Additive Manufacturing: lo sviluppo della ricerca applicata nel territorio piemontese

THE ADDITIVE MANUFACTURING REVOLUTION IN THE PIEMONTE REGION

STATE OF THE ART AND STRATEGIC APPROACH

PAOLO FINO & DANIELE UGUES

Professor at Politecnico di Torino, Department of Applied Science and Technology (DISAT)
Senior Scientist of Center for Space Human Robotics (CSHR)– Istituto Italiano di Tecnologia (IIT)

Elisa Ambrosio, Flaviana Calignano, Massimo Lorusso, Diego Manfredi – IIT - CSHR@Polito
Sara Biamino, Mariangela Lombardi, Matteo Pavese, Daniele Ugues - @DISAT.Polito.it
Luca Iuliano, Eleonora Atzeni, Paolo Minetola, Alessandro Salmi - @DIGEP.Polito.it

- AM -

ADDITIVE MANUFACTURING

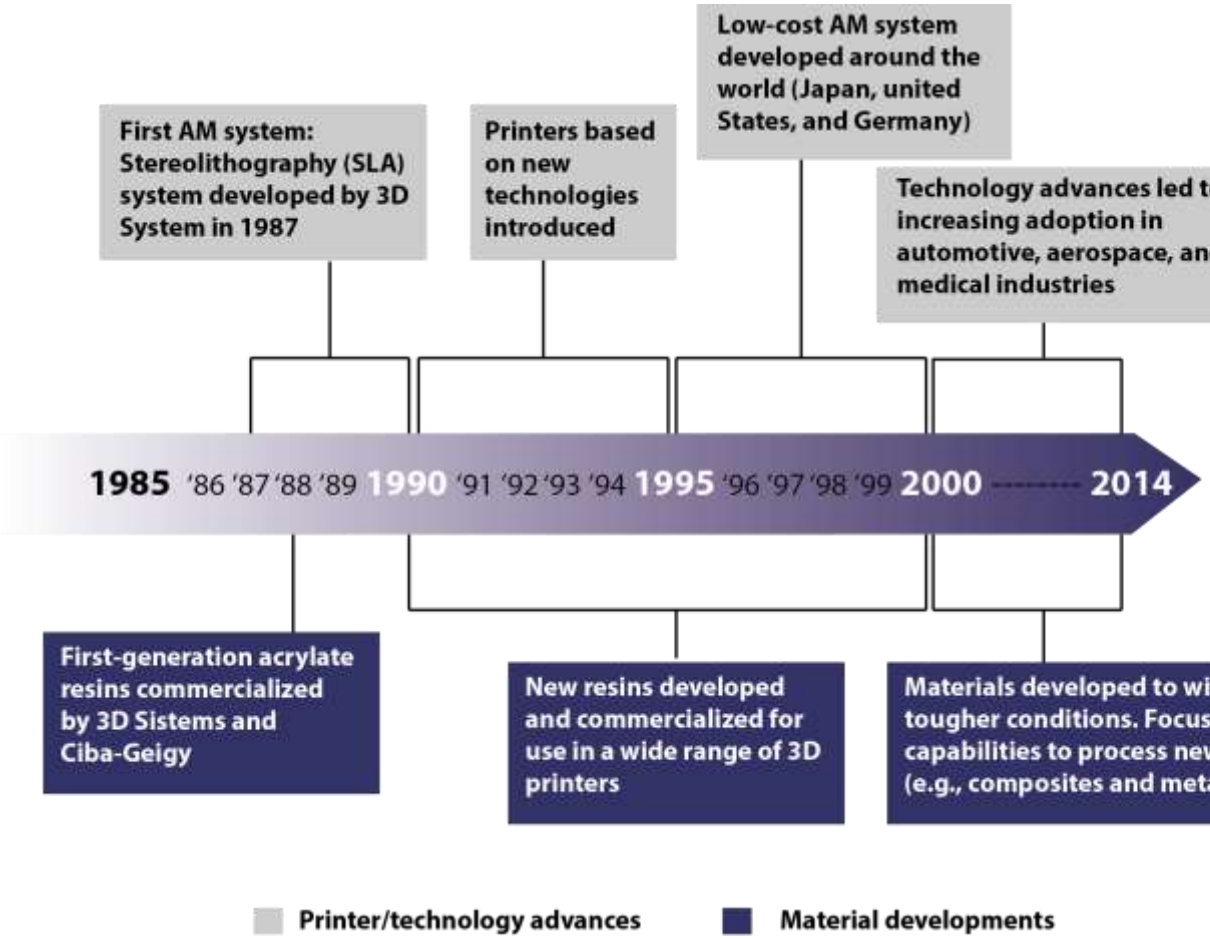
WHY ADDITIVE MANUFACTURING?

- **Additive Manufacturing** refers to a process that **builds up a component in layers**, as opposed to a subtractive operation, which removes matter from a block of material to form a product.

- This approach permits to extend the **freedom of design** and manufacture by allowing, for example, to create an object with **desired shape** and **internal structure** in a single fabrication step

- The design of the part can be **tailored** to meet specific functions and properties (e.g. physical, mechanical, chemical, etc.) using **different materials** (copper, nickel, cobalt, chromium, tool steel, polyamides, ABS, polycarbonate, polyphenylsulfone, titanium, aluminum)

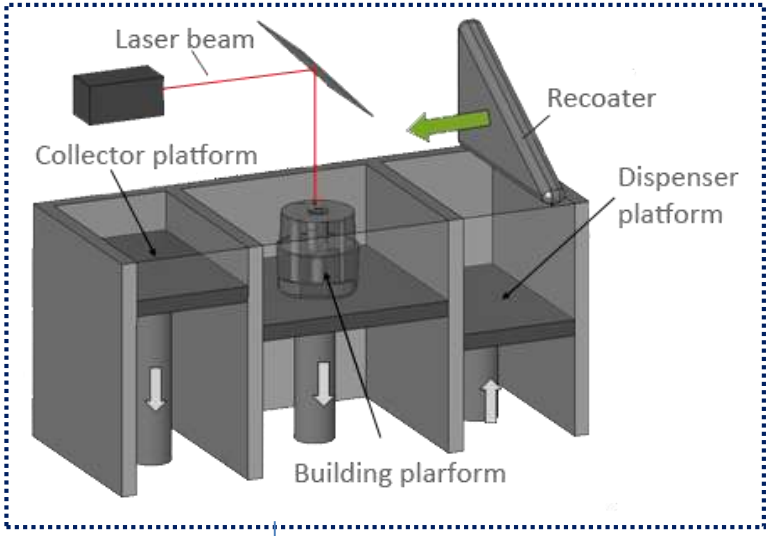
Evolution of AM



Developments for the near future:
fabricating big components

Source: Deloitte University; Wohlers Associates, Additive manufacturing and 3D printing state of the industry, 2012

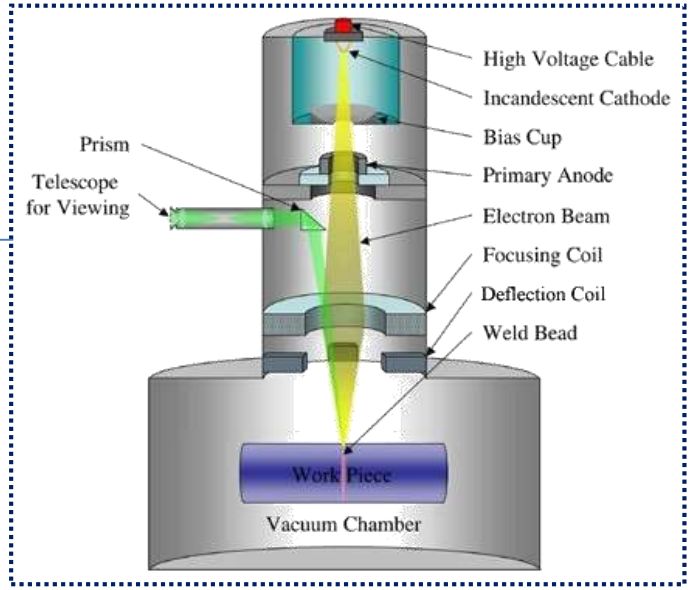
Metal



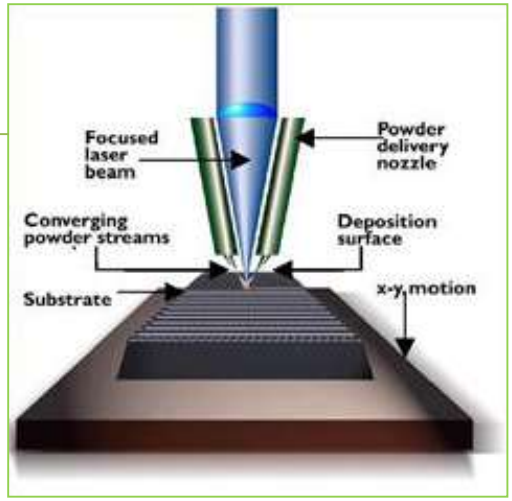
Laser

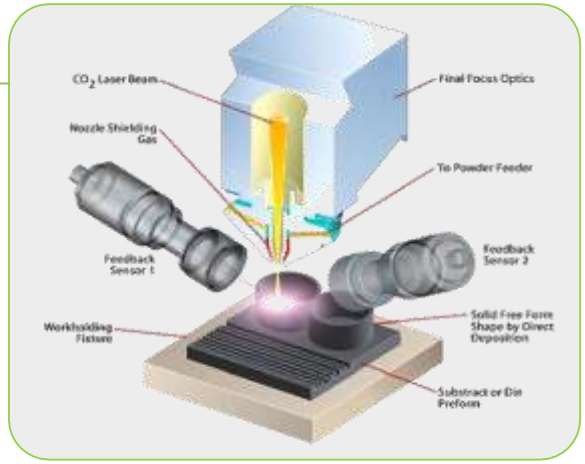
Powder Bed

EBM



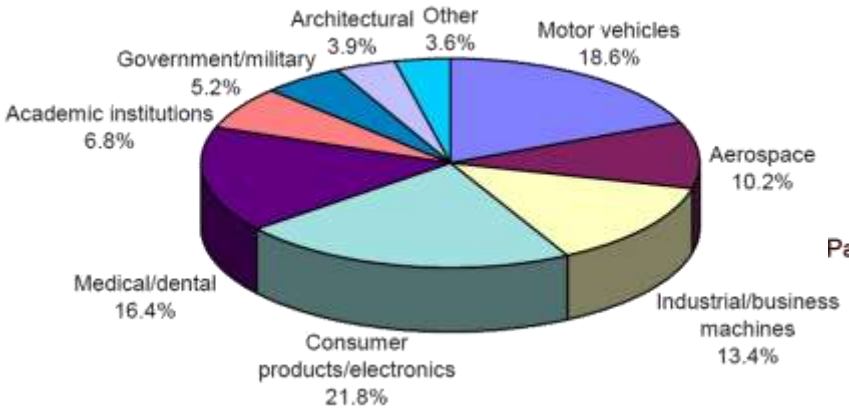
Blown powder



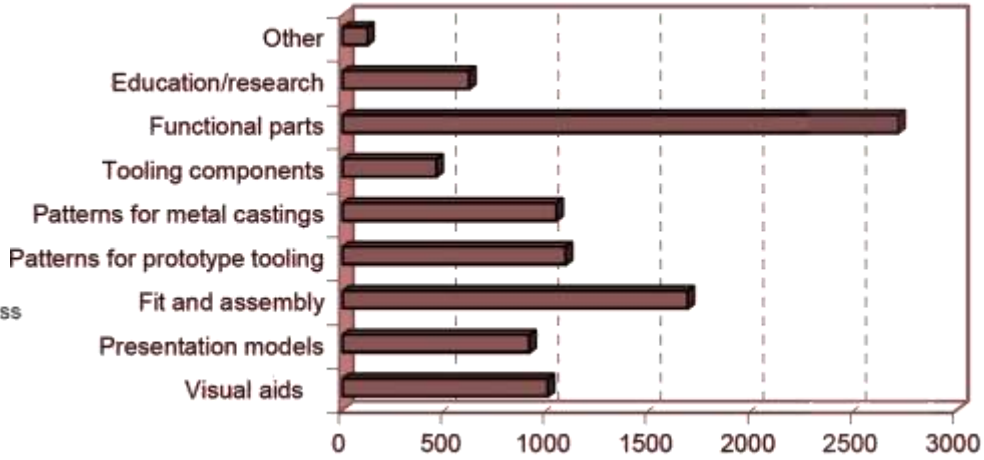


State of the Art

INDUSTRIAL SECTORS

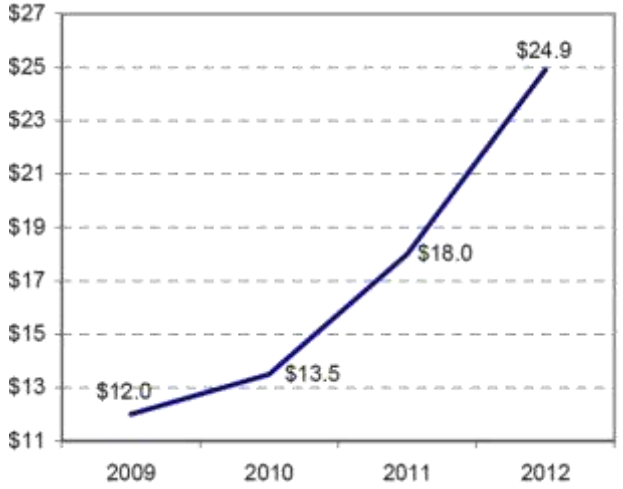


HOW COMPANIES ARE APPLYING AM PROCESSES



MARKET OPPORTUNITY AND FORECAST

REVENUE FROM METALS IN MILLION OF $



Source: Terry Wohlers Report 2013 - Annual Worldwide Progress Report

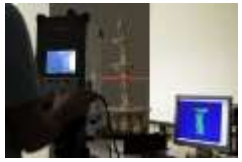
Strategy to share competences

AMTech Research Group

Prof. Luca Iuliano

Full Professor

CAD/CAE/CAM and 3D scanning systems



Advanced CNC machining and additive manufacturing

Politecnico di Torino DIGEP

Politecnico di Torino DISAT

CSHR@IIT

DiSAT chemistry physics materials science meets engineering

Prof. Paolo Fino

Full Professor

Materials Science and Technology

Prof. Fabrizio Pirri

IIT Center Coordinator

AM@POLITO

Polito @ Tecnogrnada Spa

M250 EOS
CoCr alloy

M270 EOS
Lightweight
Composites
SMA

Arcam A2
Intermetallics
Superalloy
Ceramics

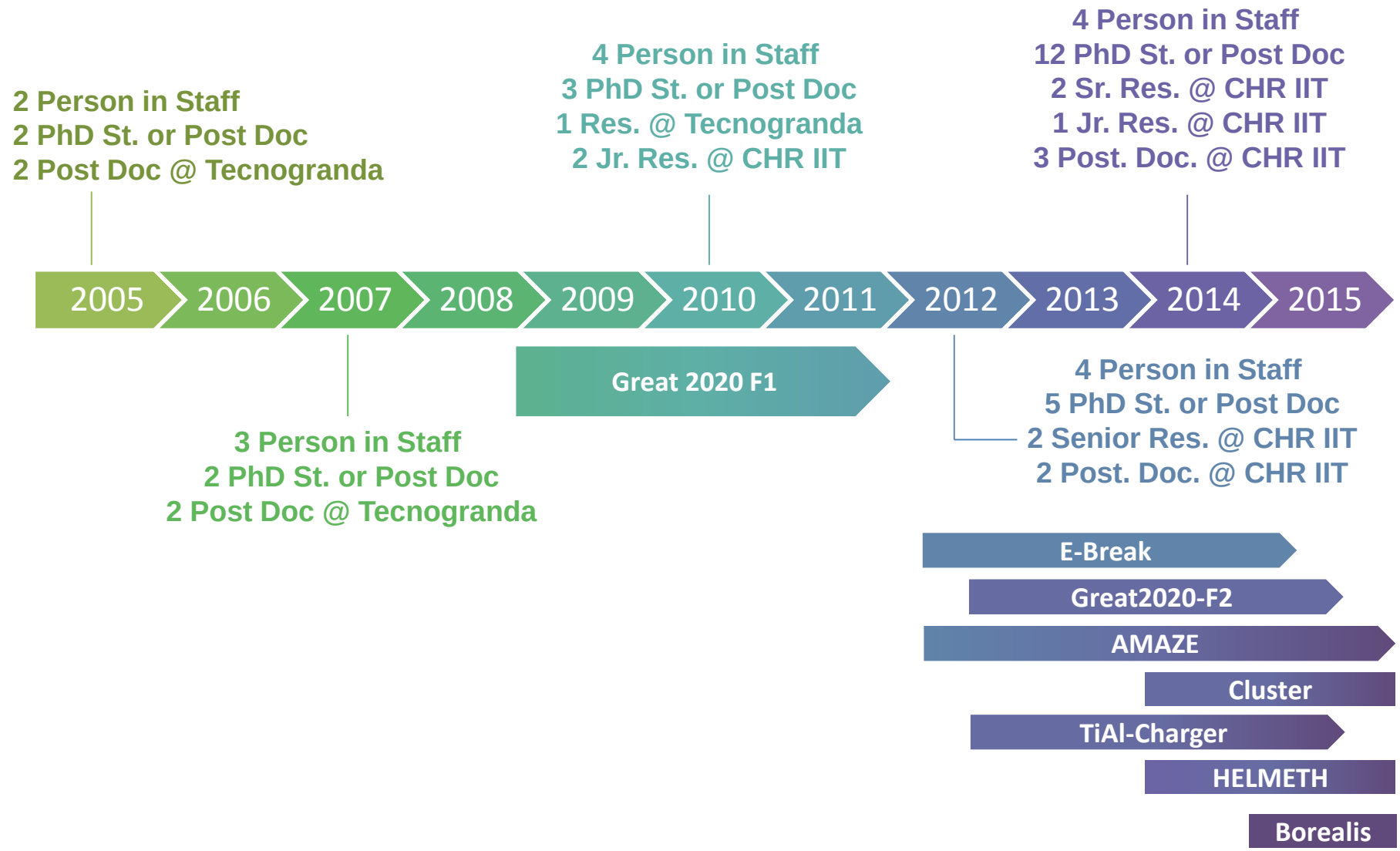
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015

Partnership AVIO – Polito
Regional research project

EBM - TiAl Intermetallics

Blow Powder Tech.
Alloy development
Large components

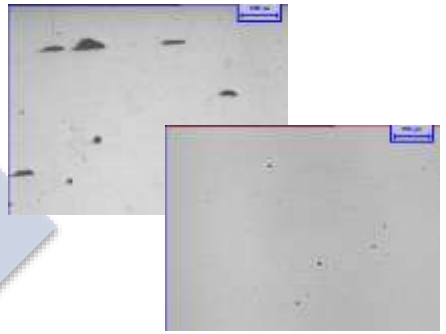
Material Science
AM Research

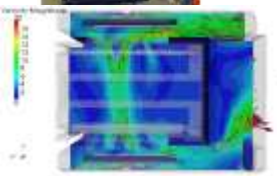


Activities on EBM - Approach

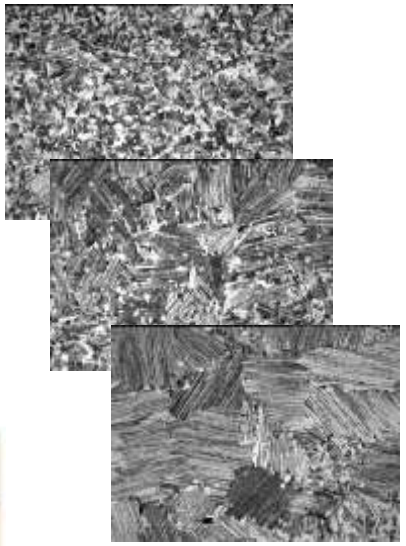
Materials of interest:
TiAl 4822 / TiAl Hi Nb / Renè 80

EBM production → **Alloy selection** → **Process optimization**



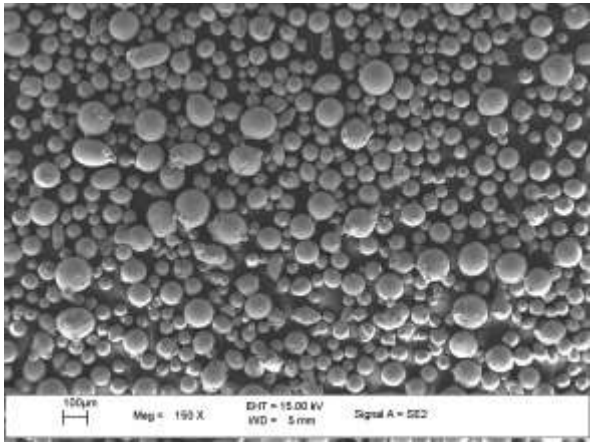


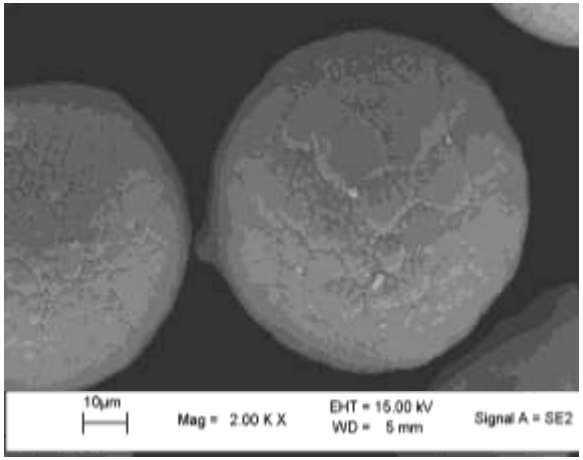
Heat treatmet setup → **Microstructure selection** → **Optimal Microstructure definition**

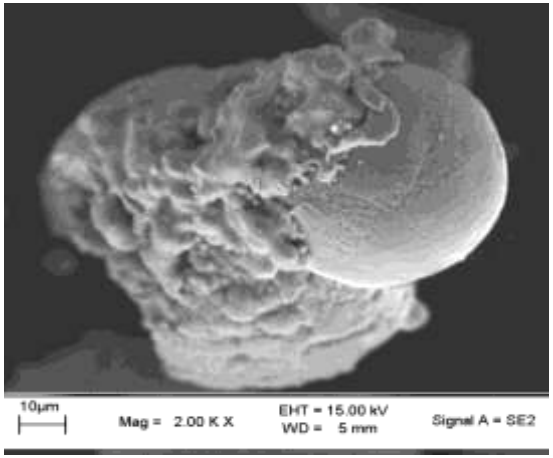


Mechanical and thermal properties tests

EBM - Powder morphology







Spherical particles **Powder defects**

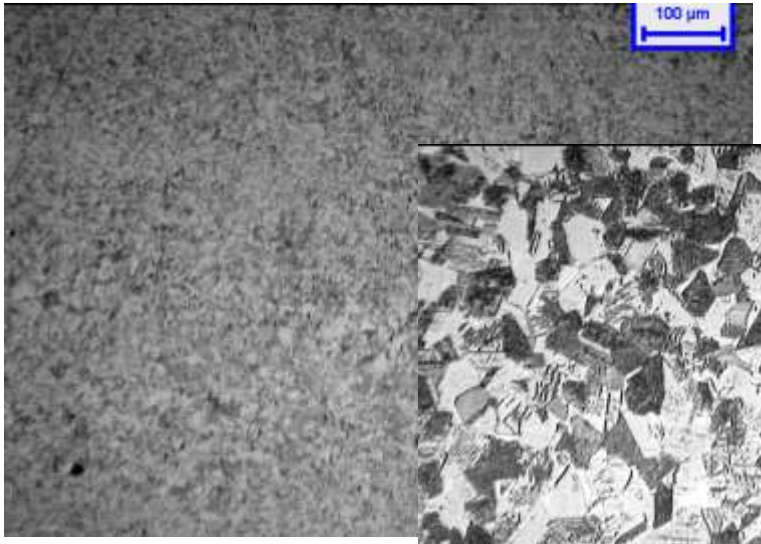
Powder	defects (%)	BET area (m^2/g)
A	16	0.036±0.002
B	15	0.028±0.002

EBM Ti-48Al-2Cr-2Nb

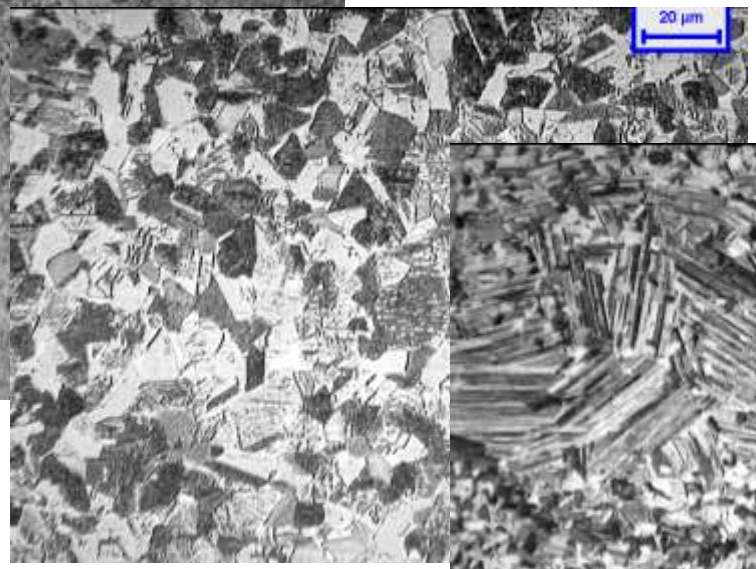
	Chemical composition in wt%						
	Al	**Cr**	**Nb**	**Fe**	**C**	**O**	**Ti**
Powder B	34.0	2.4	5.3	0.05	0.015	0.096	Bal.
Material built with Powder B (200 micron, 1050°C)	33.2	2.2	5.1	0.03	0.015	0.11	Bal.

- **Approx. 1 wt% Al loss due to evaporation**
- **Very low pickup of O thanks to vacuum environment**

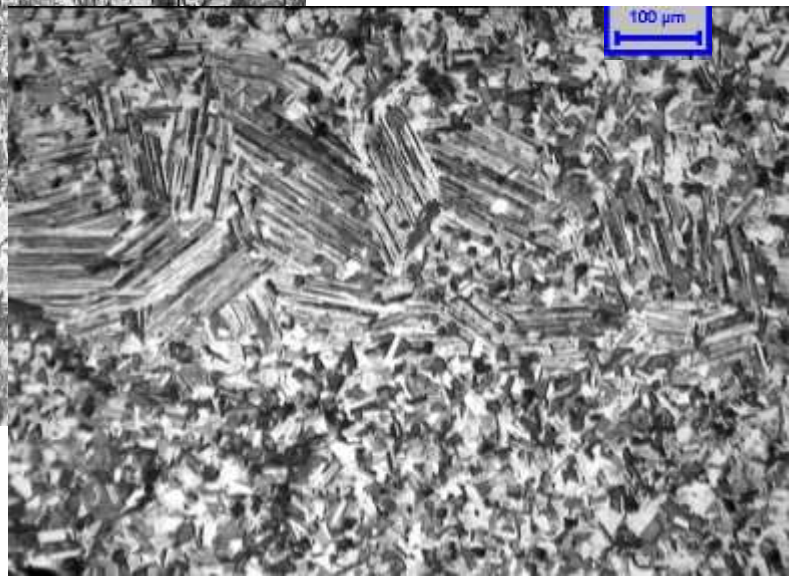
EBM Ti-48Al-2Cr-2Nb Microstructures & HT



As-built by EBM



HIP
Fully equiaxed
Grain size <50 µm



Heat Treatment
Duplex structure
Lamellar colonies ~150 µm
Lamellar phase fraction ~ 40%

Activities on SLM - DMLS

EOSINT M270 Xtended version

It is a net-shape process, producing parts with very high mechanical properties due to **the very fine microstructure** typical of this process.

When metallic powders are used for the production of parts, this process is generally known as **Selective Laser Melting (SLM)**.

DMLS is an EOS Gmbh tradename for SLM

SLM Process

The accuracy of CAD represented surface increases as the number of facets increases.

A key enabling principle of AM part manufacture is the use of layers as finete 2D cross-sections of the 3D model

Shot-peening, polishing and sandpapering, or application of coatings.

3D CAD model → **STL file** → **Support structure** → **Slicing** → **Part build** → **Stress relieving** **Part removal** → **Post-processing**

A set of parameters must be defined in order to respect the specifications as well as the manufacturing constraints (thicknesses, filled radii, ...)

The main functions of the supports are to fix the part to building platform and conduct excess heat away from the part.

Stress relieving is used to remove residual stresses which have accumulated from manufacturing processes.

The part must be either separated from a build platform on which the part was produced

Activities on SLM – DMLS: Approach

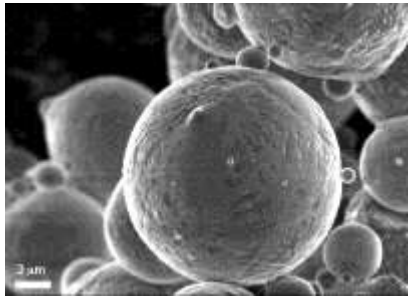
Materials of interest:
Al and Al based composites; Ti alloys; Ni- superalloys

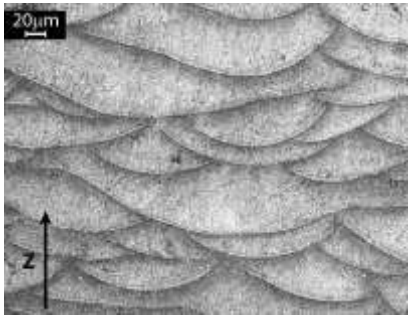
DMLS design and production → **Alloy selection and design** → **Process optimization**

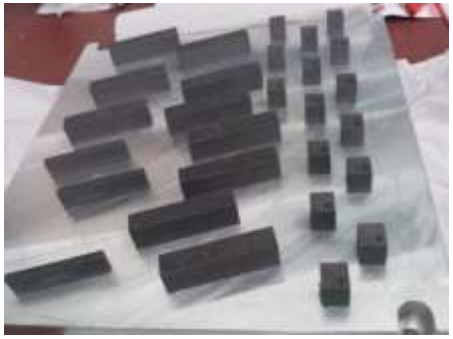
Heat treatmet setup and surf. finishing → **Microstr. selection** → **Optimal Microstructure definition**

Mechanical and thermal properties tests

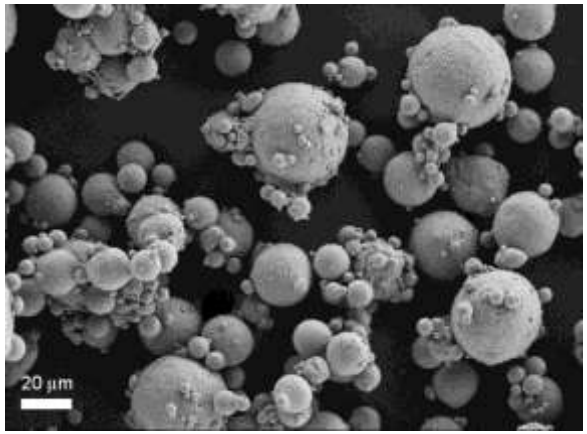
AlSi10Mg

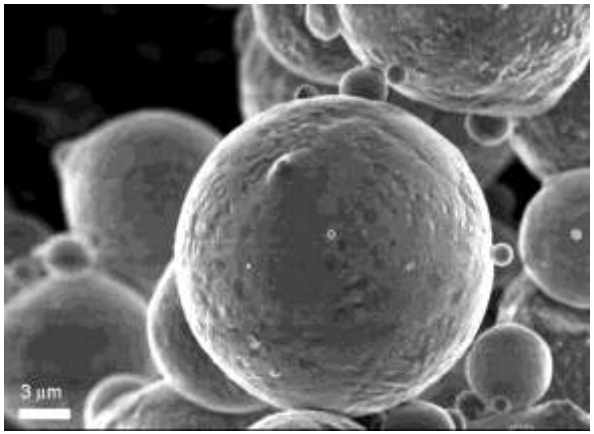






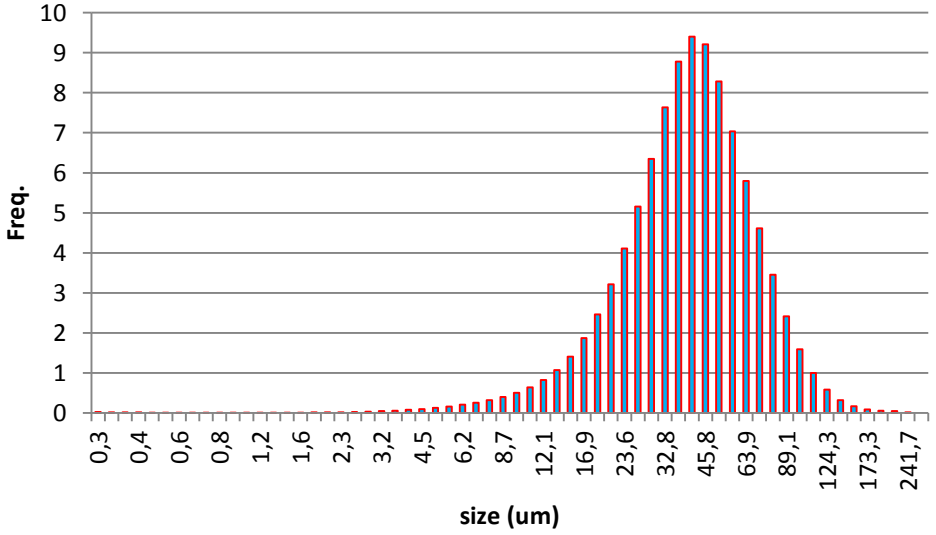
Activities on SLM – DMLS: Powder characterization





Spherical powder particles shape ranging from about 1 up to 44 µm with a mean size of 25 µm

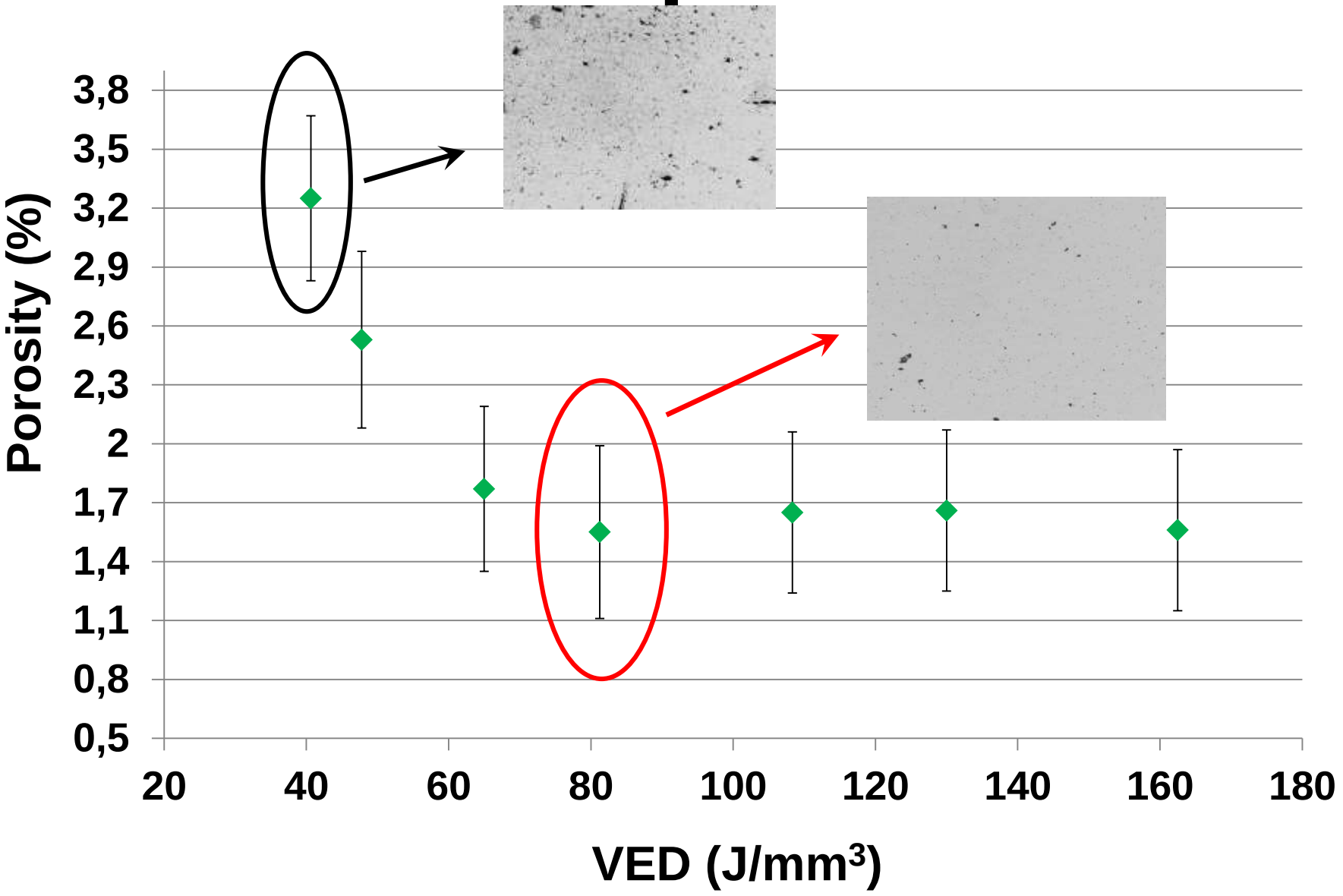
Laser granulometry test – Volumetric distribution



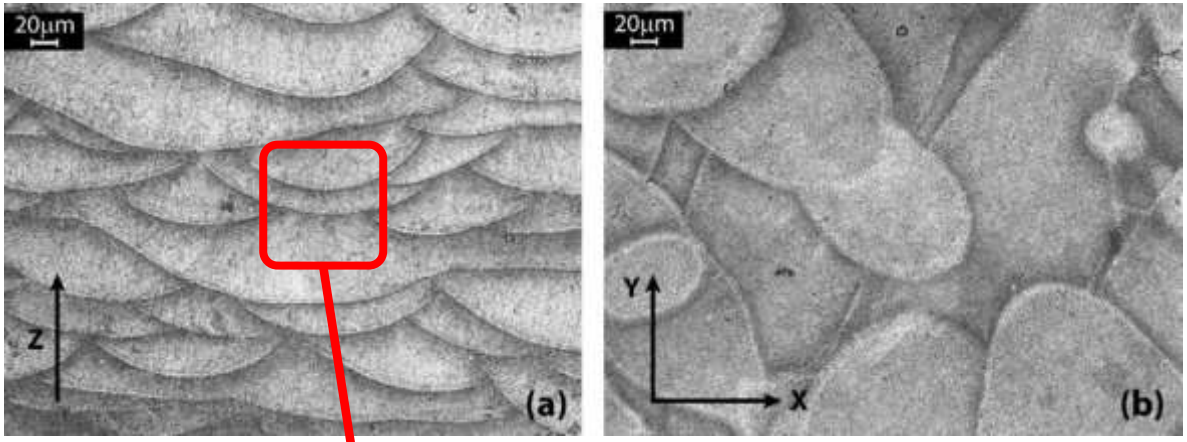
ICP compositional test

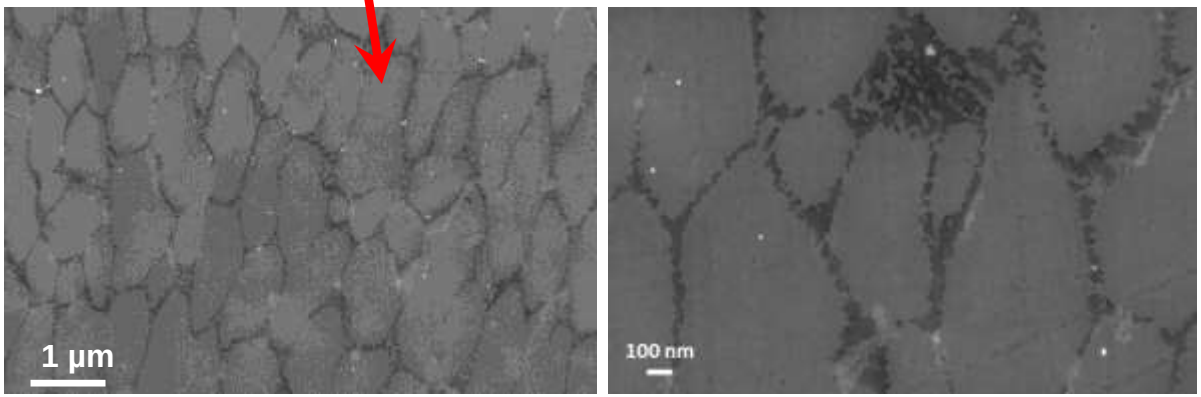
Element	Weight [%]
Si	10,08
Mg	0,35
Fe	0,16
Mn, Zn	0,002
Al	balance

Activities on SLM – DMLS: Process optimization

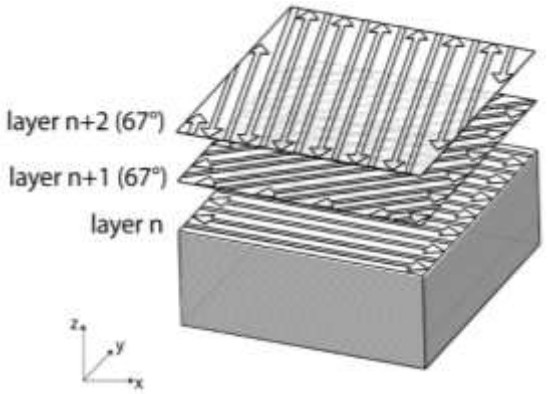


Activities on SLM – DMLS: microstructures





Typical microstructural details of the Al alloy by DMLS highlighted by chemical etching:
(a) scan tracks signs, **melt pools** (along z axis)
(b) melt pools on xy section



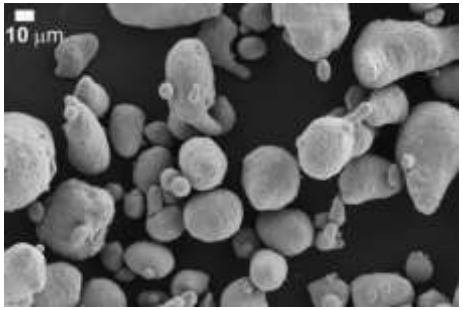
Darker areas → Si rich
Grey areas → Al euctectic zones

EXTREMLY FINE

AM in Polito/iit DMLS machine

MATERIALS DEVELOPED @ CSHR

A357



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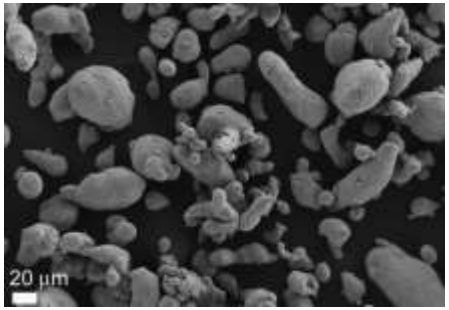
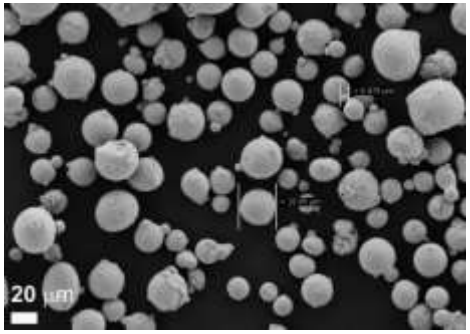
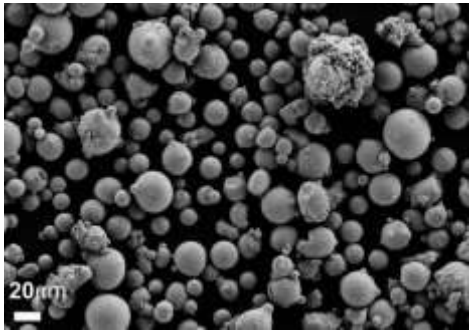


In718



In625



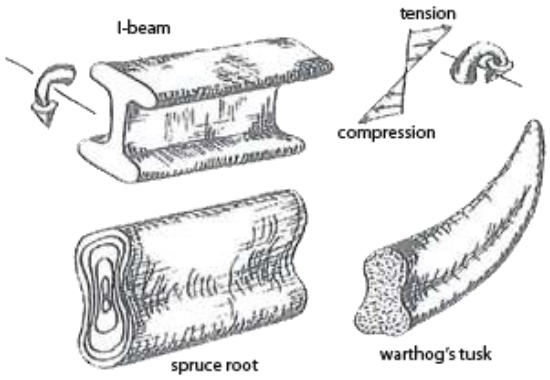
MATERIALS TO BE DEVELOPED

- Al alloys for aerospace (2xxx, 6xxx, etc)
- Al based Composites
- Ti based Composites
- Cu and Cu based alloys
- Functional materials (e.g. SMA)

Design Optimization

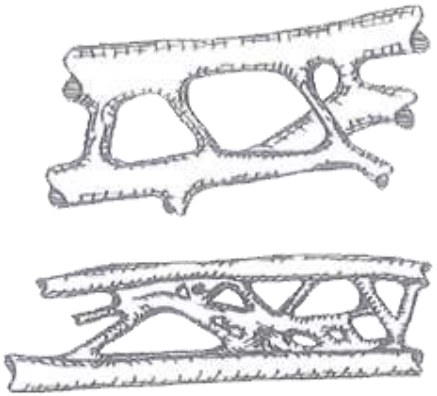
Design structures bio-inspired

**"In her (nature's) inventions,
nothing is lacking,
and nothing is superfluous"**
Leonardo Da Vinci



C. Mattheck
Design in Nature
Ed. Springer 1998

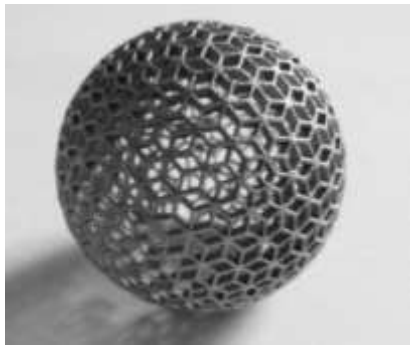
Examples from nature



STRUT LIGHTWEIGHT SUSPENSION FOR AUTOMOTIVE FABRICATED BY DMLS

AM in Robotic Structures

STRUCTURES FABRICATED inside IIT - CSHR@Polito labs



Hydraulic Manifolds for HyQ

Robotic assembly that can be manufactured

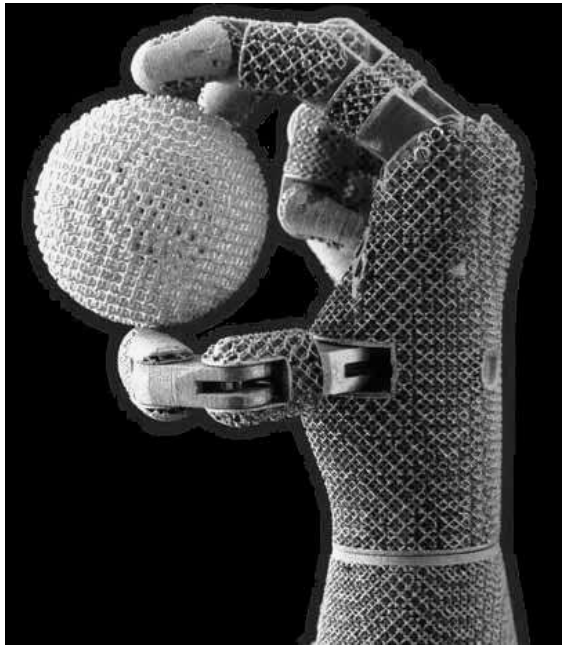


Photo courtesy Oak Ridge National Laboratory's Manufacturing Demonstration Facility

AM for heat sinks

New design structures in heat exchangers increase compactness and effectiveness

e-Manufacturing Solutions

Industry: Example Complex Components

Conceptual heat exchanger

Application

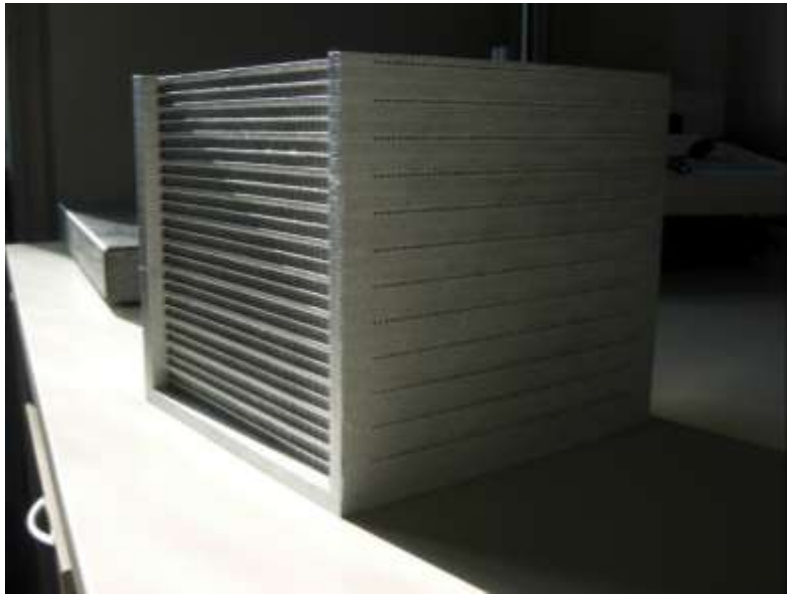
- Design study for heat exchanger
- Repeated sub-elements can be formed into almost any shape
- Self-supporting, integrated cooling fins on outside surfaces
- Turbulators inside the cooling tubes disrupt the flow of the cooled fluid
- Material: Aluminum

Advantages

- Compact and scalable design
- Maximum heat transfer

Source: Within, 3T, EOS

Produced in AlSi10Mg @ IIT-PoliTo

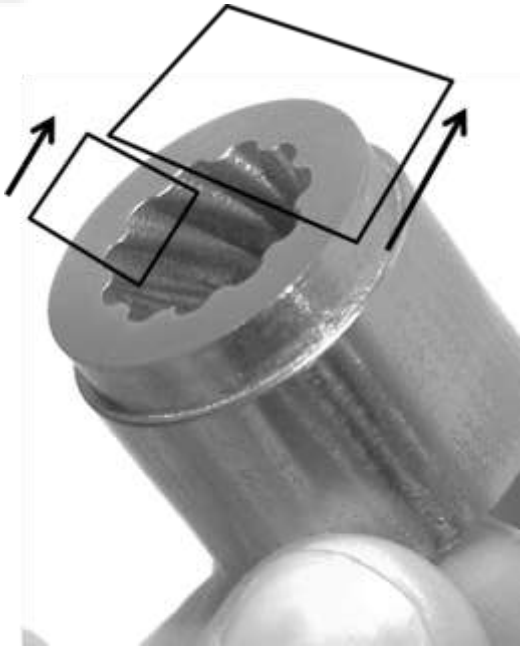


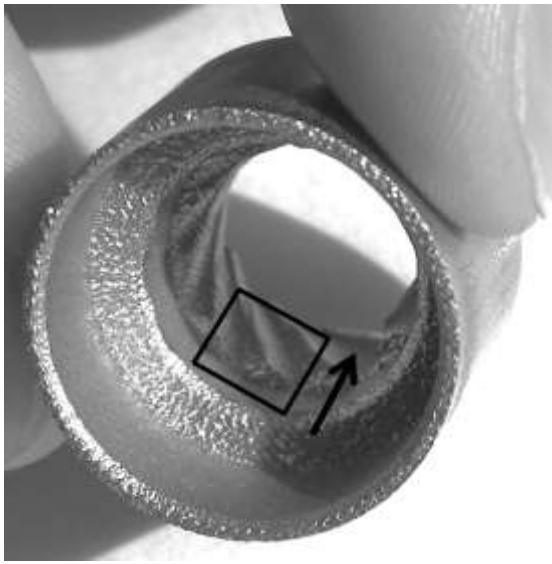
For each layer 6320 ellyptical fins

Current research topics: surface post processing

Combination of mechanical and electrochemical polishing, abrasive flow machining (AFM)

Surface post processing → and subsequent stereomicroscope analysis





Base/Applied research

Base and applied Research, innovative concept, know how

Applied Sciences and Technology Dep.
Production systems Dep.
Mechanical Eng Dep.

Avio Aero
A GE Aviation Business

ThalesAlenia Space
A Thales / Finmeccanica Company

PRIMA INDUSTRIE

Requirements, market needs, specifications, design constraints

Widen the frontiers of AM

Additive Manufacturing:
broad term → include many technologies

Polito and CSHR@Polito Know-how developed on the entire additive manufacturing process chain, comprising the development, application and implementation of additive manufacturing methods and processes

IMAGINE TO CREATE A NEW MACHINE for..

BOREALIS

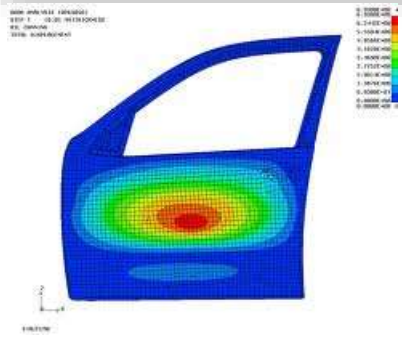
Multifunctional Materials

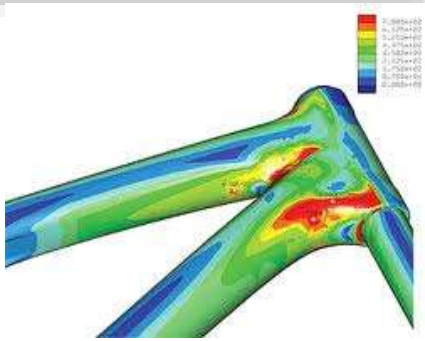
Following a user-driven strategic review of global AM research, it has been identified that basic research must now move away from established single material, ‘passive’ AM processes and applications that exhibit conventional levels of functionality, toward the challenges of investigating next generation, **multi-material active AM processes**, **materials and design systems**.

By contemporaneously depositing dissimilar materials, multifunctional AM will enable the production of entirely novel, high-value, multifunctional products

For example: Multi-axes machine able to use different feeding materials

In situ advanced analyses





Imagine to detect thermal stresses DURING the AM process, employing different Artificial Vision systems

Thanks to a smart electronic and closed loop control, change the AM process parameters to reduce these stresses

A sort of ADAPTIVE Additive Manufacturing Process

Structural funding opportunity

POLITO and IIT are officially involved in
Metallurgy EUROPE - EUREKA

WORK PROGRAMS in H2020 INVOLVING ADDITIVE MANUFACTURING

Future and Emerging Technologies (FET)

Enabling and industrial technologies (LEIT)

Information and Communication Technologies

Nanotechnologies, Advanced Materials (NMP, FoF),

Biotechnology and Advanced Manufacturing and Processing

Space

Innovation in small and medium-sized enterprises

Smart, green and integrated transport

Kic - EIT

Metallurgy Europe Cluster

Italian institution onboard:

Politecnico di Torino, Politecnico di Milano, IIT, Università di Roma, Università di Torino, Università di Trento

Some Italian industrial partners onboard:

AVIOAERO, CRF, CSM, Dalmine, Fomas, LucchiniRS, Prima Industrie, Gruppo Riva, Sigmaelle, Thales Alenia Space

Also involving:

AIM, INSTM, AIMAT

Projects

GREAT 2020 – GReen Engine for Air Traffic 2020 – Regional project (2009-2012).

ProTiAl – Developing of a new concept for optimal Production and machining of aerospace components in TiAl (2009-2012).

AMAZE – Additive Manufacturing Aiming Towards Zero Waste and Efficient Production of High-Tech Metal Products – UE Project, VII FP (2012-2015).

E-BRAKE – Demonstration of breakthrough sub-systems enabling high overall pressure ratio engine – UE Project, VII FP (2012-2015).

TiAl Charger – Titanium Aluminide Turbochargers – Improved Fuel Economy, Reduced Emissions – UE Capacities Project, VII FP (2012 – 2014).

EXOMET – Physical processing of molten light alloys under the influence of external fields – UE Large-scale integrating collaborative project, VII FP (2012-2015).

HELMETH – Integrated High-Temperature Electrolysis and Methanation for Effective Power to Gas Conversion - New generation of high temperature electrolyser, UE Project, VII FP (2014-2016).

BOREALIS - the 3A energy class Flexible Machine for the new Additive and Subtractive Manufacturing on next generation of complex 3D metal parts – UE Horizon2020 Project (2015-2018).

GETREADY - HiGh spEed TuRbinE cAsing produced by powDer HIP technologY – UE JTI Cleansky (2014-2015)

GREAT 2020 phase 2– GReen Engine for Air Traffic 2020 – Regional project (2009-2012).

Cluster Aerospazio – Greening the propulsion – National project (2014-2017).

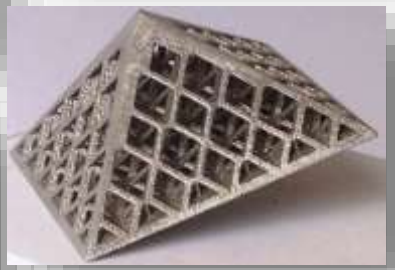
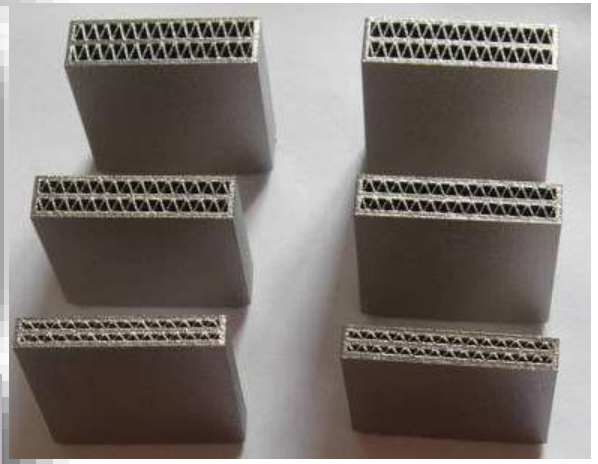
POP3D – Progetto ASI - Validazione del livello di maturità tecnologica di un sistema di fabbricazione additiva polimerica in microgravità per utilizzo a bordo della Stazione Spaziale Internazionale (2014-2016).

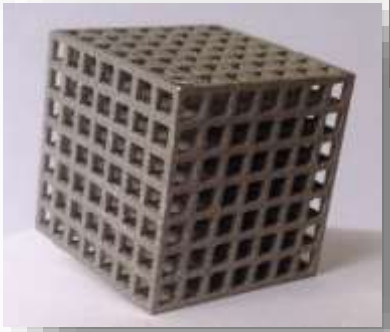
Several new proposal focused on AM tech under evaluation (Redemption, Ramlight, Lotsize1, Made in Nephos, Optimus, Levante).










For more information: paolo.fino@polito.it; daniele.ugues@polito.it