2015: Fabio Miani co-inventor in an European Patent with Fabio Giolo, IMR of a new metal 3d printing machine

Prehistory 2 - University of Udine and the AIST European Member Chapter – MIT Prof. D. Sadoway AIST John F. Elliott Lecture

May 14 and 15th, 2018 - Two-Day Event Hosting the
AIST - John F. Elliott Lecture

- locally based multinational companies and international researchers working in the iron and steel sector shared several interesting trends and inspiring topics together with a wide and diversified audience.
- the long-awaited moment was the AIST John F. Elliott Lecture, delivered by Prof. Donald R. Sadoway from the Massachusetts Institute of Technology.



Prehistory 2 - University of Udine and the AIST European Member Chapter – MIT Prof. D. Sadoway AIST John F. Elliott Lecture

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Prehistory 2 - University of Udine and the AIST European Member Chapter - AIST John F. Elliott Lecture

- First day was designed especially for undergraduates, offering them the chance to meet with several steel related companies.
- On second day the conference moved inside the Castle of Udine, indeed one of the most emblematic landmarks of the Friuli region
- Lessons learned:
 - students enjoyed participating to the event and organizing it, as they understood the importance of Prof. Donald Sadoway activities.
 - Collaboration with AIST European branch was key - as AIST sponsored Prof. Sadoway's trip with John F. Elliott Lectureship

Prehistory 3 - AIST European Steel Forum 3–5 October 2018 • Loggia del Lionello • Udine, Italy

An international technical and scientific conference on technological innovation for industry 4.0, involving all the most important companies in the metalworking / steel sector in the region



Prehistory 3 - AIST European Steel Forum 3–5 October 2018 • Loggia del Lionello • Udine, Italy

Companies presented to an international audience, but also to our students, the brilliant results obtained from a technological and environmental sustainability point of view

- Cimolai: work in progress for the coverage of the Mineral Park at Arcelor Mittal - Ilva in Taranto, Ferriere Nord the results and
- Ferriere Nord: results and prospects of steel from a circular economy perspective,
- Danieli Automation: DIGI & MET project which has the ambition to revolutionize the world of steel by introducing the new Industry 4.0 approach
- ABS Acciai: innovations with a view to social, economic and environmental sustainability
- Nextema, the winner of the recent startup contest at Innova, the Italian convention on steel innovation

The event included AIST John F. Elliott Lecture, with Kenneth S. Coley, professor and associate dean, McMaster University.

Prehistory 3 - AIST European Steel Forum 3–5 October 2018 • Loggia del Lionello • Udine, Italy

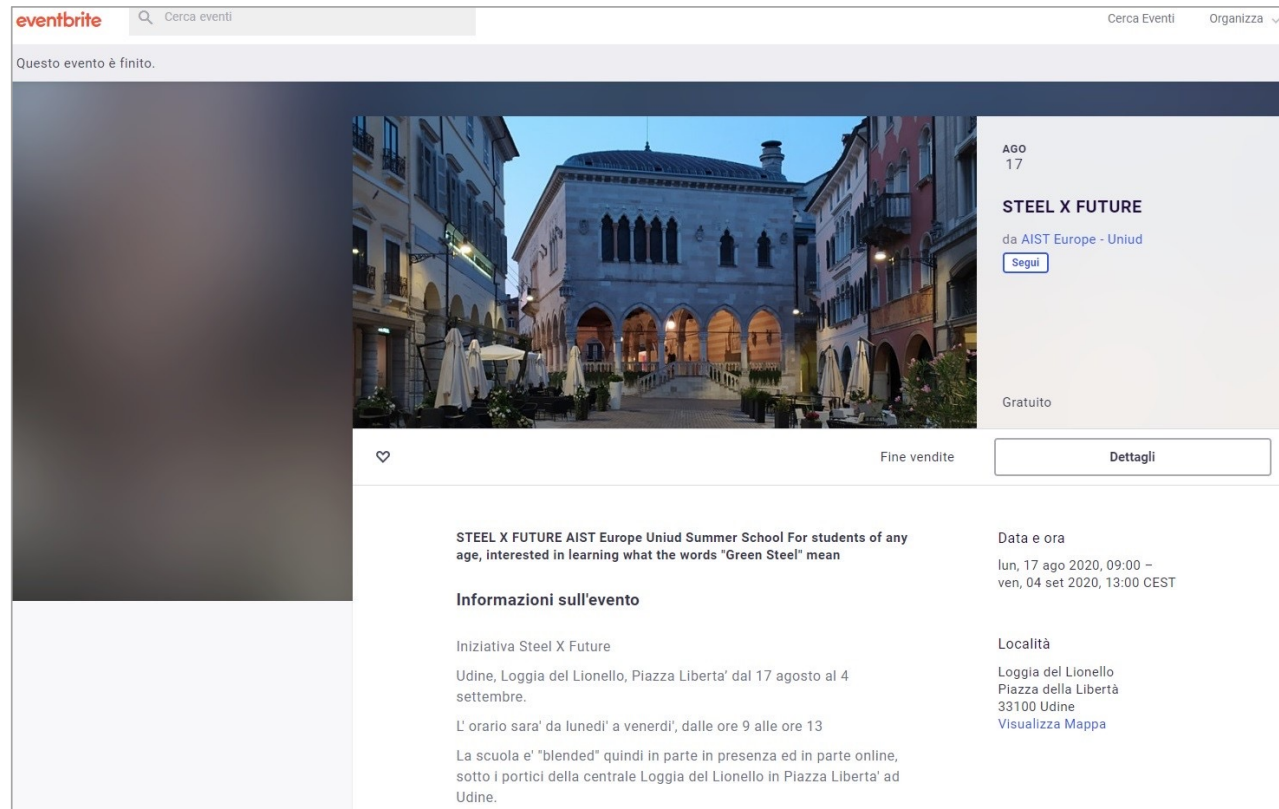
The second day, October 4, was focused on business and includes thematic meetings organized directly by AIST:

- Among the speakers, Axel Sormann (University of Leoben), Marc Bläsing (University of Aachen), Mats W. Lundberg (Sandvik Materials Technology), Christer Ryman (HYBRIT Development AB).
- "Successful case studies", with speakers Mario Llamas, Pelletizing and DRI process manager, Ternium and Stefano Maggiolino, president & CEO, Tenova HYL, Carlo Travaglini , director technology, Gerdau AmeriSteel and Gianluca Maccani , CEO BMGroup USA .
- Focus on "Innovation in steel plant design: a vision to the horizon" and "Women in steel, success stories" with speakers Anna Mareschi Danieli, vice president Danieli & C. Officine Meccaniche Spa and president of Confindustria Udine, Maria Elena Fabiani, CEO of SIME srl, Lisa Karlsson , product line manager Bearing, Ovako, Paola Pedani , sales manager application products Italy & Adriatic Region, Sandvik, Elena Petraskova , VP Subsidiaries and Services, US Steel Košice, sro, Monika Pretorius , managing director by BBD Steel Suppliers.

Prehistory 4 - AIST Uniud Steel X Future Open Air Summer School - August 17 to September 10, 2020

An open-air Summer School
- probably the only one Italy
in the period immediately
recovering from the
Pandemics...

... involving participants
from both University and
Industry



The screenshot shows an Eventbrite event page for 'STEEL X FUTURE'. The event is listed as 'AGO 17' and is 'Gratuito' (free). The event is organized by 'AIST Europe - Uniud'. The event is marked as 'Questo evento è finito.' (This event is finished). The event details include the date and time: 'Lun, 17 ago 2020, 09:00 - ven, 04 set 2020, 13:00 CEST'. The location is 'Loggia del Lionello, Piazza della Libertà, 33100 Udine'. The event description states: 'STEEL X FUTURE AIST Europe Uniud Summer School For students of any age, interested in learning what the words "Green Steel" mean'. The event is described as 'blended' and will take place in the Loggia del Lionello in Piazza Libertà in Udine.



Prehistory 4 - AIST Uniud Steel X Future Open Air Summer School - August 17 to September 10, 2020


- AIST European Member
Chapter <https://www.aist.org/local-member-chapters/find-a-chapter/european/chapter-history/>
- Atanor, Udine Italy - <https://sites.google.com/atanor-materials.com/atanor-materials/home>
- ABS Acciai, Udine Italy <http://www.absacciai.it/>
- ACM ABS Acciai Metz France <http://www.abscm.fr/>
- Municipality of Udine, Italy <https://www.comune.udine.it/>
- Danieli Metallics Udine Italy <https://www.danieli.com/>
- Ergolines, Trieste Italy <https://www.ergolines.it/>
- Exone, Germany <https://www.exone.com/de-DE>
- Italian Embassy in Berlin, Germany
https://ambberlino.esteri.it/ambasciata_berlino/it/ambasciata/gli_uffici/gli%20uffici.html
- LIMA Corporate, Udine Italy <https://limacorporate.com/>
- Quaker Italy <https://it.quakerchem.com/>
- SIME Automation, Udine, Italy <http://www.simeautomation.com/it/>
- Regional Centre of Advanced Technologies and Materials, Czech Republic <https://www.rcptm.com/>
- Scafom-rux, Netherlands <https://www.scafom-rux.com/>
- Tenova Energiron, Mexico City <https://www.energiron.com/>
- La Sapienza University of Rome, Italy
<https://www.uniroma1.it/it/pagina-strutturale/home>

Prehistory 4 - AIST Uniud Steel X Future Open Air Summer School - August 17 to September 10, 2020

- Lessons Learned:
 - Probably the open-air choice in historical buildings is NOT the best for summer schools, too noisy indeed
 - students enjoyed hands on activities on 3d printing, which were carried out in Atanor Materials
 - presentations, comments and suggestions by prof. Alberto Boschetto and prof. Luana Bottini were indeed very much appreciated



Current tentative program for the Steel X Future Initiatives for the year 2022

- February & March → [Steels course by prof HDKH Bhadeshia Emeritus Tata Steel Professor of the University of Cambridge](#) 
- June → Rome (University La Sapienza, professors Alberto Boschetto and Luana Bottini)
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Current tentative program for the Steel X Future Initiatives for the year 2022

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LPBF Fundamentals

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Defects and anomalies in powder bed fusion metal additive manufacturing 

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- *Department of Mechanical Engineering, University of Wisconsin-Madison, Madison, WI 53706, USA l NextManufacturing Center, Carnegie Mellon University, Pittsburgh, PA 15213, USA*



LPBF Fundamentals

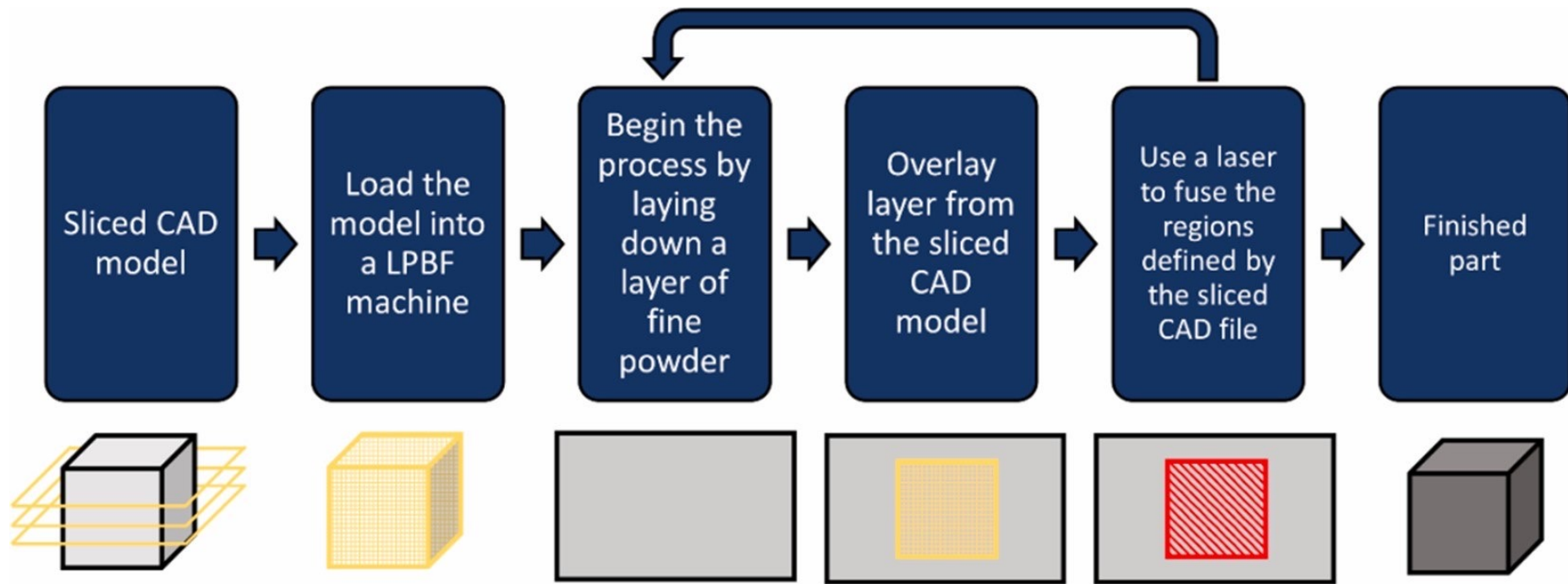
Keywords:

Additive manufacturing Powder-related defects
Processing-related defects
Post-processing-related defects
Defect mitigation
Process-structure-property relationship

Metal additive manufacturing is a disruptive technology that is revolutionizing the manufacturing industry. Despite its unrivaled capability for directly fabricating metal parts with complex geometries, the wide realization of the technology is currently limited by microstructural defects and anomalies, which could significantly degrade the structural integrity and service performance of the product. Accurate detection, characterization, and prediction of these defects and anomalies have an important and immediate impact in manufacturing fully- dense and defect-free builds. This review seeks to elucidate common defects/anomalies and their formation mechanisms in powder bed fusion additive manufacturing processes. They could arise from raw materials, processing conditions, and post-processing. While defects/anomalies in laser welding have been studied extensively, their formation and evolution remain unclear. Additionally, the existence of powder in powder bed fusion techniques may generate new types of defects, e.g., porosity transferring from powder to builds. Practical strategies to mitigate defects are also addressed through fundamental understanding of their formation. Such explorations enable the validation and calibration of models and ease the process qualification without costly trial-and-error experimentation.



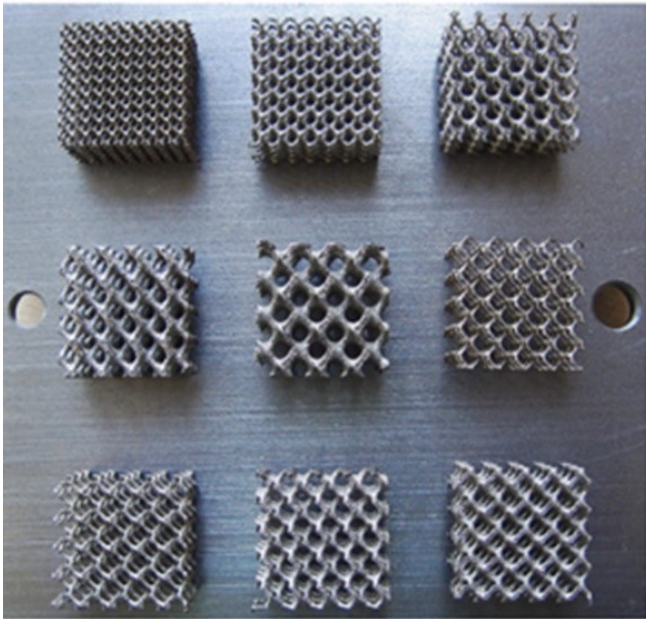
LPBF Fundamentals





LPBF Geometries

(a)



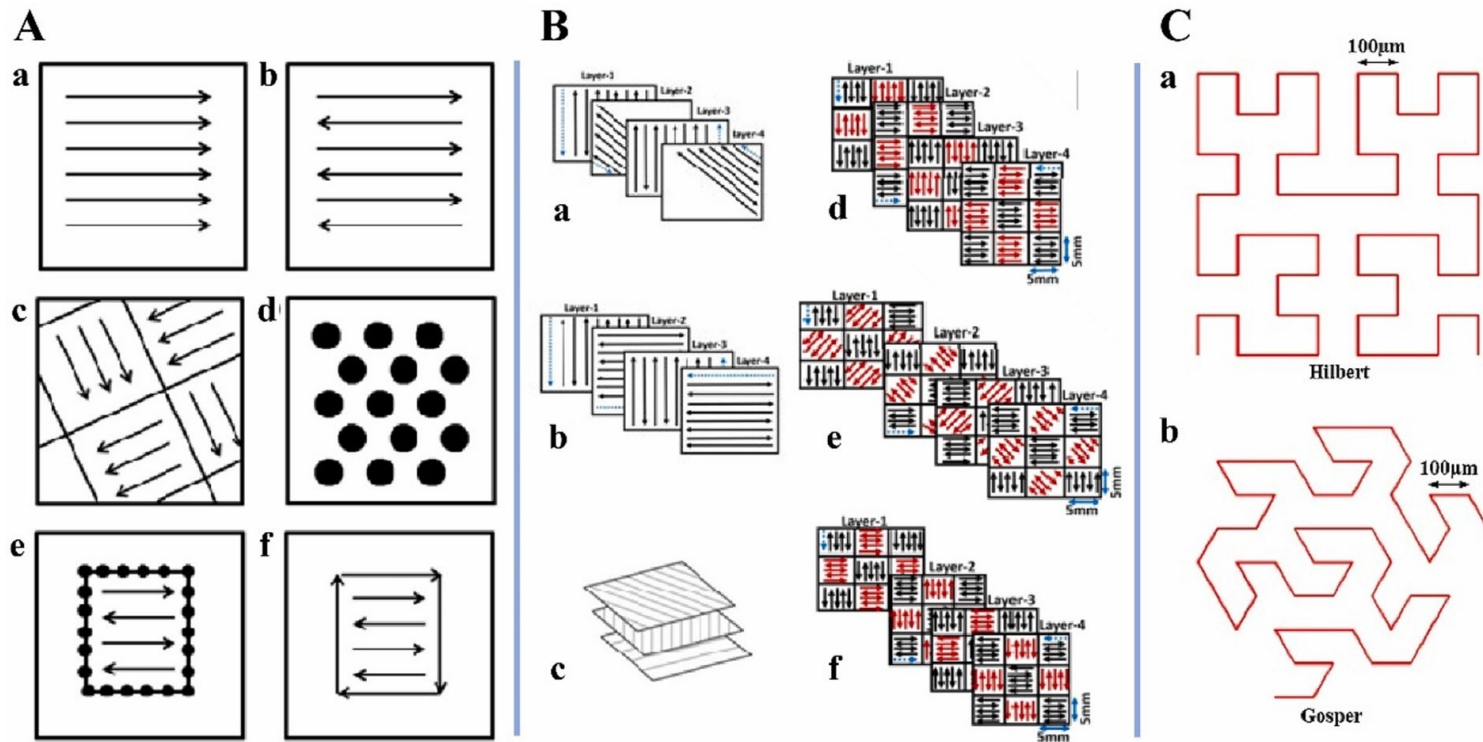
(b)



(c)



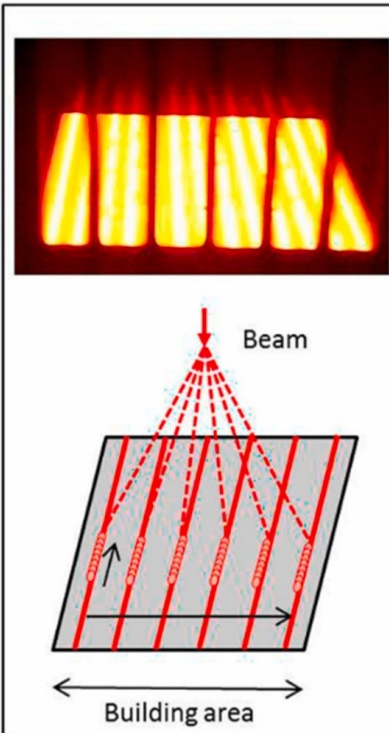
LPBF Laser Scanning Strategies



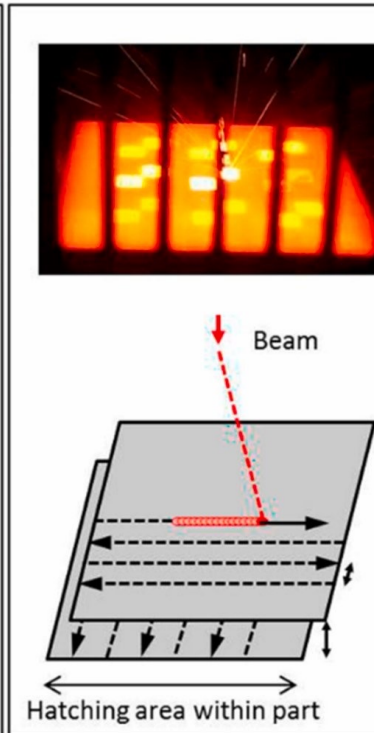


LPBF Laser Scanning Strategies

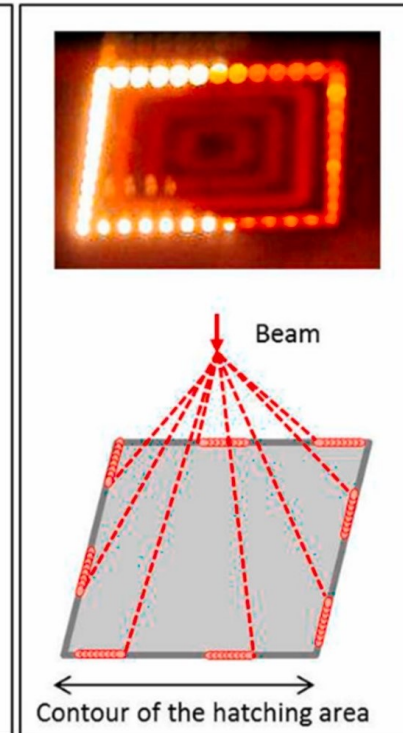
(a) Heating



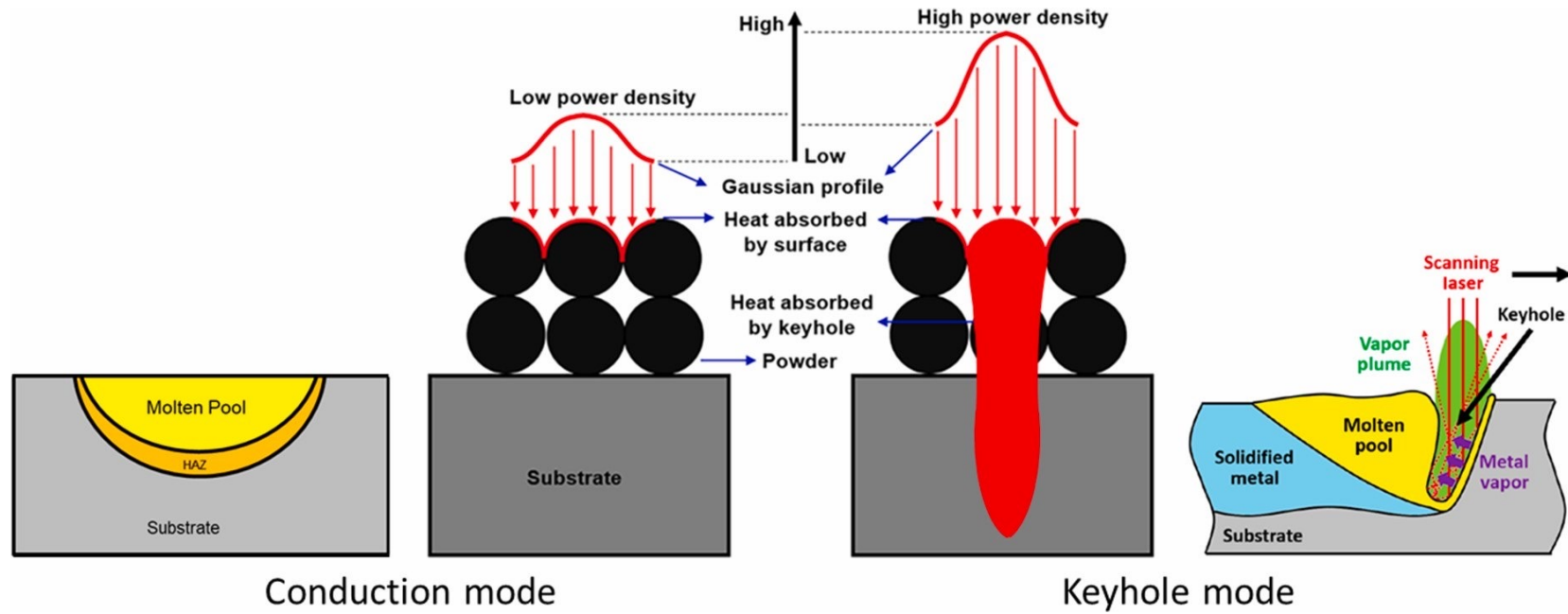
(b) Melting: Hatching



(c) Melting: Quasi-multi-beam



LPBF Laser Scanning Strategies





Classification and Sources of Defects

Powder-related defects

- Powder characteristics
- Surface contamination and oxidation
- Trapped Gas

Processing-related defects

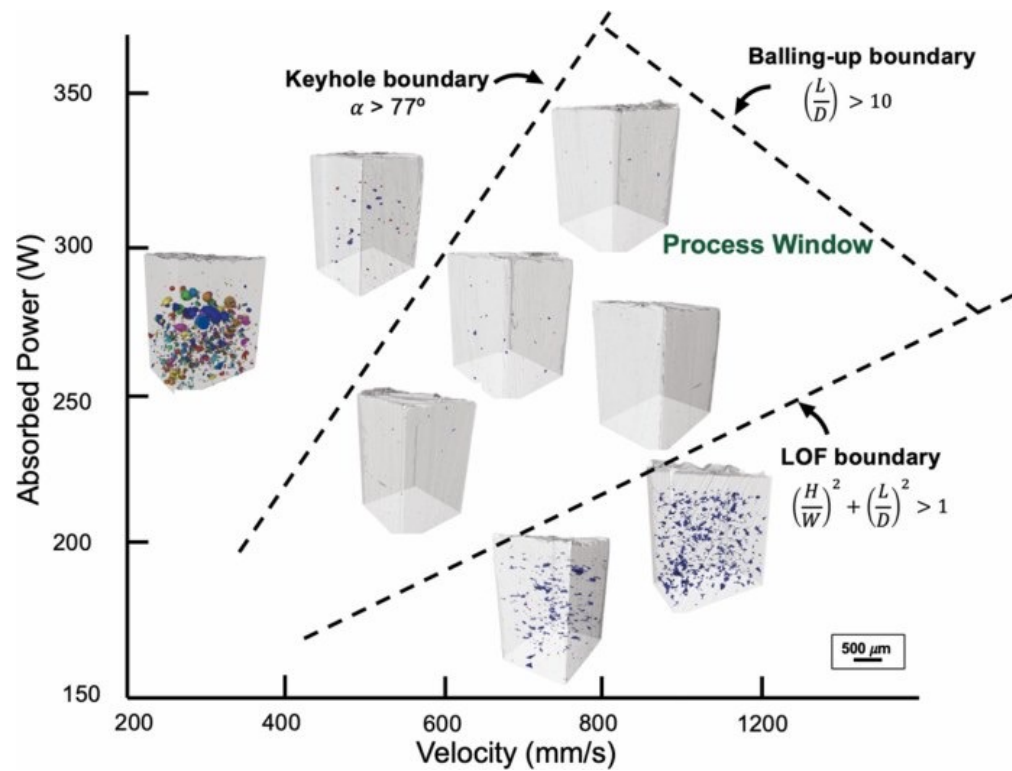
- Powder spreading dynamics and anomalies
- Balling or bead-up
- Lack of Fusion Porosity
- Keyhole Porosity
- Microstructural Inhomogeneities and Impurities
- Formation of Columnar Grains
- Loss of Alloying Elements
- Spattering
- Turnarounds and End of Track Porosity
- Residual Stresses, Cracking and Delamination
- Geometric Defects and Dimensional Accuracy
- Surface Finish and Roughness

Post-processing-related defects

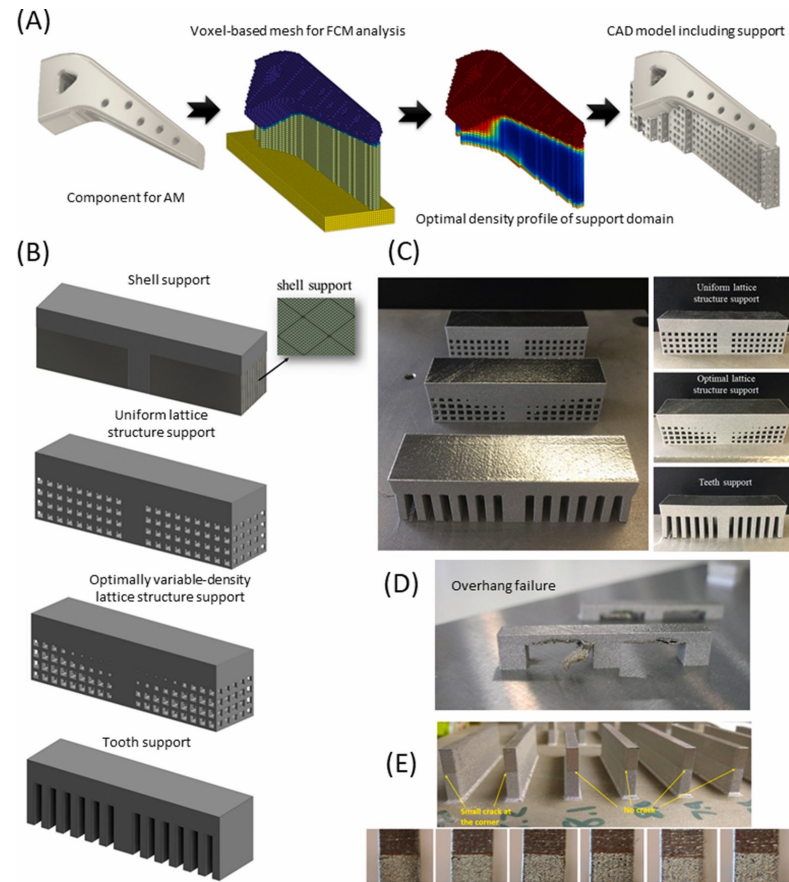
- Thermally induced porosity



Right Power (W) and Speed (mm/s) selection

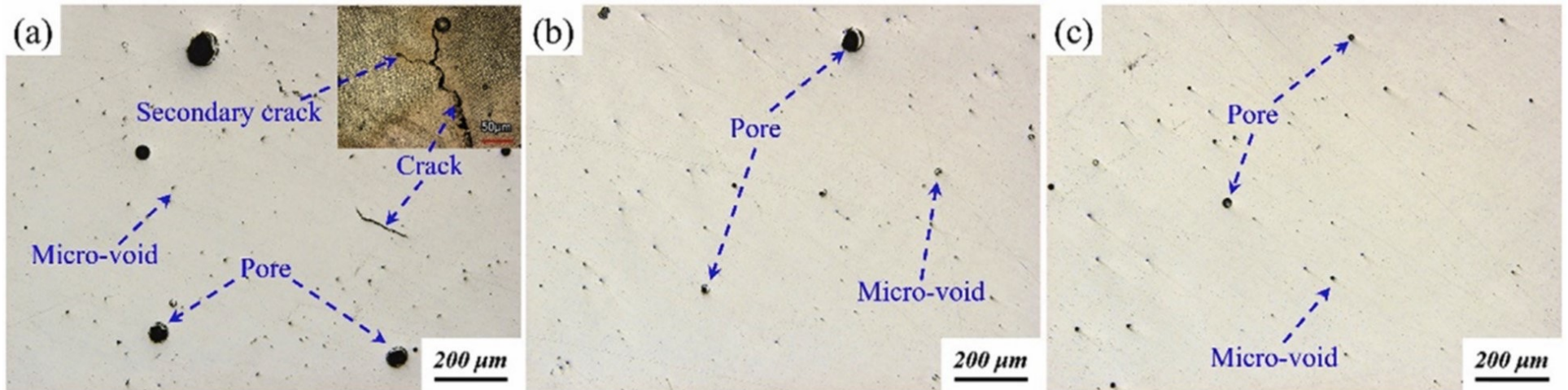


Geometry: not unlimited!!

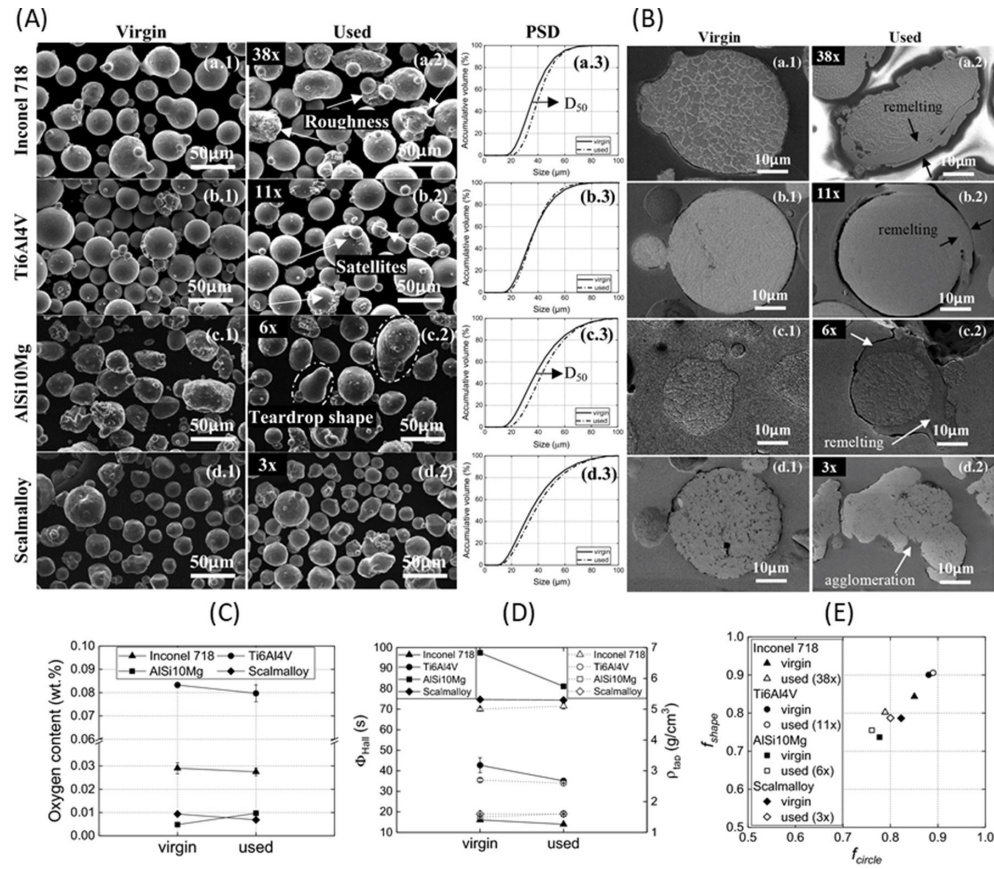




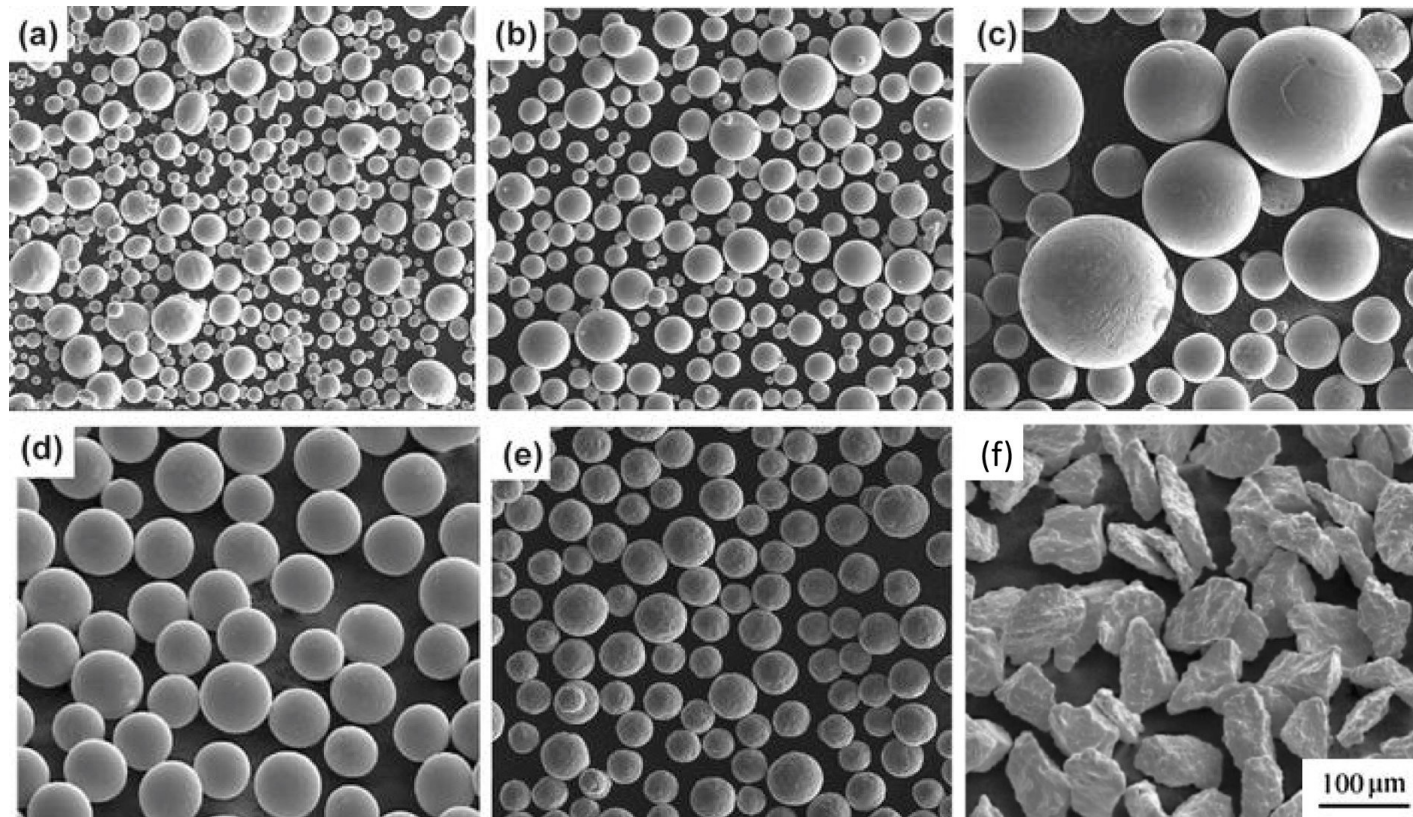
Porosity and cracks



Powders and Powder-related defects



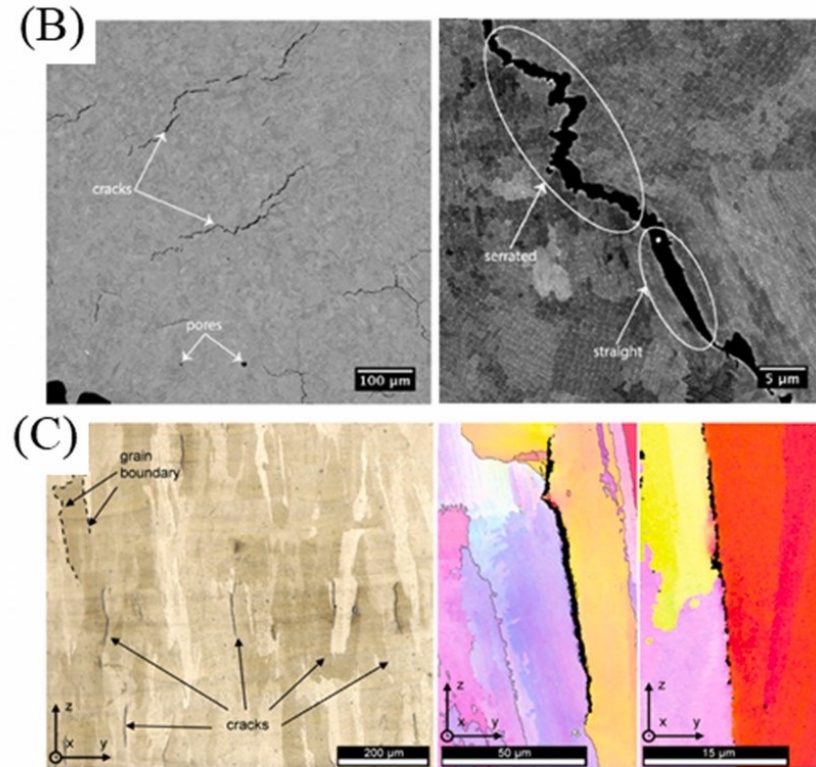
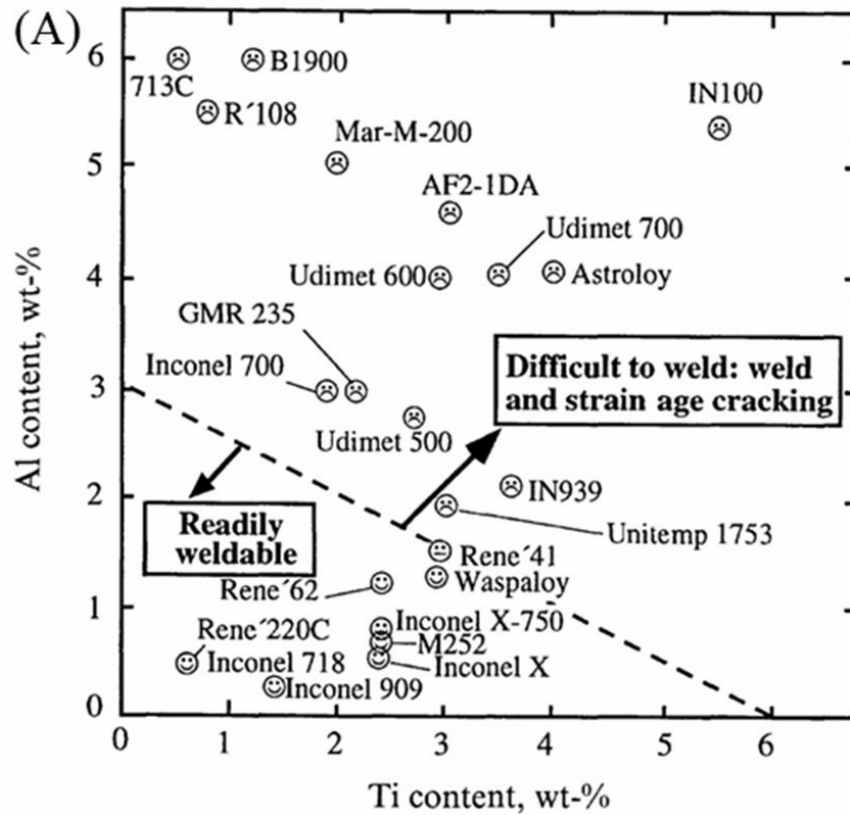
Powders: they are different!





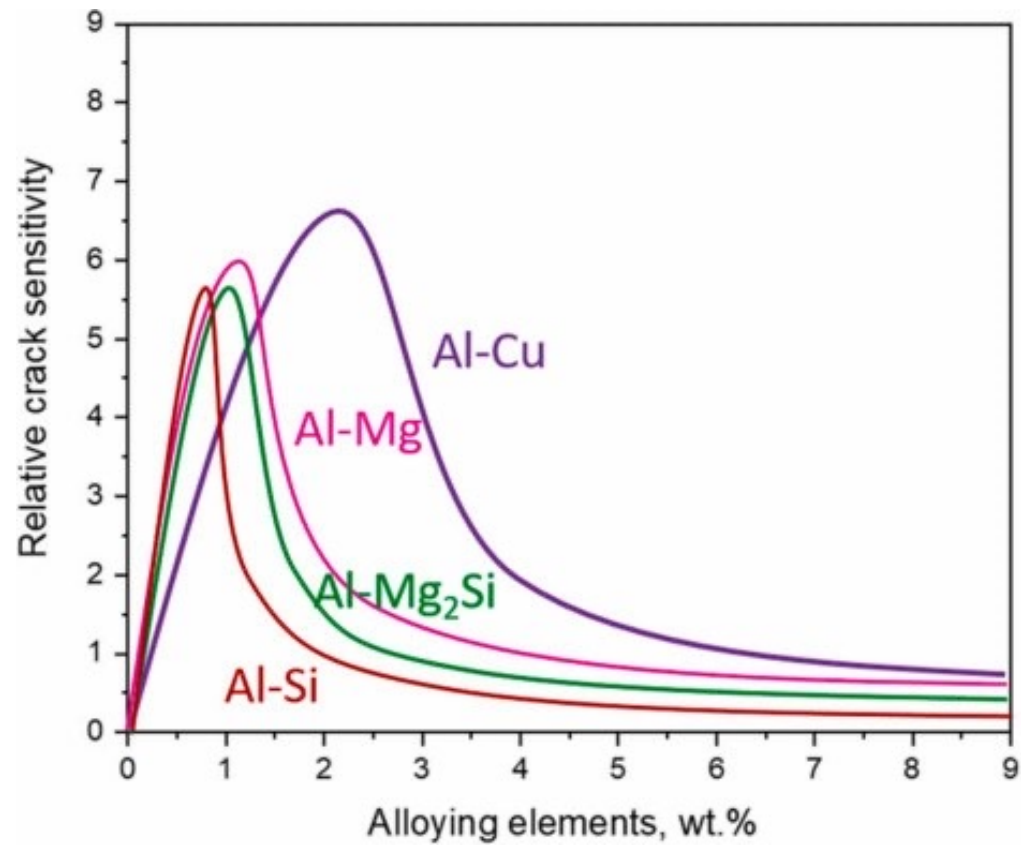
Common metals and defects

Nickel-based superalloys



Common metals and defects

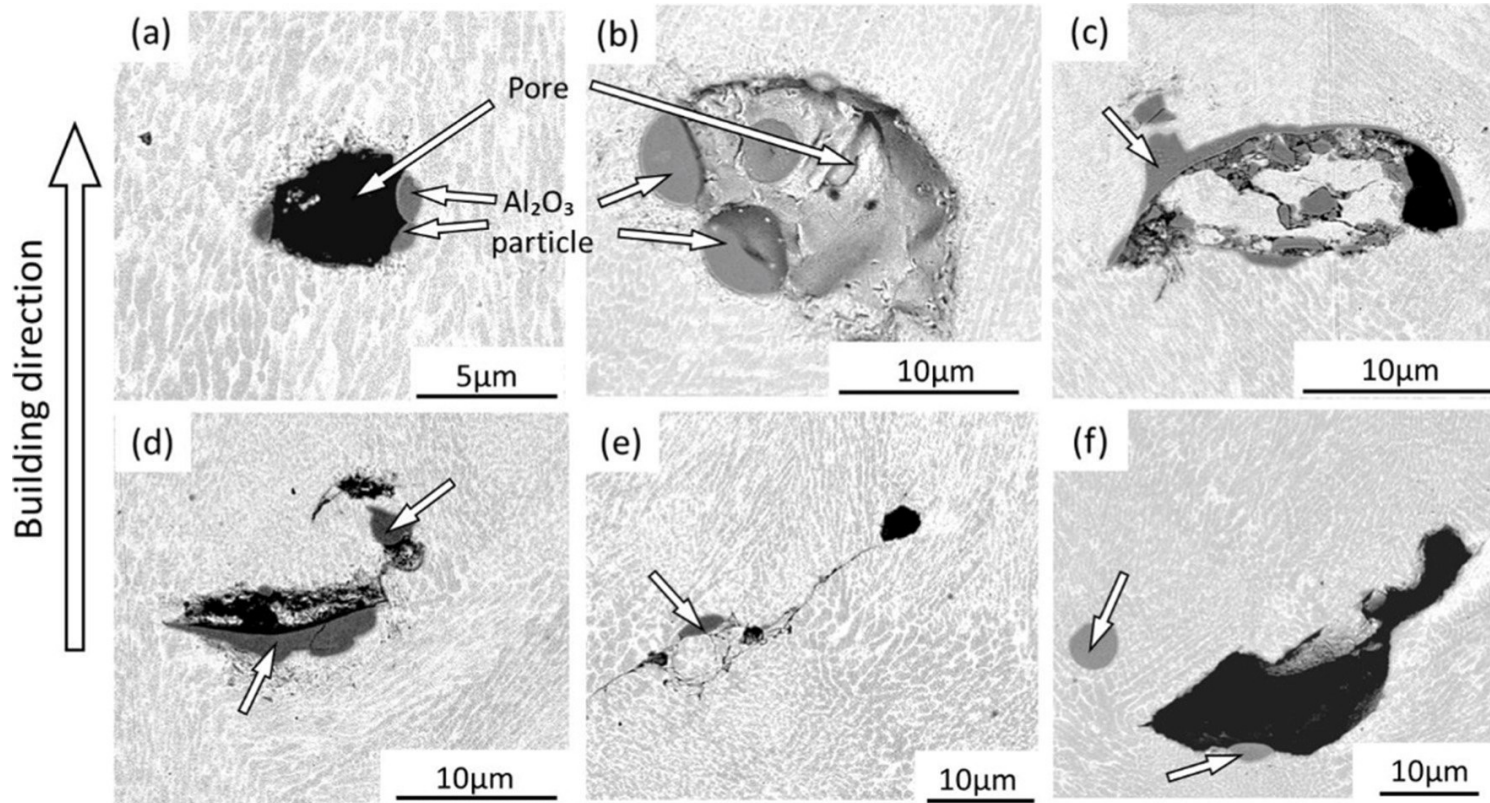
Aluminum alloys





Common metals and defects

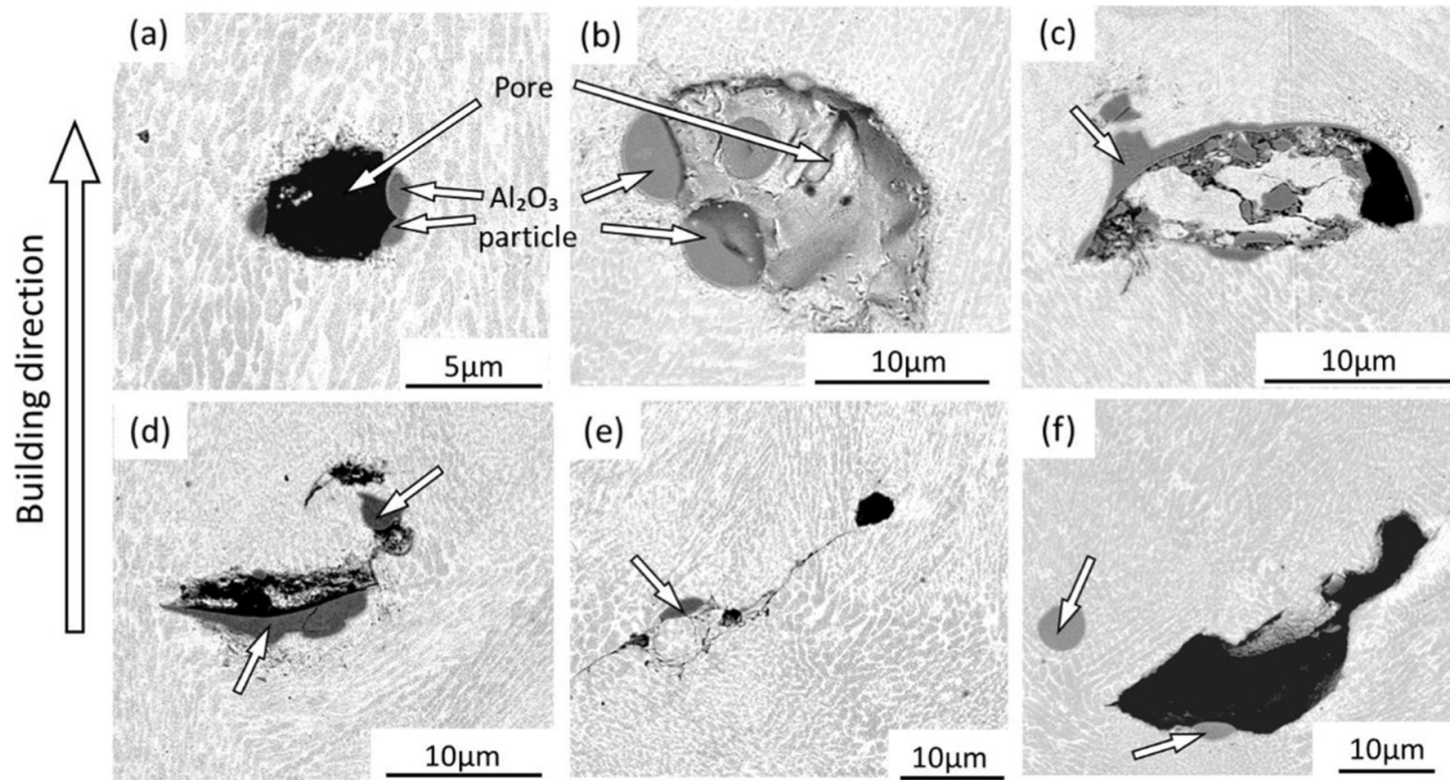
Aluminum alloys





Common metals and defects

Aluminum alloys

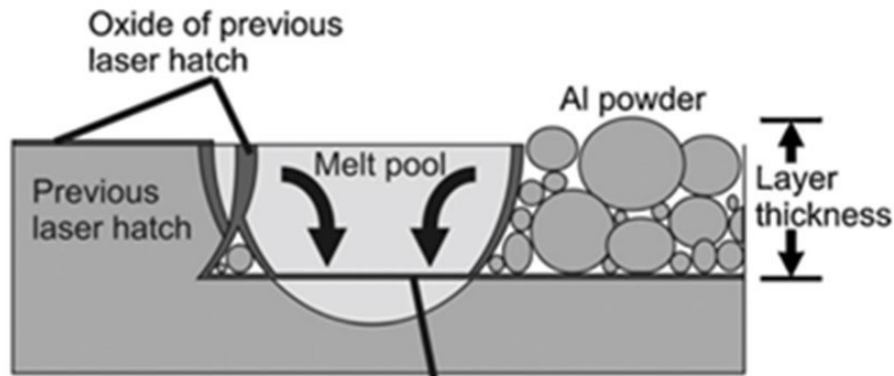




Common metals and defects

Aluminum alloys

(A)

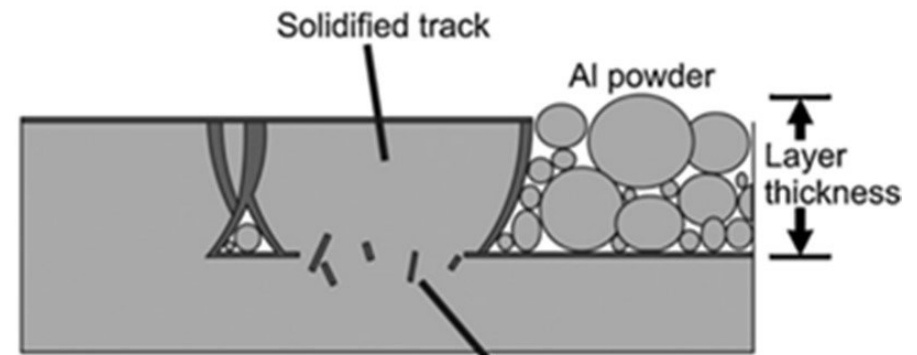


Oxide of previous layer's top surface

■ Solid aluminium

■ Liquid aluminium

(B)

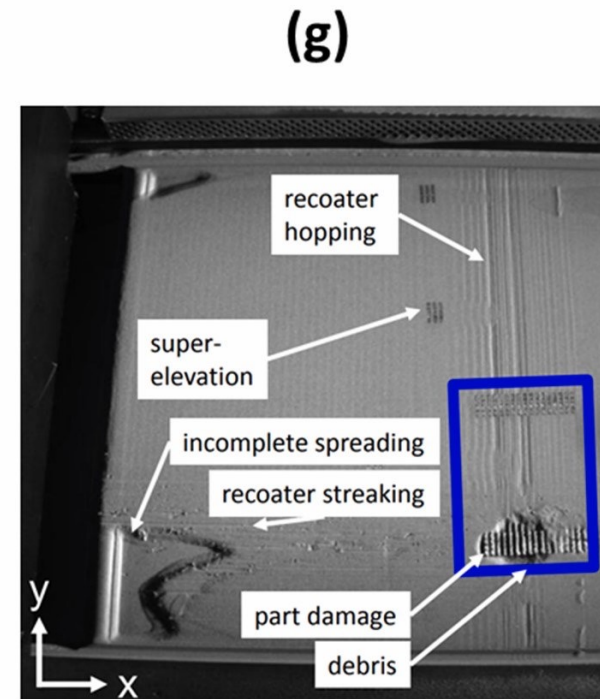
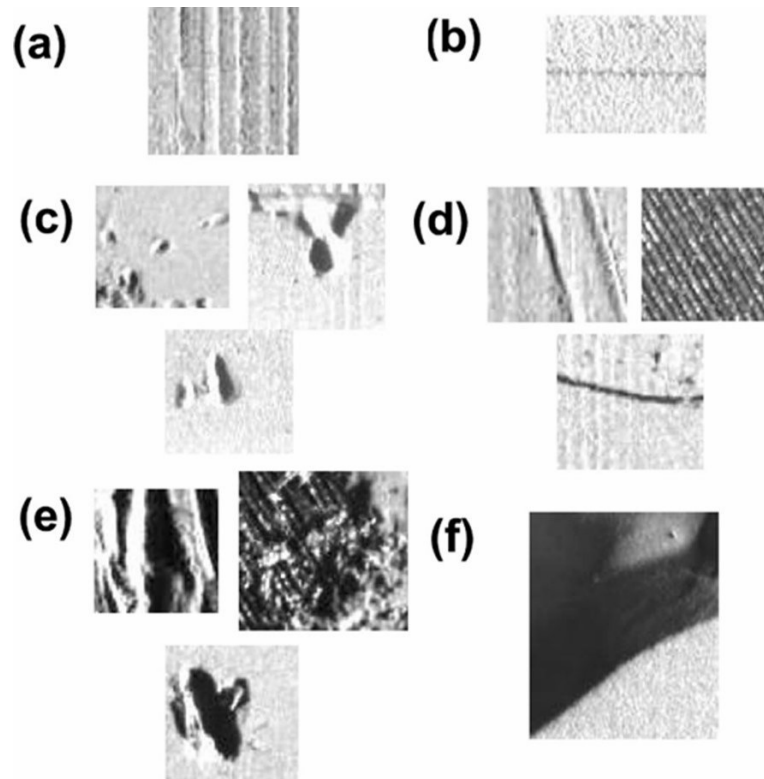


Disrupted oxide

■ Oxide

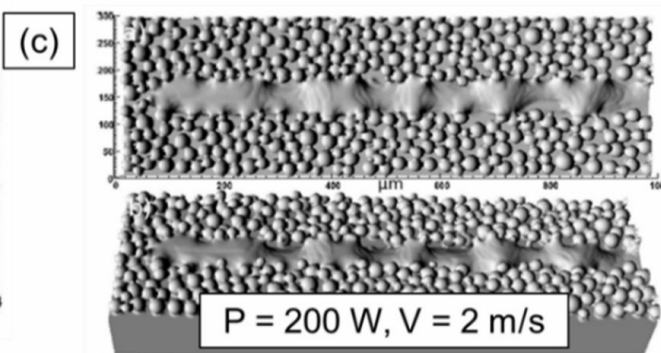
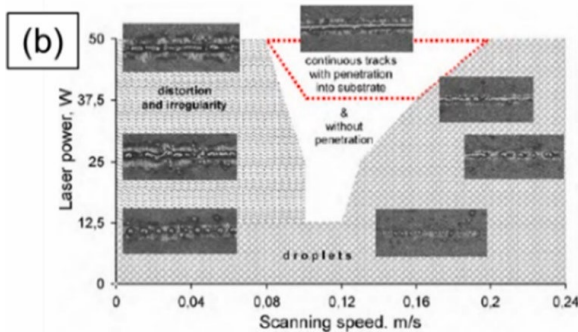
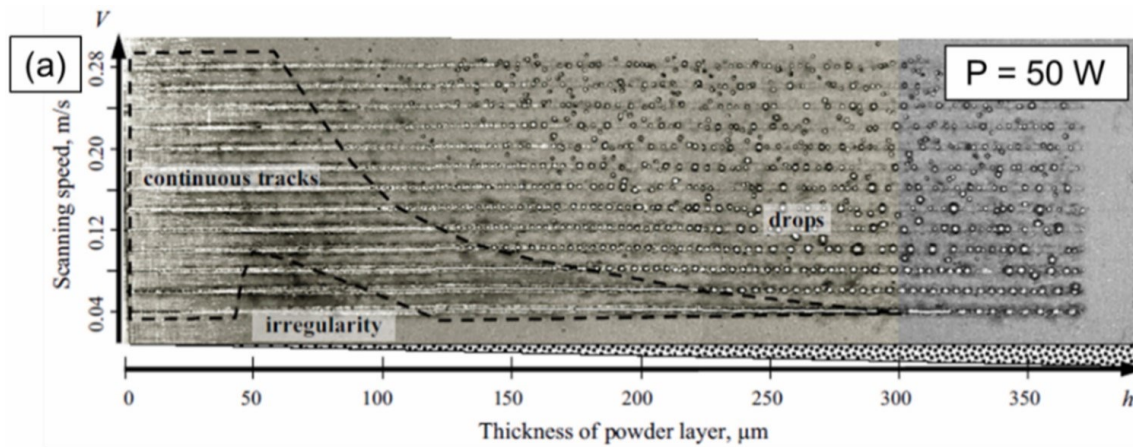
Process-related defects and anomalies

Recoater



Process-related defects and anomalies

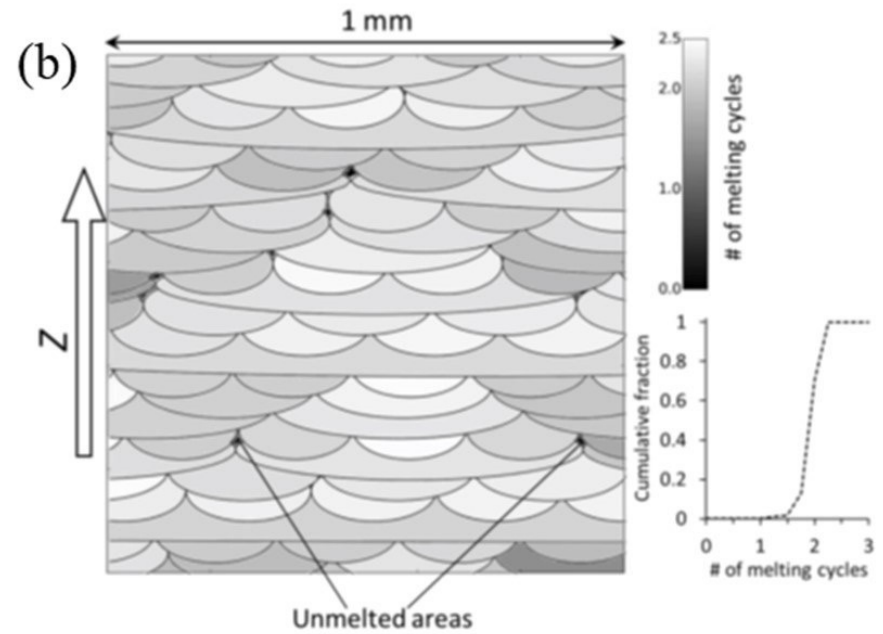
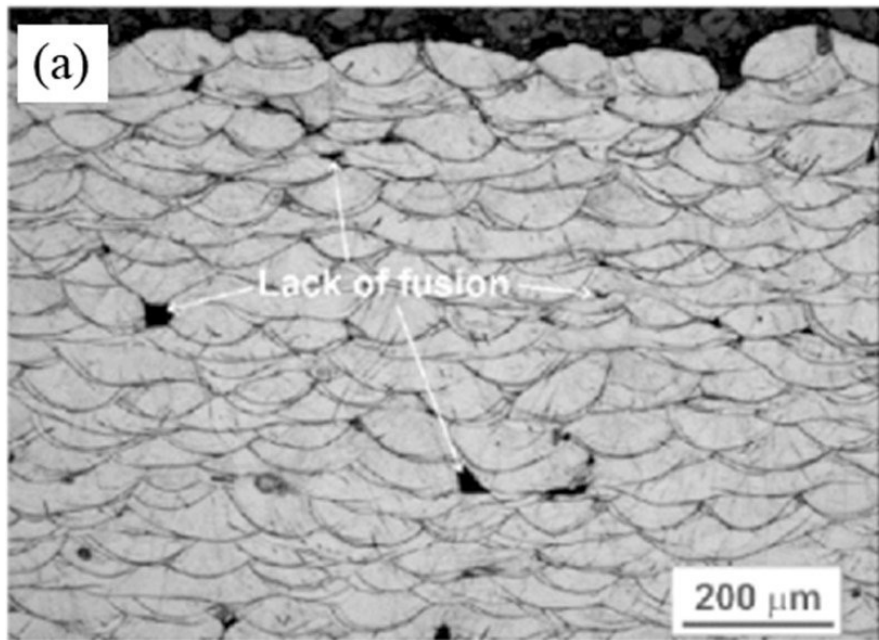
Balling





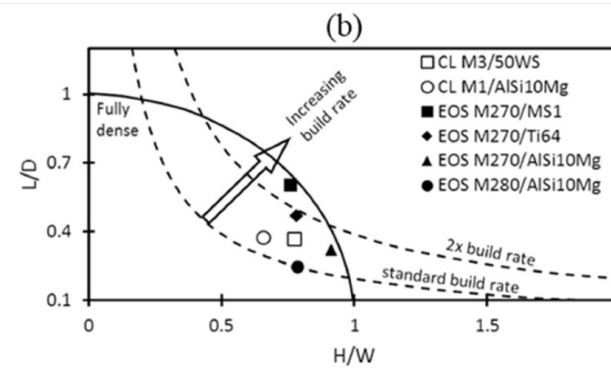
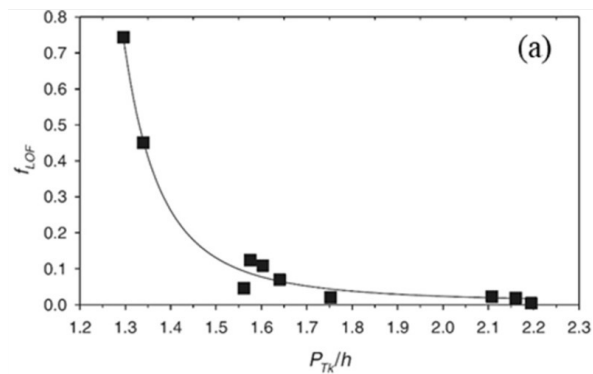
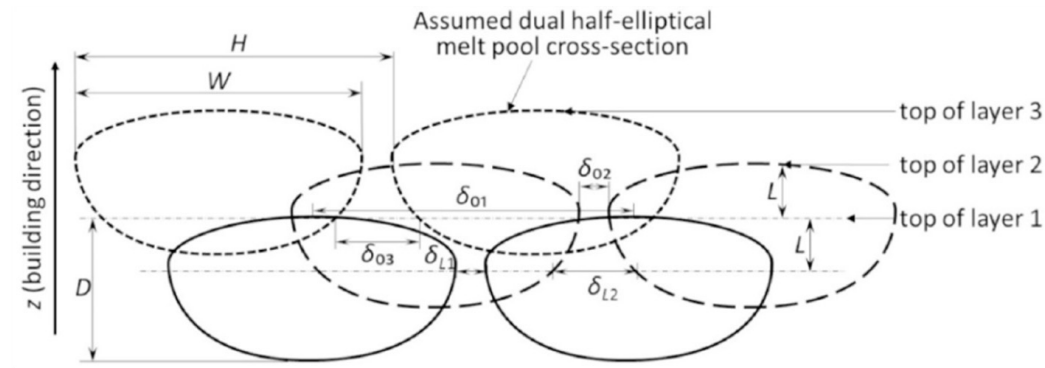
Process-related defects and anomalies

Lack of Fusion



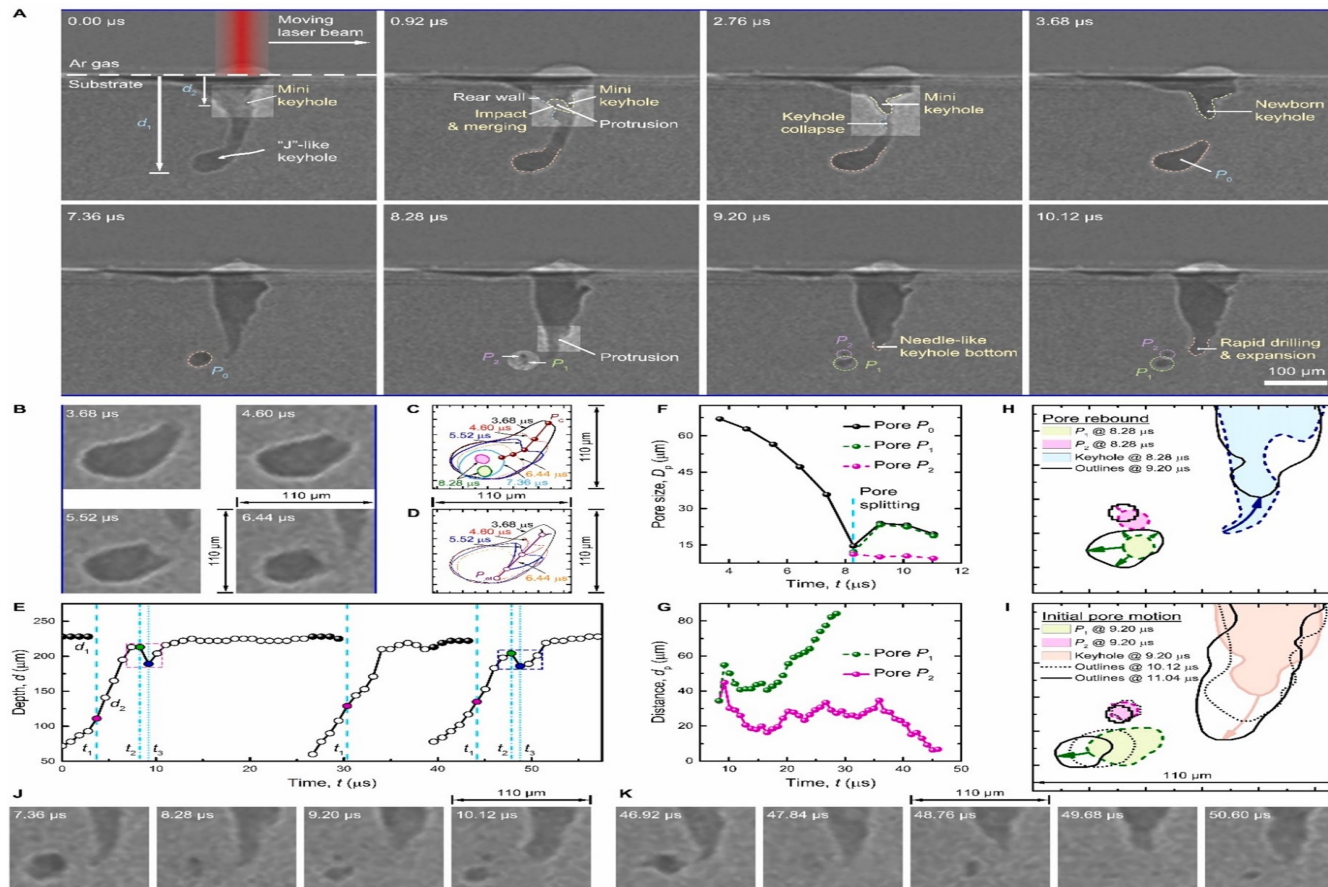
Process-related defects and anomalies

Lack of Fusion



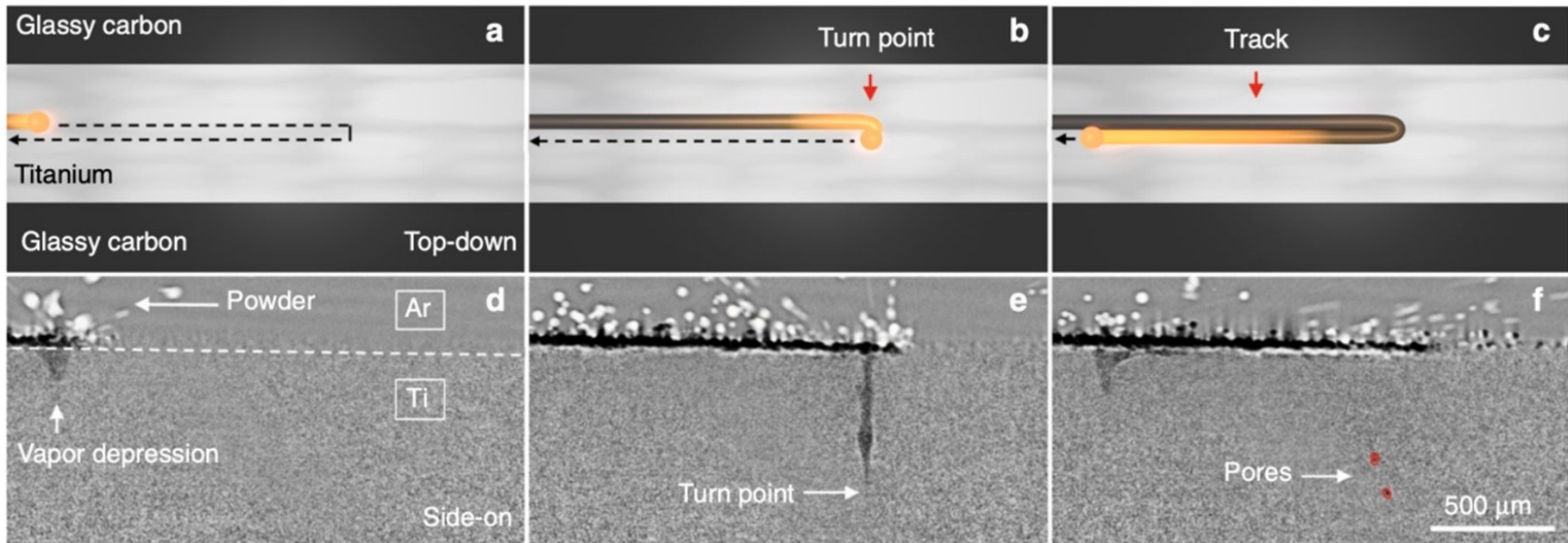
Process-related defects and anomalies

Keyhole Porosity



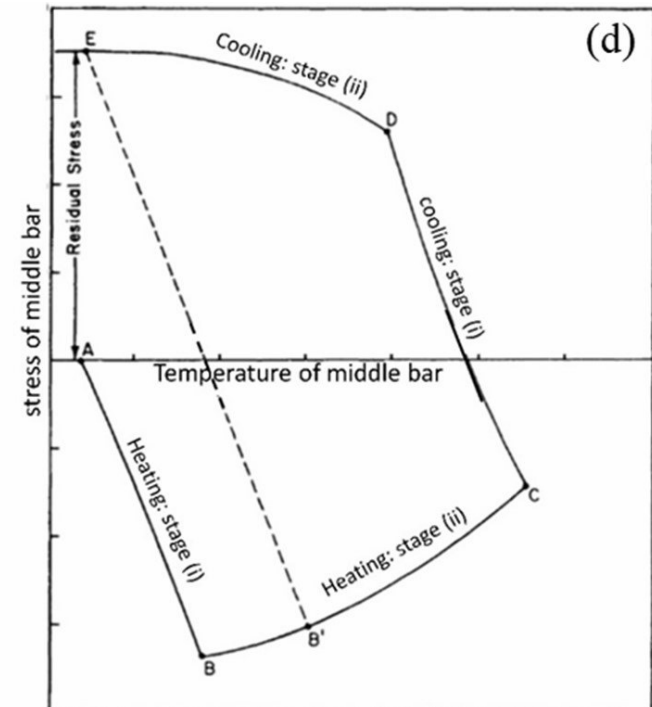
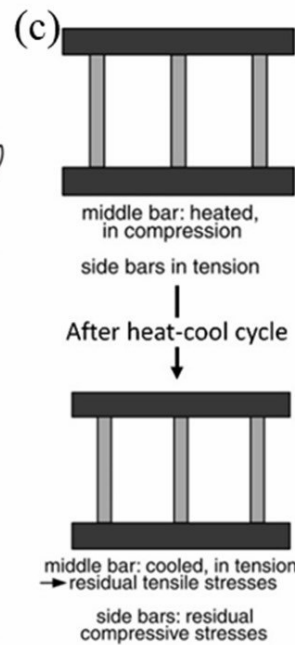
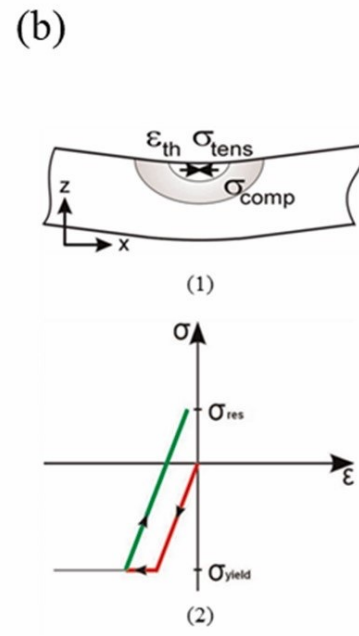
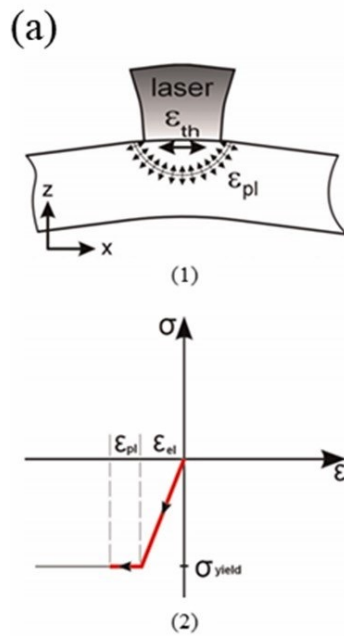
Process-related defects and anomalies

Porosity Induced change of velocity of laser scan



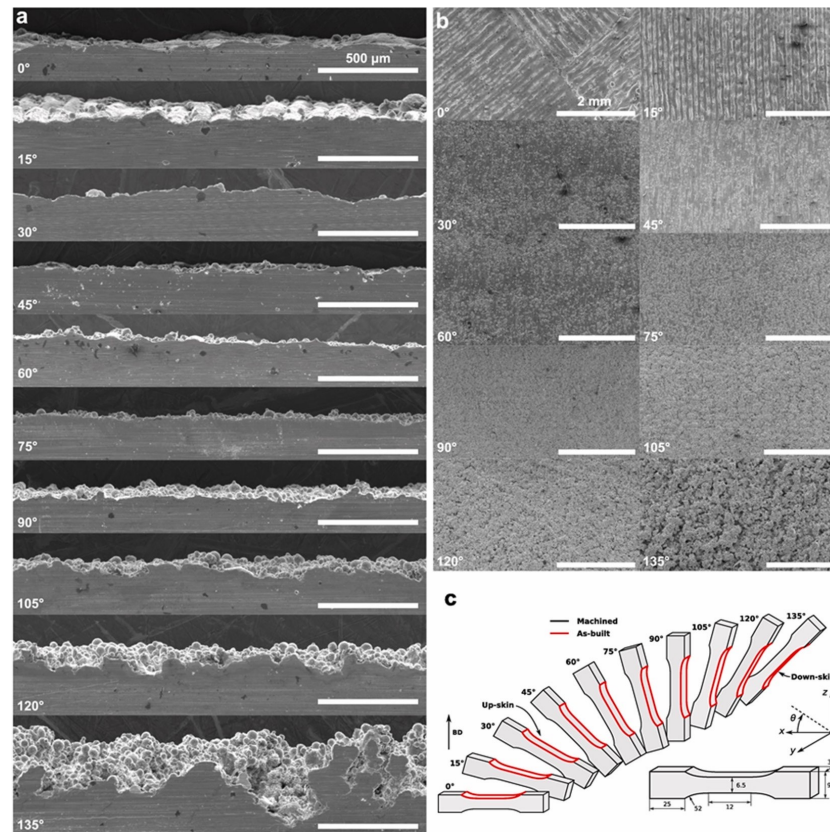
Process-related defects and anomalies

Residual stresses, cracking, and delamination



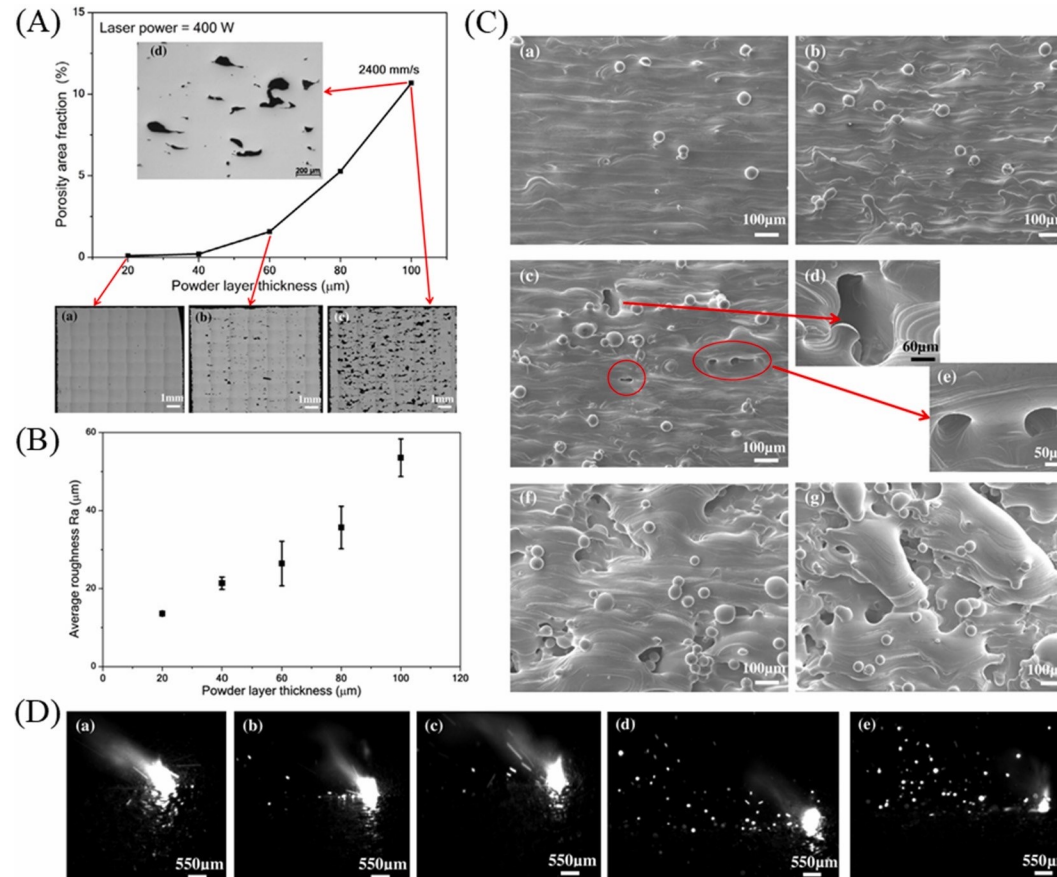
Process-related defects and anomalies

Surface finish and roughness



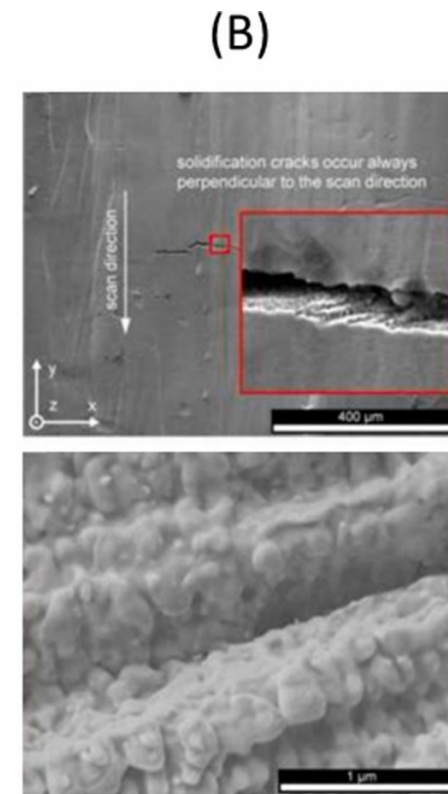
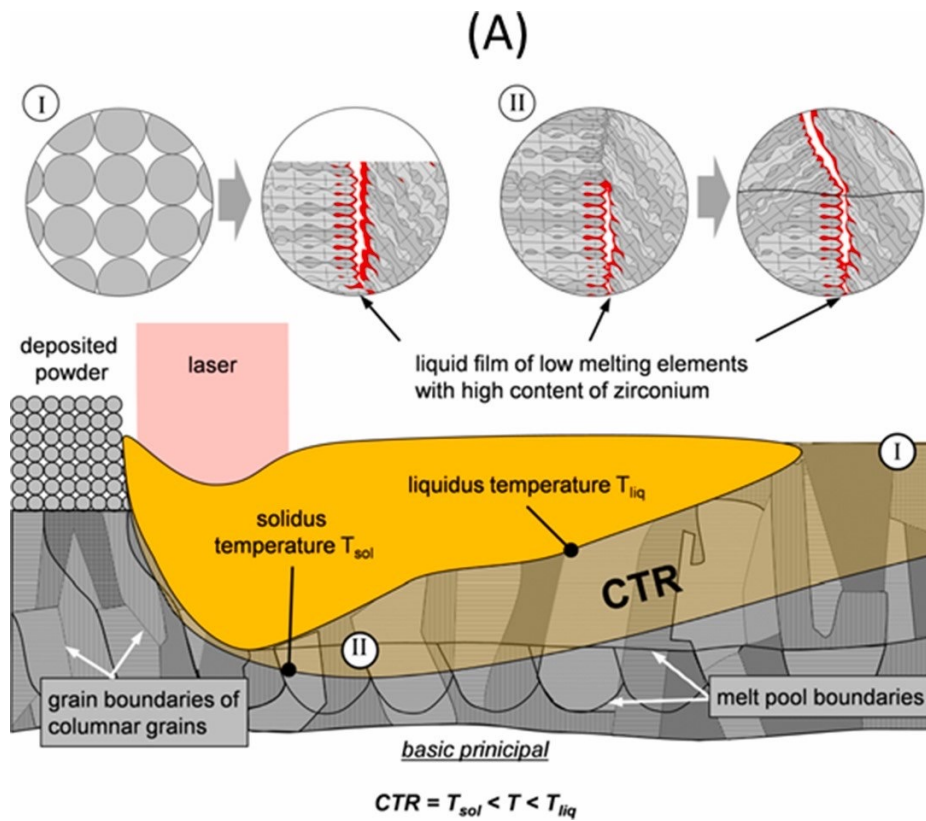
Process-related defects and anomalies

Surface finish and roughness



Process-related defects and anomalies

Metallurgical factors for defect generation





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Open Discussion 1

Post-processing-related defects?



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Open Discussion 2

Mitigation of defects?