cross-ING
Pure Cross Development

Driving Forces behind Developing AM-Specific Materials

Güven Kurtuldu

QSmetalAM 2024 «Materials – The name of the game»
20 June 2024, Park Innovaare, Villigen

Key factors driving innovation in AM materials

cross-ING
Pure Cross Development

Property Requirements

- Desired mechanical, thermal and electrical properties
- Enhancing corrosion and wear resistance

Process Compatibility

- Suitability for AM processes
- Optimizing flowability and reducing residual stresses

Design Flexibility

- Enabling complex geometries and lightweight structures
- Customizing properties for different component sections

Cost Efficiency

- Reducing material waste and production costs
- Minimizing post-processing and energy consumption

Sustainability

- Using renewable materials
- Reducing environmental impact and carbon footprint

Regulatory and certification standards

- Meeting industry-specific requirements and standards
- Enhancing competitive advantage with advanced materials

Processes in Conventional vs. Additive Manufacturing of Metals

cross-ING
Pure Cross Development

Processing → Microstructure → Property

Conventional

Melting of bulk material

- Casting
- Homogenization
- Rolling
- Extrusion
- …

→ Solidification + Heat Treatment + Deformation

cooling rates 1-100 K/s

2 m

20 µm

Additive

Melting of bulk material

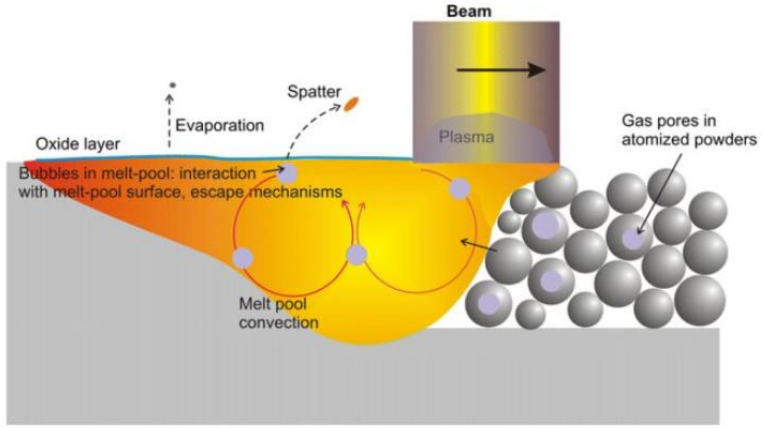
- Production of powder, filament, wire, …

- Laser Powder Bed Fusion (LPBF)
- Directed Energy Deposition (DED)
- Electron Beam Melting (EBM)
- …

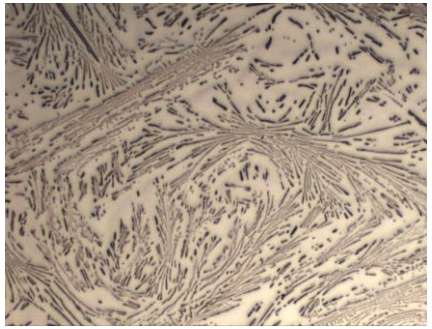
→ Melting cycles + Solidification + Heat Treatment

cooling rates 10^3-10^6 K/s

No deformation!



500 µm



5 µm

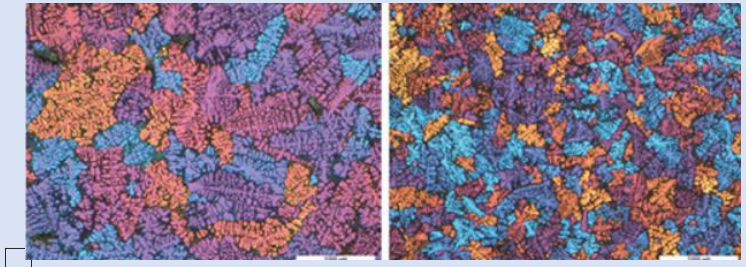
Hebert RJ. J. Materials Science. 2016 Feb;51:1165-75.

Development of a conventional alloy: Al 7075

Aerospace material designed in 1943 in Japan

Al - 5.5Zn - 2.5Mg - 1.5Cu - 0.2Cr - 0.3Fe - 0.3Si - 0.2Mn - 0.2Ti - 0.01B

Roles of alloying elements



- Ti and B : Grain refinement
- Zn: Strengthening with MgZn□
- Mg: MgZn□precipitates, solid solution hardening
- Cu: Al□CuMg precipitates, solid solution hardening
- Cr: Dispersoids inhibit recrystallization during HT
- Fe: High temperature strength
- Si: Increases fluidity and castability
- Mn: Solid-solution strengthening

Possible defects

Hot tearing

Porosity

Segregation

Inclusions

Processing steps

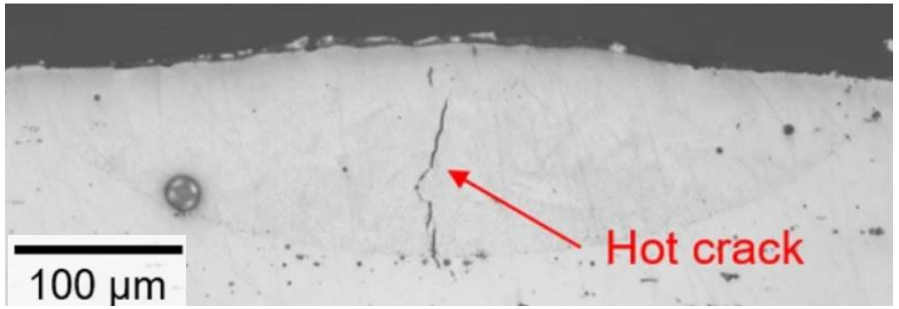
- Direct Chill Casting
- Homogenization
- Hot Rolling
- Cold Rolling
- Solution Heat Treatment
- Aging

Additive Manufacturing of Al 7075 alloy

Processing ⟶ Microstructure ⟶ Property

Al - 5.5Zn - 2.5Mg - 1.5Cu - 0.2Cr - 0.3Fe - 0.3Si - 0.2Mn - 0.2Ti - 0.01B

- Hot tearing due to rapid heating and cooling cycles



- Grain refinement effect of Ti and B reduces due to melting cycles.
- High cooling rates promotes microsegregation, where alloying elements like zinc and magnesium concentrate in certain areas.
- Significant vaporization of Mg and Zn

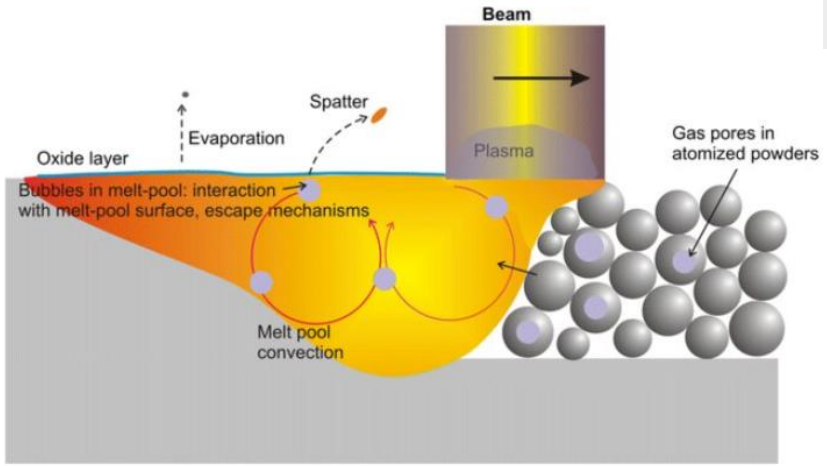
Melting of bulk material

- Production of powder
- Laser Powder Bed Fusion (LPBF)
- Electron Beam Melting (EBM)

Melting cycles + Solidification + Heat Treatment

cooling rates 10^3-10^6 K/s

No deformation!

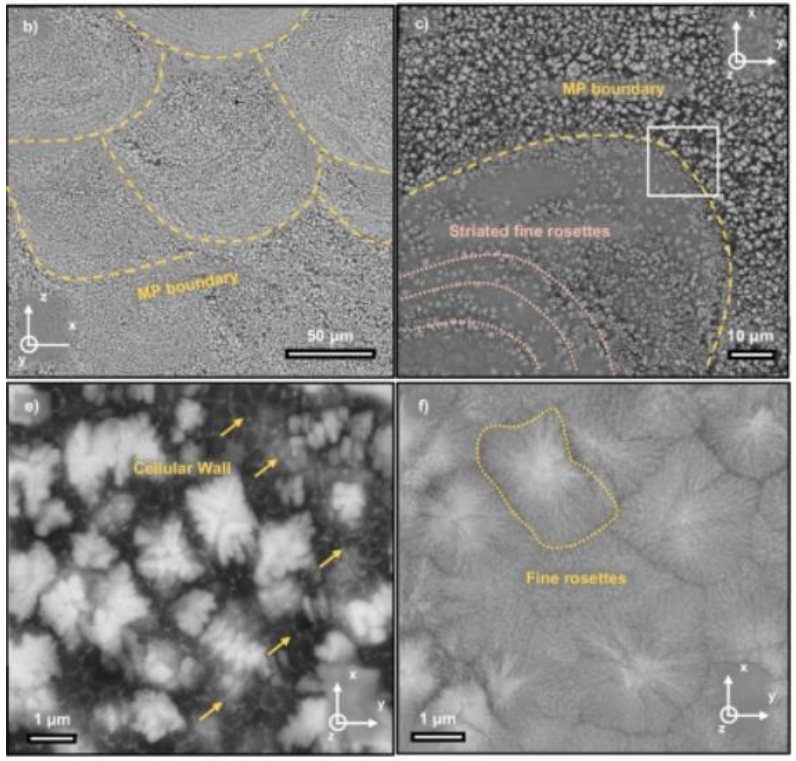


Hebert RJ. J. Materials Science. 2016 Feb;51:1165-75.

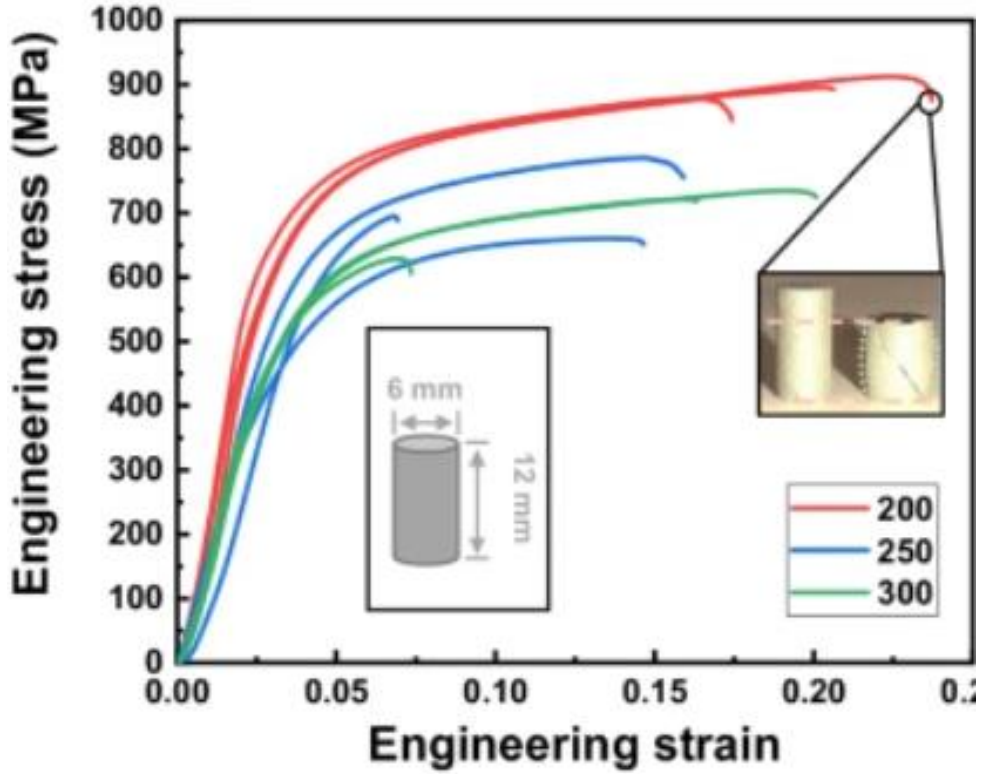
Development of an LPBF-specific alloy: Al-2Ti-2Fe-2Co-2Ni

cross-ING
Pure Cross Development

- Benefits from rapid solidification conditions to form fine intermetallic lamellae
- Potential for manufacturing lightweight, strong, and deformable components



Formation of heterogeneous nanoscale medium-entropy intermetallic lamellae



Good printability and mechanical properties, high strength and plastic deformability

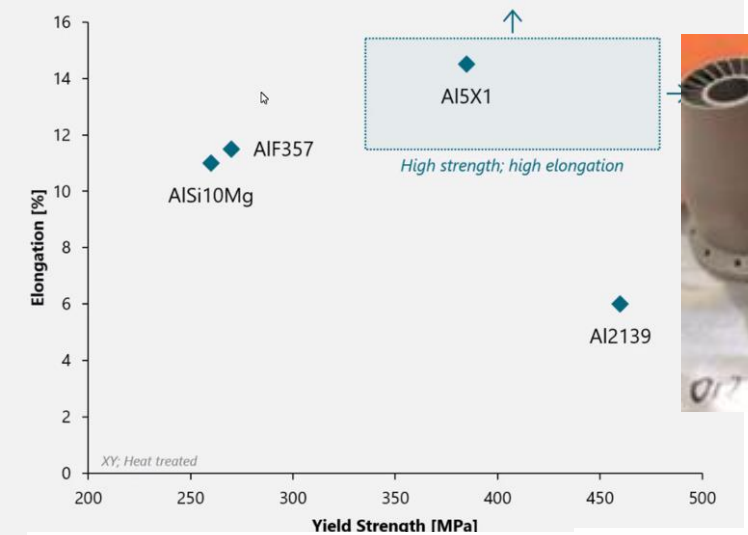
Shang, Anyu, et al. Nature Communications 15.1 (2024): 5122.

Emerging alloys in AM

cross-ING
Pure Cross Development

EOS Aluminium
AlSX1

Al-3Mg-1.2Zr-0.5Mn



Constellium

Aheadd® CP1 20/63
ALUMINIUM POWDERS
FOR ADDITIVE MANUFACTURING

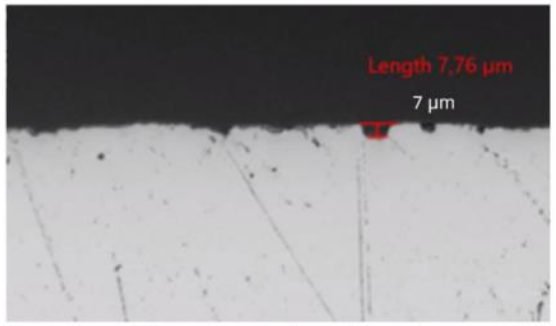
CHEMICAL COMPOSITION
(Aluminum Association No 8A61)

	Fe	Zr
Wt% Min	0.8	0.9
Wt% Max	1.4	1.4

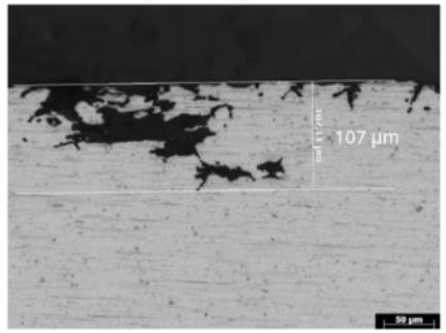
MECHANICAL PROPERTIES

	Tensile properties (Z axis) at 25°C		
	YS MPa	UTS MPa	El%
As built	137	203	23
Heat treated 4h-400°C	323	342	13

AlSX1, Heat treated



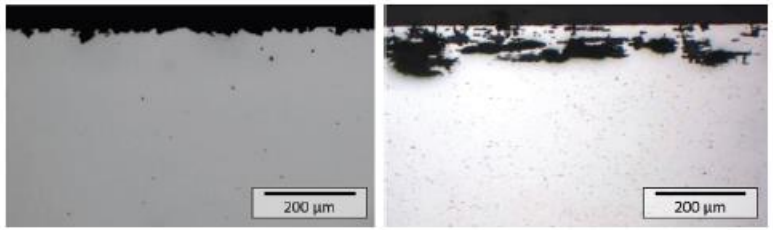
AA6082 T6, Wrought



Heat treatment improves corrosion resistance

L-PBF Aheadd® CP1
4h – 400°C

Extruded 6061 T6



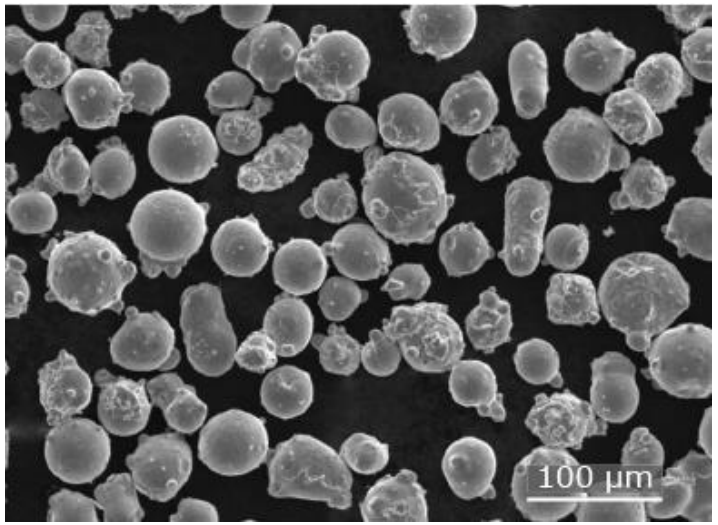
Corrosion test: 24h immersion, 30g/L NaCl + 10ml/L HCl, 30°C (ISO 11846B)

Importance of Powder Production for Material Innovation

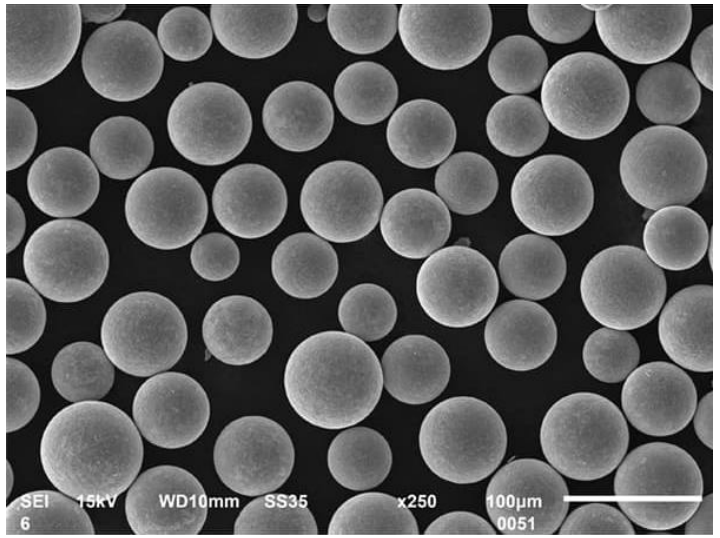
The ability to quickly produce and test new powders accelerates the development cycle for new materials

Powder Characteristics

- Particle Size Distribution
- Flowability
- Particle Shape
- Chemical Composition
- Moisture Content
- Oxygen Content
- Powder Ageing and Recycling



Metal powder with satellites



Spherical metal powder

Challenges & Solutions for AM-specific Materials

cross-ING
Pure Cross Development

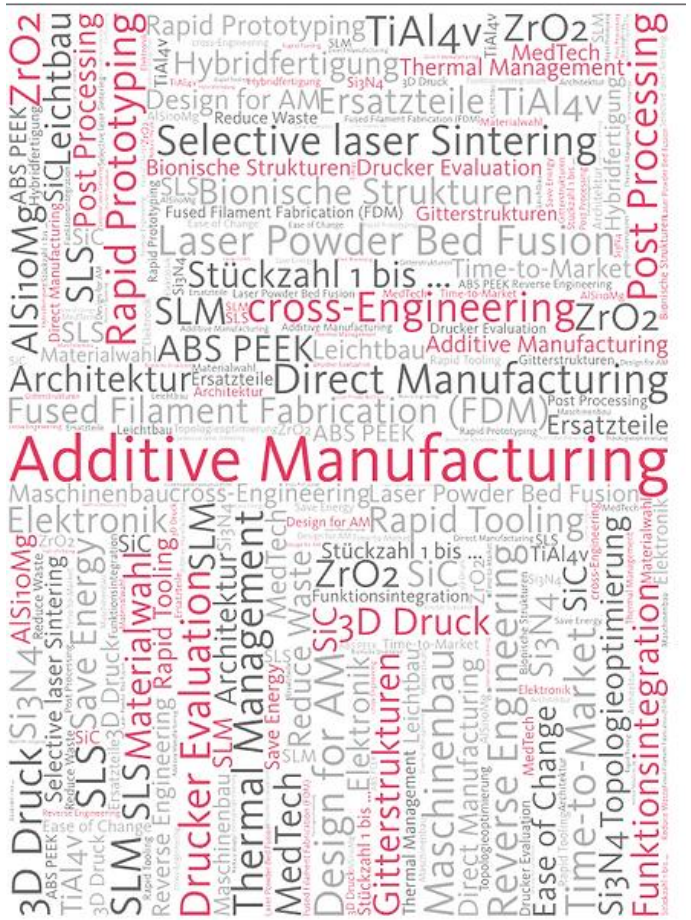
Challenges :

- Material consistency and quality control
- Compatibility with various metal AM processes
- Cost of developing and qualifying new materials

Solutions:

- Advances in metallurgy (including powder) and material characterization
- Standardization efforts and process optimization
- Real-time process monitoring

Our expertise in developing solutions



Design and process optimization

Material selection and development

Big data analysis

Questions & Discussion

cross-ING
Pure Cross Development

Thank you!