



UNIMORE

UNIVERSITÀ DEGLI STUDI DI
MODENA E REGGIO EMILIA

Dipartimento di Scienze e Metodi dell'Ingegneria
Campus San Lazzaro
Reggio Emilia

Additive Manufacturing: presente e futuro della ricerca industriale

Ing. Leonardo Orazi

Additive Manufacturing: 30 anni di storia

United States Patent
Hull

[11] Patent Number: 4,575,330
[45] Date of Patent: Mar. 11, 1986

[54] APPARATUS FOR PRODUCTION OF THREE-DIMENSIONAL OBJECTS BY STEREO LITHOGRAPHY

[75] Inventor: Charles W. Hull, Arcadia, Calif.

[73] Assignee: UVP, Inc., San Gabriel, Calif.

[21] Appl. No.: 638,905

[22] Filed: Aug. 8, 1984

[51] Int. Cl.⁴: B29D 11/00; G03C 00/00

[52] U.S. Cl.: 425/174.4; 425/174; 425/162; 264/22; 430/269; 156/58; 365/119; 365/120

[58] Field of Search: 425/162, 174, 174.4, 425/425; 264/22, 183, 40.1; 430/269; 156/38, 58, 275.5; 365/107, 119, 127

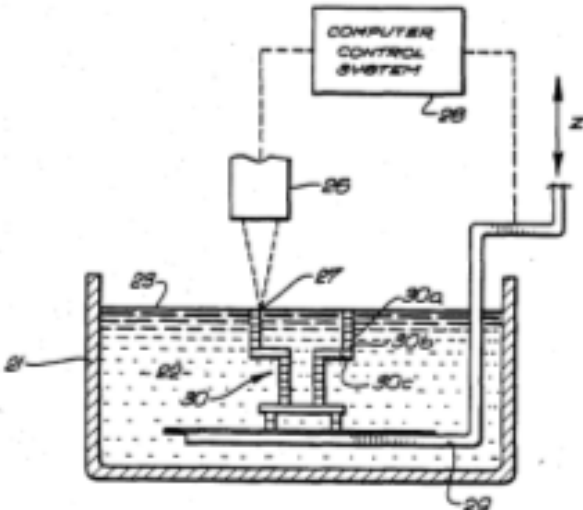
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Primary Examiner—J. Howard Flint, Jr.
Attorney, Agent, or Firm—Fulwider, Patton, Rieber, Lee & Utecht

ABSTRACT

A system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed at a selected surface of a fluid medium capable of altering its physical state in response to appropriate synergistic stimulation by impinging radiation, particle bombardment or chemical reaction, successive adjacent laminae, representing corresponding successive adjacent cross-sections of the object, being automatically formed and integrated together to provide a step-wise laminar buildup of the desired object, whereby a three-dimensional object is formed and drawn from a substantially planar surface of the fluid medium during the

Stereolitografia: SLA



08.08.1984

United States Patent
Deckard

[11] Patent Number: 4,863,538
[45] Date of Patent: Sep. 5, 1989

[54] METHOD AND APPARATUS FOR PRODUCING PARTS BY SELECTIVE SINTERING

[75] Inventor: Carl R. Deckard, Austin, Tex.

[73] Assignee: Board of Regents, The University of Texas System, Austin, Tex.

[21] Appl. No.: 920,580

[22] Filed: Oct. 17, 1986

[51] Int. Cl.⁴: B27N 3/00; B32B 31/00; B23K 9/00; B29C 67/00

[52] U.S. Cl.: 156/62.2; 156/272.8; 219/121.66; 219/121.8; 219/121.85; 264/58; 264/113; 264/125

[58] Field of Search: 219/121 LE, 121 LF, 219/121 LC, 121 LD, 121 LW, 121 LM; 419/5, 8; 427/53.1; 428/548; 156/630, 643, 345, 272.8, 62.2; 264/56, 58-67, 113, 122, 125, 126, 127

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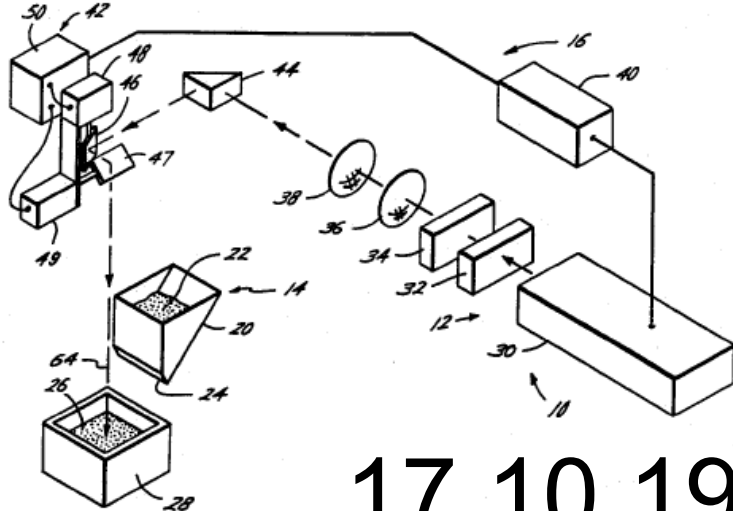
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Lasers Carve Complex 3-D Parts (pp. 1-11).
Sample Cover Letter from Hydronetics, Inc.
Electronic Engineering Times, Issue 430 (Apr. 20, 1987).

Primary Examiner—William A. Powell
Attorney, Agent, or Firm—Arnold, White & Durkee

ABSTRACT

A method and apparatus for selectively sintering a layer of powder to produce a part comprising a plurality of

Selective Laser Sintering: SLS



17.10.1986

United States Patent
Melners et al.

[10] Patent No.: US 6,215,093 B1
[45] Date of Patent: Apr. 10, 2001

[54] SELECTIVE LASER SINTERING AT MELTING TEMPERATURE

[75] Inventors: Wilhelm Melners, Aachen; Konrad Wiesenbach, Herzogenrath; Andres Gasser, Aachen, all of (DE)

[73] Assignee: Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung E.V., Munich (DE)

[21] Appl. No.: 09/319,132

[22] PCT Filed: Oct. 27, 1997

[86] PCT No.: PCT/EP97/05935

§ 371 Date: Jul. 12, 1999

§ 102(e) Date: Jul. 12, 1999

[87] PCT Pub. No.: WO98/24574

PCT Pub. Date: Jun. 11, 1998

[30] Foreign Application Priority Data
Dec. 2, 1996 (DE) 196 4 196 4

[51] Int. Cl.⁷: B22F 3/00

[52] U.S. Cl.: 219/121.61; 219/121.62; 219/121.85; 419/447, 57, 427/594; 264/125, 508

[58] Field of Search: 219/121.6, 121.61, 219/121.62, 121.65, 121.66, 121.68, 121.85; 419/447, 57, 427/594; 264/125, 508

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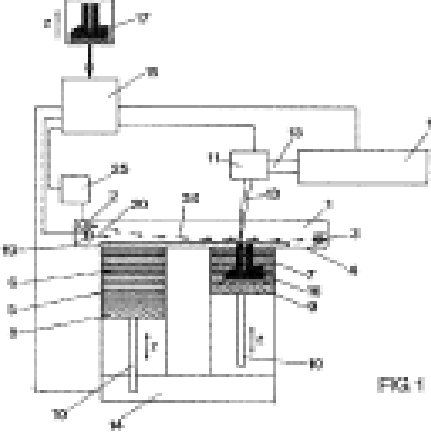
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Primary Examiner—Patrick J. Ryan
(74) Attorney, Agent, or Firm—Milde, Hoffberg & Macklin, LLP

ABSTRACT

A method is disclosed for manufacturing a molded body, in accordance with three-dimensional CAD data of a model of a molded body, by depositing layers of a metallic material in powder form. Several layers of powder are successively deposited one on top of the other, whereby each layer of

Selective Laser Melting: SLM



12.07.1999

G.N. Levy - Additive Manufacturing in Production Engineering: Chances and Challenges.
9th CIRP Conferences on Intelligent Computation in Manufacturing Engineering - Capri 2014

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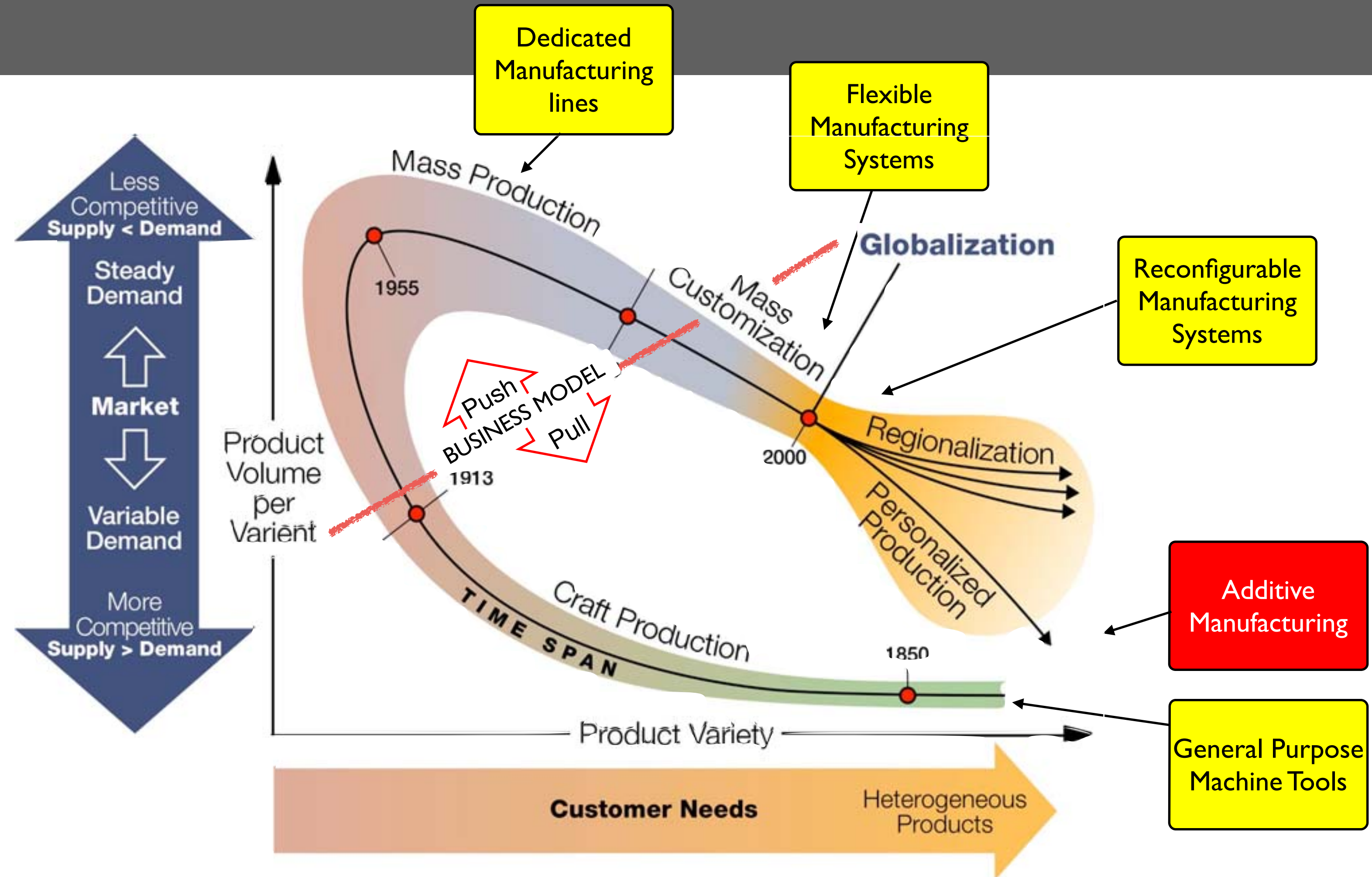
L. Orazi

Additive Manufacturing:
presente e futuro della ricerca industriale

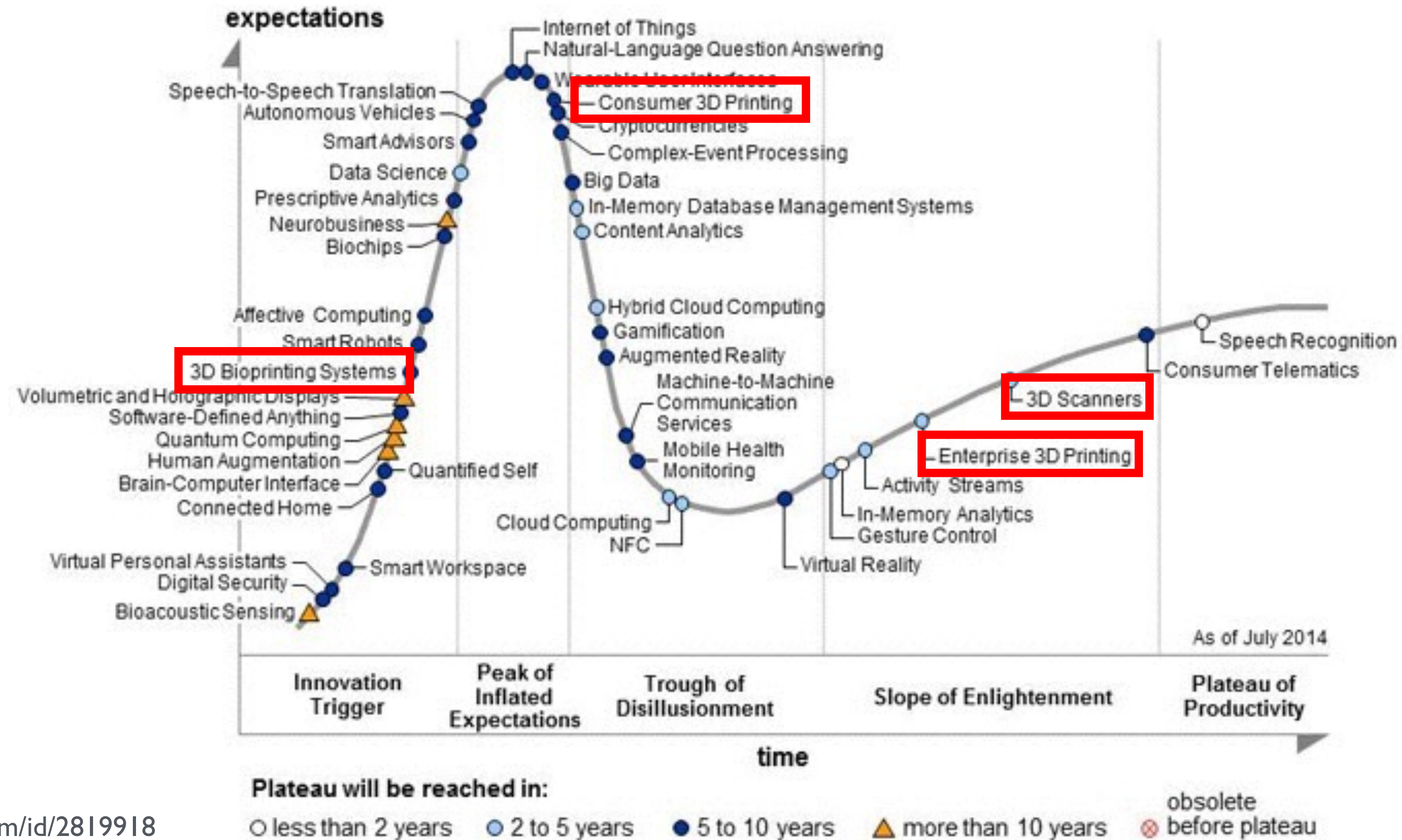
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Tecnologia e Sistemi di Lavorazioni

2

Additive Manufacturing: il nuovo artigianato digitale



Gartner Hype Cycle of Emerging Technologies, Trends for 2014



<http://www.gartner.com/newsroom/id/2819918>

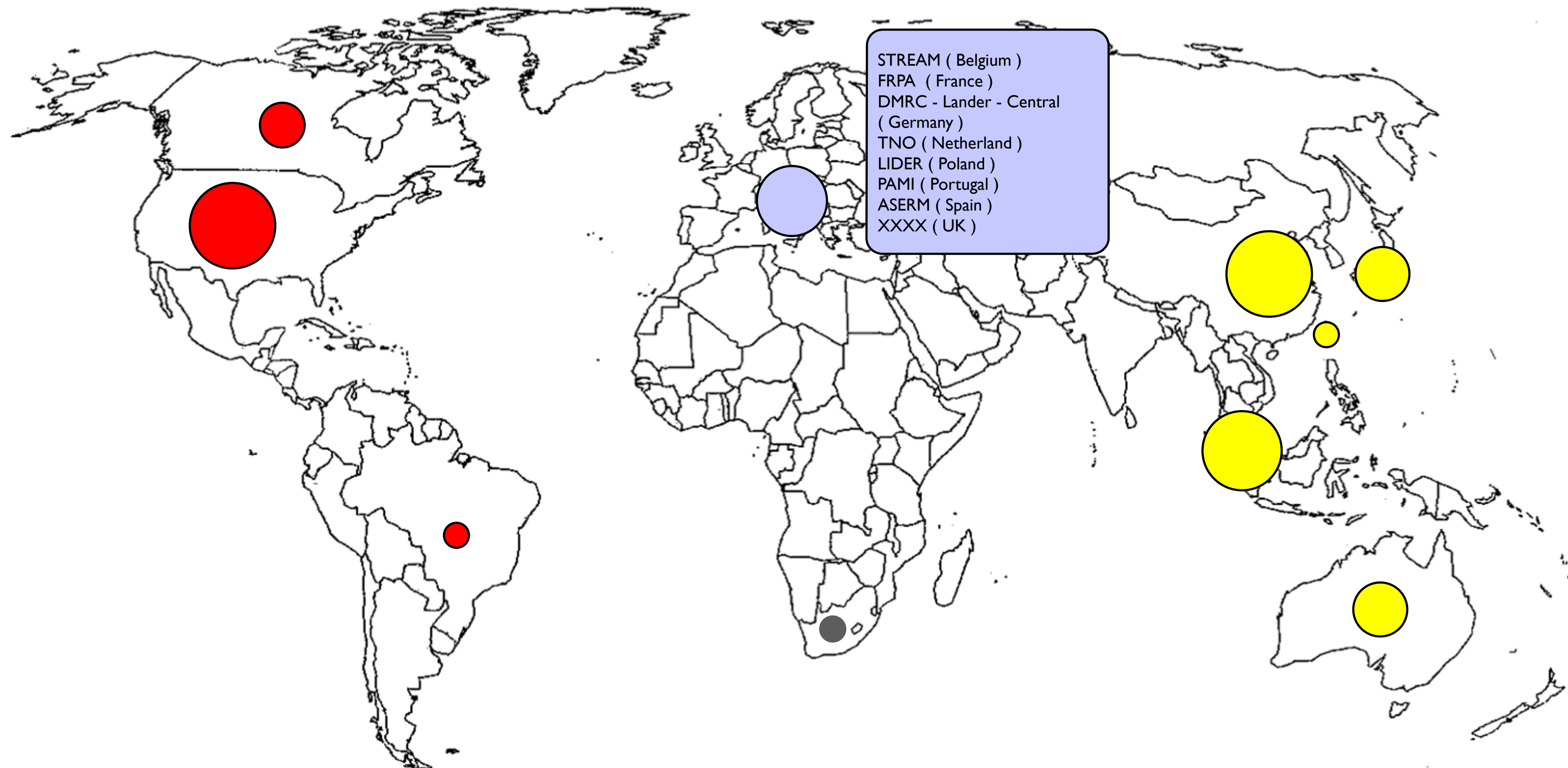
Additive manufacturing technologies

TECNOLOGIA	MATERIALI	MERCATI TIPICI	APPLICABILE AL METALLO
 Powder bed fusion – Energia termica fonde selettivamente un letto di polvere	Metals, polymers	Prototipazione, produzione	●
 Directed energy deposition – Energia termica è utilizzata per fondere il materiale mentre è depositato	Metals	Produzione, riparazione	◐
 Sheet lamination – Lamine di materiale sono depositate ed incollate tra loro per formare un oggetto	Metals, paper	Prototipazione, produzione	◑
 Binder jetting – Un collante liquido è depositato selettivamente per agglomerare polveri	Metals, polymers, foundry sand	Prototipazione, produzione	◑
 Material jetting – Gocce di materiale sono depositate selettivamente nelle zone di interesse	Polymers, waxes	Prototipazione, produzione	○
 Material extrusion – Il materiale è depositato attraverso un ugello in modo continuo	Polymers	Prototipazione, produzione	○
 Vat photopolymerization – Un fotopolimero liquido è aggregato selettivamente da una radiazione luminosa	Photopolymers	Prototipazione	○

Tecnologie AM adatte ai metalli

Fonte: ASTM International Committee F42 on Additive Manufacturing Technologies; Roland Berger

Ricerca a livello mondiale: Asia, Europa, USA



Additive Manufacturing: ricerca europea da FP3 a FP7 (1991 - 2013)

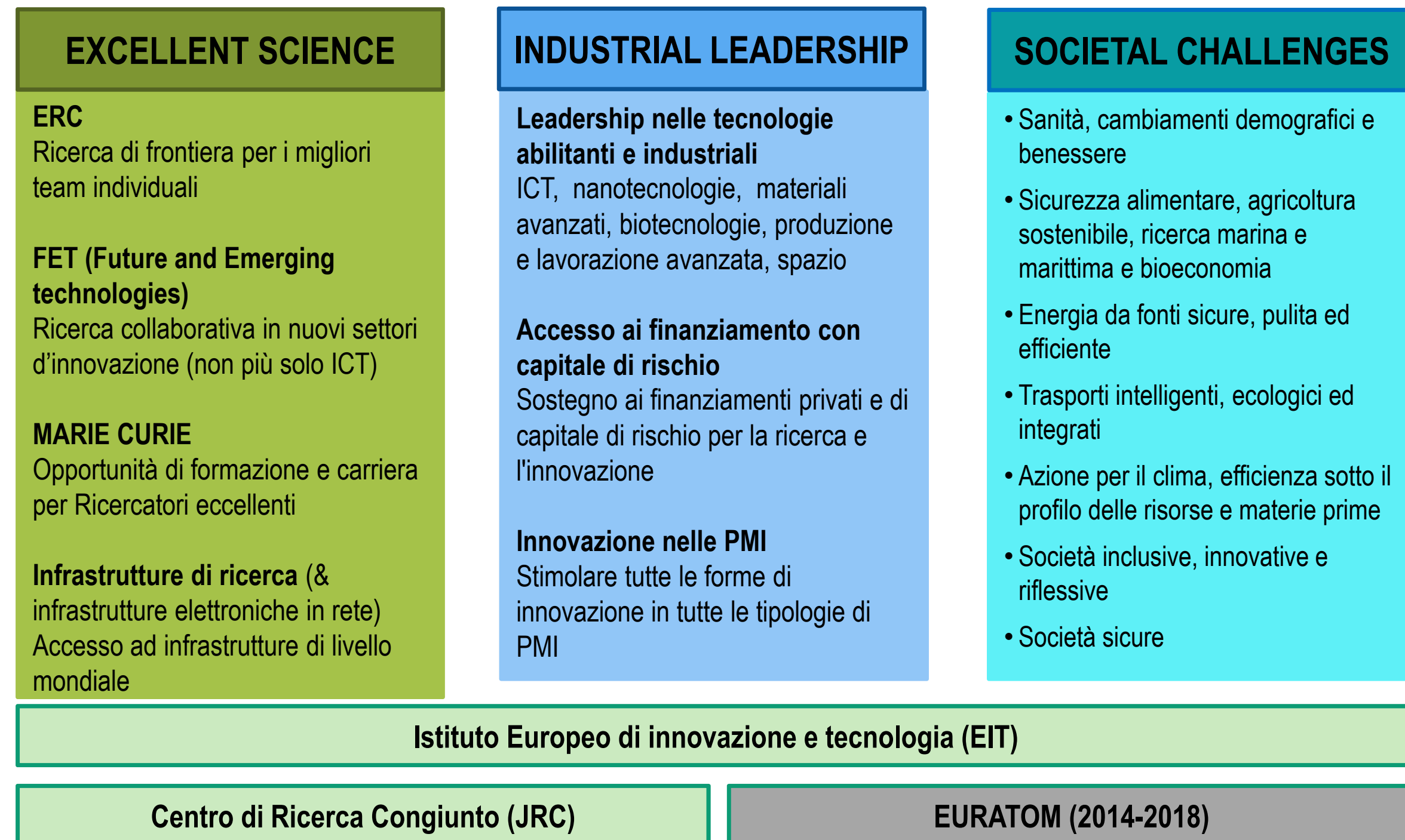
EC Programme	Number projects
FP3	4
FP4	8
FP5	3
FP6	12
FP7 IDEAS ERC	3
FP7 NMP	34
FP7 ICT	2
FP7 PEOPLE	8
FP7 SME	5
FP7 TRANSPORT	1
FP7 INCO	1
FP7 JTI	5
FP7 KBBE	1
FP7 SIS	1
TOTAL	88

225 M€

Report of EC Workshop on Additive Manufacturing - Brussels - 18/06/2014

Materials 29.6%	Metals	11.3%
	Polymers	7.0%
	Biomaterials	5.6%
	Ceramics	2.8%
	Other materials	2.8%
Technologies 34.5%	Process technologies	23.2%
	Informatics	10.6%
	Standardisation	0.7%
Applications 35.9%	Industrial processes	7.7%
	Health	4.9%
	Bio-printing	4.9%
	Aerospace	3.5%
	Moulds and tools	3.5%
	Micro 3D-Printing	2.8%
	Foot and textile	2.1%
	Consumer goods	1.4%
	Electronics	1.4%
	Skills and education	1.4%
	Microfluidics	0.7%
	Design	0.7%
	Food	0.7%

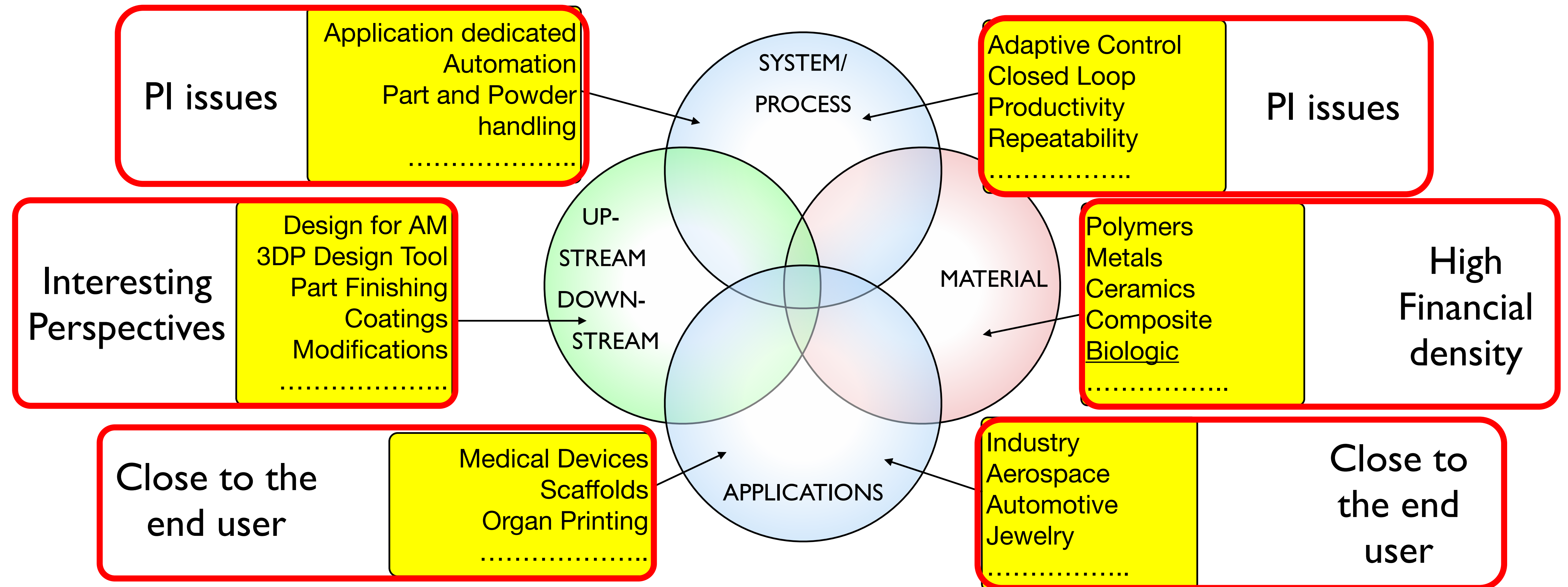
Additive Manufacturing in Horizon 2020



- ▶ AM è prevista nel II e III pilastro di H2020
“Industrial Leadership” in particolare KET e FoF e “Societal Challenges”.
- ▶ EFFRA indica AM come uno dei topic più importanti nel biennio 2016-2017.

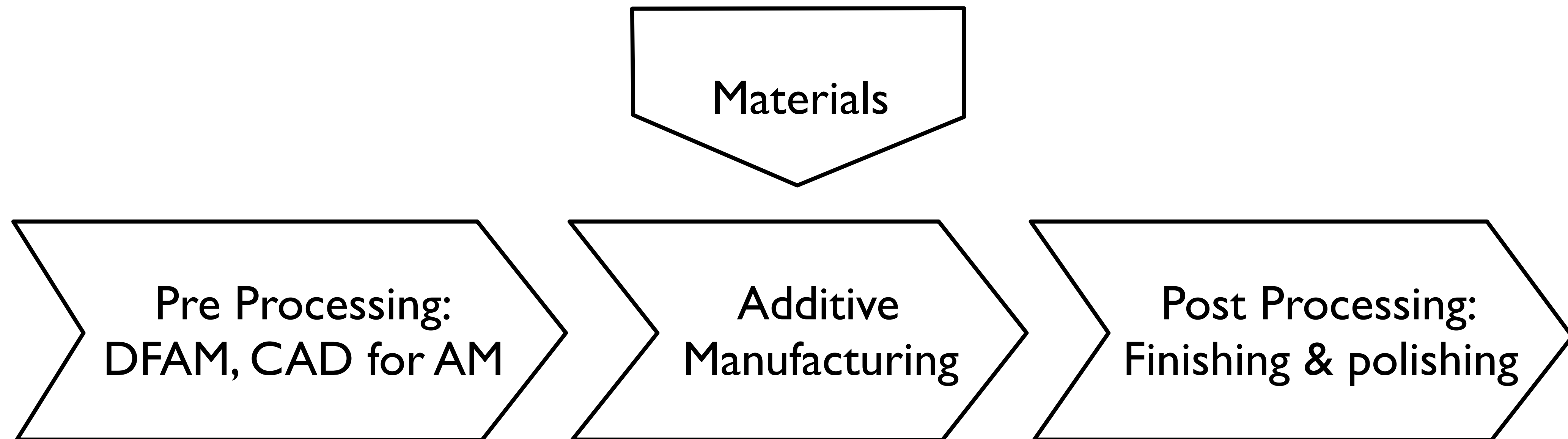
Report of EC Workshop on Additive Manufacturing - Brussels - 18/06/2014

Additive Manufacturing: approccio multidisciplinare

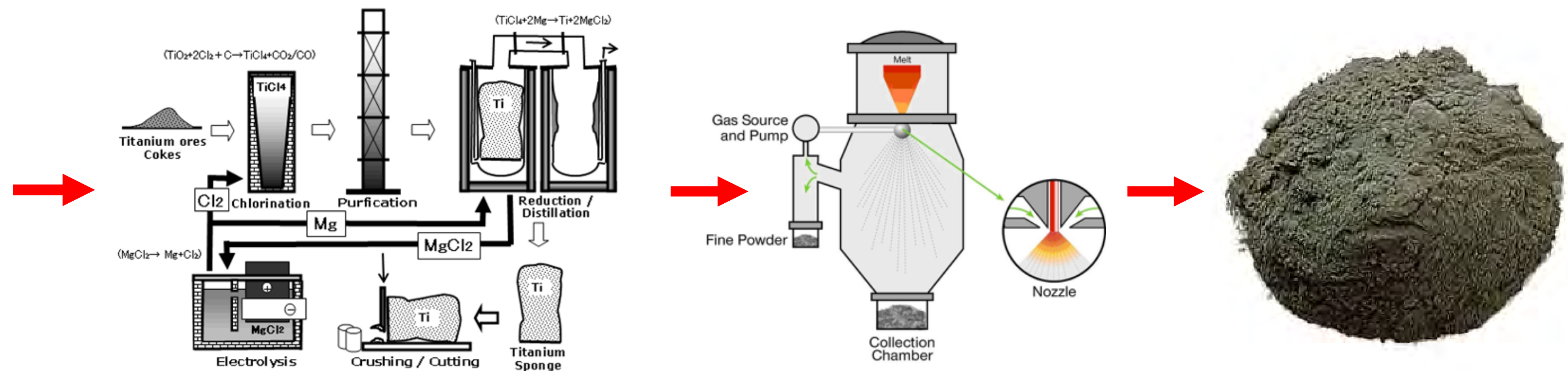
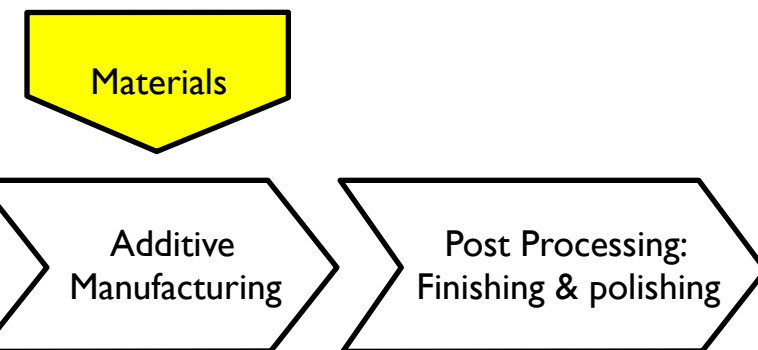


G.N. Levy - Additive Manufacturing in Production Engineering: Chances and Challenges.
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Linee di intervento della ricerca industriale

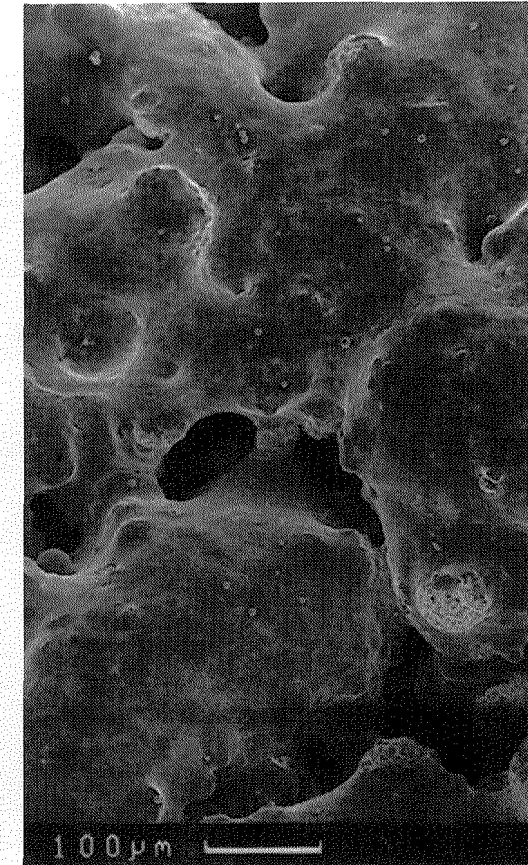
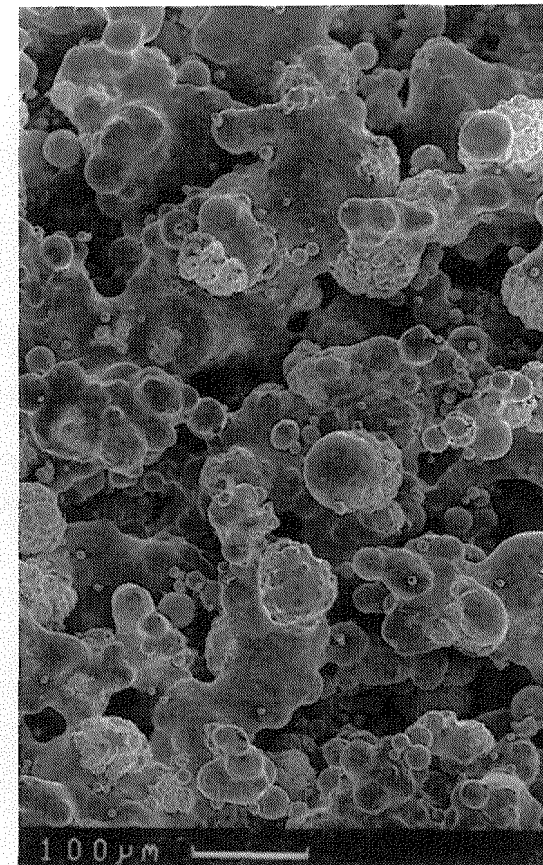
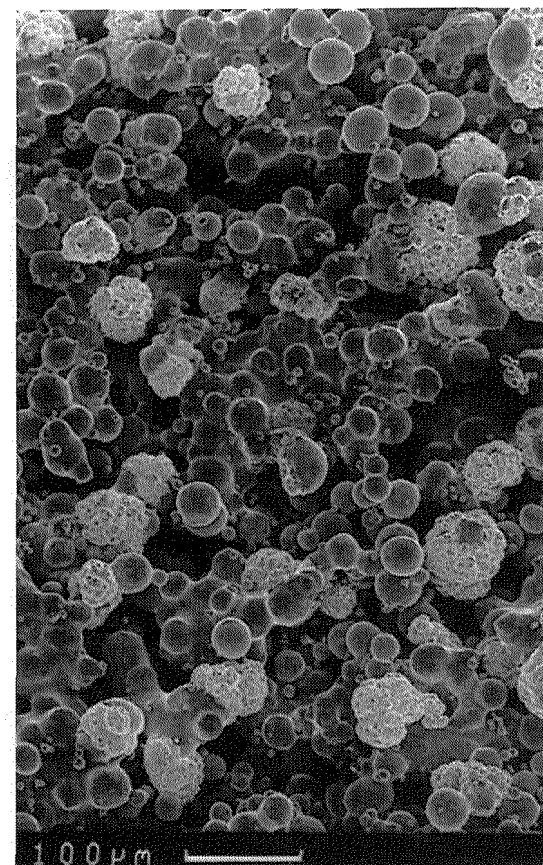
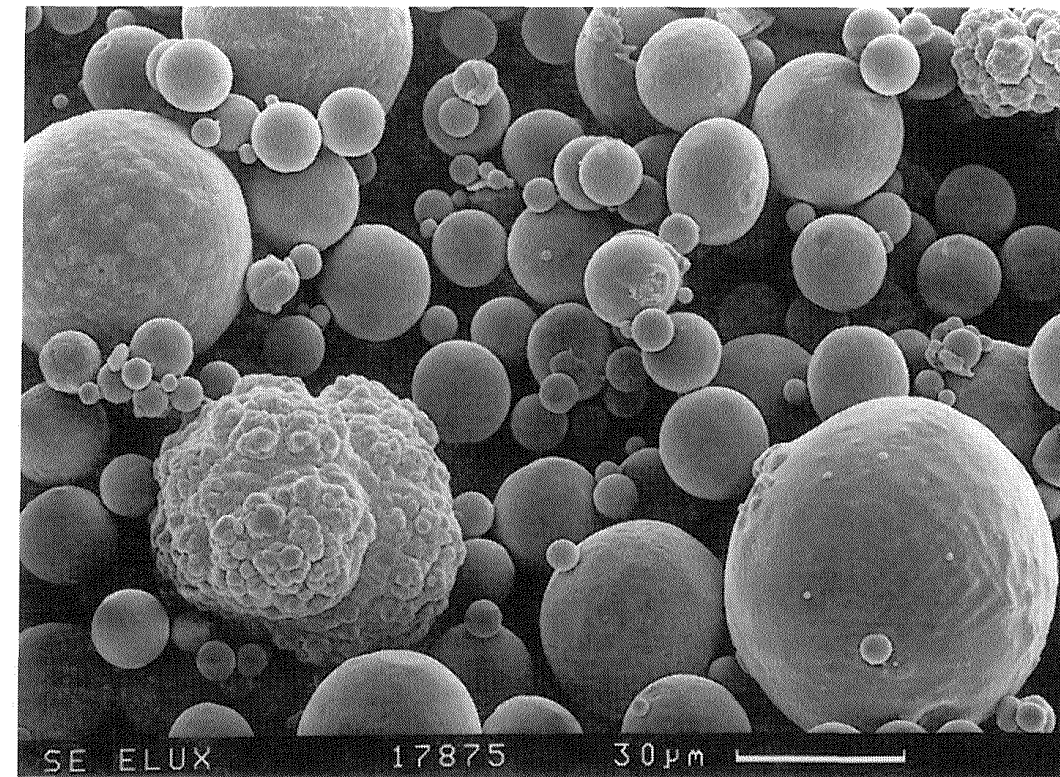
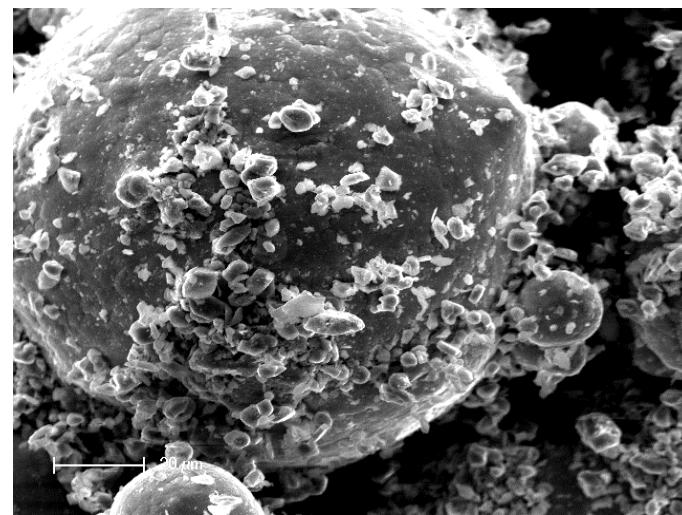
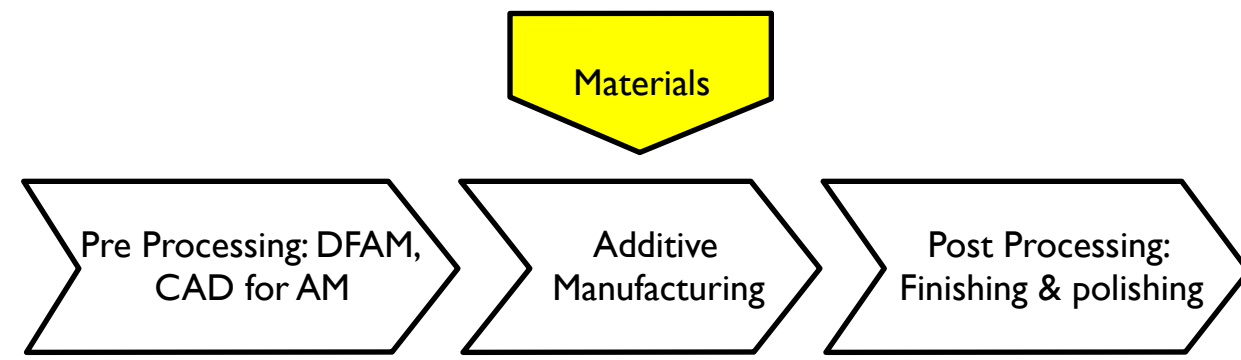


Linee di intervento della ricerca industriale: nuovi materiali



► Alta densità di finanziamento richiesta: 2 - 5 M€ per progetto

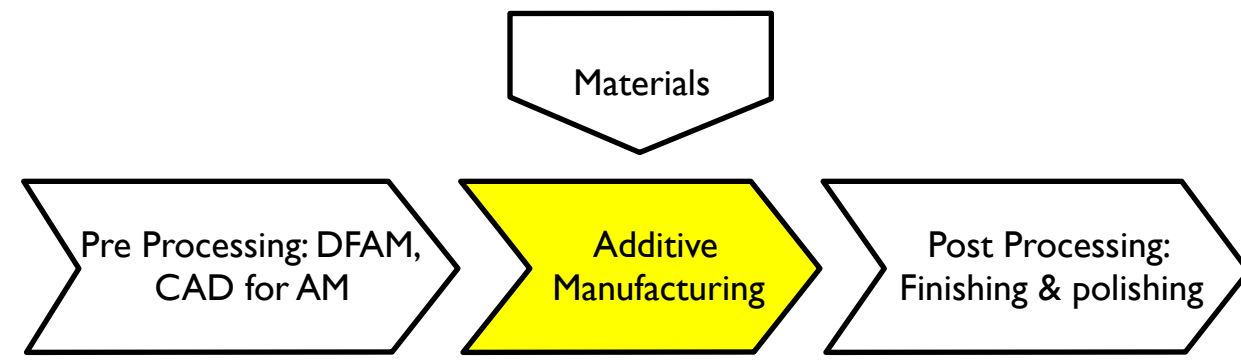
Linee di intervento della ricerca industriale: materiali



► New materials for AM processing

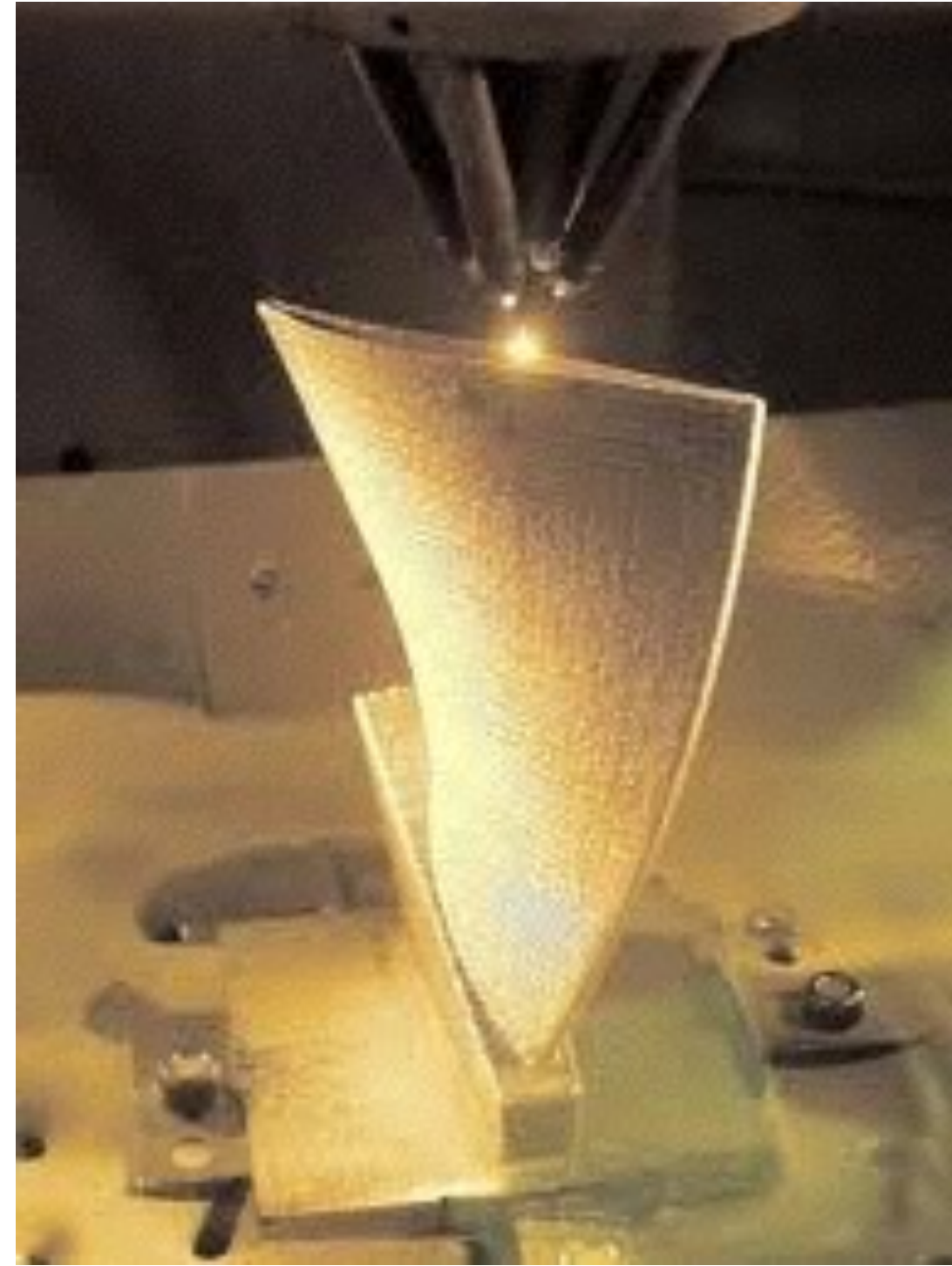
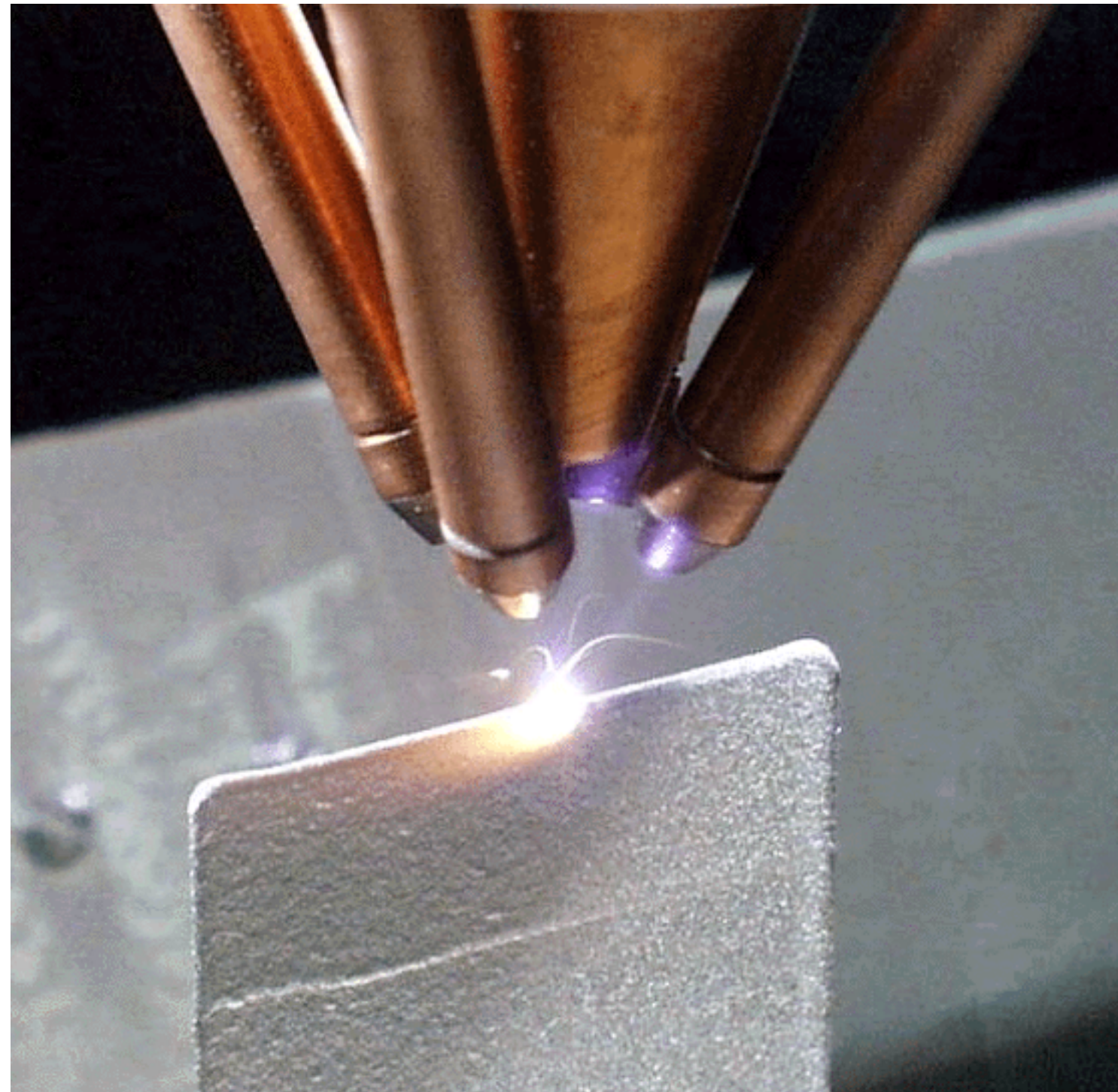
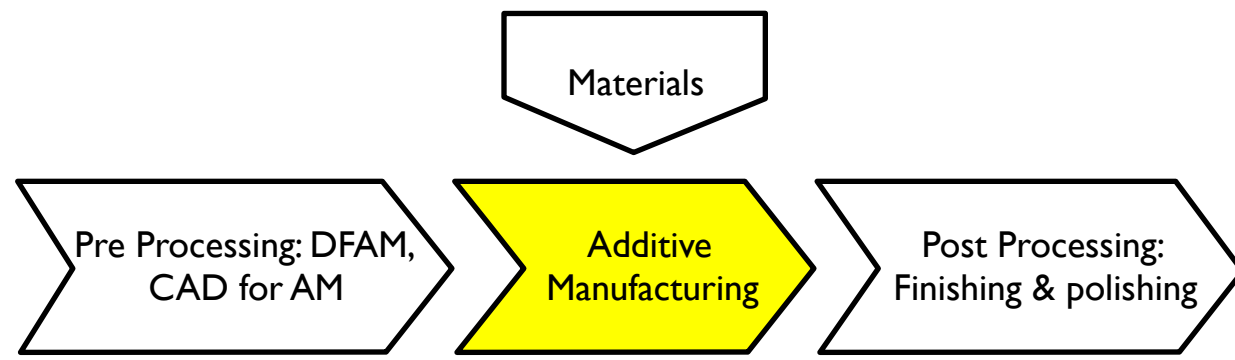
- biomaterials
- superconductors and new magnetic materials
- high performance metal alloys
- amorphous metals
- ultra-high temperature ceramic composites
- metal-organic frameworks
- new nano-particulate and nano- fibre materials.

Linee di intervento della ricerca industriale: il processo additive



► Concorrenza di tecnologie additive e sottrattive

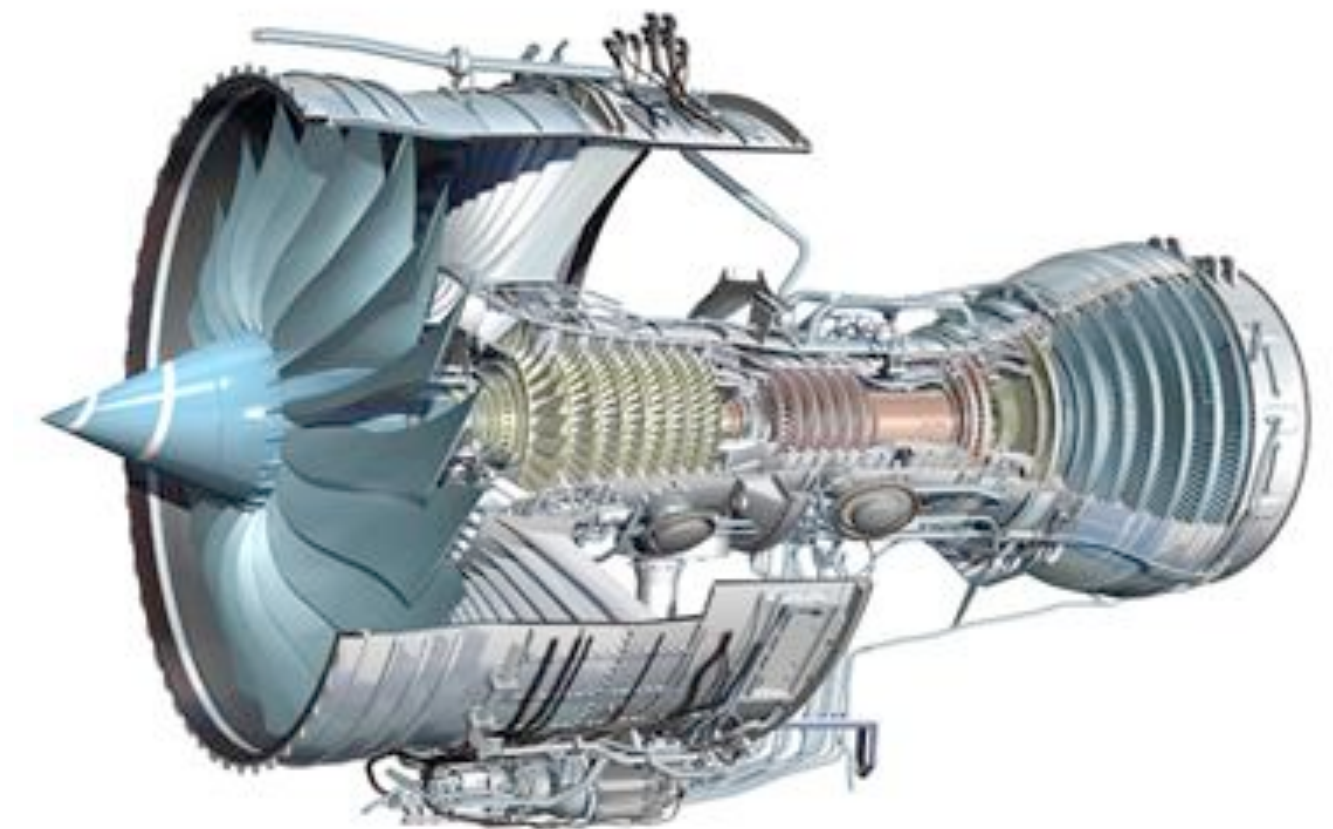
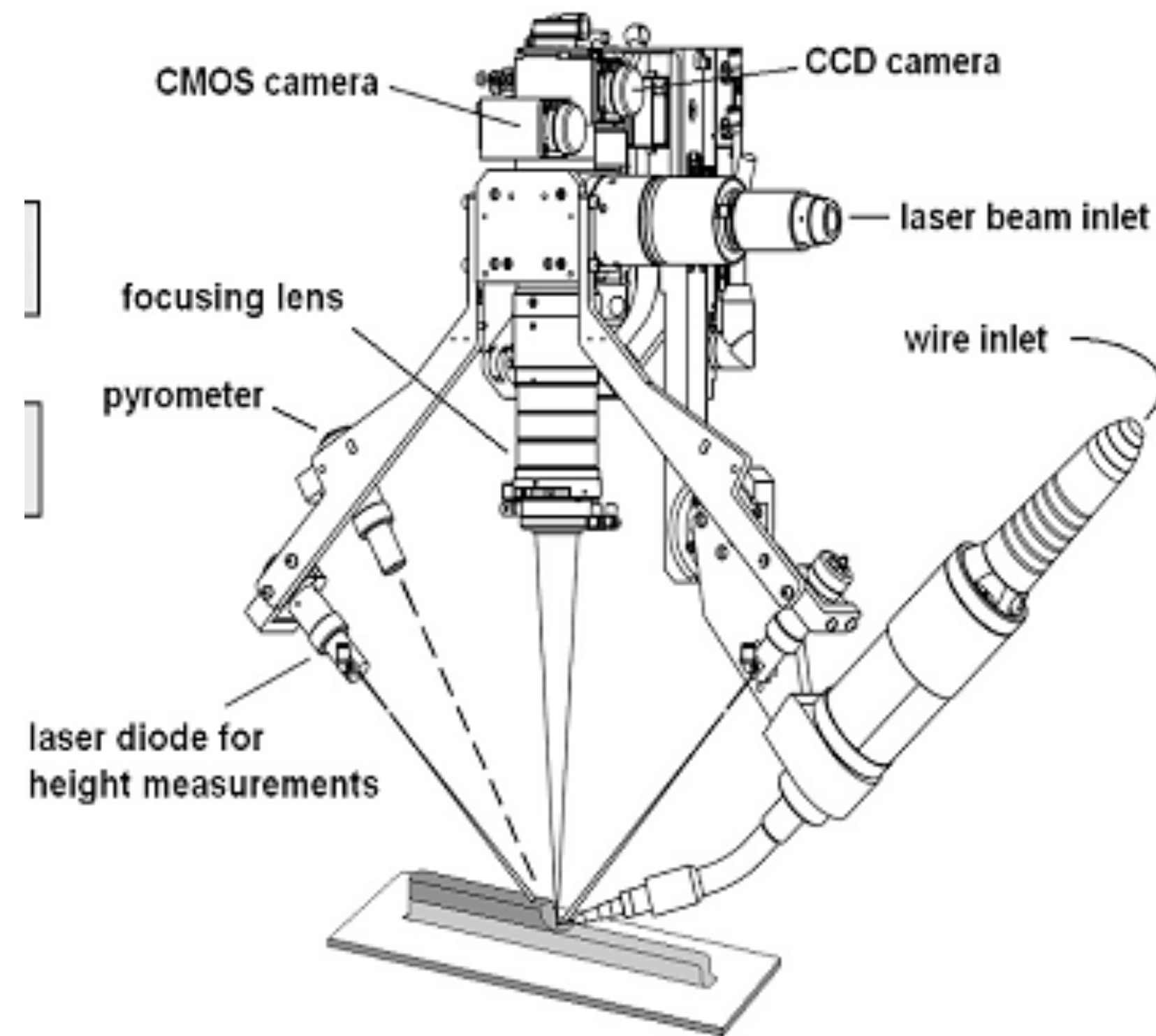
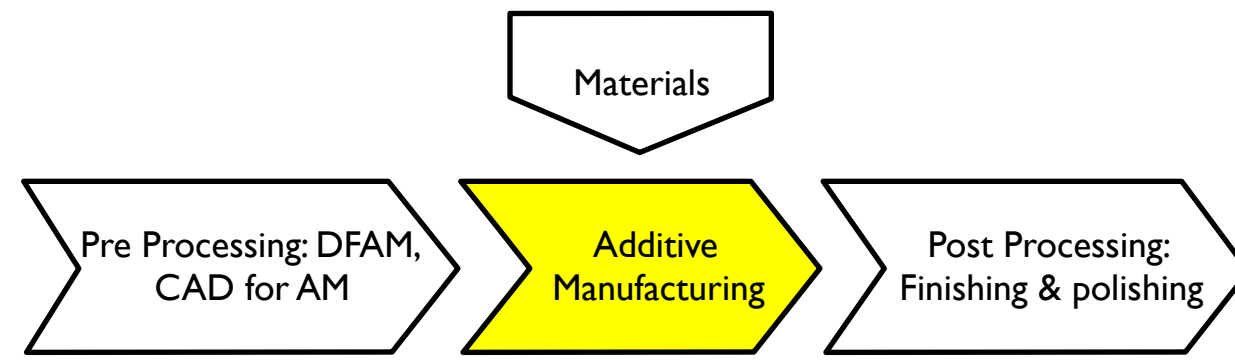
Linee di intervento della ricerca industriale: il processo additive



- Processi di deposizione a polvere (LENS e derivati).
 - Graded material
 - Remanufacturing
 - **Produttività limitata!!!**

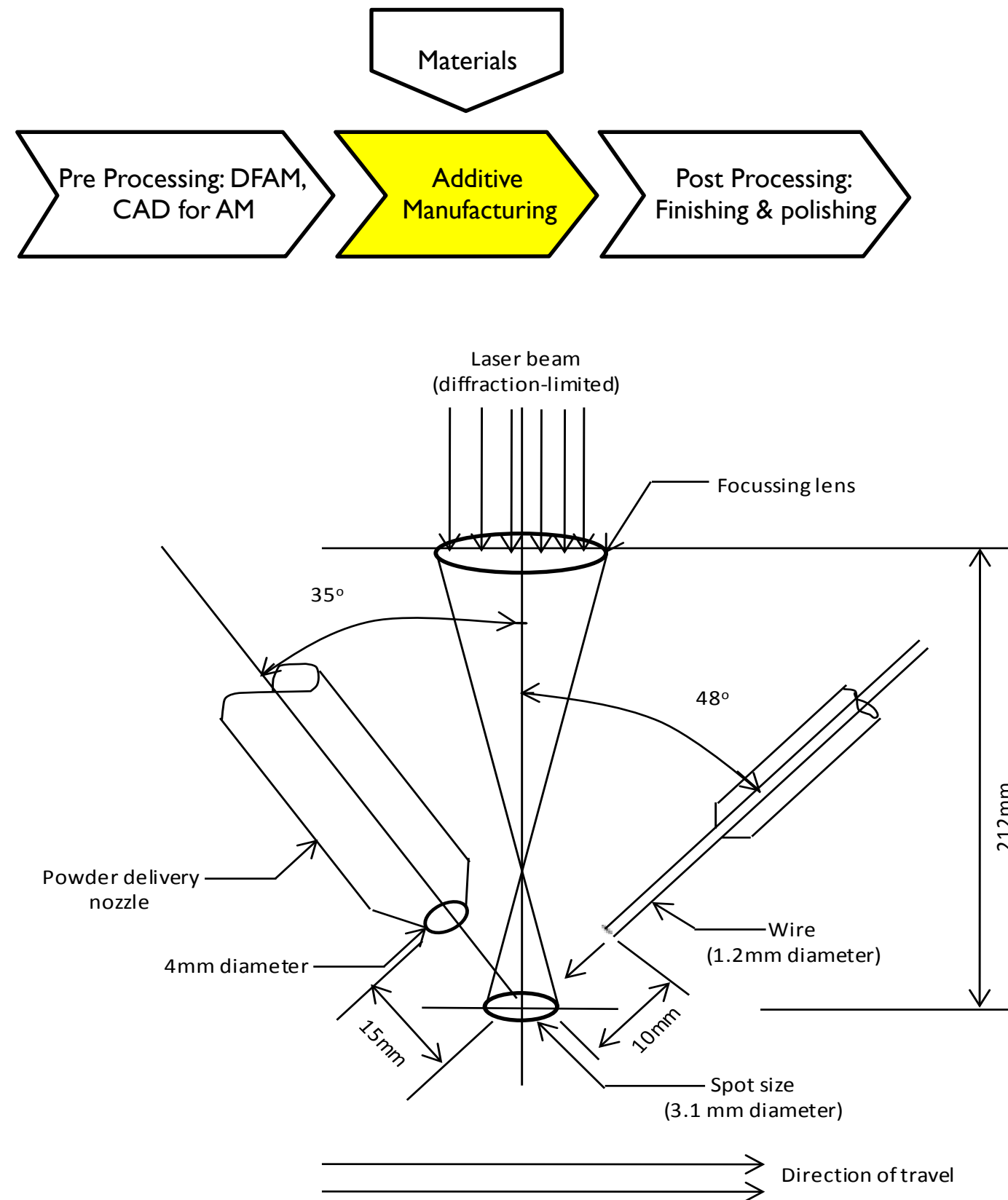
<http://www.sandia.gov/mst/technologies/net-shaping.html>

Linee di intervento della ricerca industriale: il processo additive

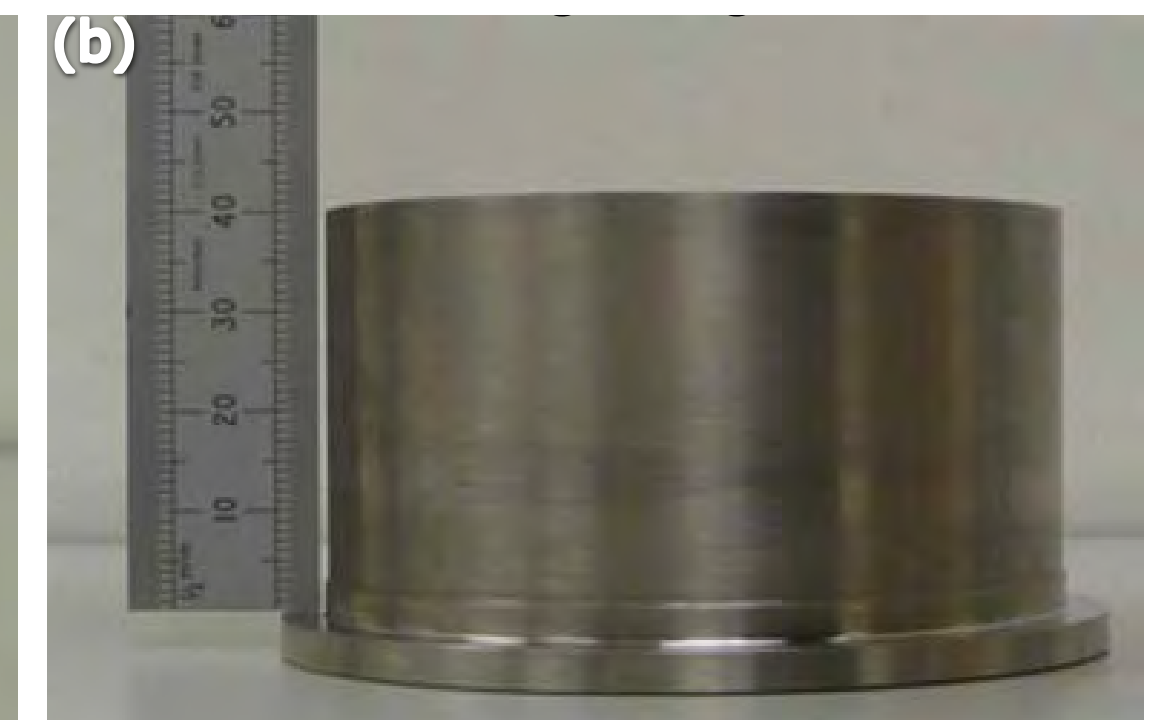
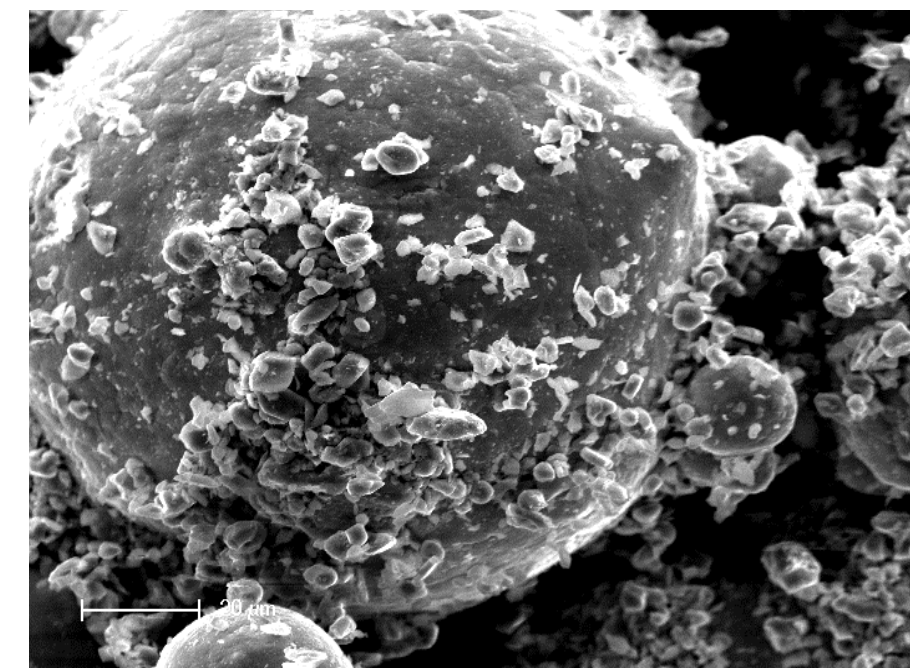
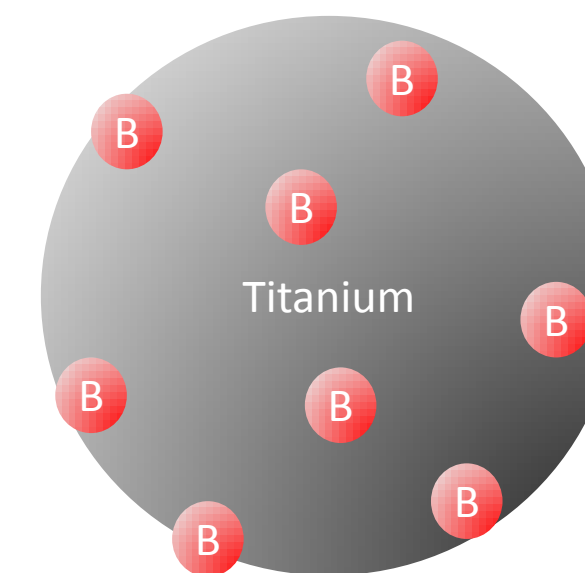
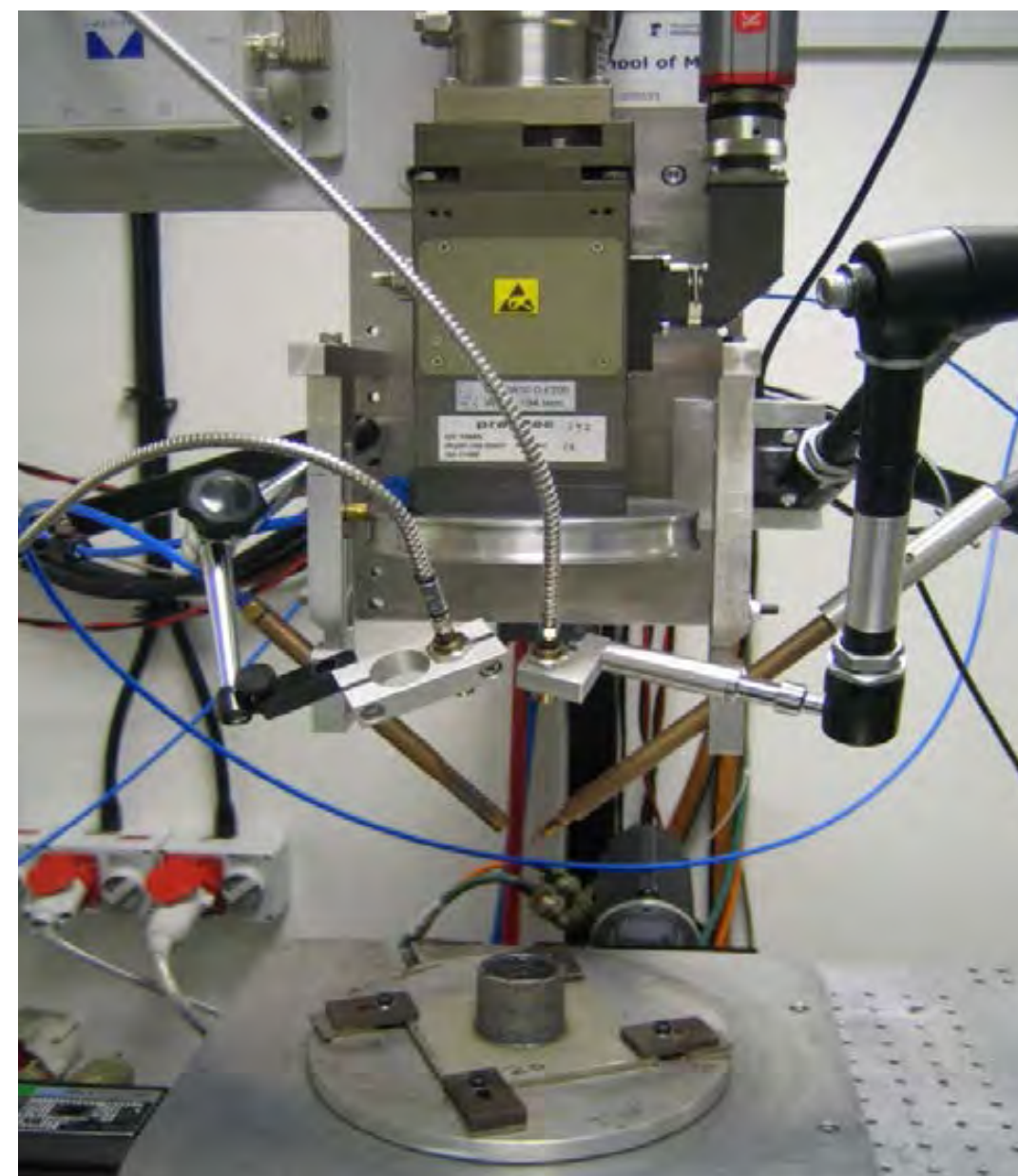


► Processi a deposizione di filo: produttività

Linee di intervento della ricerca industriale: il processo additive

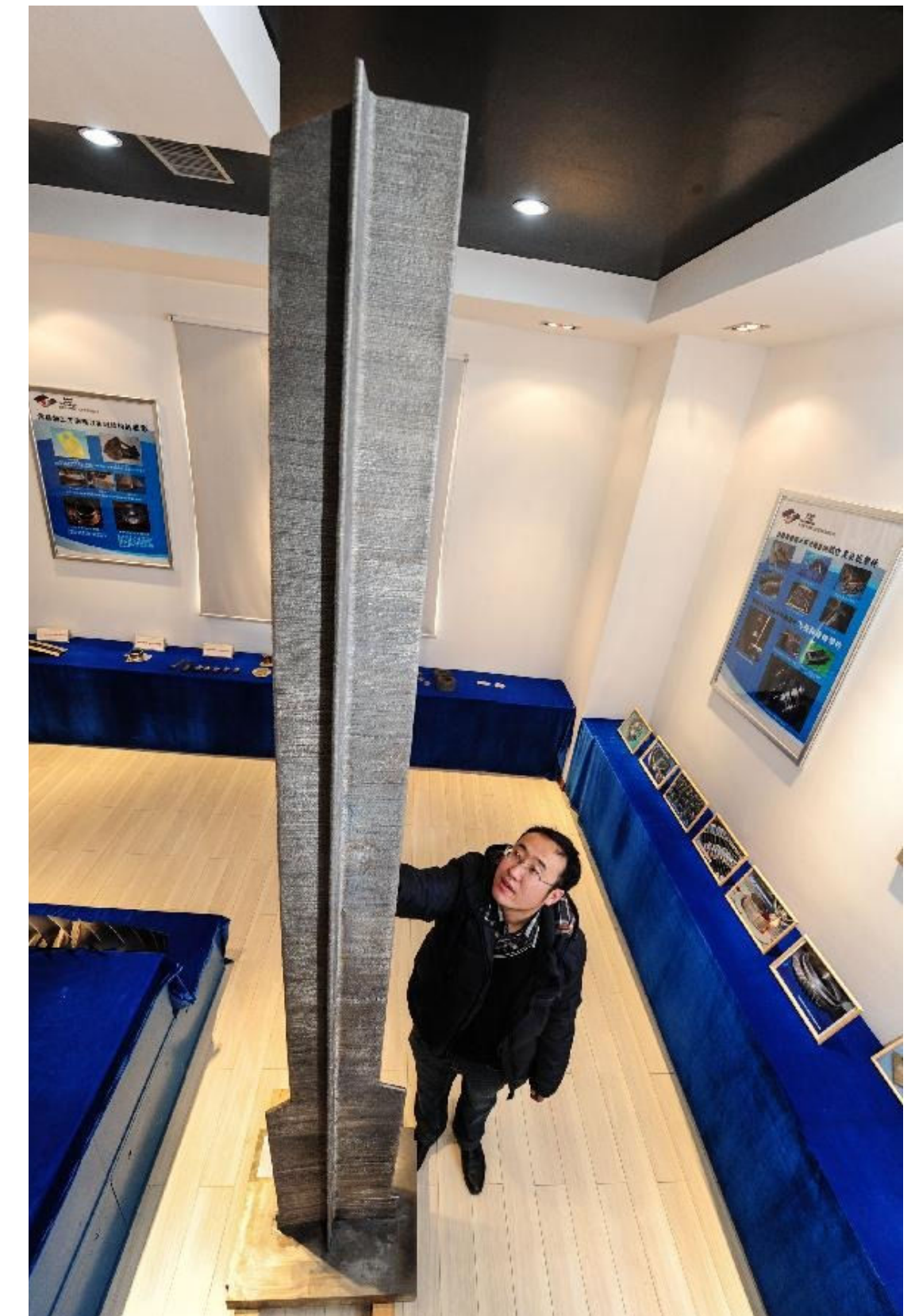
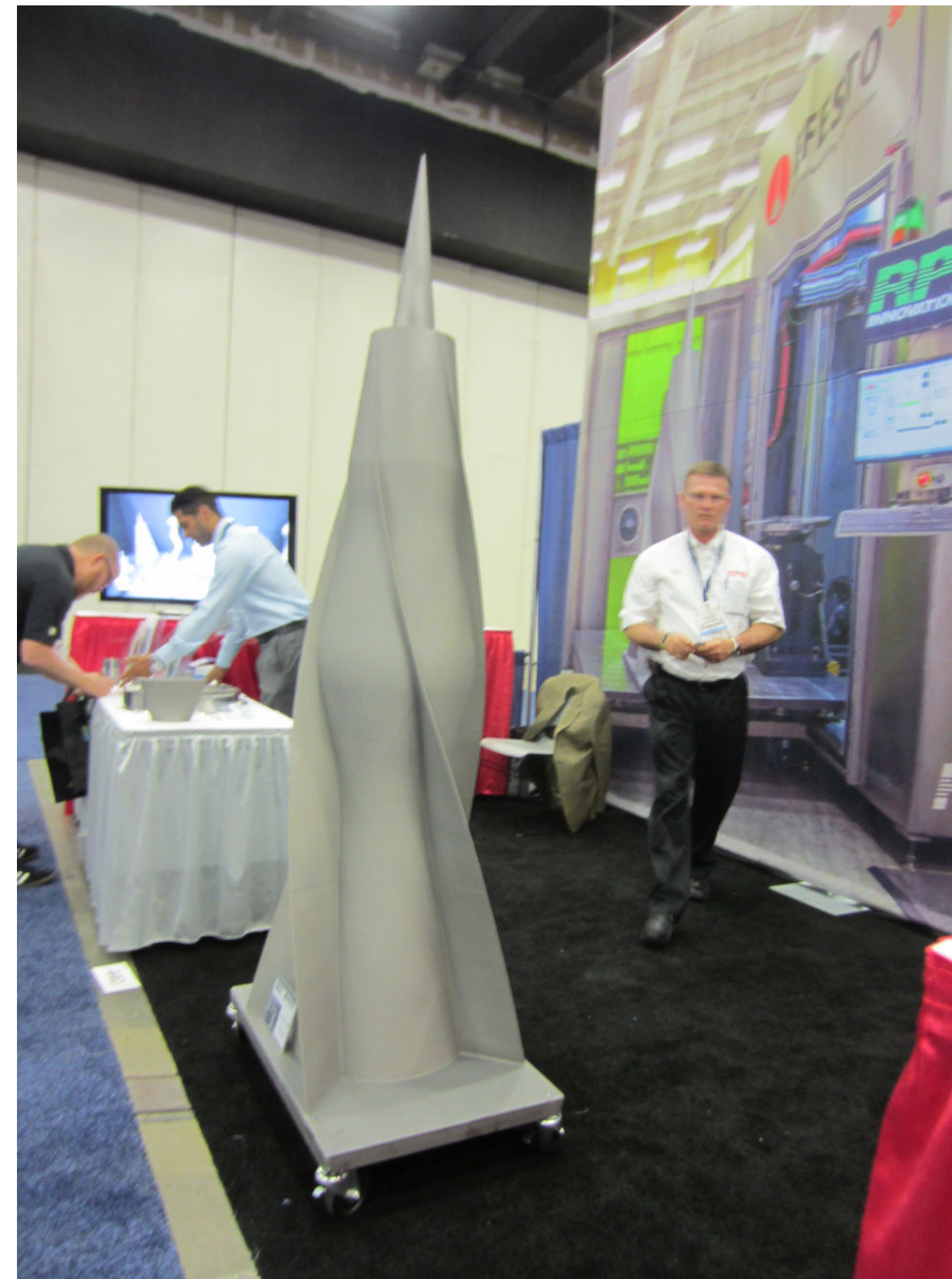
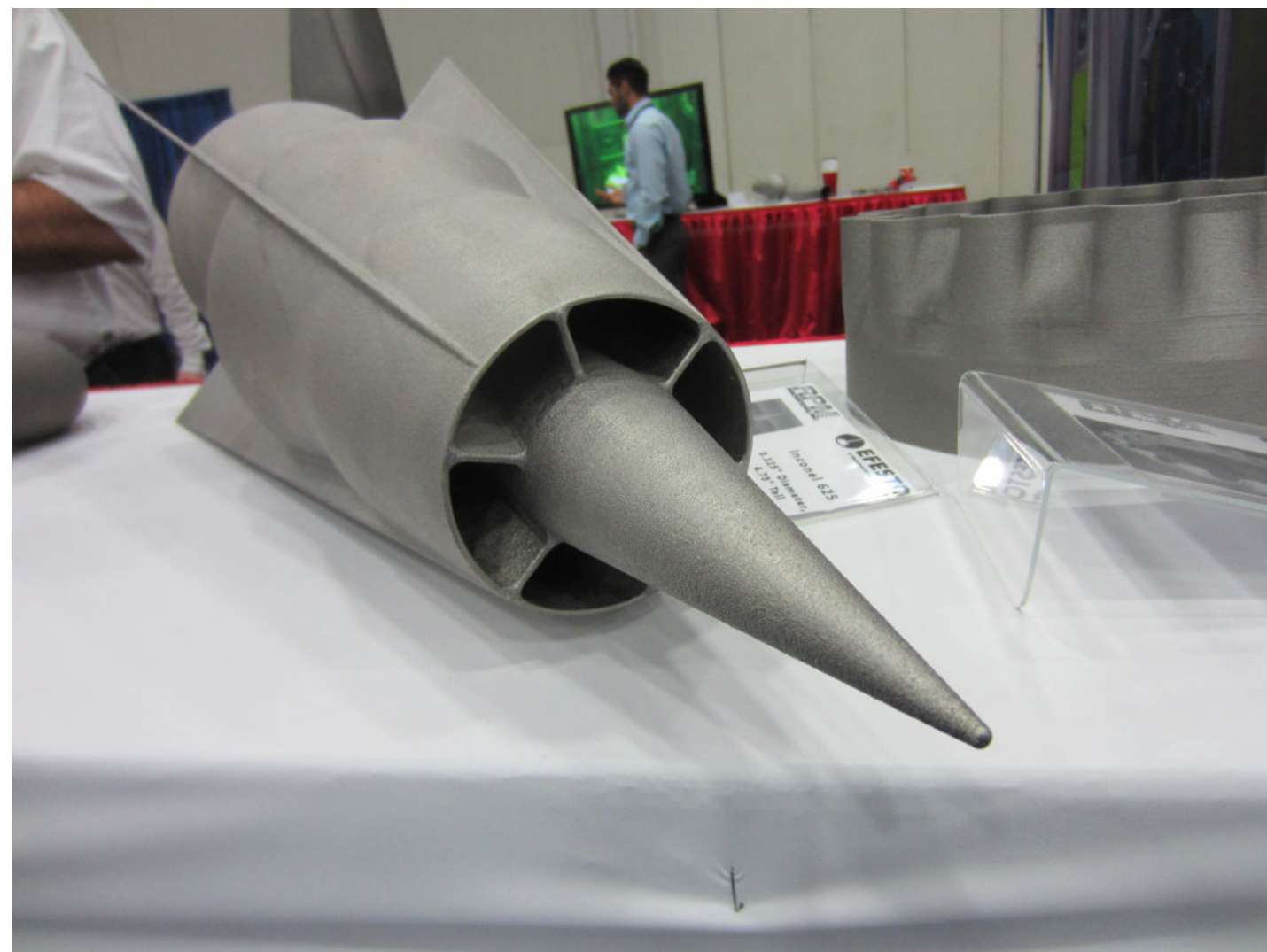
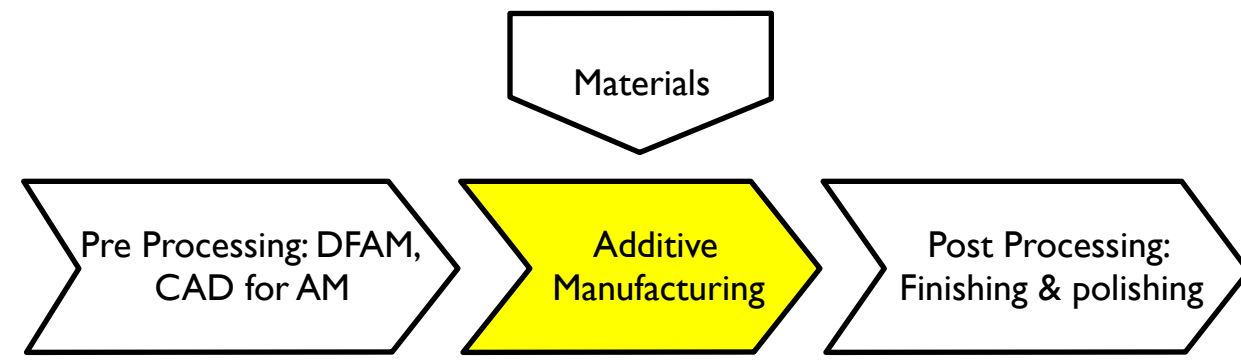


<http://www.nottingham.ac.uk>



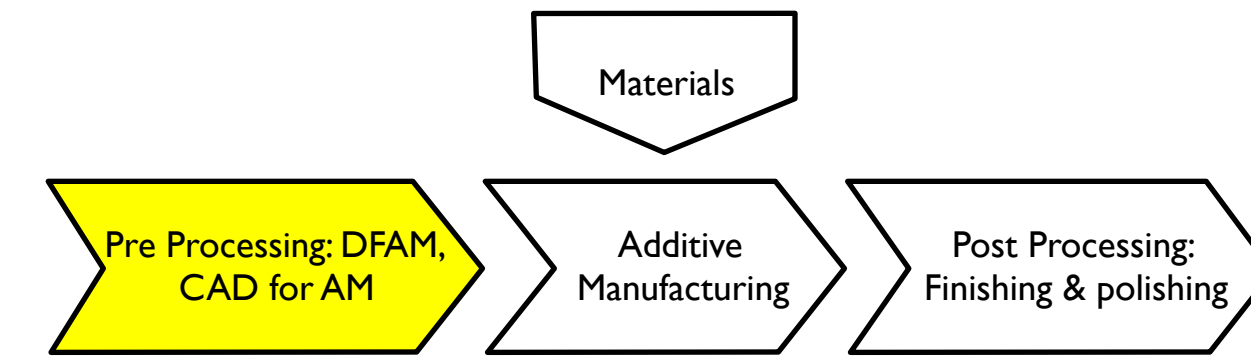
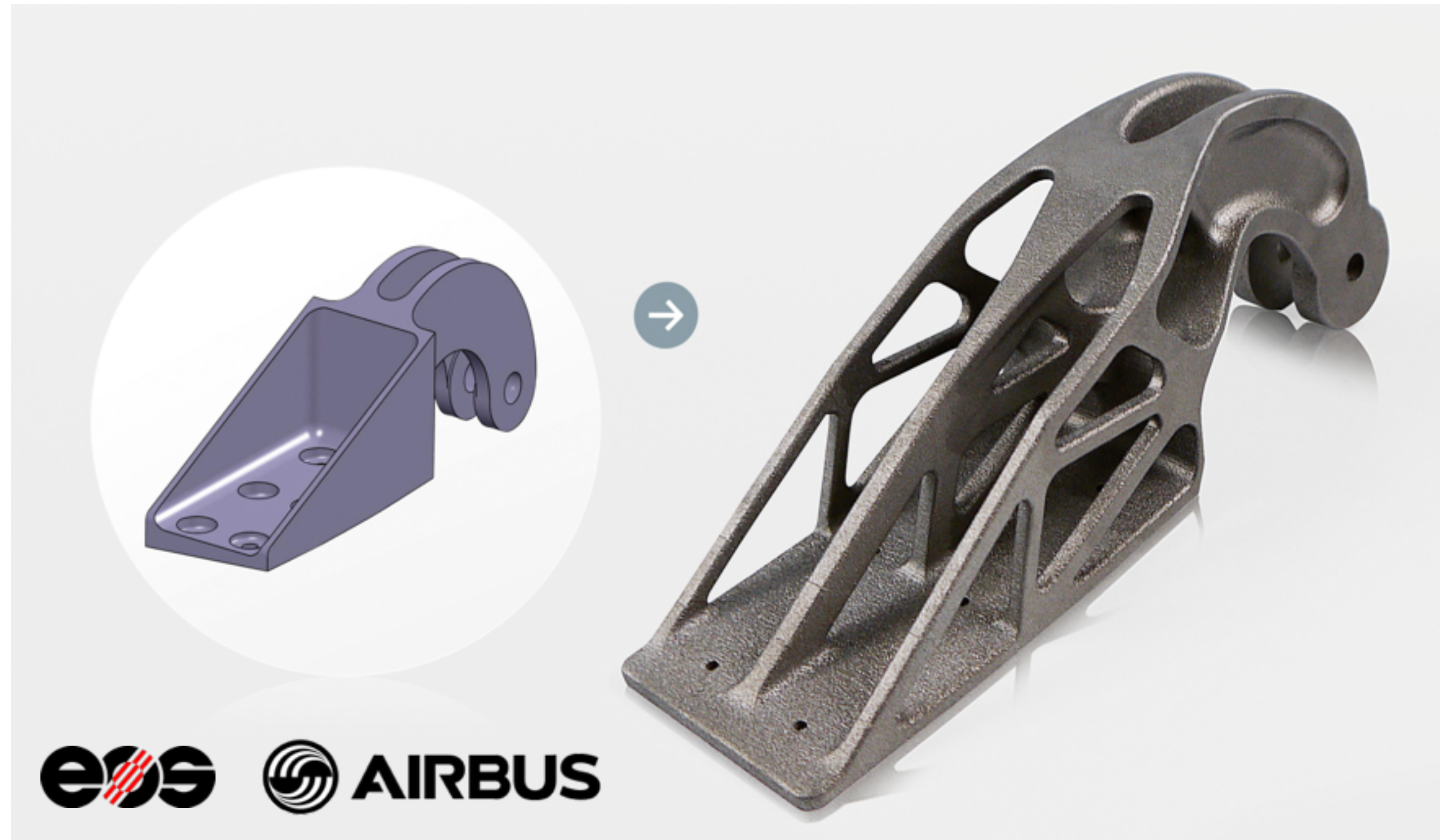
► Processi ibridi filo+polvere: graded materials + produttività

Linee di intervento della ricerca industriale: il processo additive



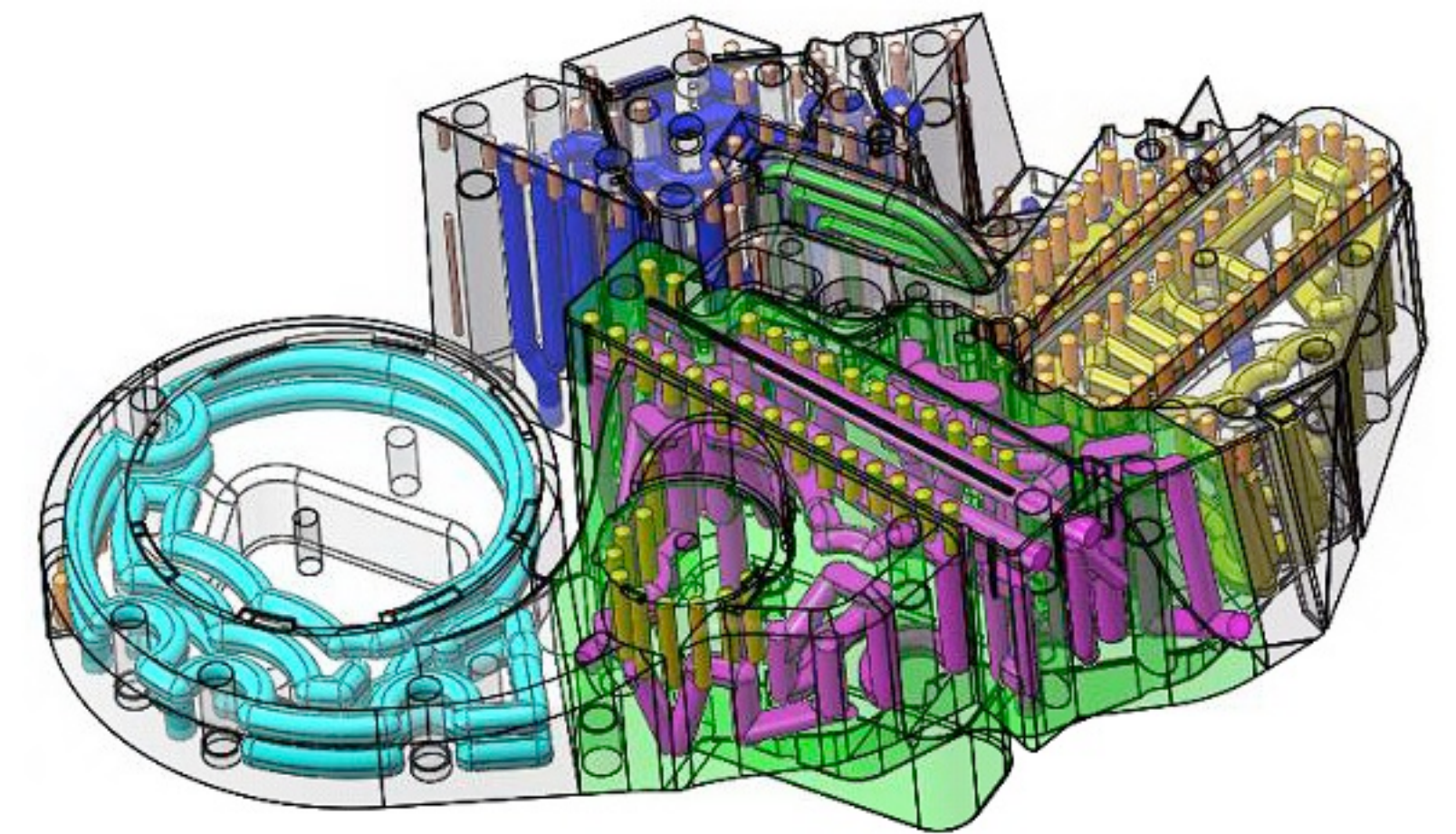
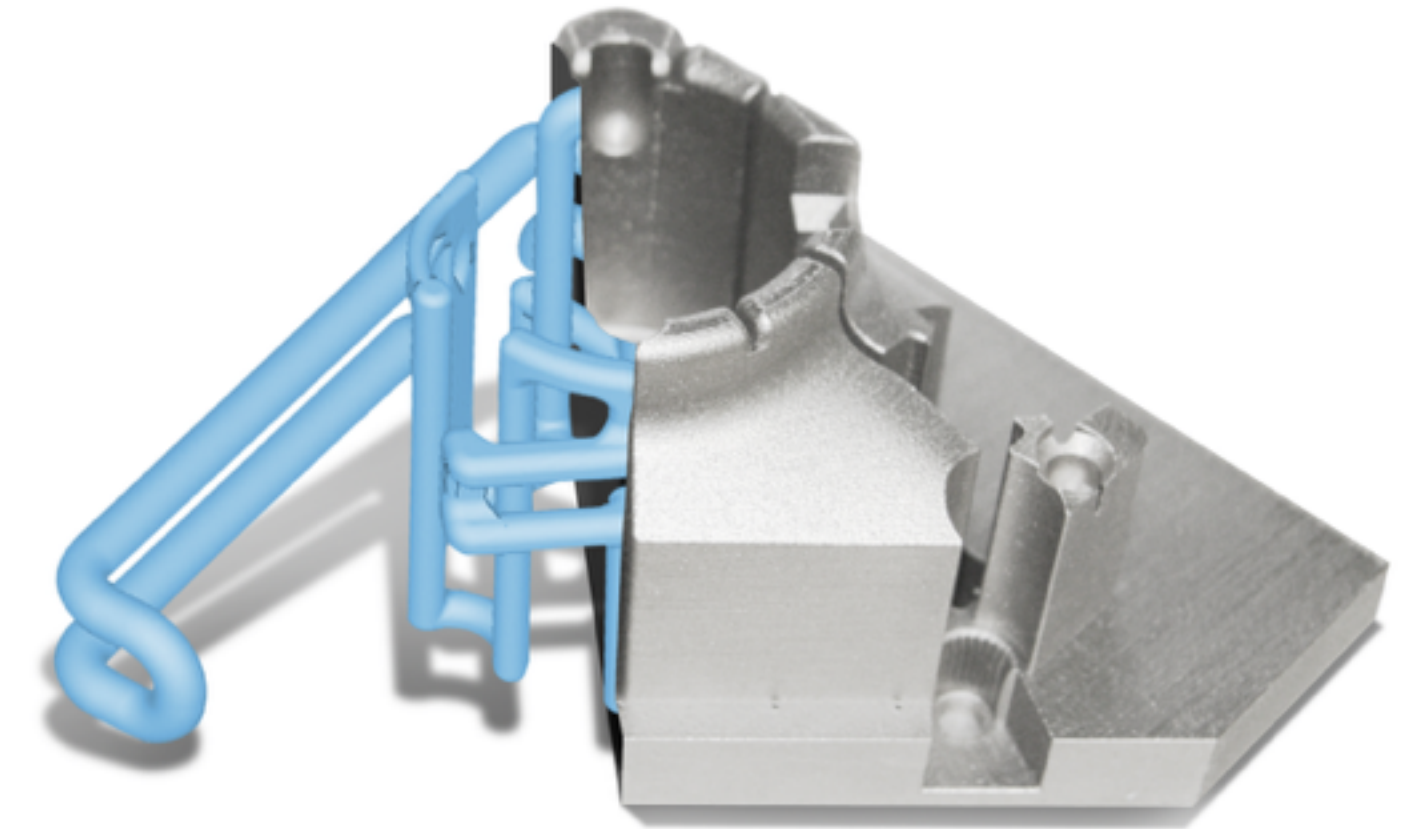
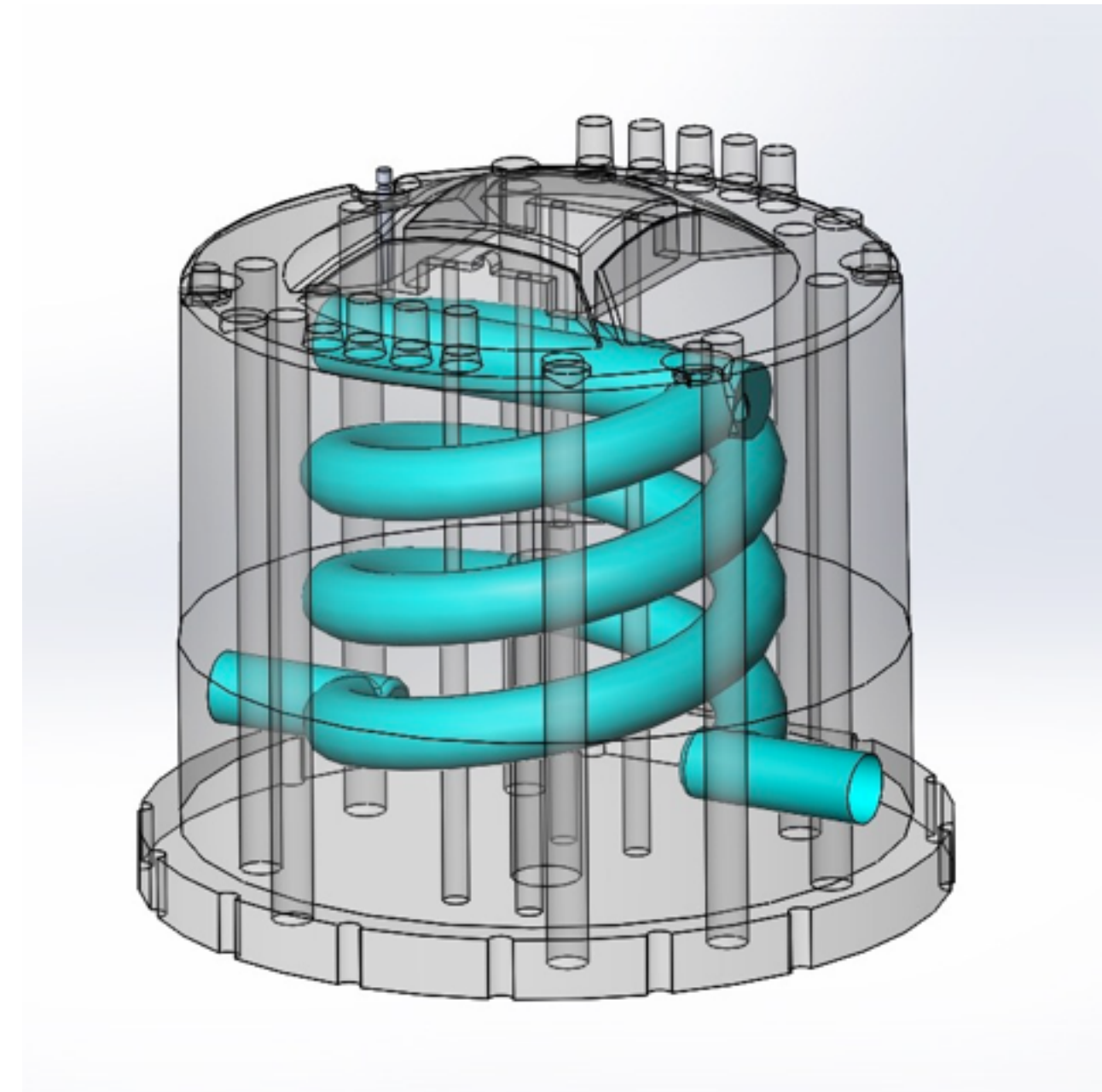
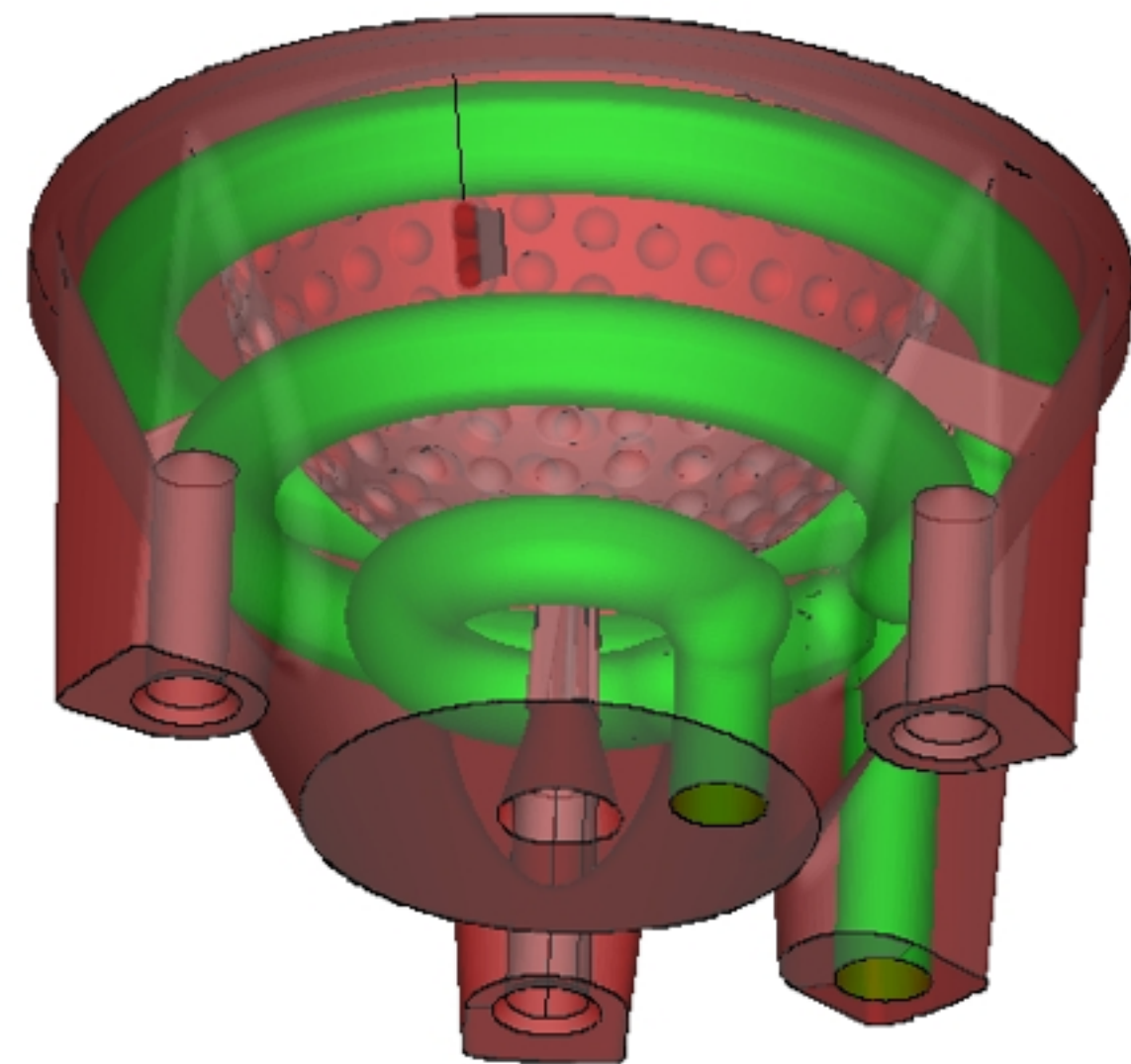
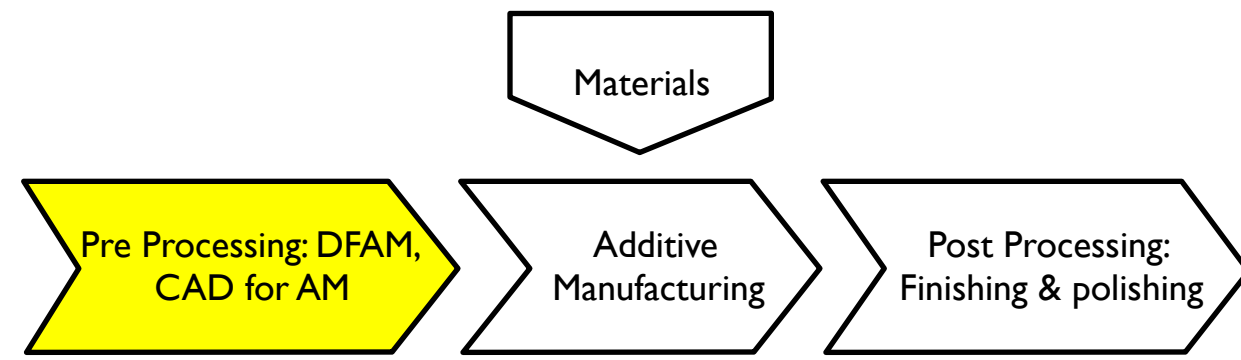
► I grandi formati

Linee di intervento della ricerca industriale: Design for Additive Manufacturing



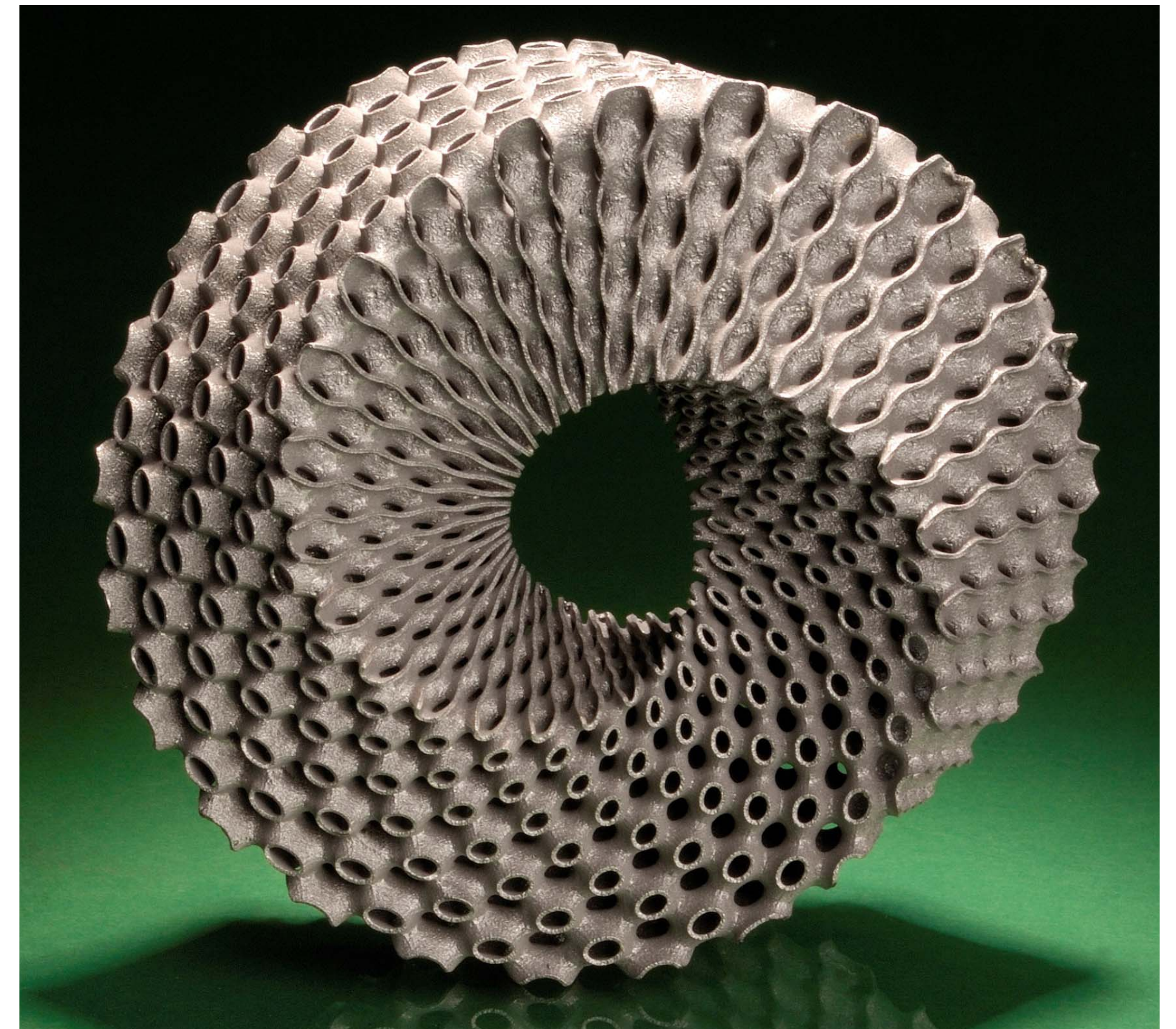
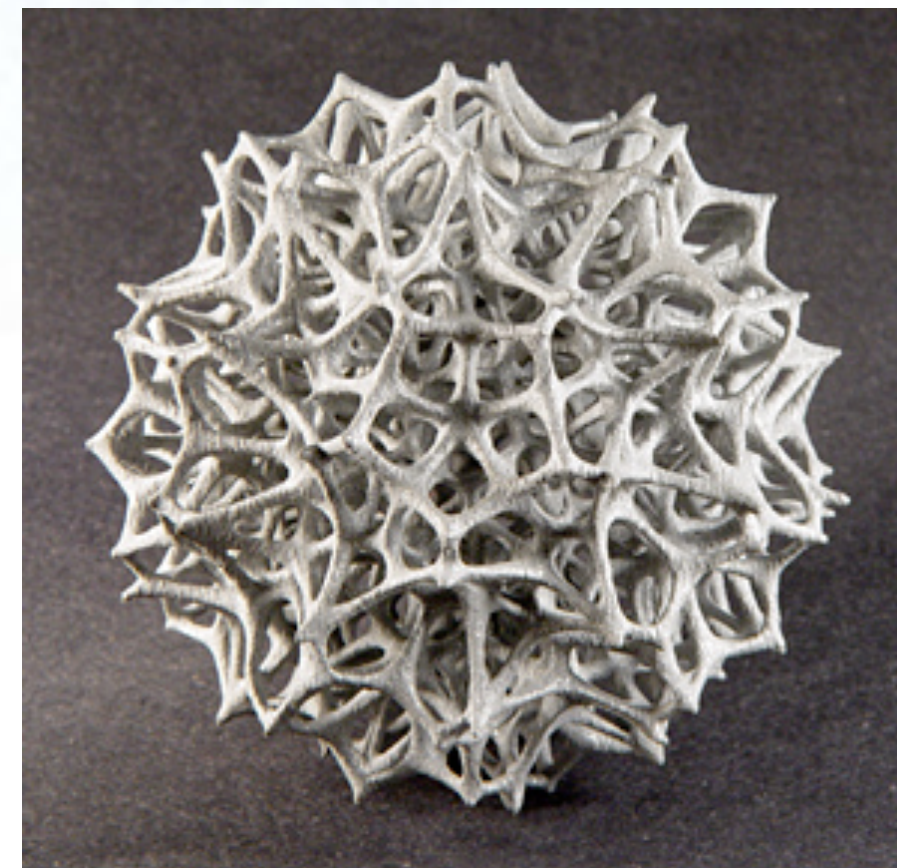
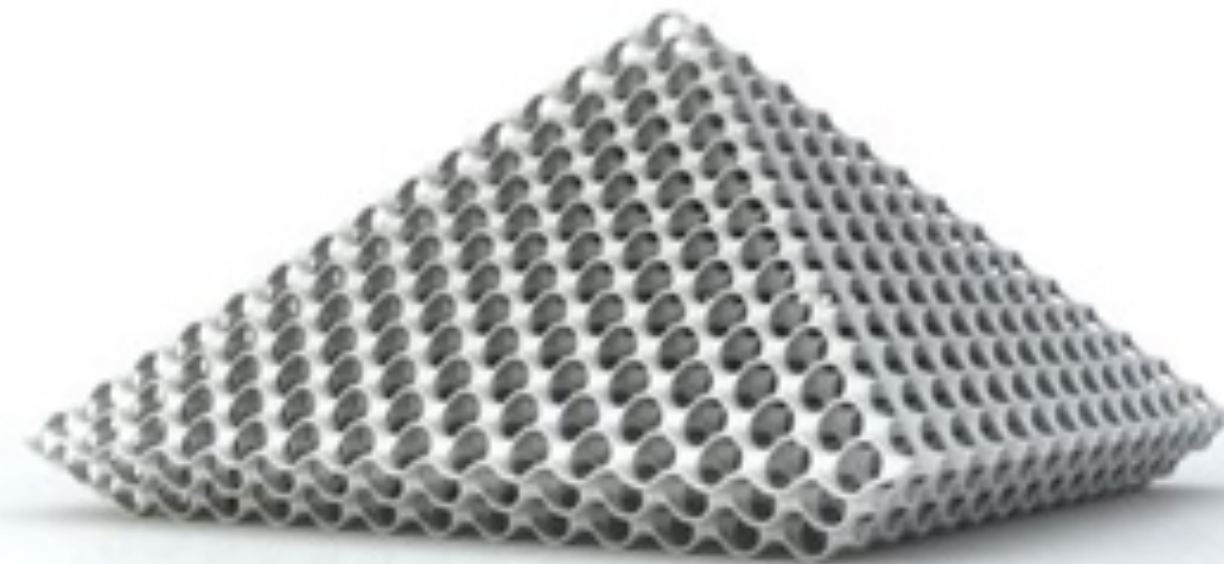
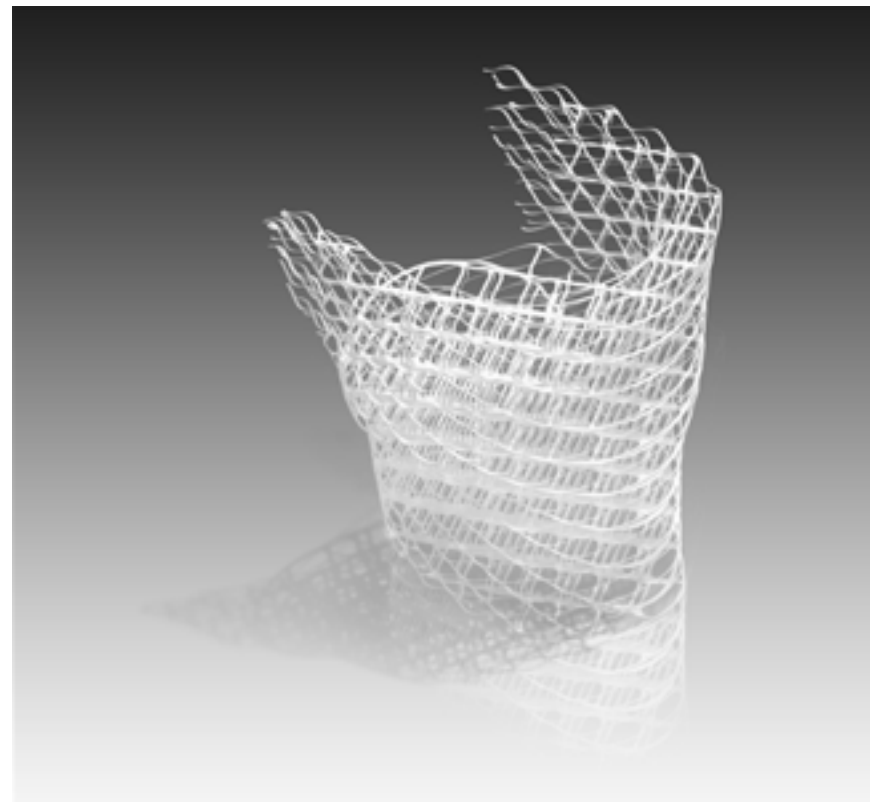
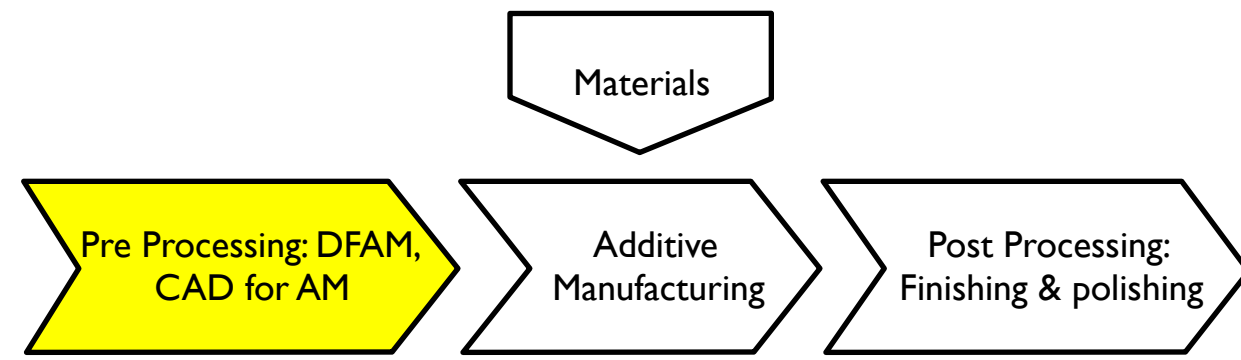
- Riprogettazione di componenti aeronautici: Leggerezza → minor materiale → minor tempo di fabbricazione → minor costo.

Linee di intervento della ricerca industriale: Design for Additive Manufacturing

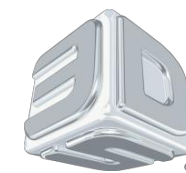
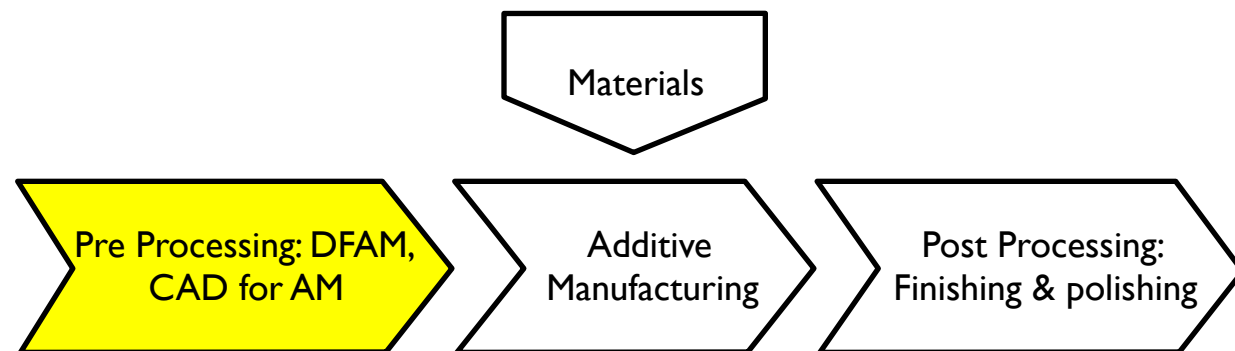


► Raffreddamento conformato.

Linee di intervento della ricerca industriale: Nuovi sistemi CAD for Additive Manufacturing



Linee di intervento della ricerca industriale: Nuovi sistemi CAD for Additive Manufacturing



News Release

3D Systems Corporation
333 Three D Systems Circle
Rock Hill, SC 29730
www.3dsystems.com
NYSE: DDD

Investor Contact: Stacey Witten
Email: Stacey.Witten@3dsystems.com

Media Contact: Wendy Pinckney
Email: Press@3dsystems.com

3D Systems Completes Acquisition of Cimatron

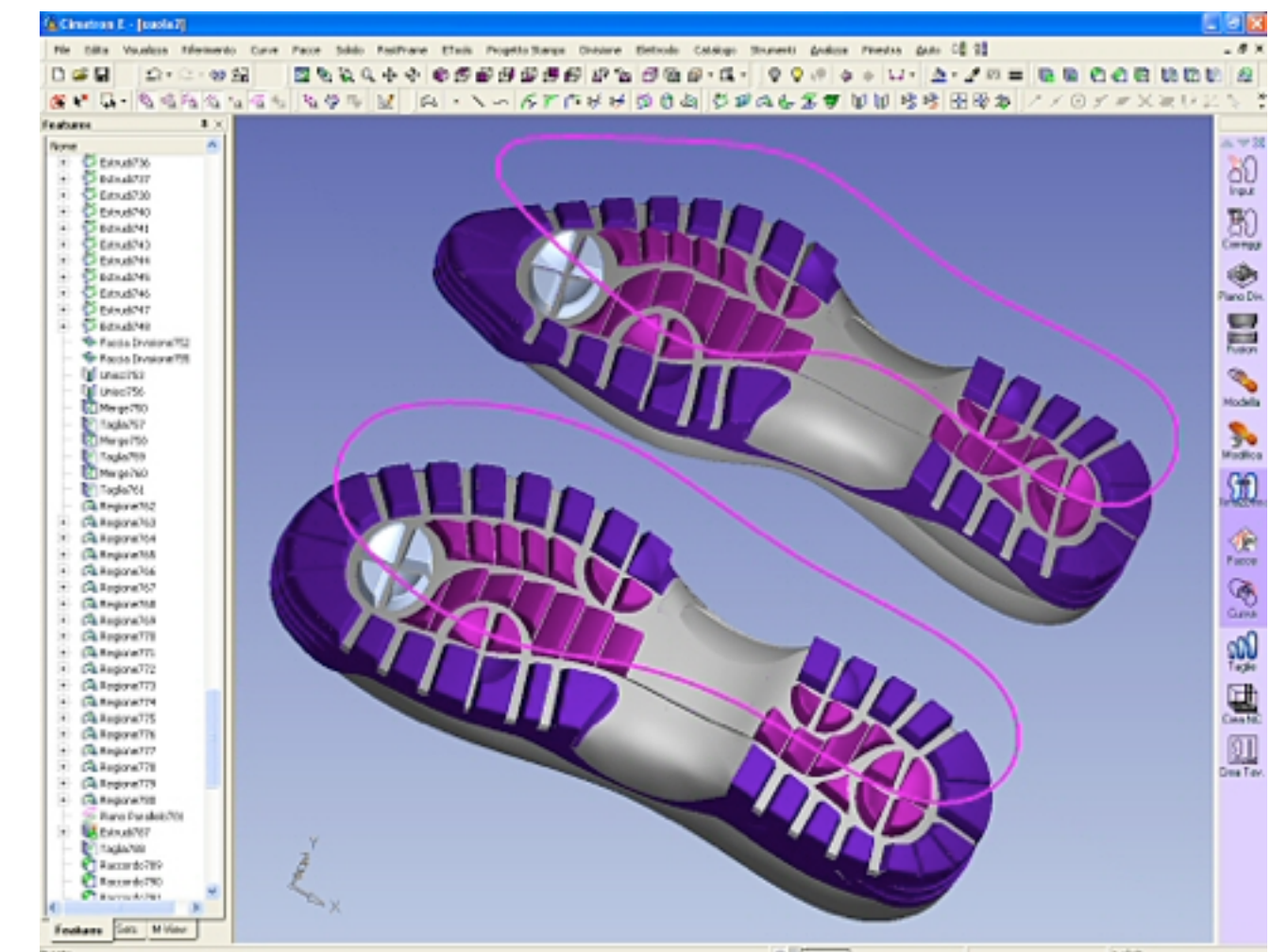
- Strengthens advanced manufacturing leadership and portfolio
- Extends global sales coverage, multiplexes cross selling opportunities
- Completes 3DS' software interoperability for 3D digital fabrication

ROCK HILL, South Carolina, February 9, 2015 – [3D Systems](#) (NYSE:DDD)

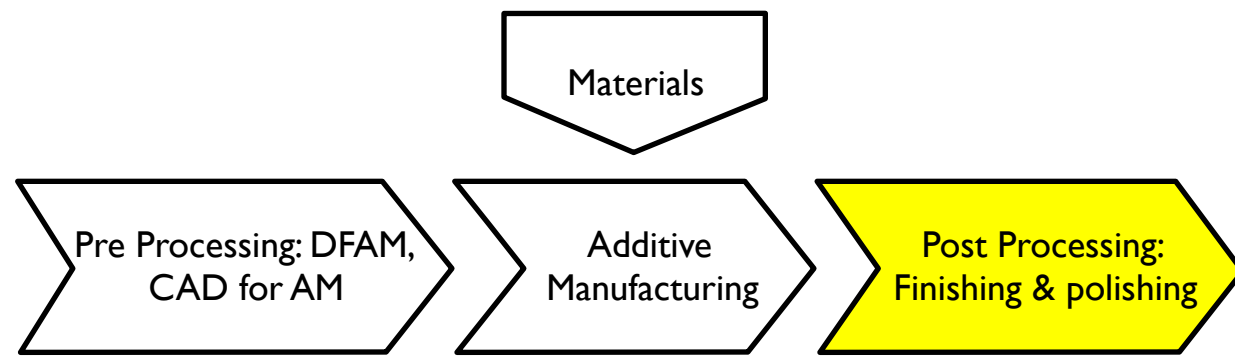
announced today that it has completed its acquisition of all shares of Cimatron Ltd. (NASDAQ:CIMT) for approximately \$97 million, inclusive of Cimatron's net cash. The integration of Cimatron's software products into the company's portfolio strengthens 3DS' leadership position in 3D-printing-centric advanced manufacturing by enabling a seamless digital workflow between design and traditional and additive manufacturing processes. The transaction adds complementary technology, extends 3DS' sales coverage globally, multiplexes cross-selling opportunities and is expected to be accretive to the company's cash generation and Non-GAAP earnings per share for the full year 2015.

"Cimatron represents a perfect strategic fit for our business by providing expanded capabilities in product development, sales coverage and complementary technology. We believe that this combination offers unique synergies with significant long-term customer benefits and shareholder value," commented Avi Reichental, President and CEO of 3DS. "We are delighted to welcome Danny Haran and his entire global team to 3DS as we complete the digital thread from design to digital fabrication."

Cimatron is a leading provider of integrated 3D digital fabrication software for manufacturing. Cimatron's products are used by a growing number of companies worldwide for their 3D production molds, tools and dies in a wide variety of functional end-use manufacturing applications. With two world renowned products, CimatronE and



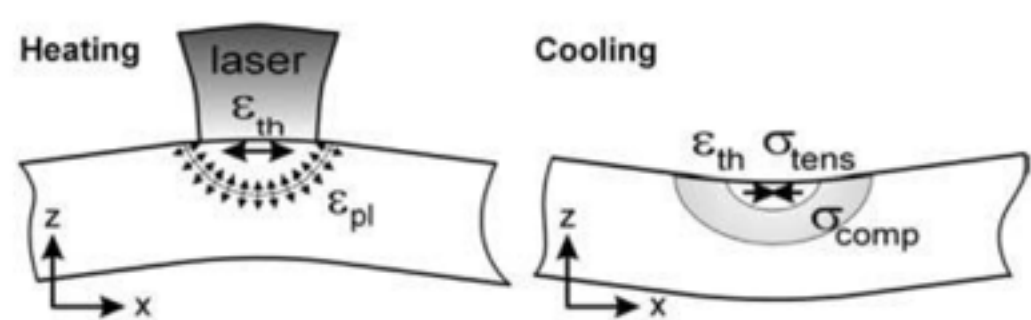
Linee di intervento della ricerca industriale: post processing e finitura



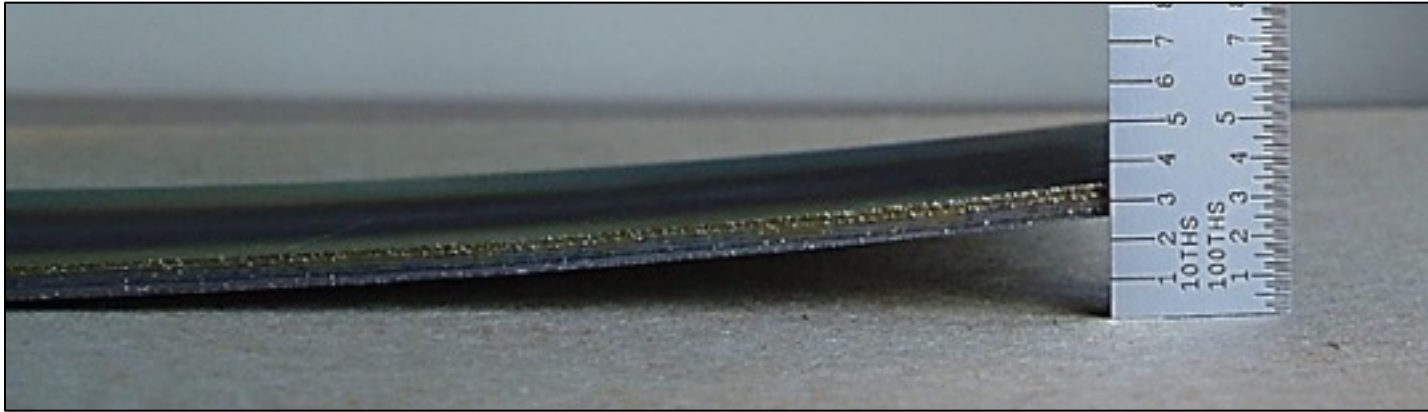
- ▶ Rimozione Supporti.
- ▶ Trattamenti di distensione termica.
- ▶ Trattamenti termici microstrutturali.
- ▶ Trattamenti per migliorare densità e porosità.
- ▶ Finitura alla macchina utensile

- ▶ Rimuovere i supporti
- ▶ Morfologia della superficie
- ▶ Accuratezza geometrica e dimensionale
- ▶ Caratteristiche fisiche e meccaniche
- ▶ Rugosità e l'aspetto estetico

Trattamenti termici: il laser come strumento per il “rapid post processing”



Fonte: Kruth et al. Rapid Prototyping Journal, Vol. 12 Iss 5 pp. 254 - 265

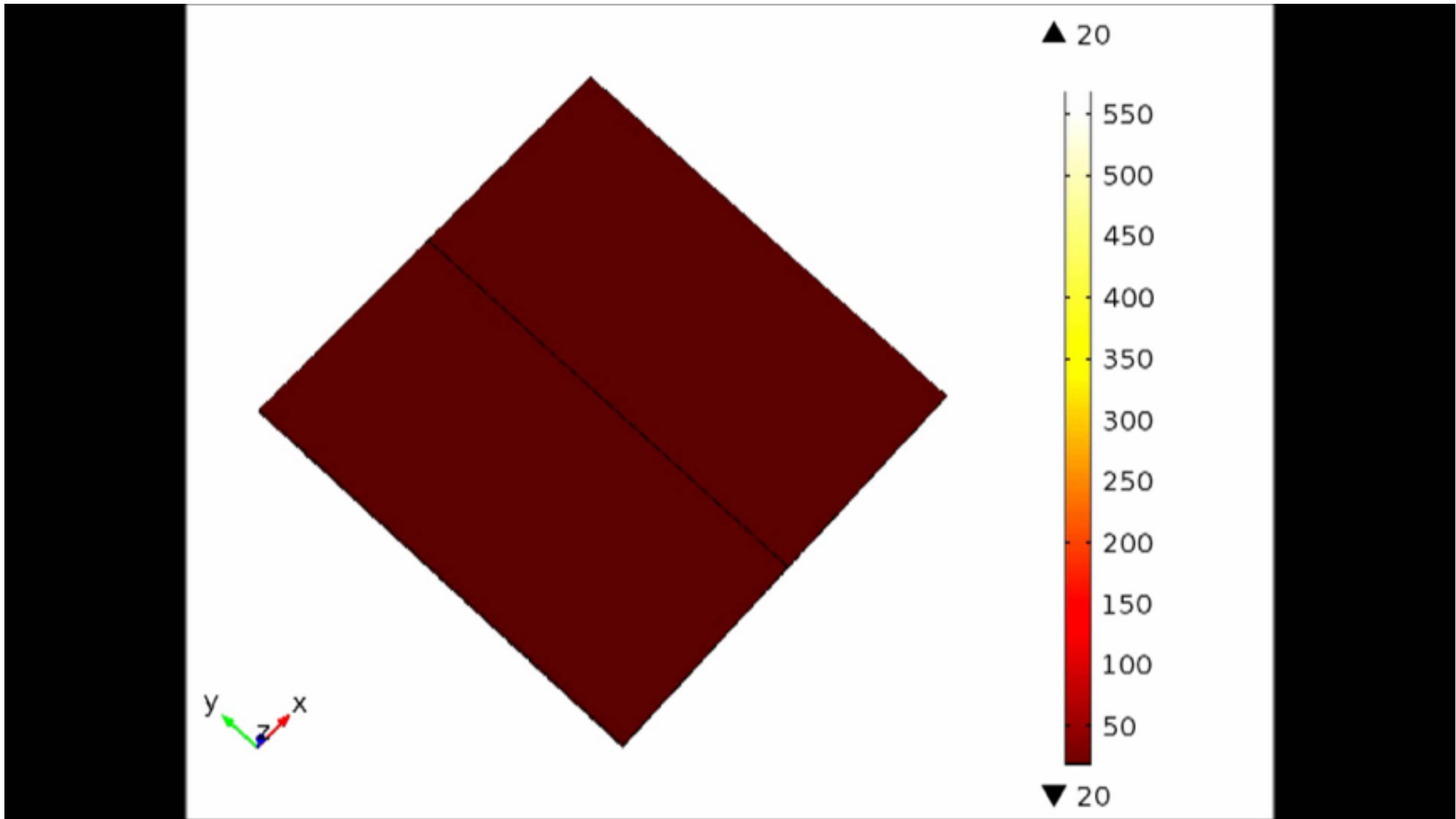


Fonte: Mike Klecka
United Technologies Research Center

I trattamenti termici massivi richiedono tempo e non sempre è necessario applicarli a tutto il componente

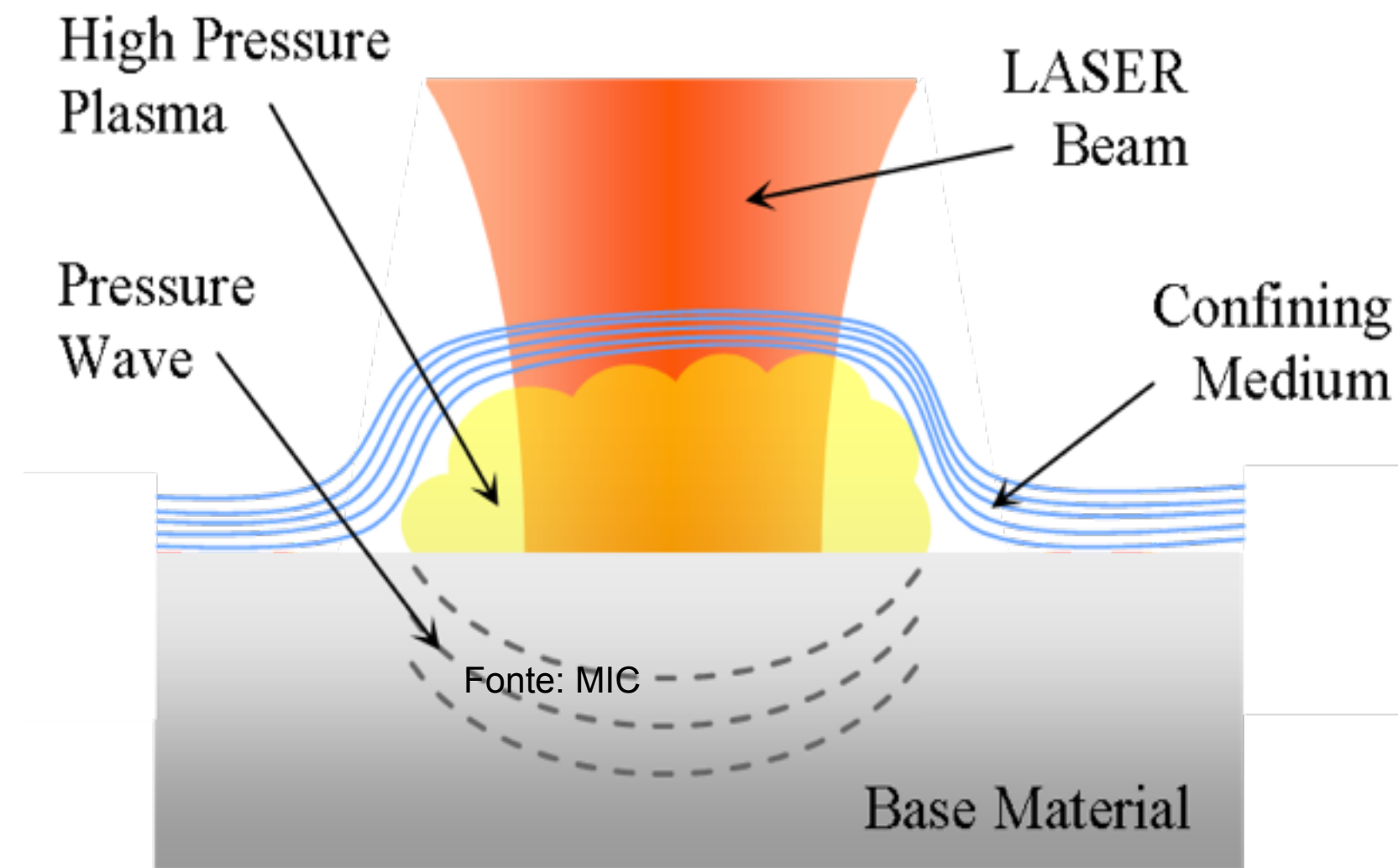
DMLS Material	Temp (C°)	Time (Hours)	Atmosphere	Benefit
Direct Metal 20, DM20	250	2	Air	Stress Relieving
Stainless Steel, GP1, 17-4	650	1	Argon / Air	Stress Relieving
Stainless Steel, PH1, 15-5	482	4	Argon / Air	Age Hardening
Maraging Steel, MS1	490	6	Air	Age Hardening
Maraging Steel, MS1	525	6	Argon	Increase Ductility
Cobalt Chrome, MP1	1050	2	Argon / Air	Stress Relieving
Cobalt Chrome, MP1	1150	6	Argon	Increase Ductility

Fonte: Solid Concepts

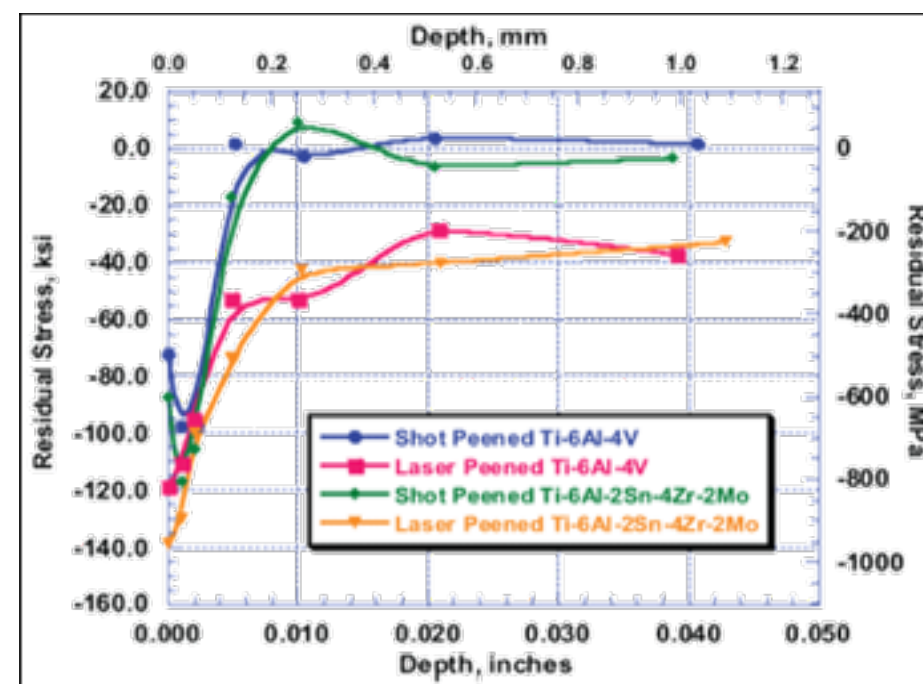


Fonte: Gruppo Laser - UNIBO

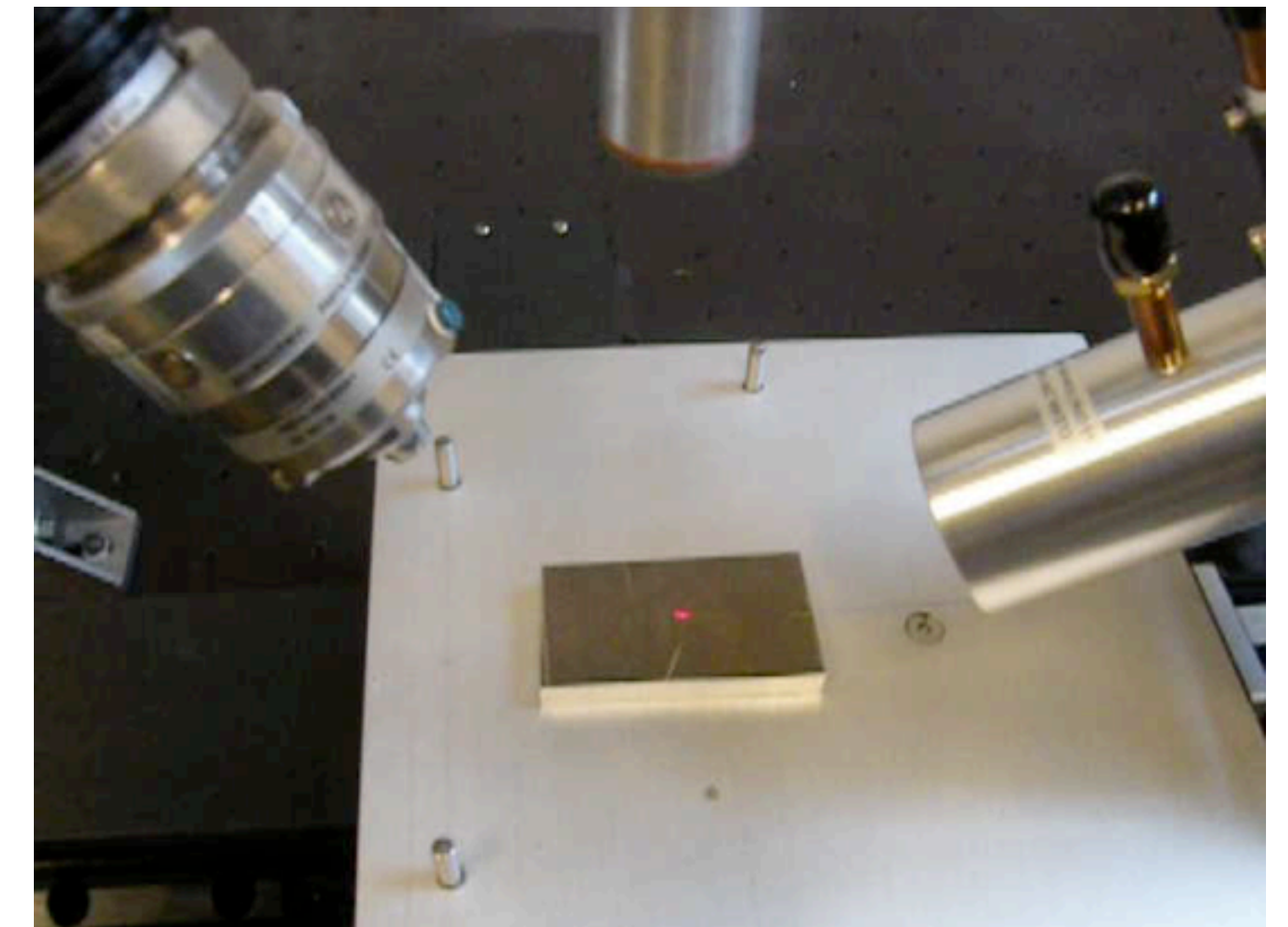
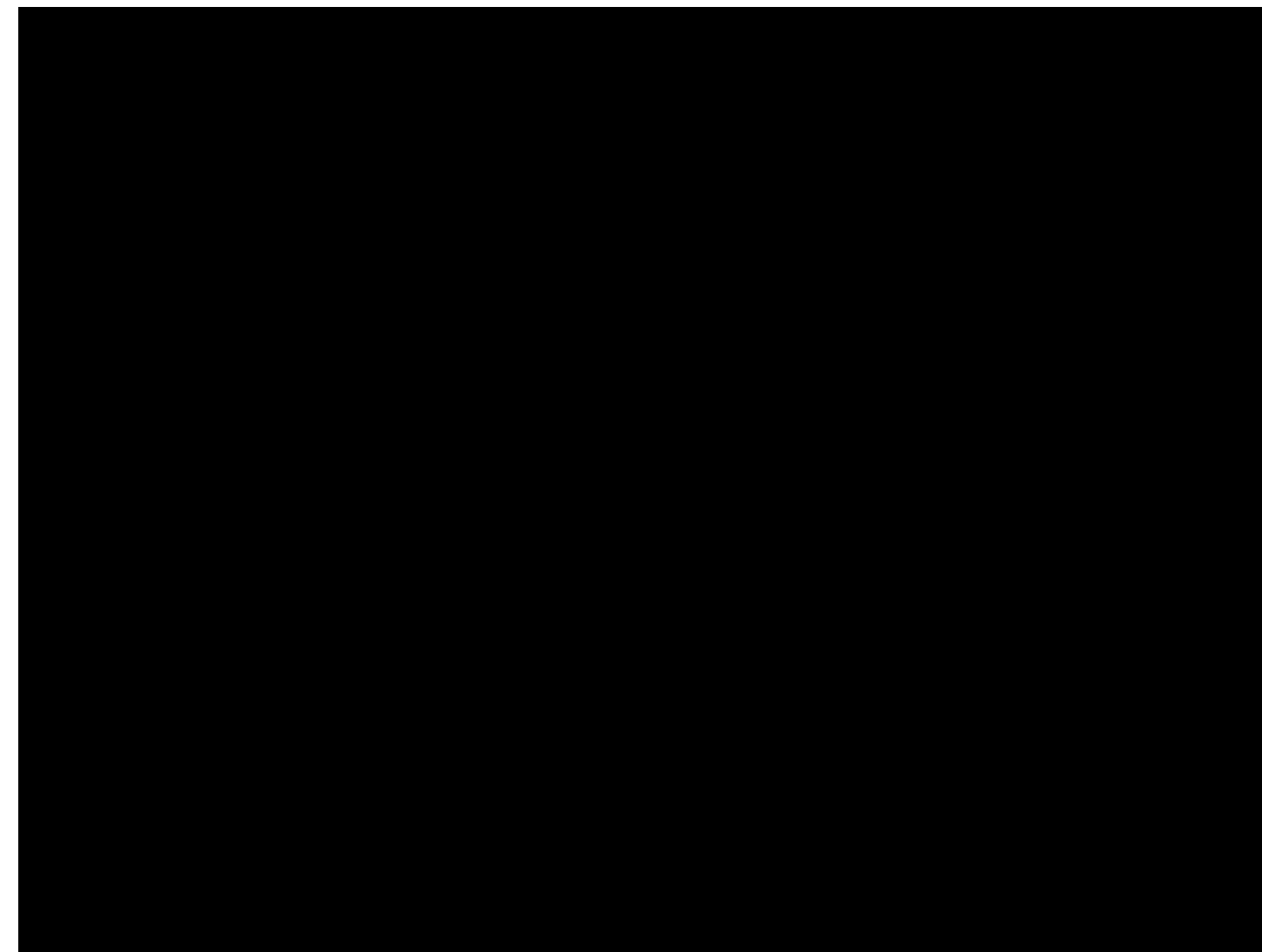
Laser Shock Peening per la riduzione delle tensioni interne e l'aumento della vita a fatica



Fonte: Tani, G., et al. CIRP Annals-Manufacturing Technology 60.1 (2011): 219-222.



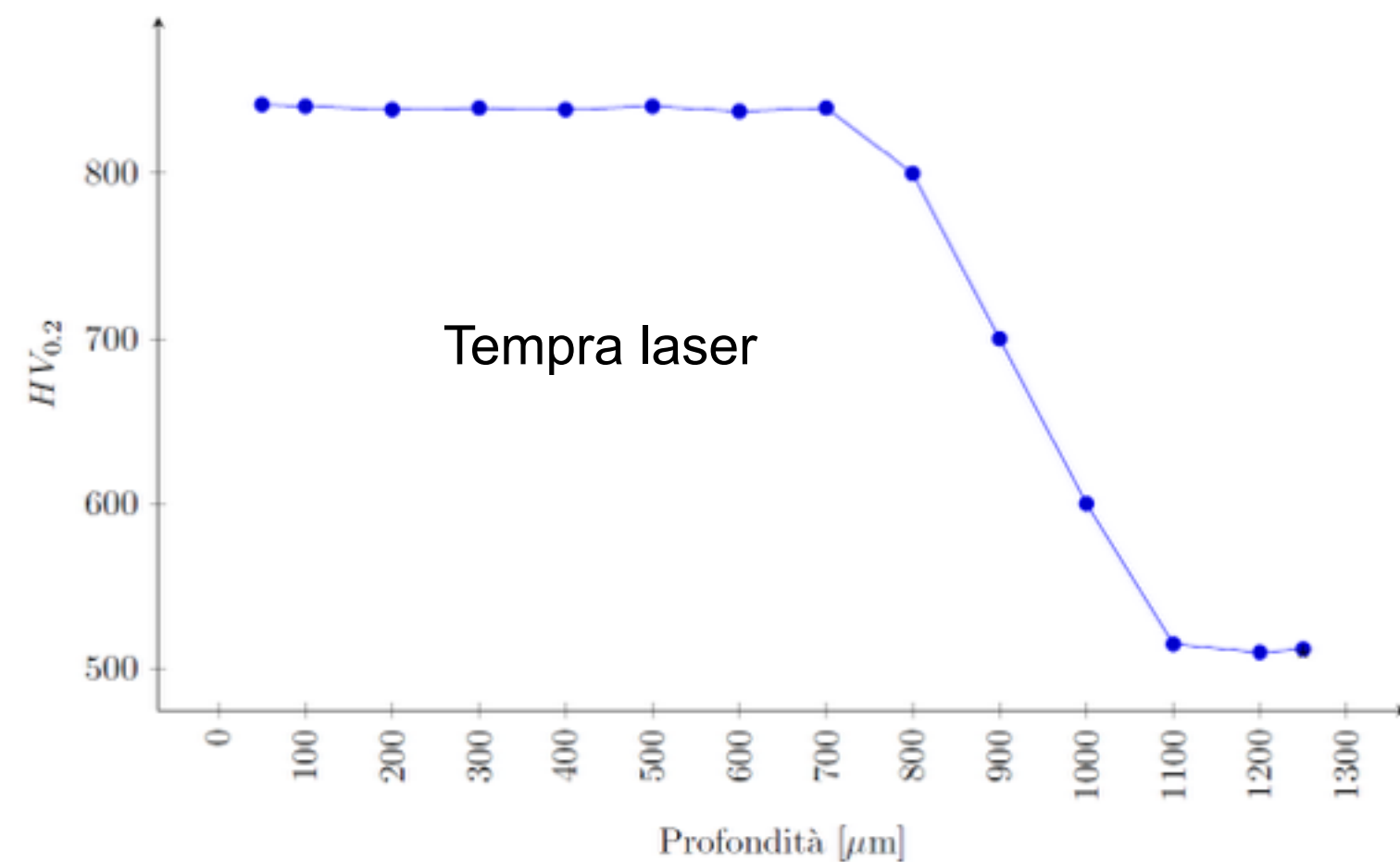
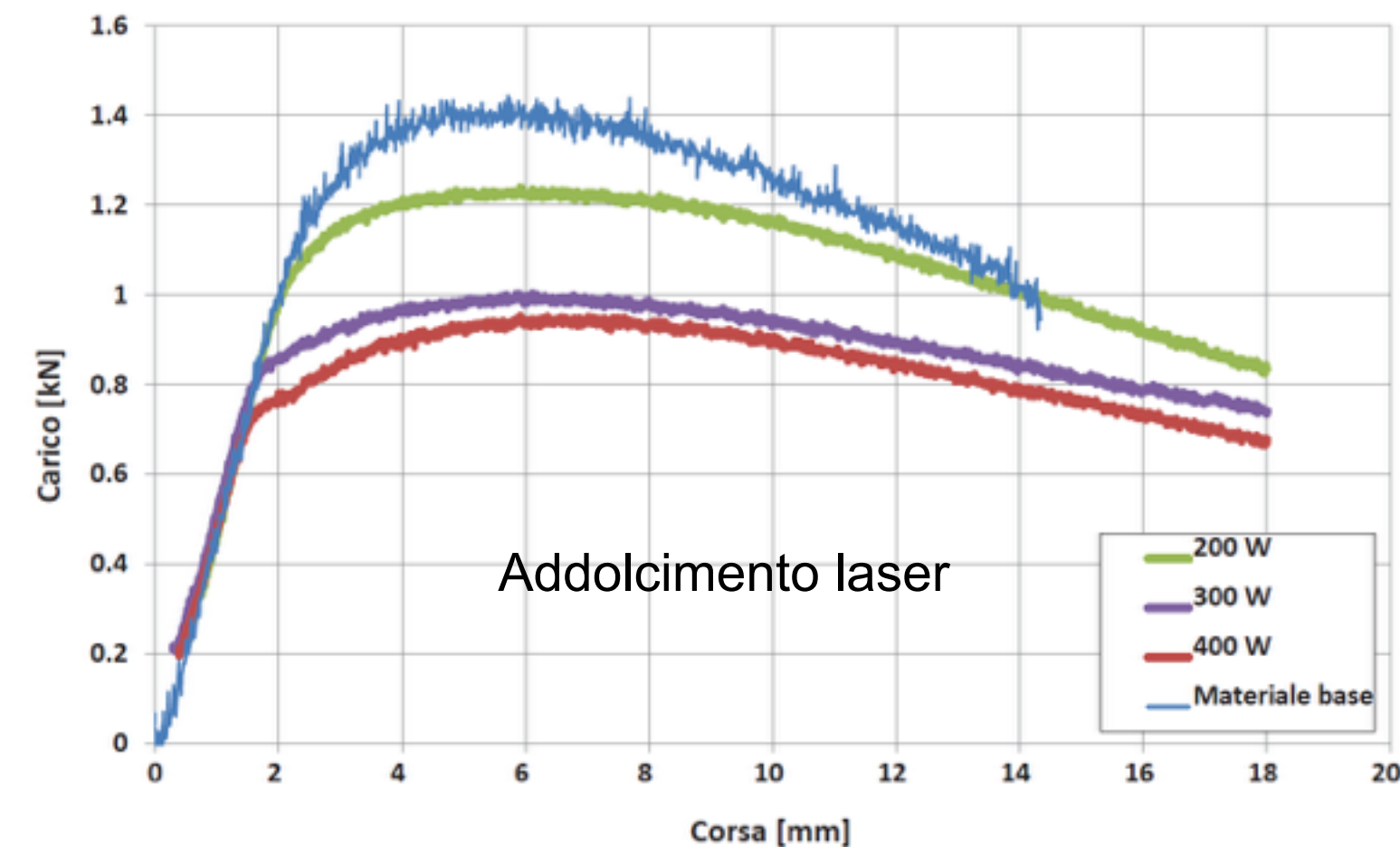
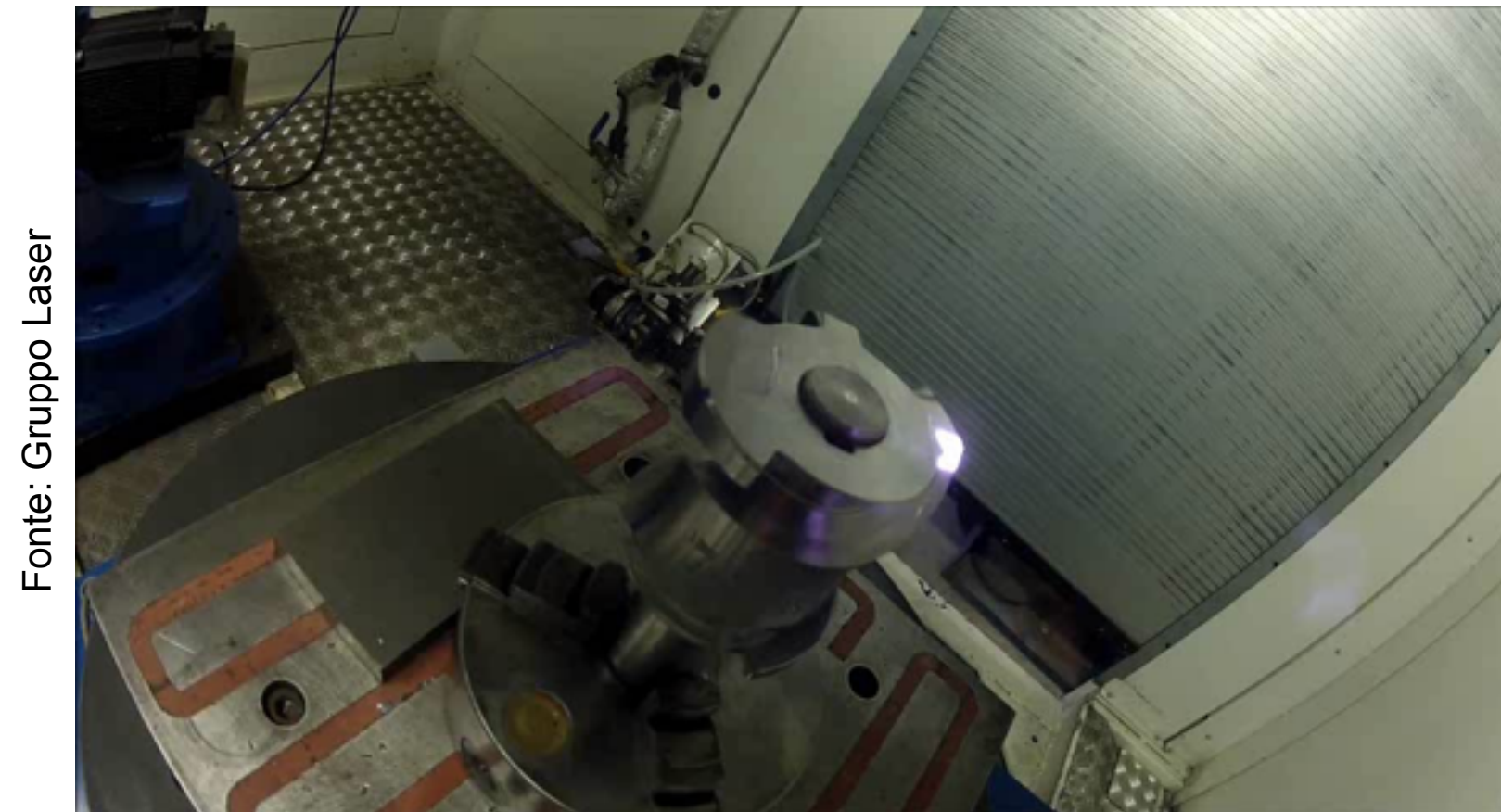
Fonte: SME- Manufacturing Engineering Magazine



Trattamenti per modificare le caratteristiche fisiche e meccaniche

- ▶ Trattamenti per eliminare le strutture di solidificazione:
 - Normalizzazione
 - Ricottura di ricristallizzazione
- ▶ Trattamenti per ridurre le direzionalità nelle strutture:
 - Omogenizzazione
 - Solubilizzazione
- ▶ Trattamenti per migliorare le caratteristiche meccaniche:
 - Solubilizzazione e invecchiamento
 - Tempra e rinvenimento

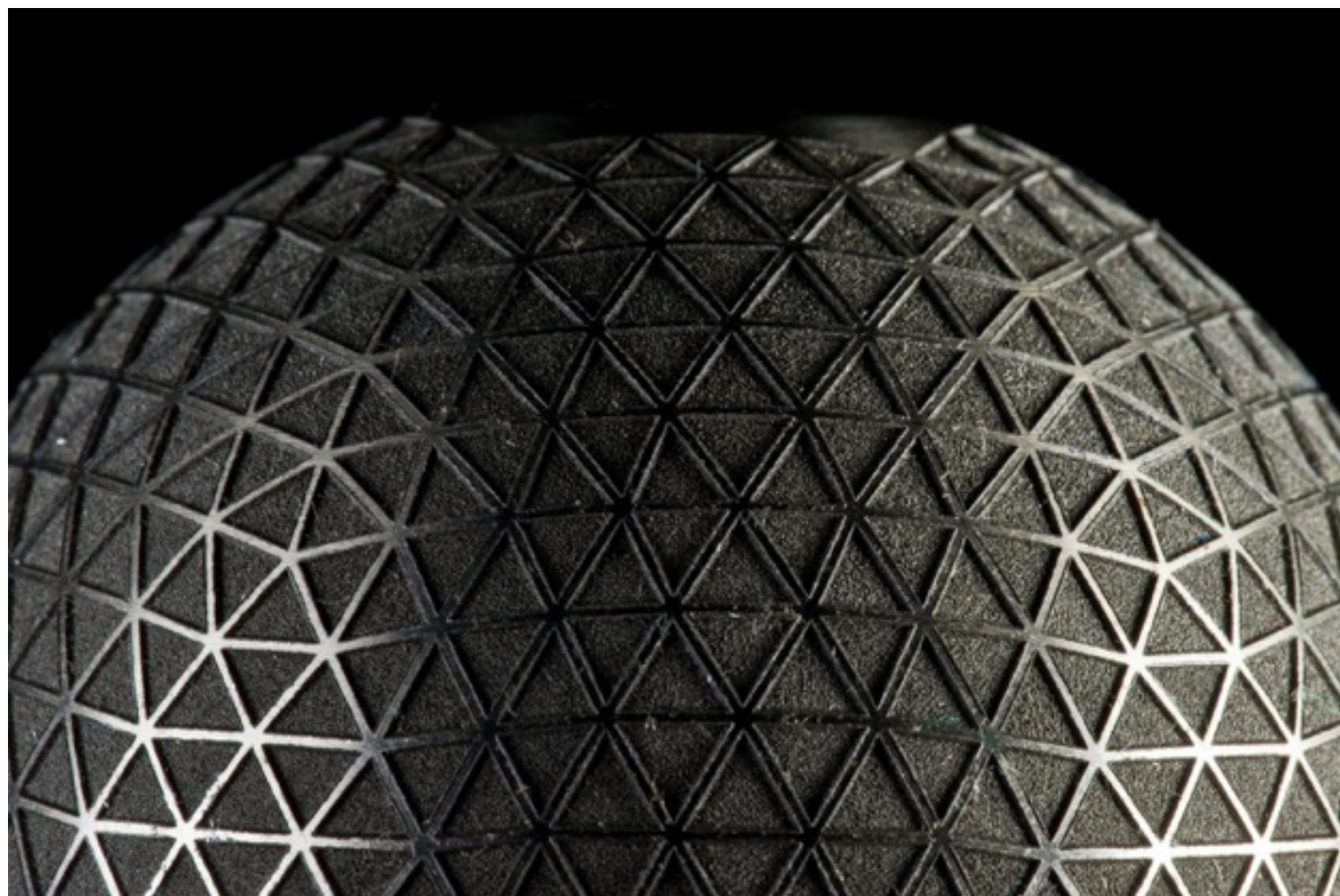
Laser Hardening: perfetta simbiosi con il Rapid Manufacturing



Modulando l'apporto termico,
attraverso il laser si possono ottenere
diversi tipi di trattamento

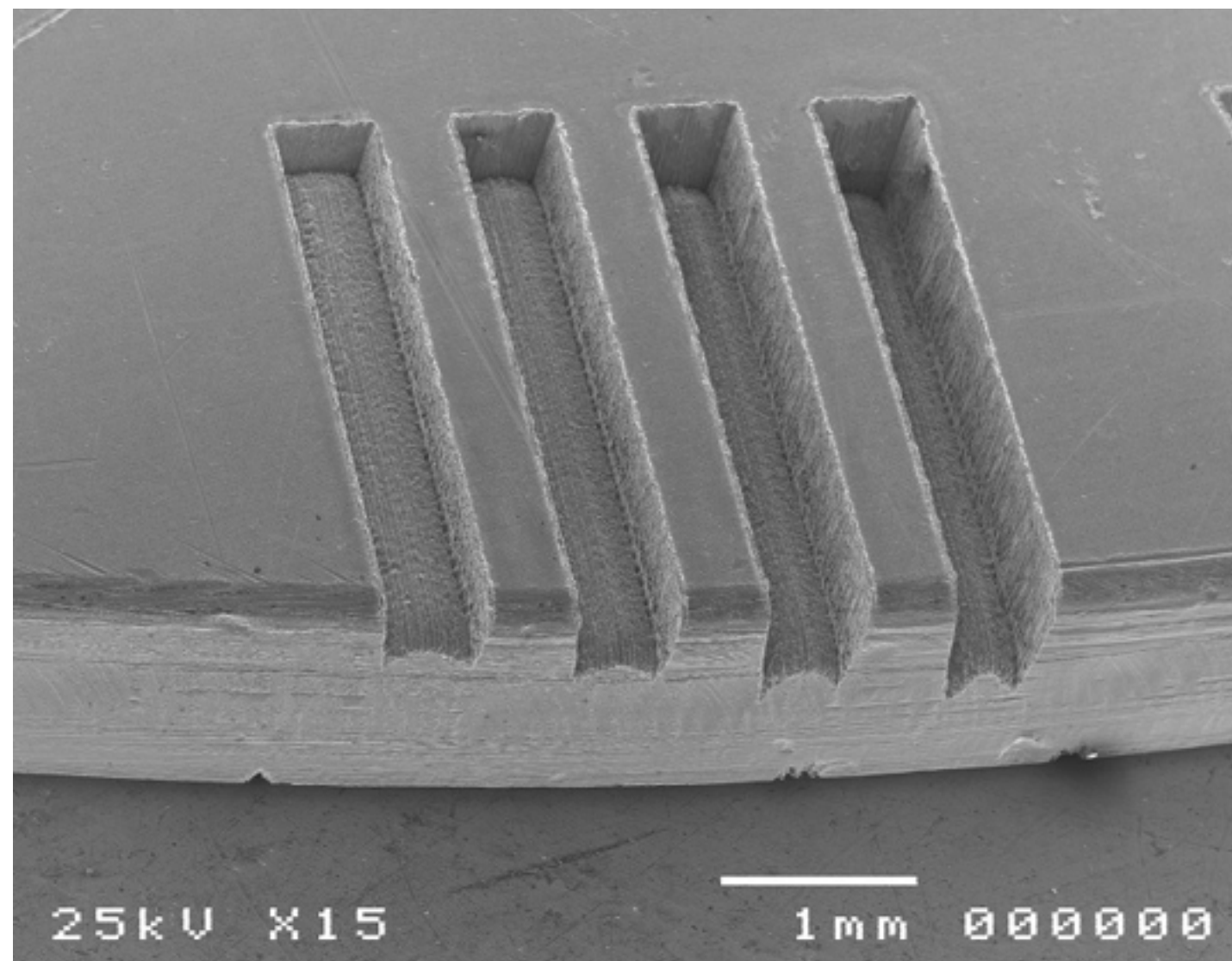
Rimozione, separazione ed asportazione

Laser texturing



Fonte: CB Ferrari

Laser milling



Fonte: Oxford Lasers

Laser drilling



Fonte: Potomac

Il laser come strumento di asportazione consente ottime risoluzioni e, soprattutto nel caso di SLS o SLM, può essere integrato in macchina molto facilmente.

Finitura superficiale, lucidatura



Fonte: Global Metalfinishing



Fonte: MIC



Fonte: SBA

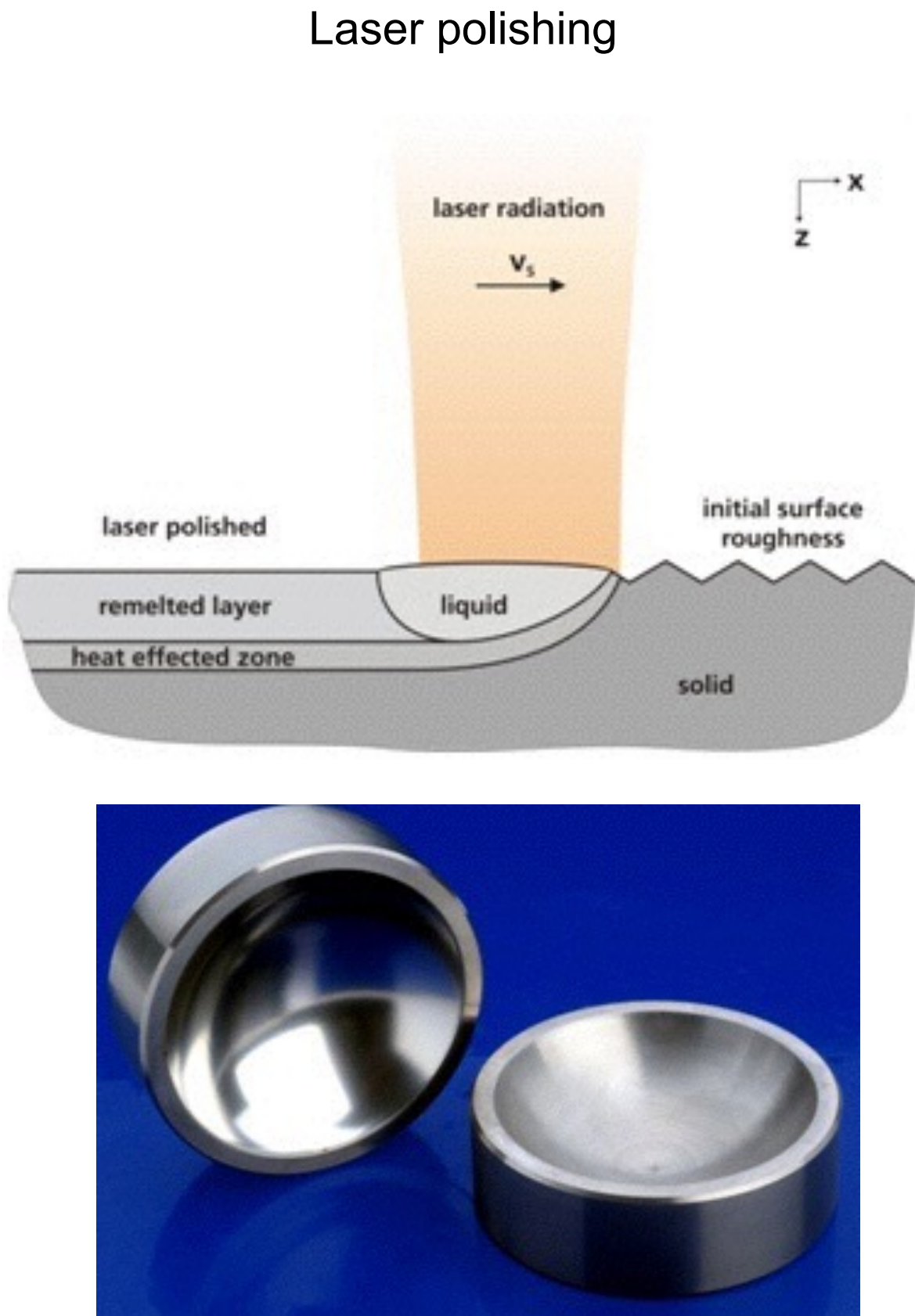
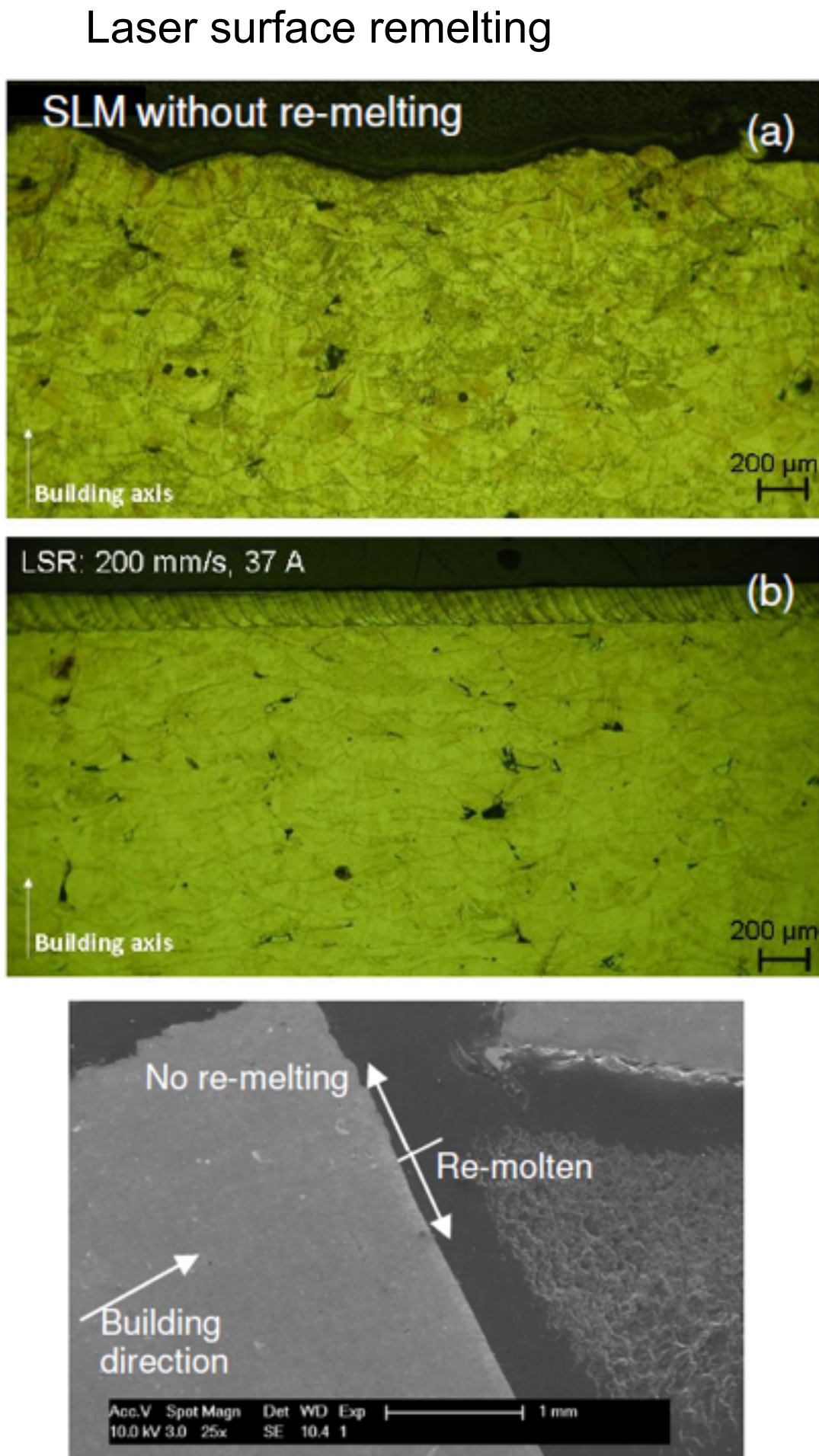


Fonte: Manzerna

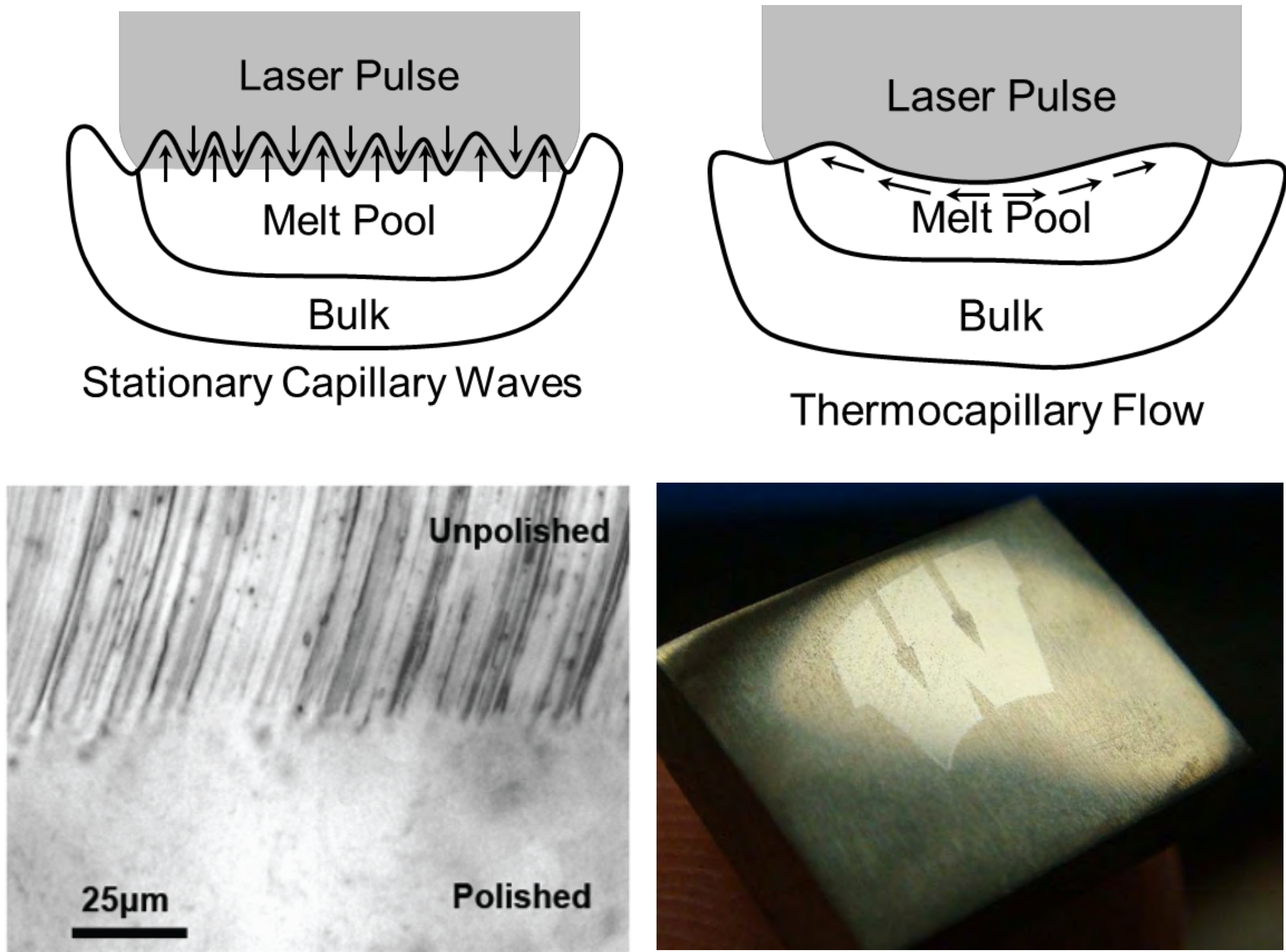
- ▶ Sabbatura
- ▶ Pallinatura
- ▶ Burattatura
- ▶ Lucidatura

Finitura superficiale, lucidatura

Fonte: Kruth et al., 16th International Symposium on Electromachining (ISEM XVI)



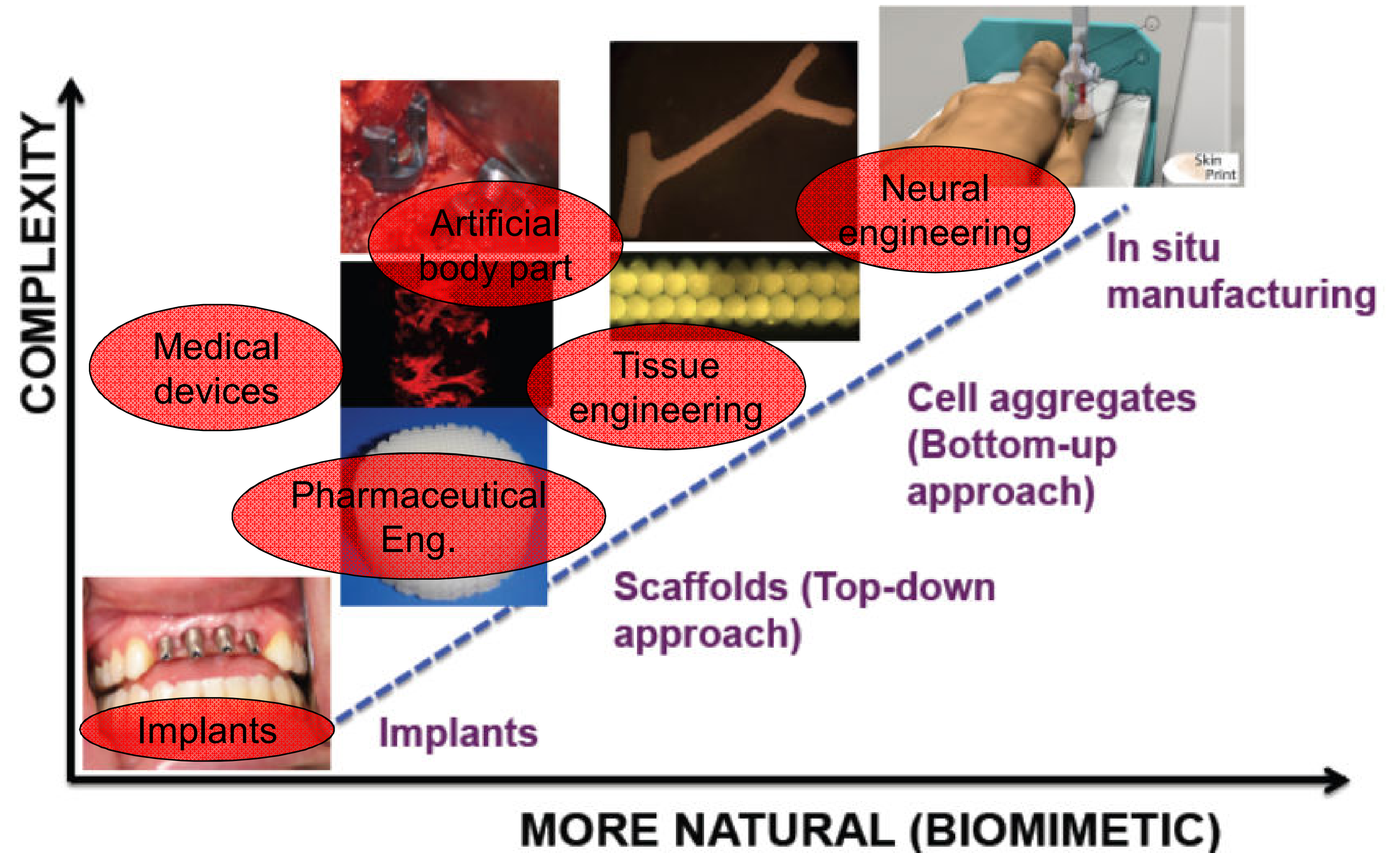
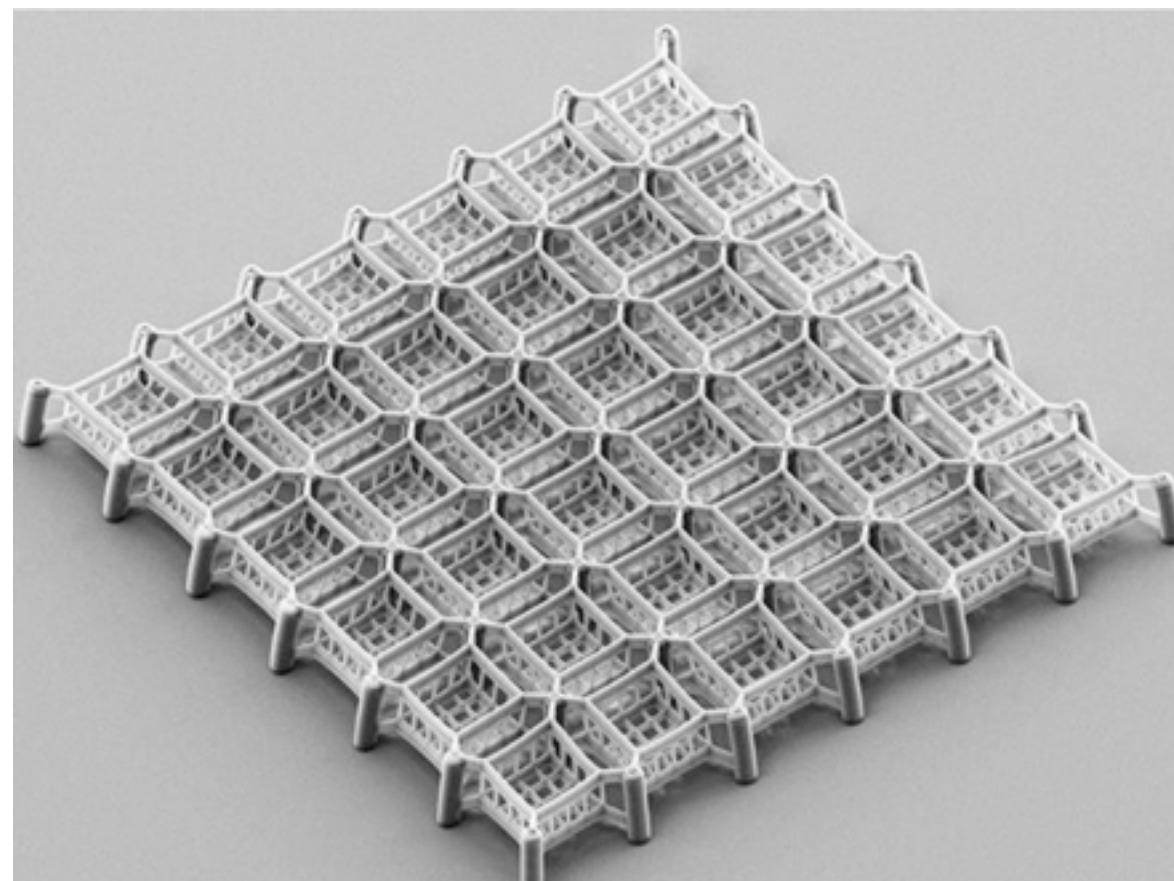
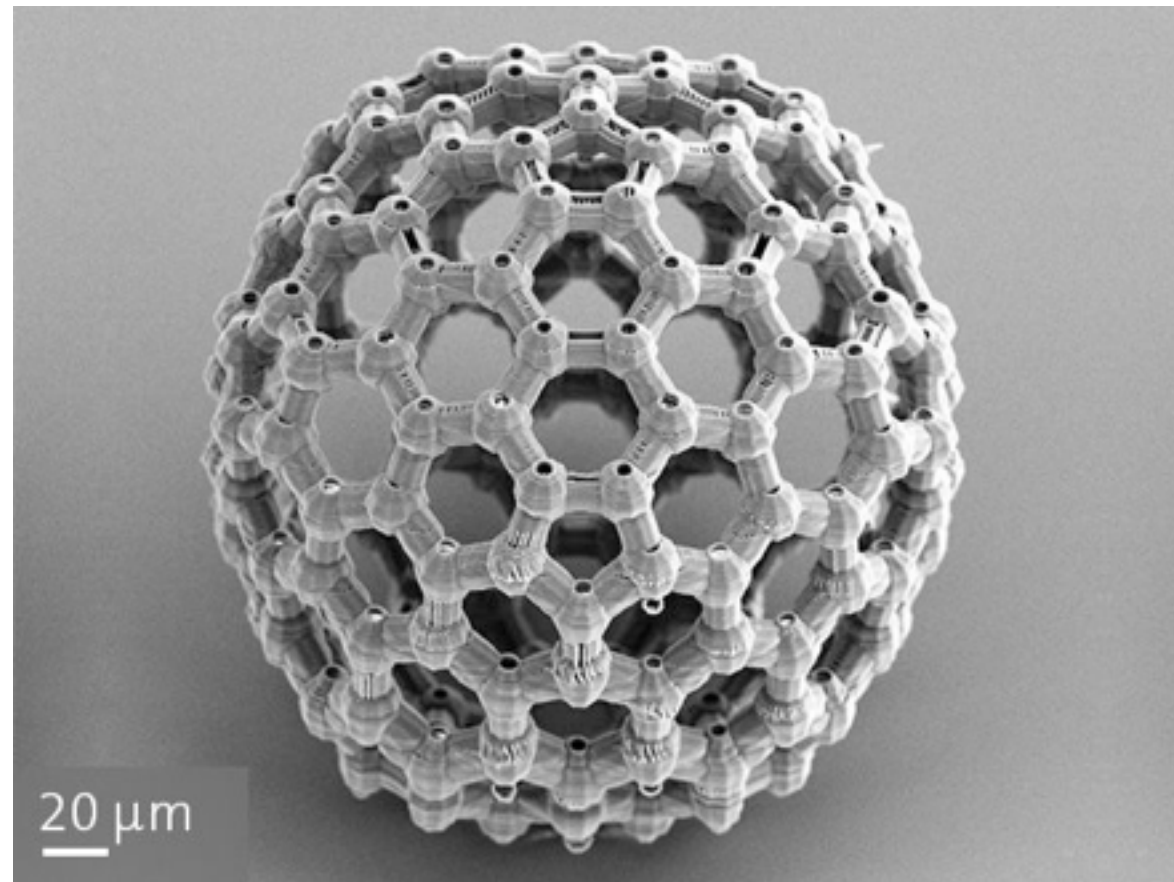
Fonte: poliMATC



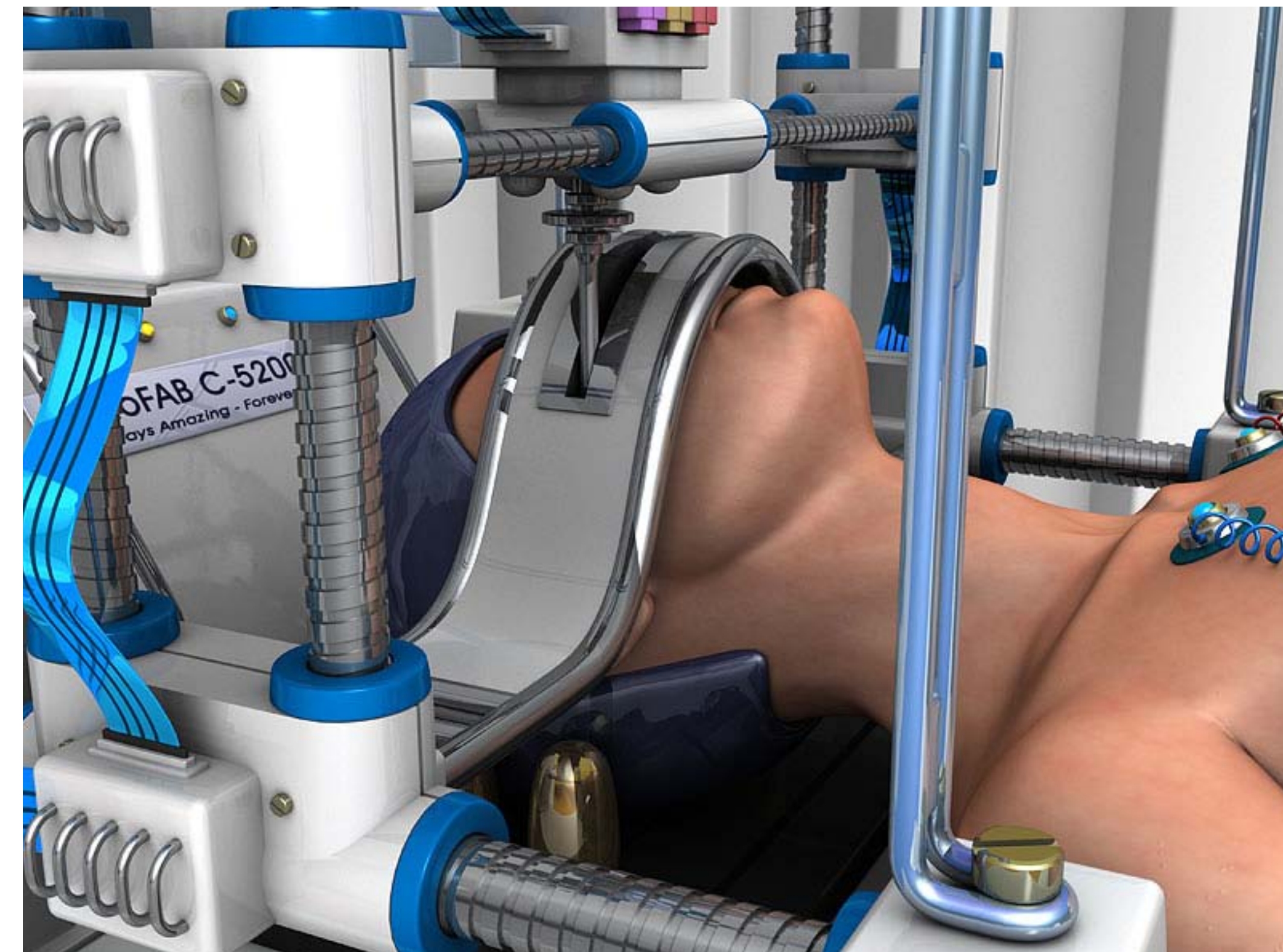
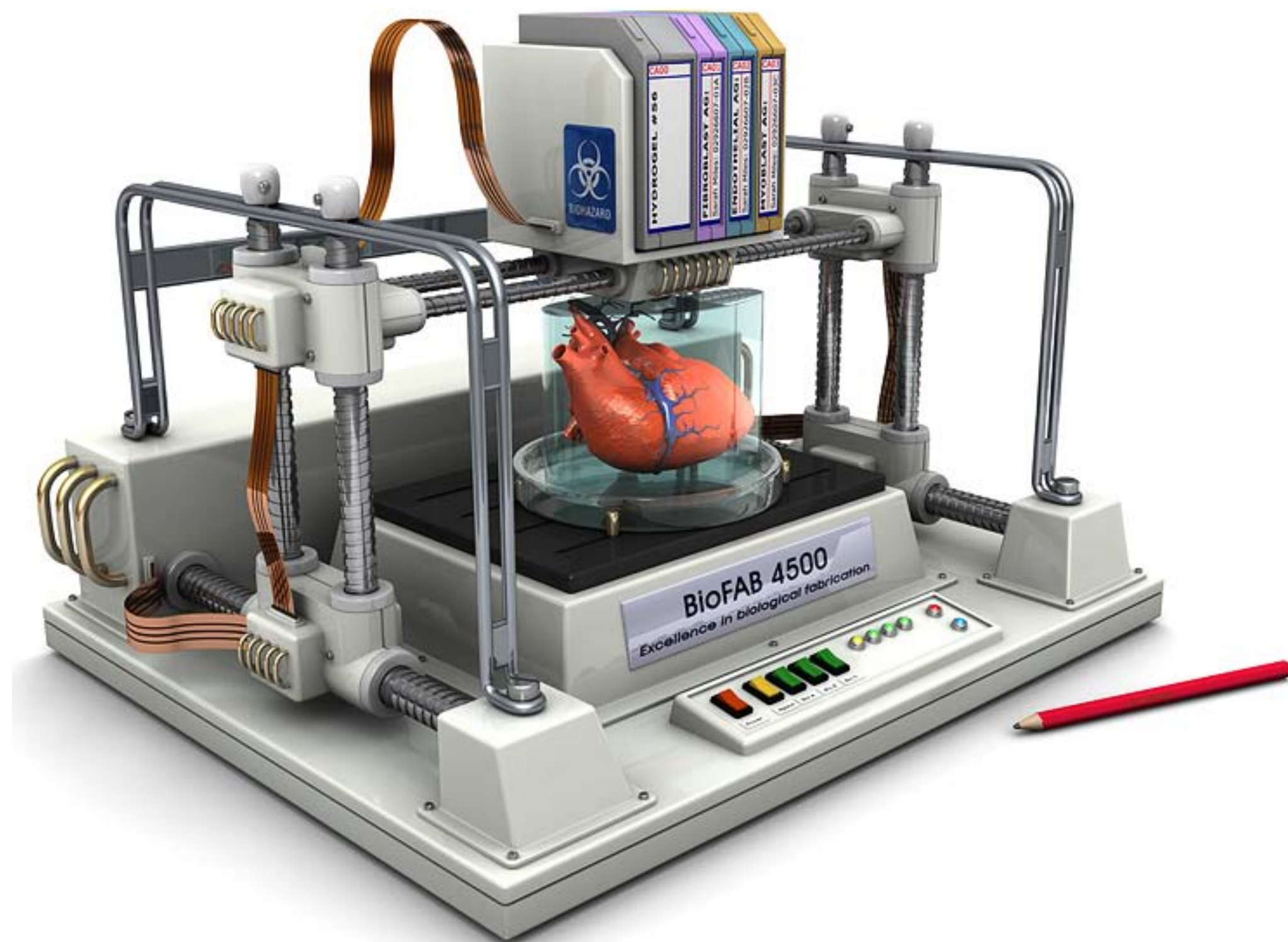
Fonte: Pfefferkorn et al.

5-mm-wide “W” polished at 1 mm²/s on ground Ti6Al4V surface.

Linee di intervento della ricerca industriale: BioMedicale, medicina rigenerativa



Linee di intervento della ricerca industriale: BioMedicale, medicina rigenerativa



Trends futuri

- ▶Alta complessità ed interdisciplinarietà.
- ▶La chiave sarà la sostenibilità del processo
- ▶Produttività, automazione e controllo per un miglioramento continuo.
- ▶Nuovi modalità di fabbricazione guidate da esigenze del prodotto sono in arrivo.
- ▶Nuove modalità di progettazione guidate dalla modalità di fabbricazione.
- ▶5 anni da ora.



UNIMORE

UNIVERSITÀ DEGLI STUDI DI
MODENA E REGGIO EMILIA

Dipartimento di Scienze e Metodi dell'Ingegneria
Campus San Lazzaro
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Additive Manufacturing: nuove sfide per la ricerca industriale

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