

Jornada de Fabricación Aditiva MATERPLAT-READI

PLATAFORMA TECNOLÓGICA
DE MATERIALES AVANZADOS
Y NANOMATERIALES

materplat...

9 DE JUNIO

9.00 - 16.00

Instituto IMDEA Materiales

Modeling of Microstructures in Additive Manufacturing of Metals

Damien Tourret

damien.tourret@imdea.org

IMDEA Materials Institute

www.materials.imdea.org

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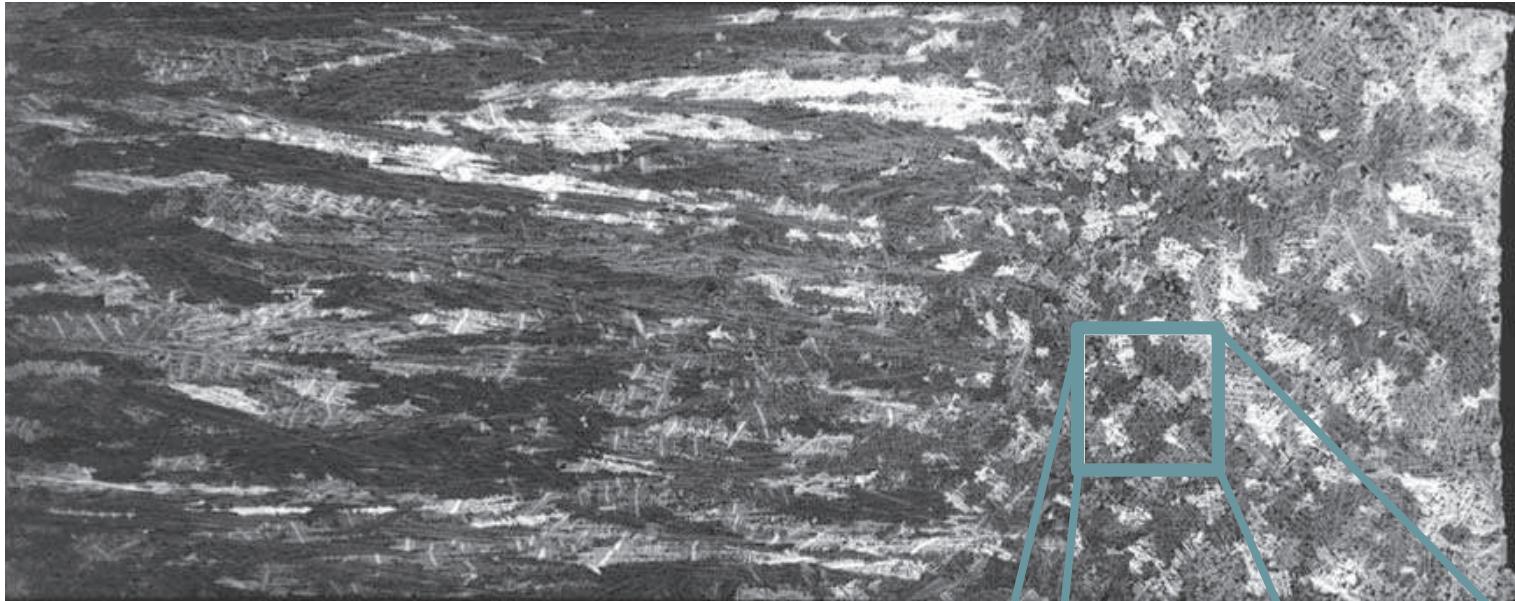
CER-20191020

PTR-2020-001235

Microstructures

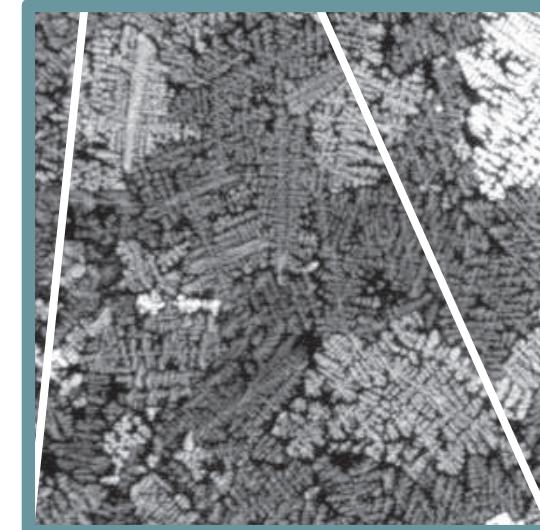
Introductory Remarks

Microstructures are Heterogeneous



Al-7wt%Si cylindrical casting

*Gandin, Steinbach:
ASM Handbook 15, 435 (2008)*



**Growth
direction**

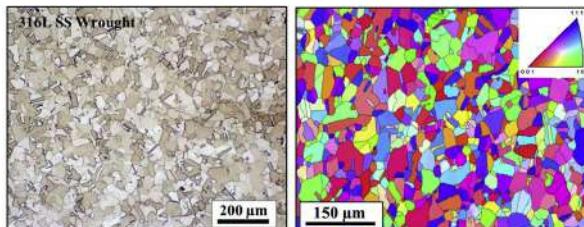
**Grain
structure**

**Dendritic
microstructure**

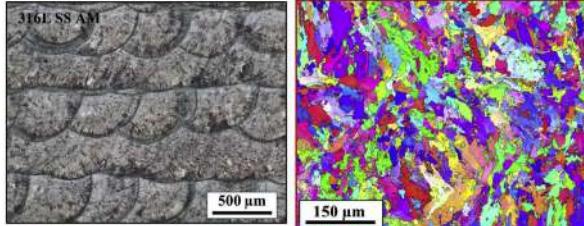
Properties & Performance depend on Microstructures

Processing

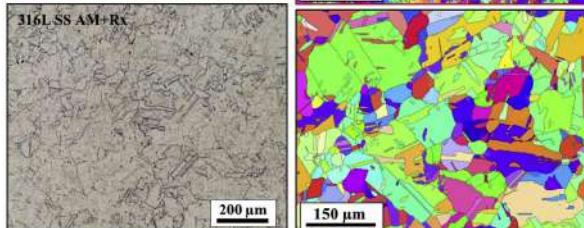
316L Stainless Steel Wrought



316L SS AM

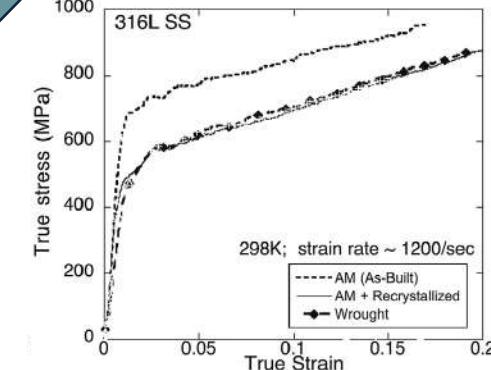
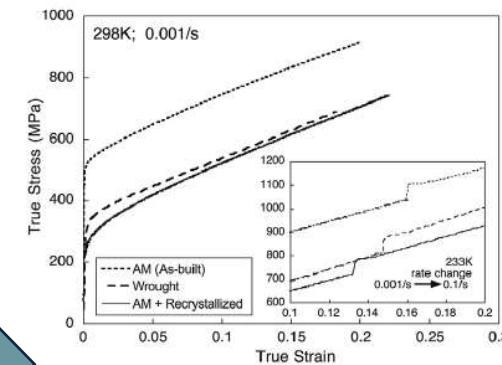


316L SS AM + Rx

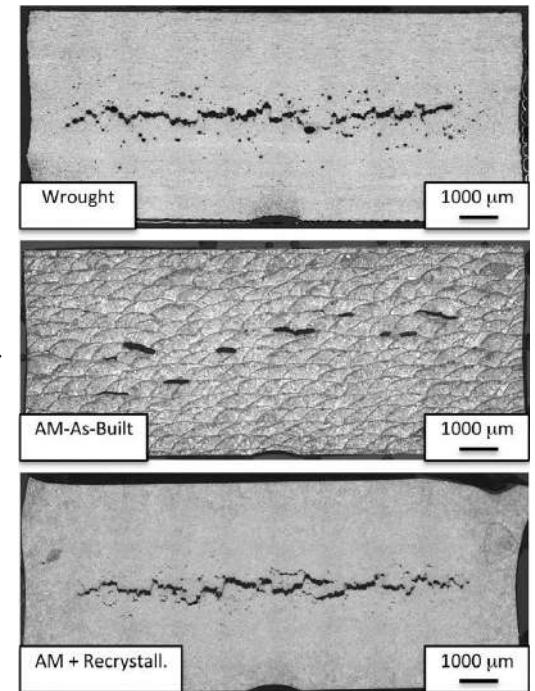


Structure

Properties



Performance



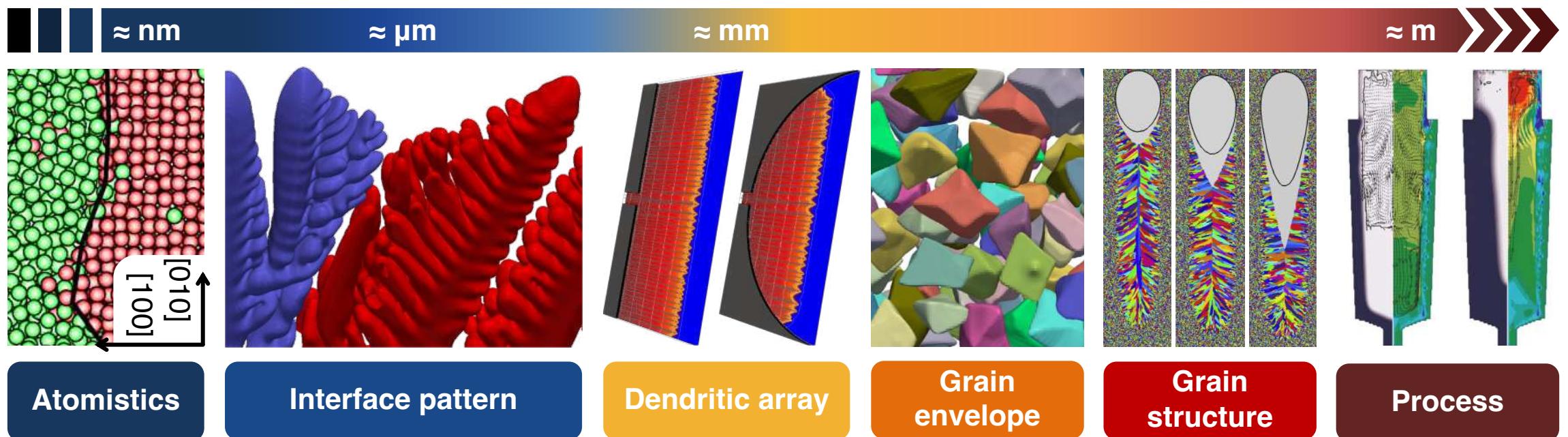
Gray et al.: Acta Materialia 138 (2017) 140

Microstructure Modeling

A multiscale problem

Modeling of Solidification across Scales

- No such thing as “one model to solve all problems”
 - *Step #1: Select the model (and scale) appropriate to the problem at hand*
- Challenge specific to fusion-based metal AM: *Is AM rapid solidification?*



Hoyt, Asta, Karma:
Mater Sci Eng R
 41, 121 (2003)

Tourret et al: *Acta
 Mater* 122, 220 (2017)

Tourret et al:
JOM 67, 1776 (2015)

Souhar et al: *Comp
 Mater Sci* 112, 304
 (2016)

Chen, Gandin,
 Guillemot: *Acta Mater*
 115, 448 (2016)

Combeau et al: *Metall
 Mater Trans B* 40, 289
 (2009)

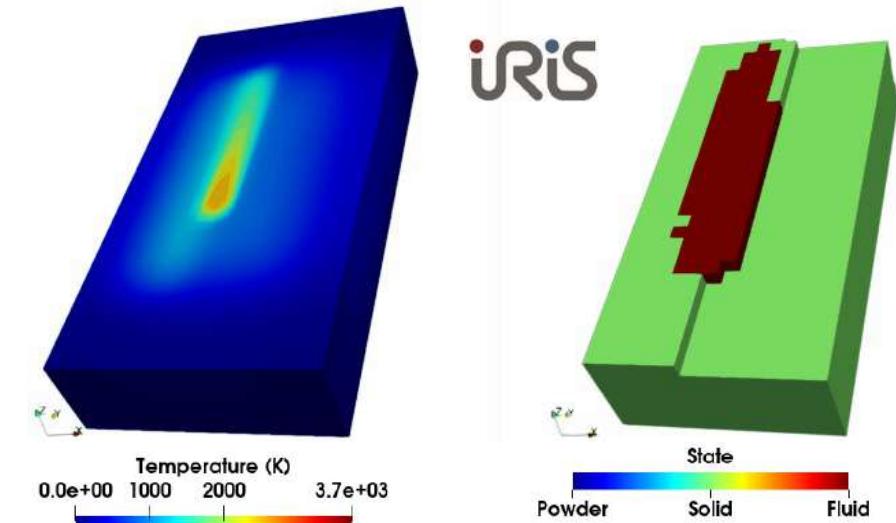
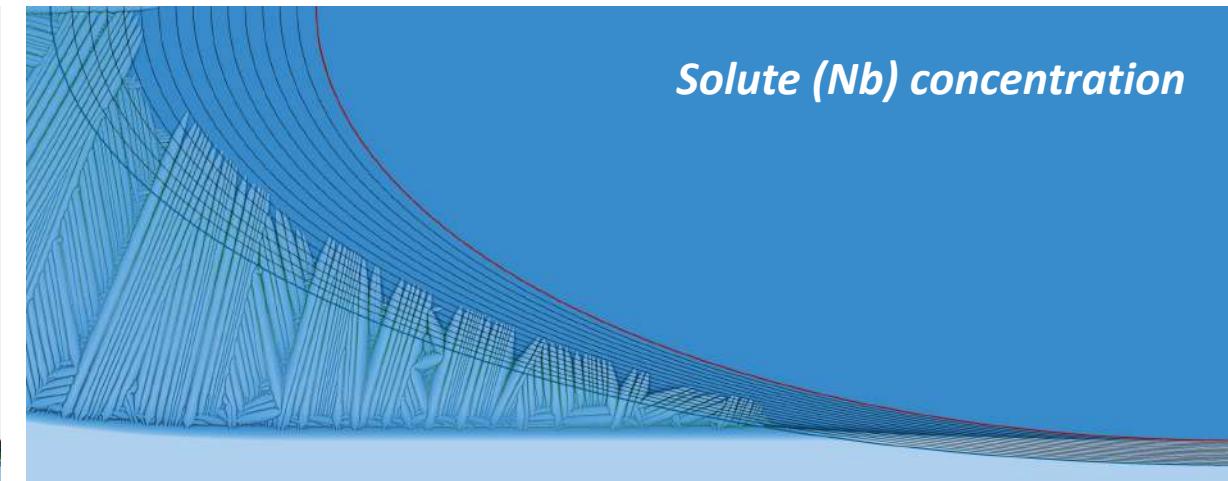
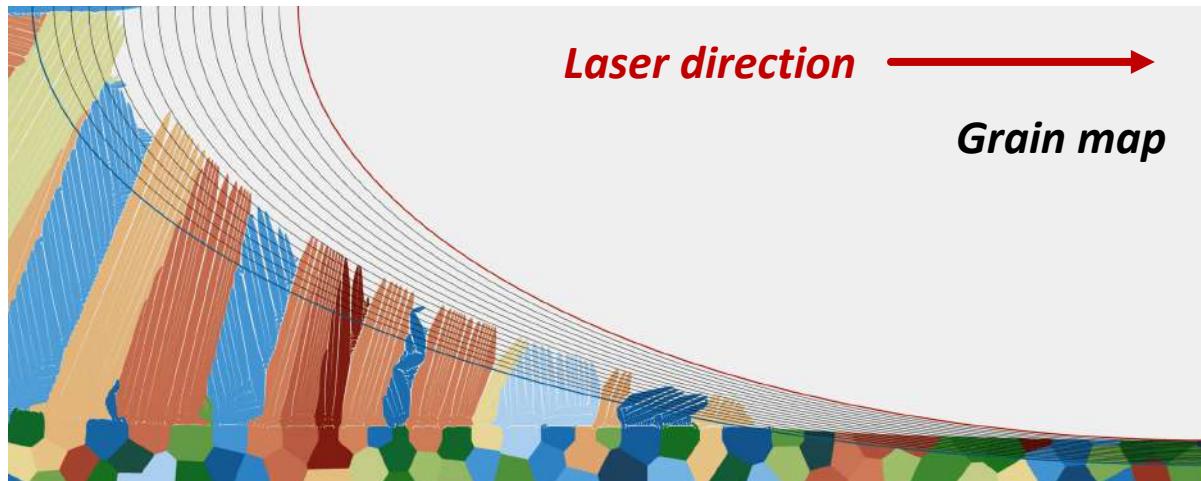


Recent & Ongoing Developments at IMDEA Materials

Multiscale Modeling of Powder-Bed Fusion

- Combining complementary approaches at different scales
 - Multicomponent alloys* → **CalPhaD** 
 - Macroscale thermo-mechanics* → **Finite Elements**
 - Microscale microstructure formation* → **Phase-Field**

Powder-bed fusion of Inconel 718 alloy



Upscaling Phase Field with Cellular Automaton

- Quantitative comparison between *fast CA* and *accurate PF*
 - “*Calibration*” of numerical CA parameters, e.g. grid size, for PF-like predictions



Phase-Field

Hardware: 8-GPUs (RTX 2080 Ti)

Wall time \approx 9 days

Same size: $250 \mu\text{m} \times 100 \mu\text{m} \times 0.005 \text{s}$



Cellular Automaton

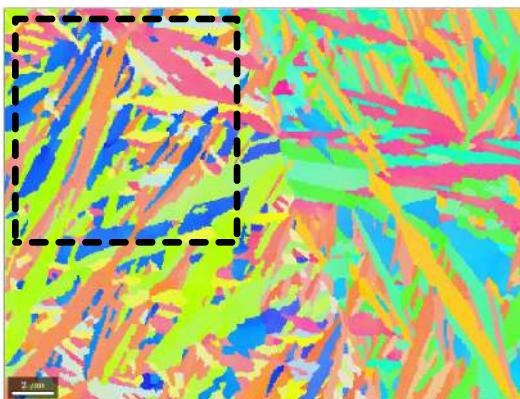
Hardware: One 2.3GHz Intel core

Wall time \approx 1 hour

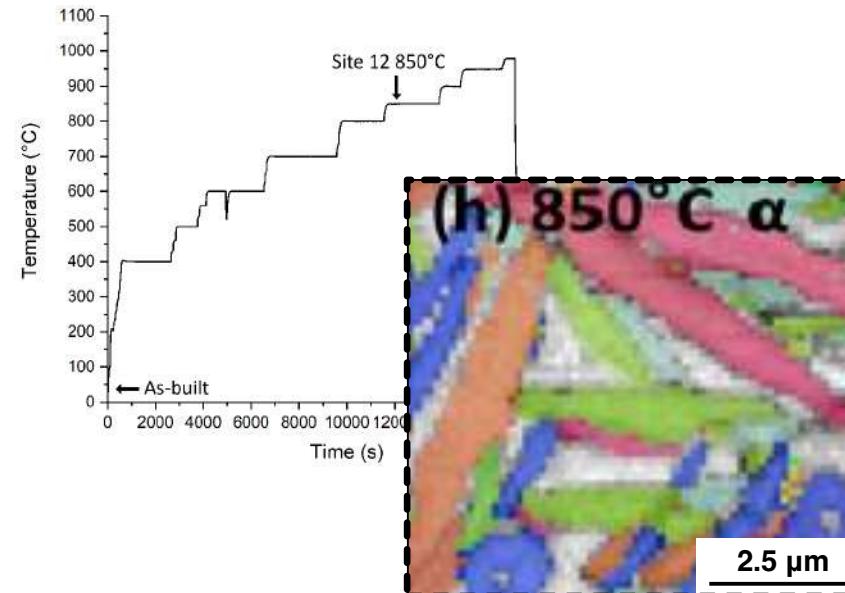
Microstructure evolution during post processing

- **Martensite decomposition in Ti6Al4V alloy** $\alpha' \rightarrow \alpha + \beta$
- *Powder-bed fusion cooling rates lead to metastable (V supersaturated) martensite*
- *Heat treatment common to reach acceptable strength/ductility trade-off*

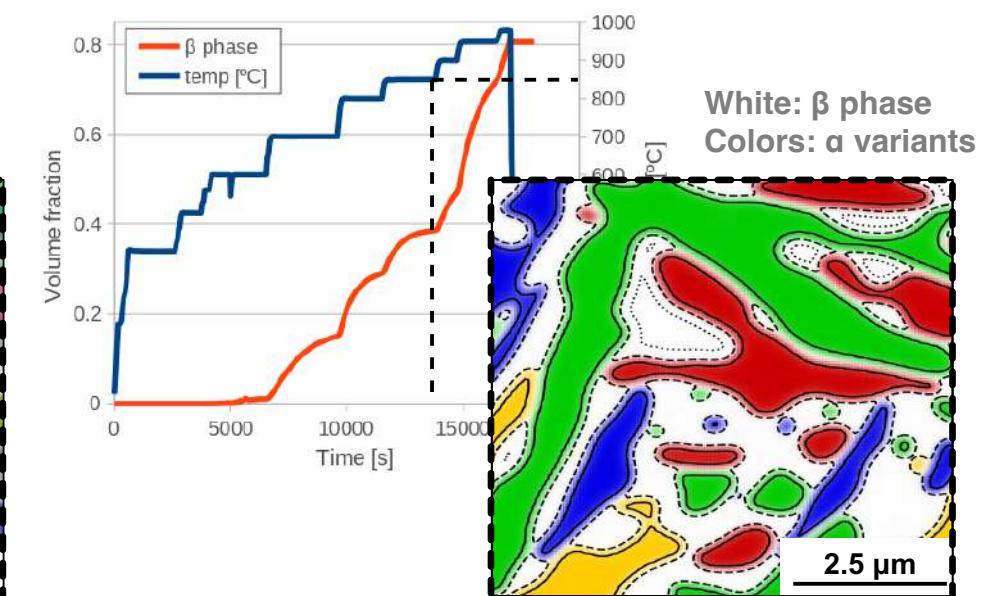
As-build martensitic microstructure



Heat treatment



Virtual Processing

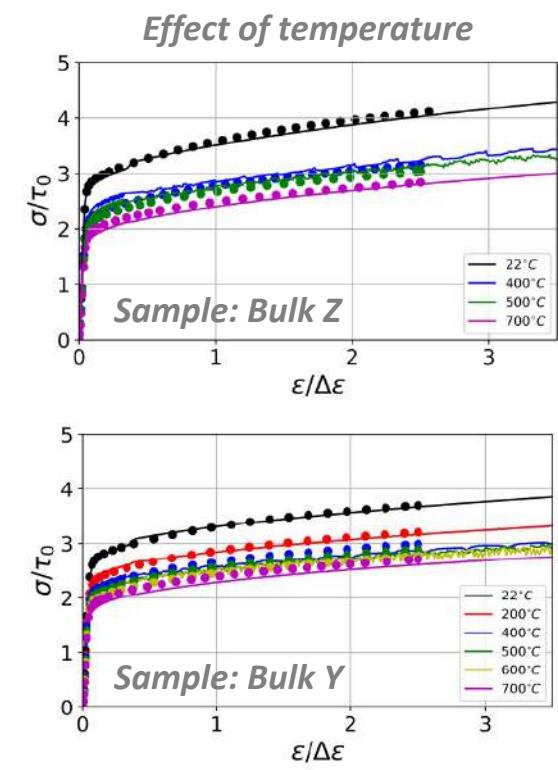
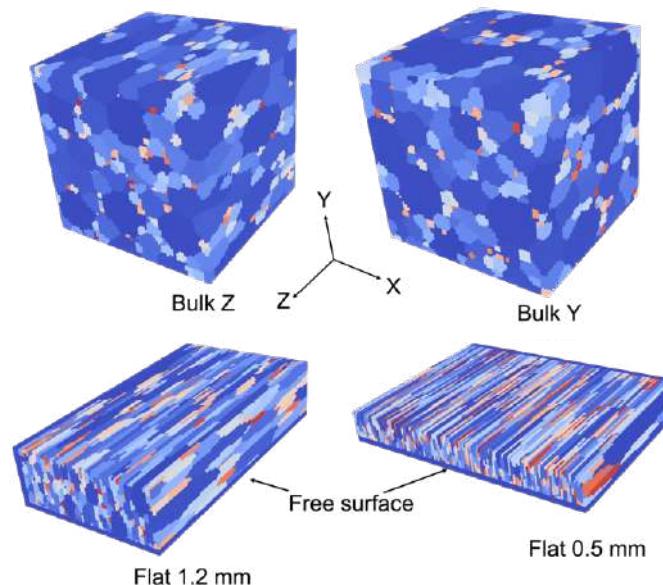
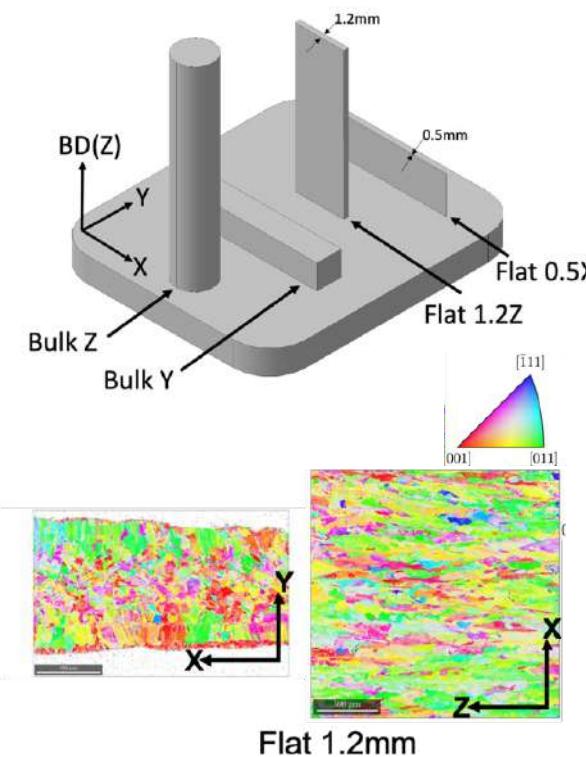


- **Crystal Plasticity Theory + Computational Homogenization**

- *Construction of statistically representative digital microstructures*
- *Calibration of CP parameters from literature & one bulk sample*
- *Prediction of temperature dependent anisotropic response of the samples*

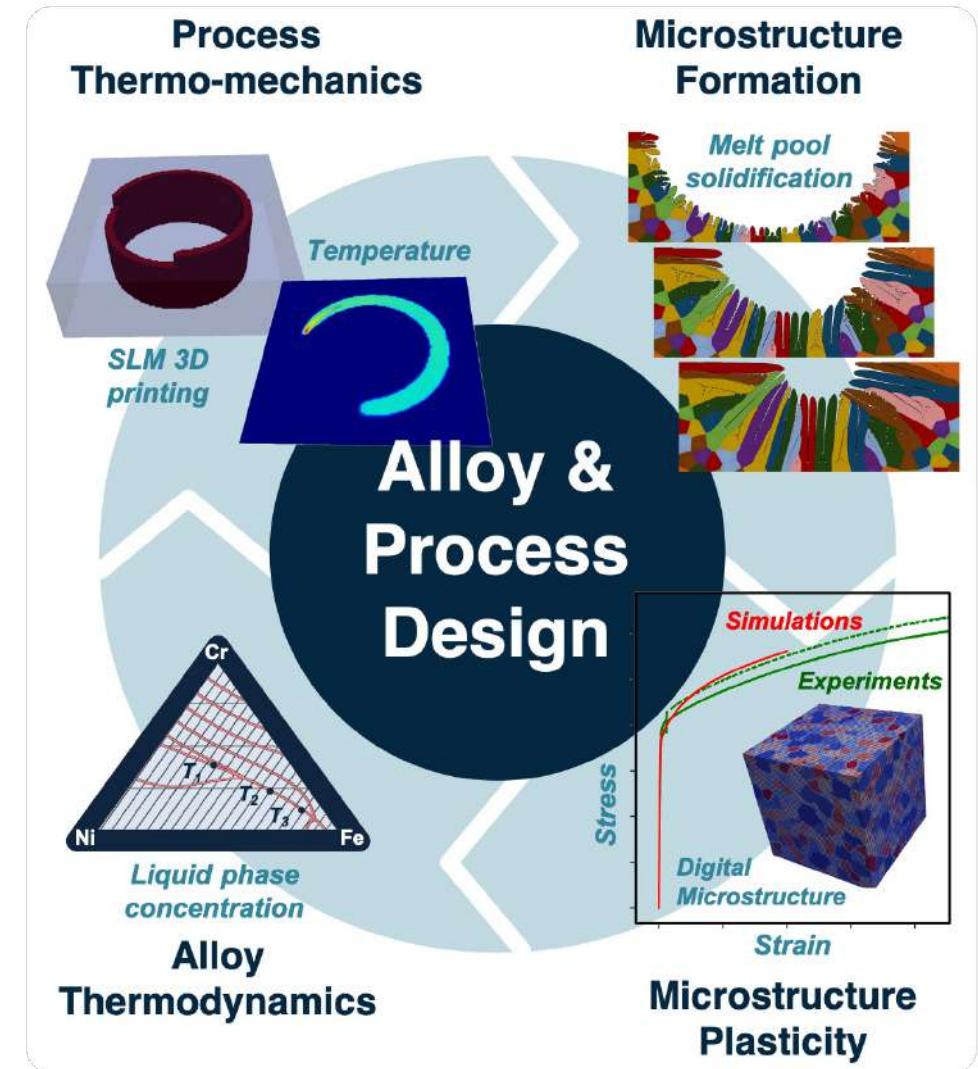


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Perspectives

- **ICME: Integrated Computational Materials Engineering**
From Processing to Microstructure to Properties to Performance
- **Location-specific microstructures from rapid solidification**
*PhD Thesis, Jose Mancias
Texas A&M University & IMDEA*
- **Multi-material – e.g. compositional grading**
*PhD Thesis, Jorge Valilla
Universidad Carlos III Madrid & IMDEA*





science



transfer



talent

Thank you for listening!

Questions?

IMDEA Materials Institute



www.materials.imdea.org

Damien Tourret



damien.tourret@imdea.org



Comunidad
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