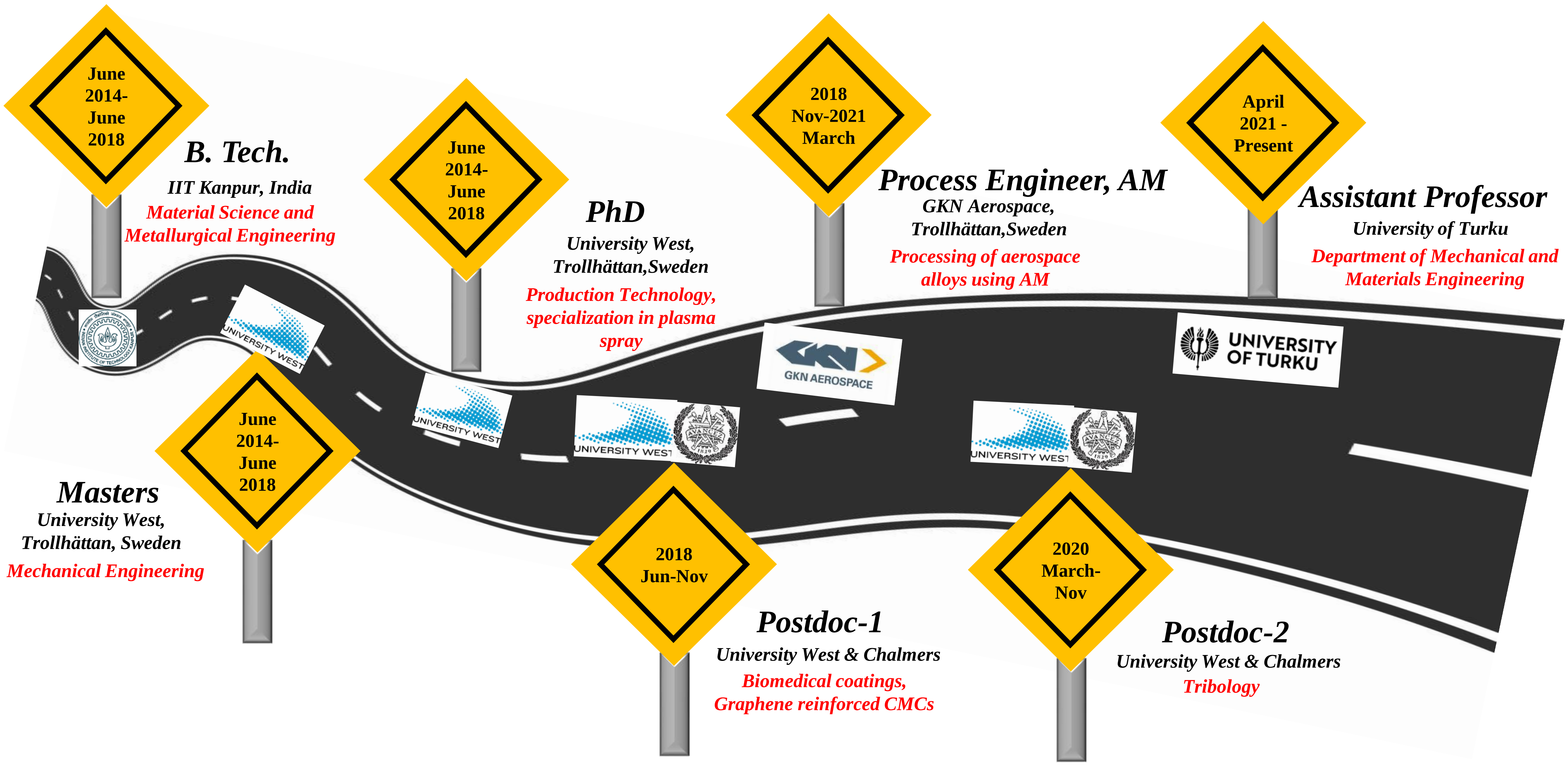
Additive Manufacturing & Surface Engineering

Ashish Ganvir
Assistant Professor
Department of Mechanical and Materials Engineering
Faculty of Technology, University of Turku
Webpage: https://www.utu.fi/en/people/ashish-ganvir
Contact: ashish.ganvir@utu.fi; +358(0)504782729; +358(0)294503736

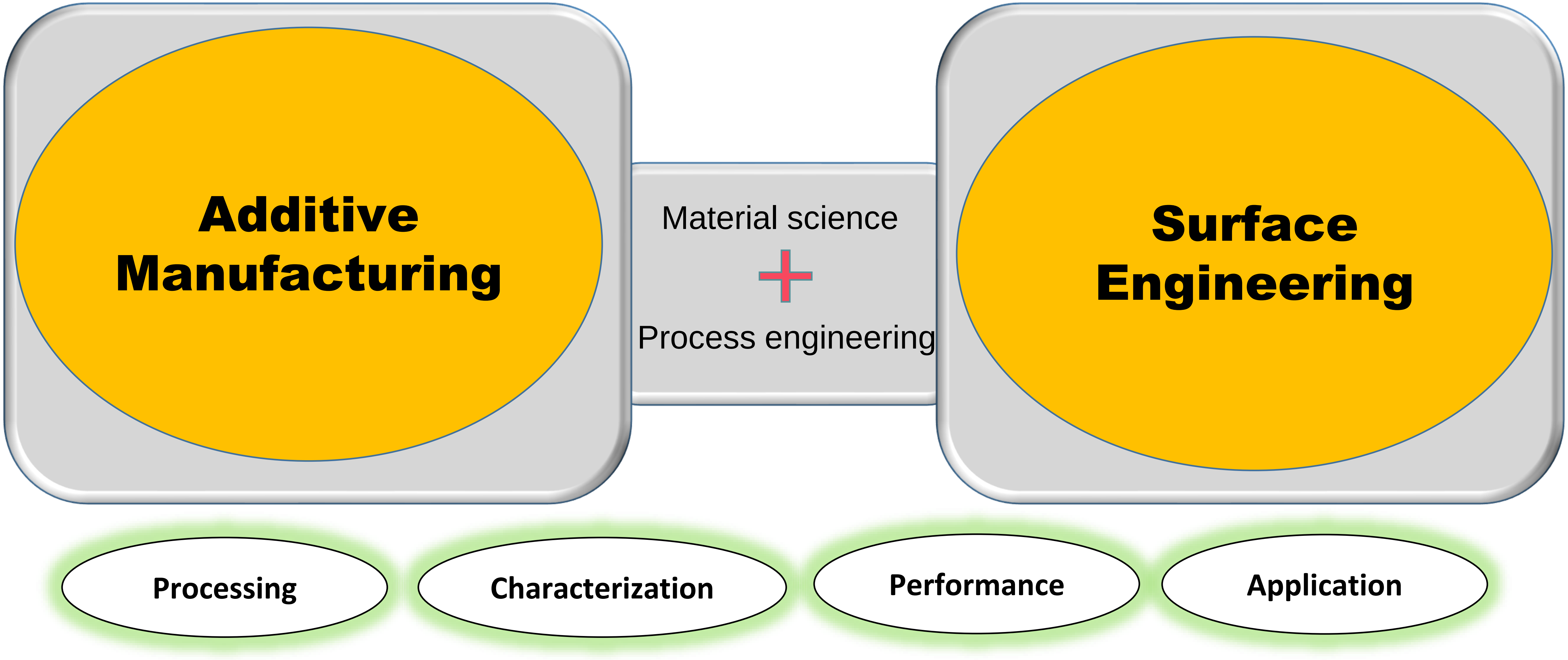
UNIVERSITY OF TURKU



My academic & professional journey so far…

UNIVERSITY OF TURKU

My research profile/domain

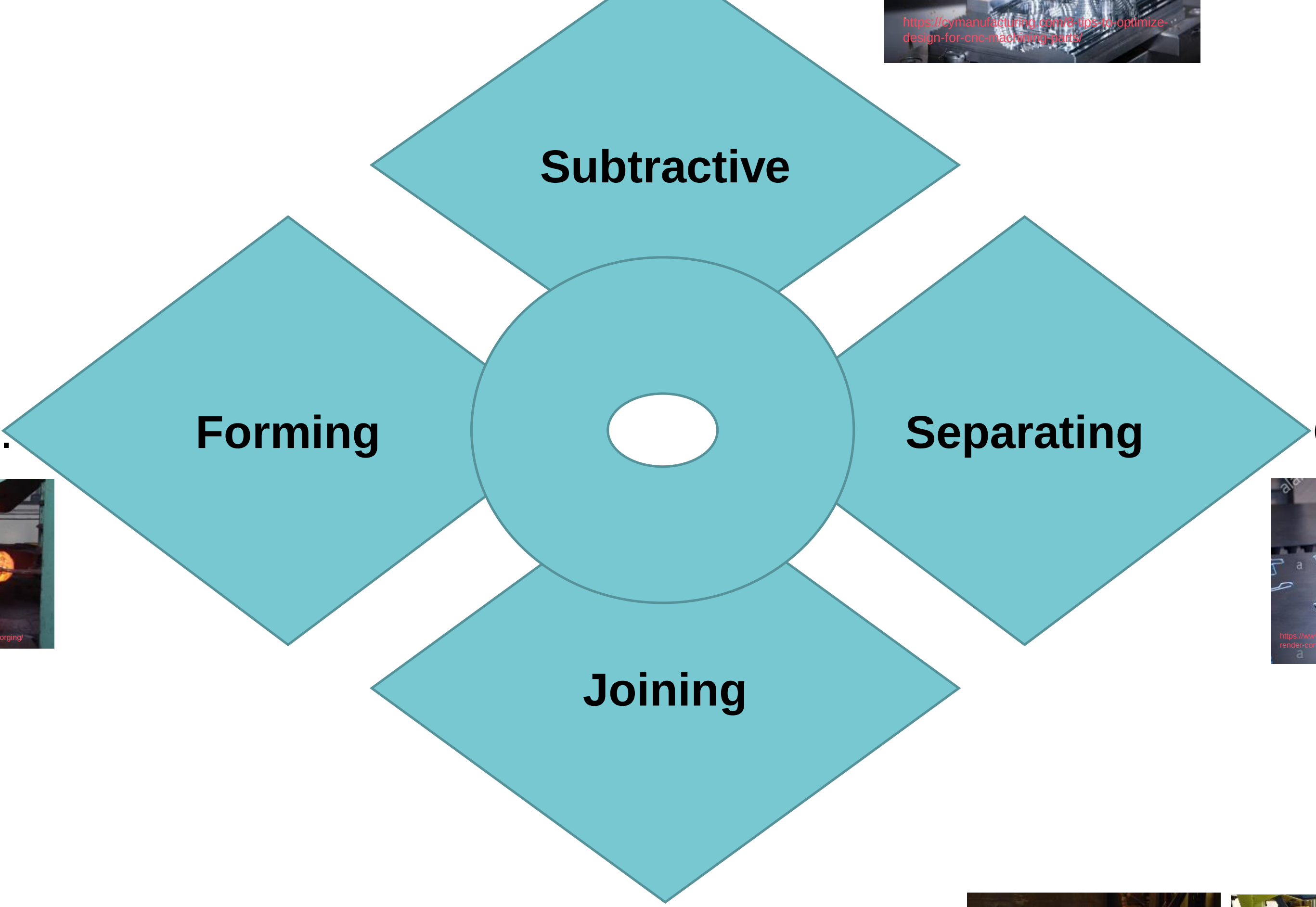


UNIVERSITY OF TURKU

Additive Manufacturing

Traditional manufacturing routes

Machining, Milling,
Drilling etc.



Casting, Forging etc.

Cutting, Sawing etc.

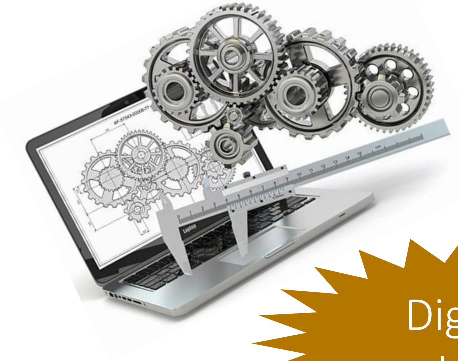
Welding, brazing, cladding,
thermal spray etc.

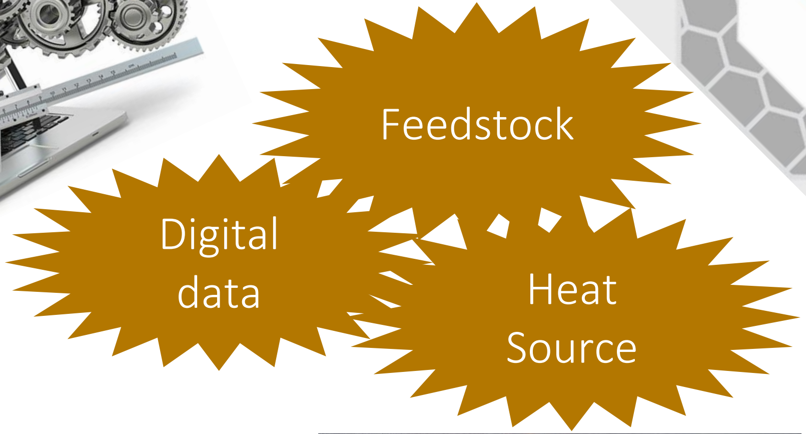
UNIVERSITY
OF TURKU

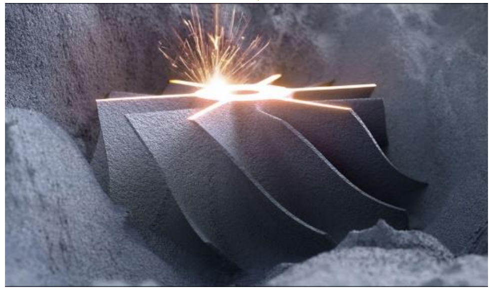
Additive Manufacturing

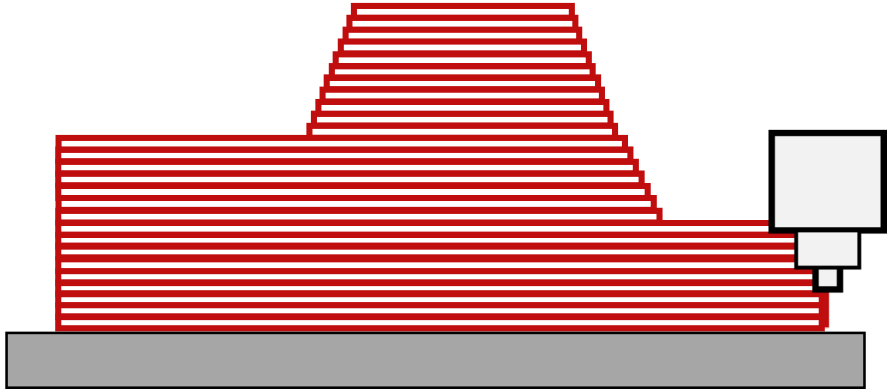
What is additive manufacturing (AM)?

- <u>**Definition as per ASTM F42 Standard :**</u> Additive manufacturing (AM) refers to a process by which digital 3D design data is used to build up a component in layers by depositing material.
- Current focus: Metals & their Composites
- Future ambition: Ceramic, Plastics & their Composites etc.









Additive manufacturing (AM)
3D printing

UNIVERSITY OF TURKU

Additive Manufacturing

Why should you board the AM Express?

https://www.abc.net.au/news/2019-12-06/expert-says-fastish-train-more-realistic-than-high-speed-service/11768896

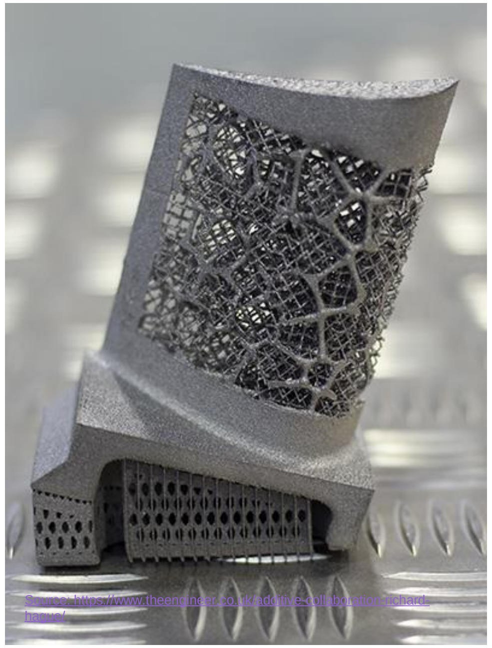
Shorter lead time


Source: https://www.accretio.io/en/blogen/how-much-time-is-money/

Reduced material wastage


Source: https://www.123rf.com/photo_24960524_pieces-of-steel-shavings-for-metal-recycling.html

Increased design freedom


Source: https://www.theengineer.co.uk/additive-collaboration-richard-hague/

And more…

UNIVERSITY OF TURKU

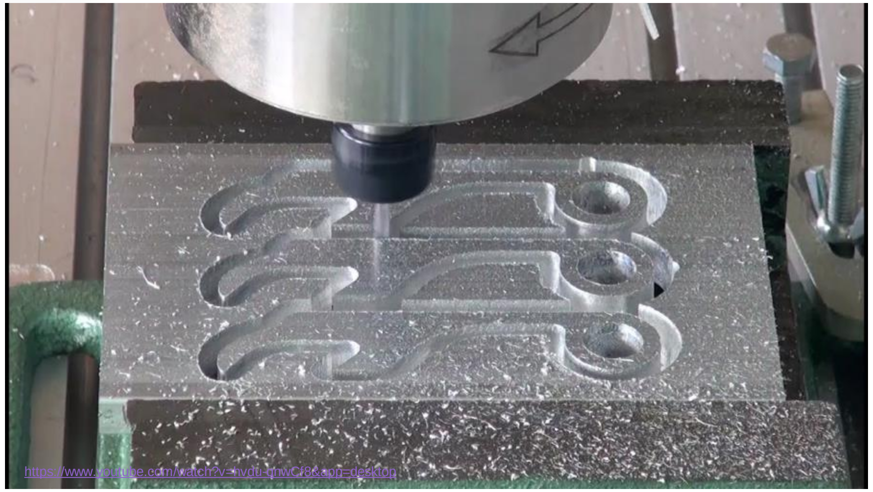
Additive Manufacturing

Why AM?: a simple case study of bottle opener


http://www.bhormetal.com/bottle-openers.htm


https://www.esajee.com/sprite-glass-bottle-soft-drink/


https://www.steelplates.in/suppliers/aluminium-products/aluminium-blocks-for-cnc/


https://www.youtube.com/watch?v=hvdu-gnwCf8&app=desktop

Additive Manufacturing

Why AM?: a simple case study of bottle opener

Increased design freedom

Shorter lead time

No tooling needed

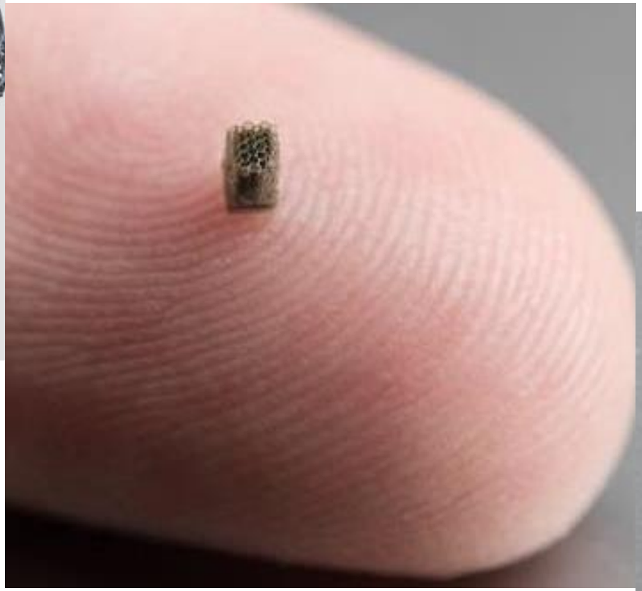
Reduced material wastage

Sustainable manufacturing

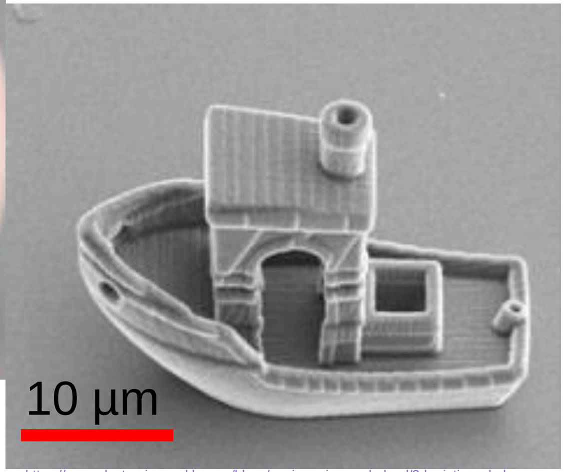
Complex design examples manufactured by AM at different length scale

https://www.nasa.gov/centers/marshall/news/releases/2020/future-rocket-engines-may-include-large-scale-3d-printing.html

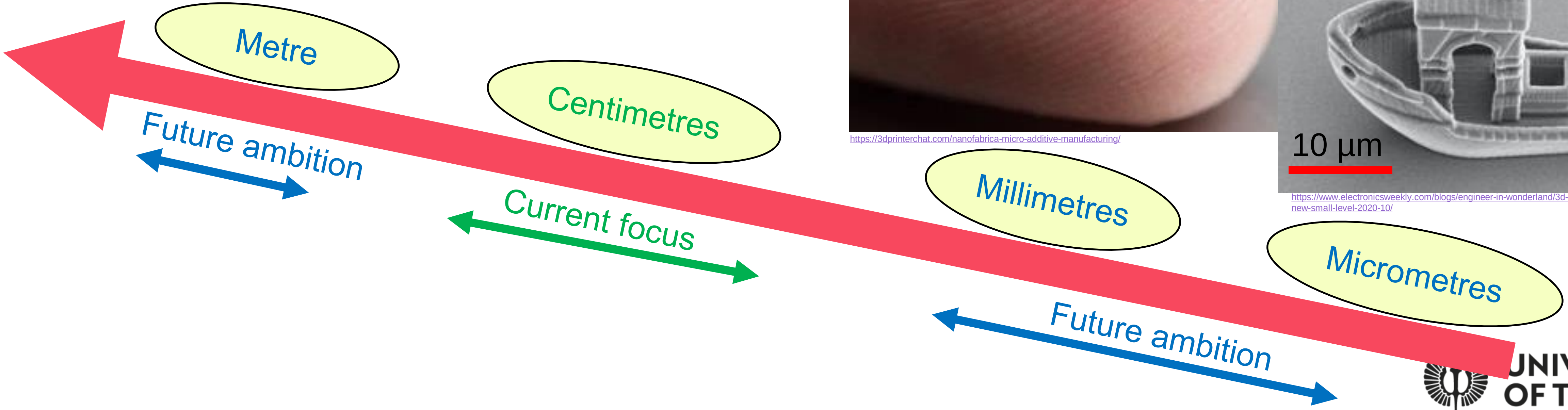
https://www.3dnatives.com/en/3d-printed-bicycle-helmet-voronoi-190820204/



https://3dprinterchat.com/nanofabrica-micro-additive-manufacturing/



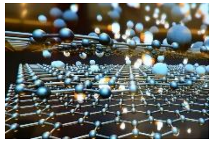
https://www.electronicsweekly.com/blogs/engineer-in-wonderland/3d-printing-whole-new-small-level-2020-10/



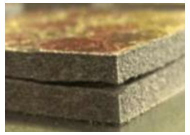
UNIVERSITY OF TURKU

Additive Manufacturing

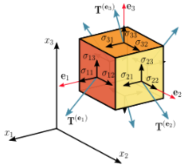
Limitations of AM yet to overcome (potential to achieve)



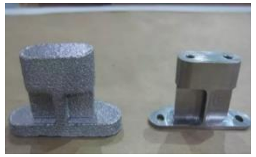
- ❑ Limited materials for AM

- ❑ Material properties and presence of anomalies/defects

- ❑ Dimensional accuracy and residual stresses



- ❑ Surface quality and need of post processing


- ❑ Process robustness & quality control

- ❑ Limited standards for AM processes

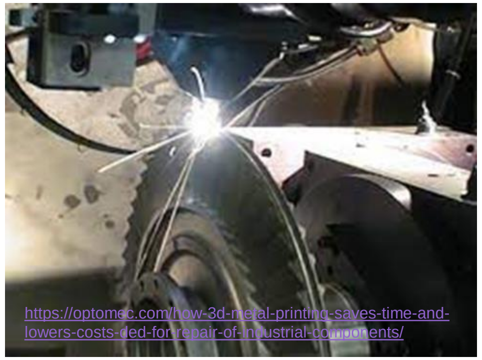
UNIVERSITY OF TURKU

Additive Manufacturing

AM for repair and remanufacturing

AM: Not only to produce bulk components but also to remanufacture and repair the damaged ones and to produce spare parts for various applications in aerospace, automotive, marine, power plants, biomedical, military etc.

- ❑ Sustainable solution to manufacturing
- ❑ Significant cost and material savings



https://optomec.com/how-3d-metal-printing-saves-time-and-lowers-costs-ded-for-repair-of-industrial-components/

https://www.tehrantimes.com/news/456194/Liquid-fuel-consumption-increases-in-power-plants

https://createdigital.org.au/navy-additive-manufacturing-submarine-repair/

https://line.17qq.com/articles/qgkhgqwky_p5.html

https://business-review.eu/business/romanias-civil-fleet-numbers-203-aircrafts-one-quarter-soviet-made-171611

https://www.kimi-sa.com/marine/diesel-engine-machinery/four-stroke-piston-repair

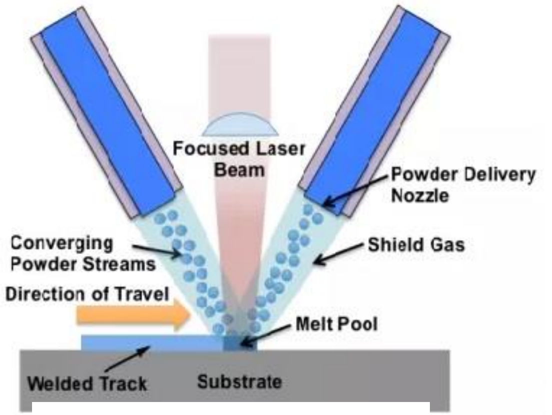
UNIVERSITY OF TURKU

Potential AM techniques for repair and remanufacturing applications

DED: Direct Energy Deposition

Current focus

DED-powder



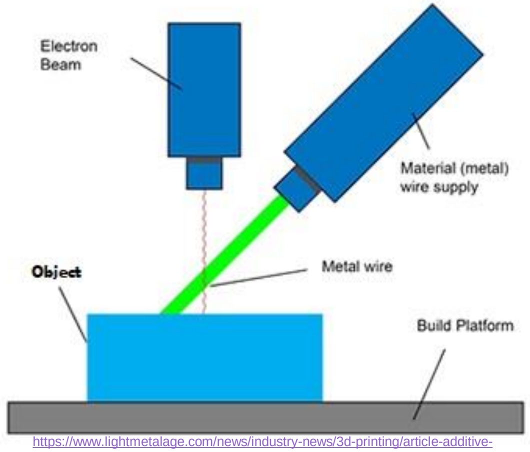
https://www.lightmetalage.com/news/industry-news/3d-printing/article-additive-manufacturing-of-aluminum-alloys/

Powder bed

https://www.eos.info/en/additive-manufacturing/3d-printing-plastic/sls-polymer-materials

Future ambition

DED-wire



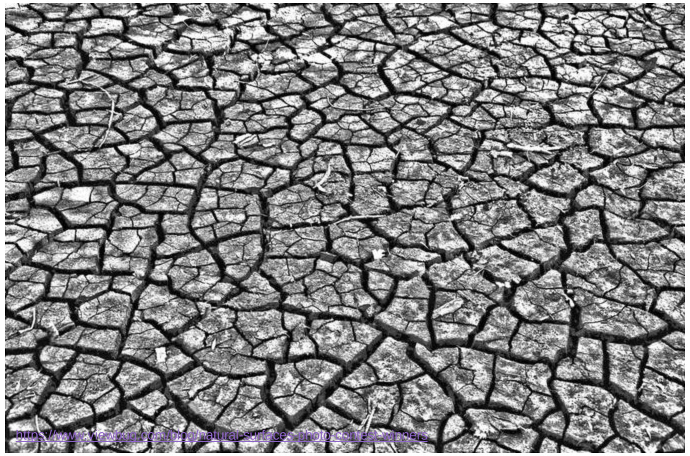
https://www.lightmetalage.com/news/industry-news/3d-printing/article-additive-manufacturing-of-aluminum-alloys/

Cold spray

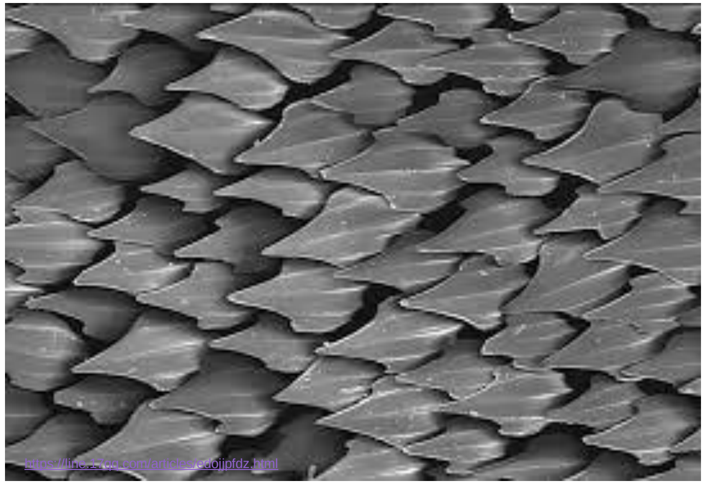
https://www.metal-am.com/inovatis-additive-manufacturing-tech-allows-navy-to-restore-worn-parts/

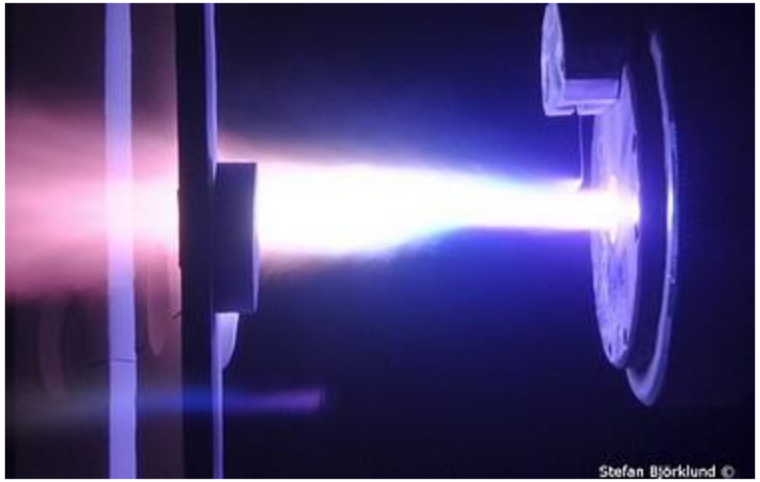
Laser cladding

https://www.twi-global.com/technical-knowledge/faqs/what-is-ehla



Surface engineering and coatings

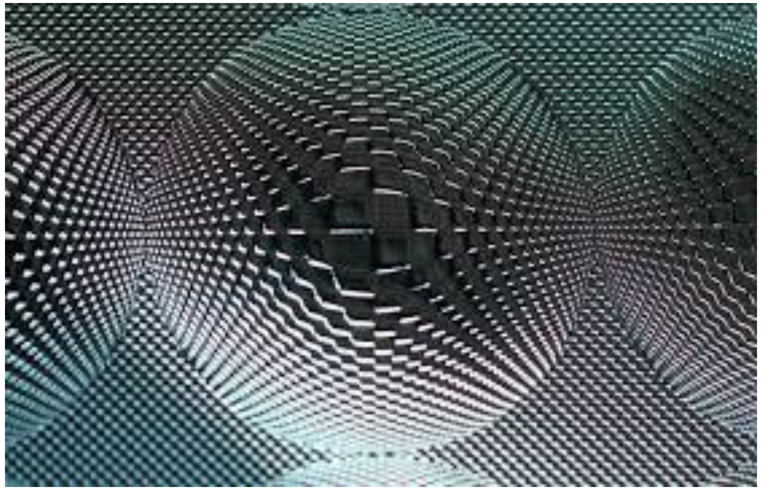




UNIVERSITY OF TURKU

Surface Engineering

What is surface engineering?



http://www.luximprint.com/portfolio/luminous-3d-patterns/

Definition as per ASTM handbook: treatment of the surface and near-surface regions of a material to allow the surface to perform functions that are distinct from those functions demanded from the bulk of the material.

https://www.masterfile.com/image/en/841-07913740/desert-dunes-punta-norte-peninsula-valdes

UNIVERSITY OF TURKU

Surface Engineering

Why do we need to engineer the surfaces?

- Bulk material properties are usually optimized for strength, stiffness, toughness, formability and cost.
- However, components remain vulnerable to surface degradation due to:

- ✓ Wear
  - Abrasion
  - Erosion
  - Sliding
  - Fretting
  - ……
- ✓ Corrosion
  - Oxidation
  - Aqueous
  - Gaseous
  - ……
- ✓ Other
  - Thermal fatigue
  - Thermal shock
  - ……

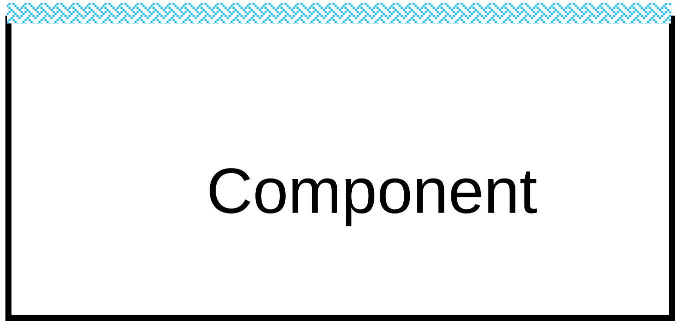
Current focus

UNIVERSITY OF TURKU

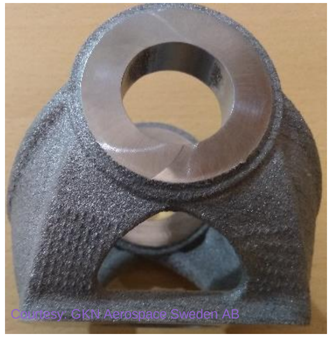
Surface Engineering

How to engineer the surfaces?

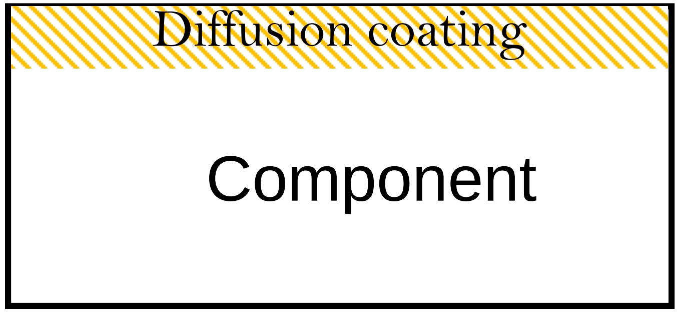
Surface modification without coating



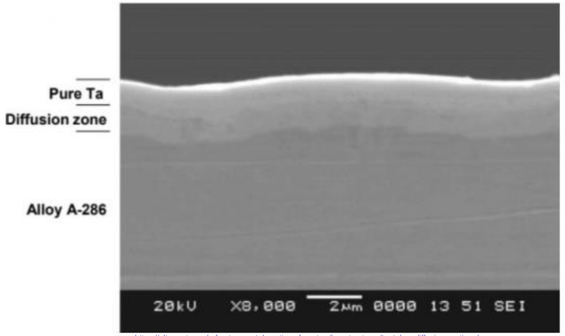
- Surface modification by mechanical or thermal means to alter the surface properties
- Examples: Grit blasting, shot peening, laser patterning, grinding, polishing, machining, heat-treatment etc.



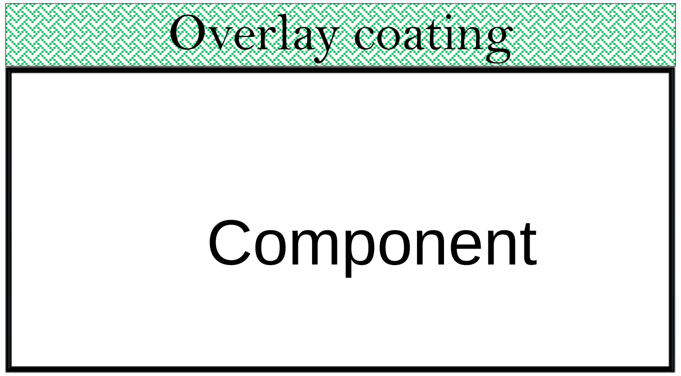
Surface modification by adding a coating



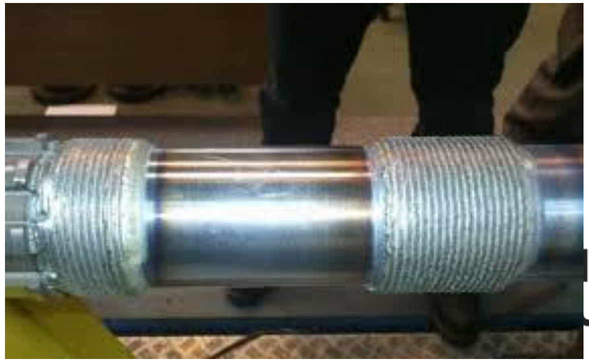
- Coating formation by diffusion of coating forming elements into substrate
- Examples: Carburized, Nitrided, Boronized and Aluminized coatings etc.



https://ultramet.com/refractory-metal-coatings-freestanding-structures/tantalum-diffusion-coatings/



- Coating formation by physical deposition of coating material on substrate
- Examples: Thermal spray coatings, laser cladding etc.



https://www.metallisation.com/applications/laser-cladding-for-critical-component-repair-duplex-stainless-steel/

Various surface engineering technologies

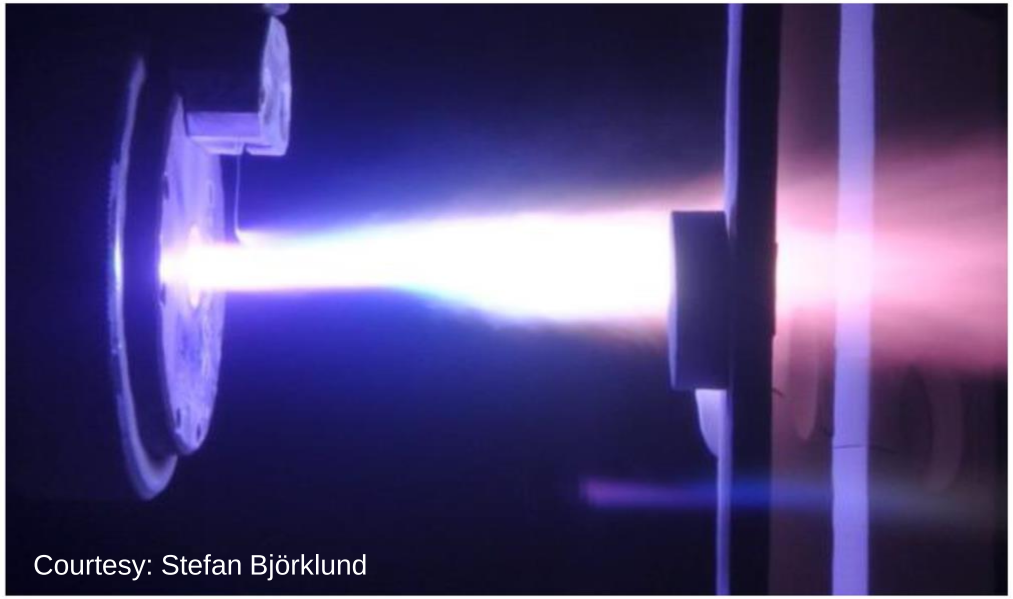
TECHNOLOGY	EXAMPLES
Thermal spray coatings	• Plasma spray • HVAF • HVOF • Cold spray • Flame spray (Plasma spray: Current focus; HVAF, HVOF, Cold spray, Flame spray, Laser cladding, EHLA: Future ambition)
Cladding	• Laser cladding • Extreme high speed laser cladding (EHLA)
Diffusion coatings	• Carburizing • Nitriding (salt bath) • Plasma nitriding • Aluminizing • Boronizing • Chromizing/vanadizing
Transformation hardening	• Induction • Electron Beam • Laser • Solar

TECHNOLOGY	EXAMPLES
Physical vapor deposition (PVD)	• Thermal evaporation • Sputtering • Ion platting • EBPVD
Chemical vapour deposition (CVD)	• Conventional • Plasma assisted
Electrodeposition	• Conventional electroplating • Electroless plating • Electrocomposite coating • Anodizing • Micro arc oxidation
Ion implantation	• Conventional • Plasma immersion ion implantation

UNIVERSITY OF TURKU

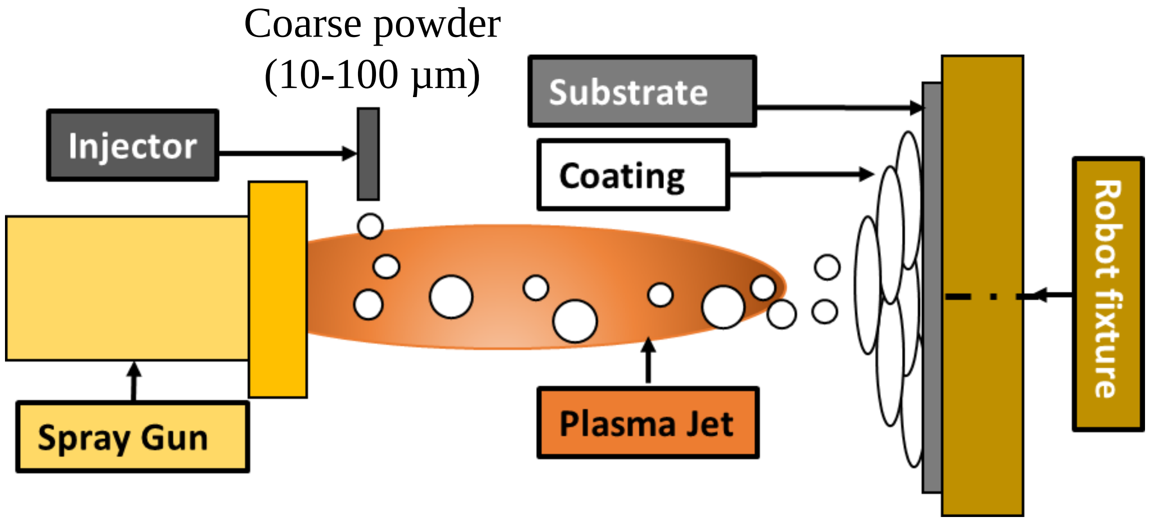
Surface Engineering

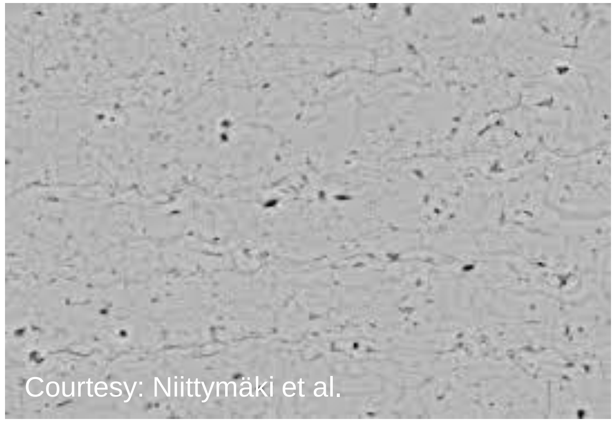
Plasma spraying


Courtesy: Stefan Björklund

A process in which powders of the coating materials are injected into the plasma plume which are partially or fully melted and accelerated towards the substrate/component to form a functional coating.

- Typically used powder size (10-100 µm)
- Limitation: Unable to spray fine powders (< 5µm)
- Use liquid feedstock (e.g. suspension & solution precursor)



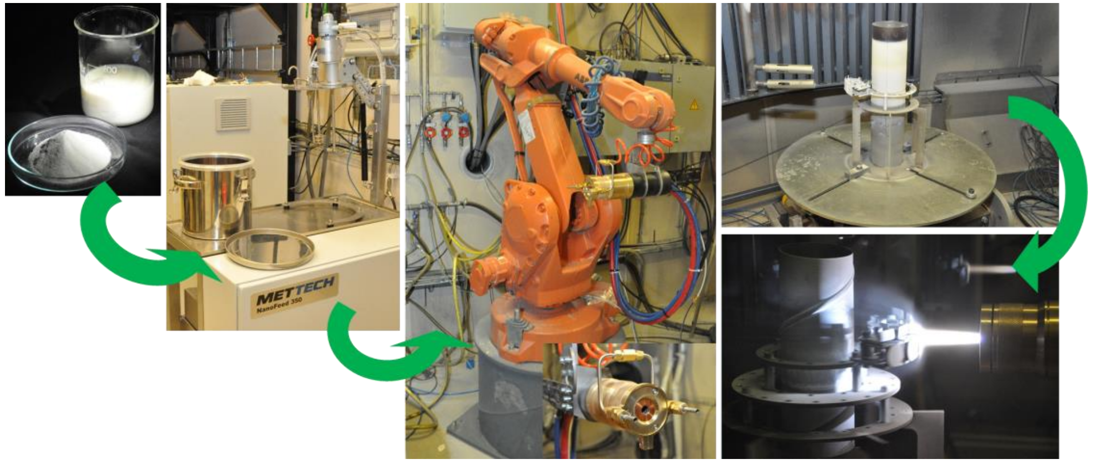

Courtesy: Niittymäki et al.


Courtesy: Stefan Björklund

UNIVERSITY OF TURKU

Surface Engineering

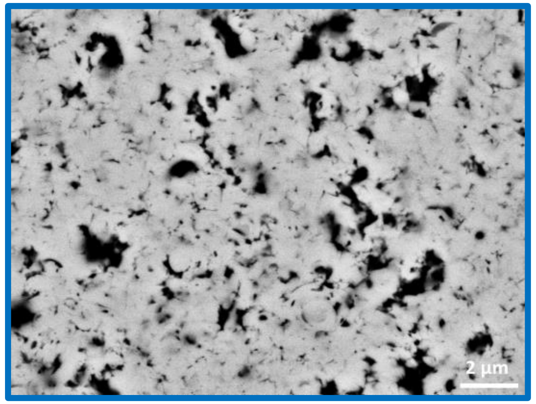
Liquid feedstock plasma spraying



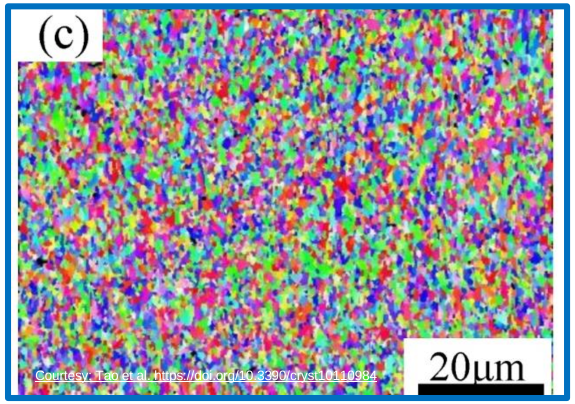
- Possible to feed nanoscale powder particles
- Can produce nanostructured coatings
- Coatings thickness from few micrometres to few millimetres
- Variety of microstructures (very dense, porous, columnar etc.)
- Various coatings architectures are possible (hybrid, gradient, layered, multi-material, composite etc.)

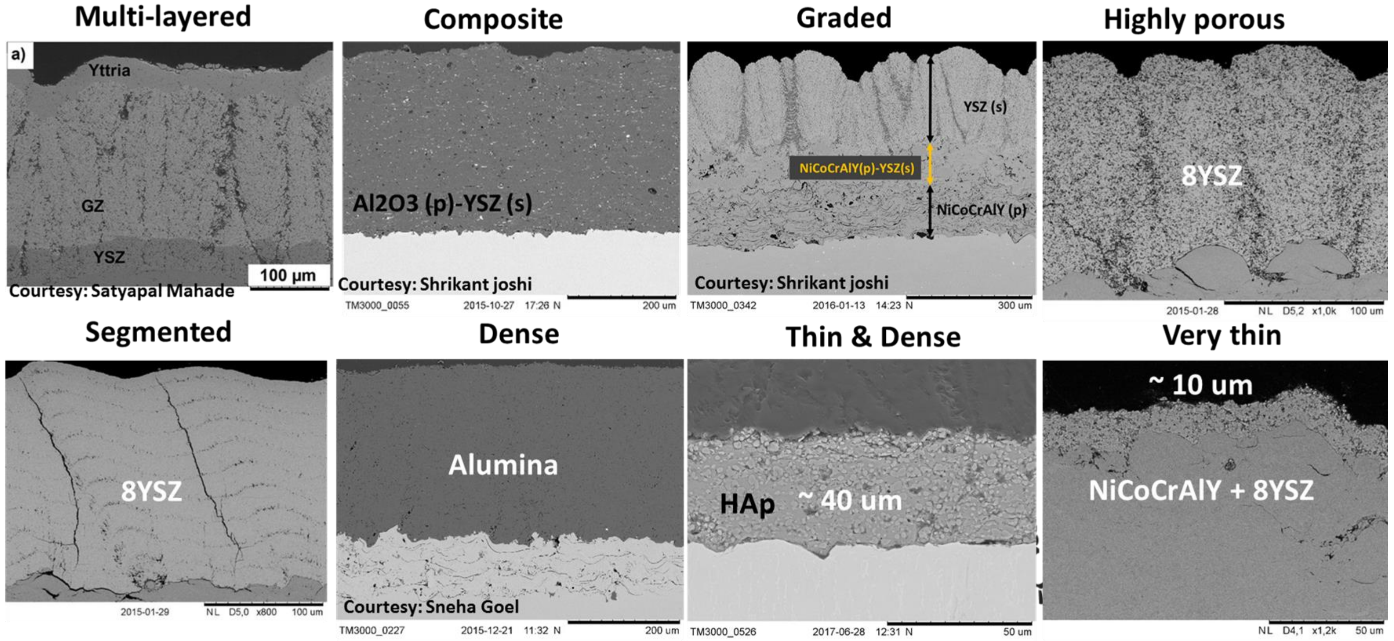
Nanostructured microstructure

Fine pores



Fine grains



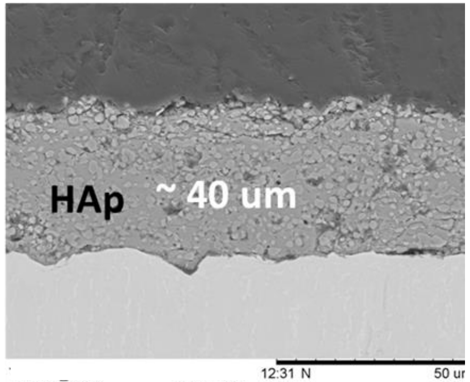


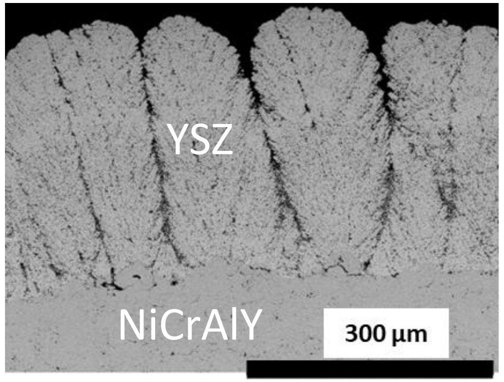
Liquid feedstock plasma spray: potential applications

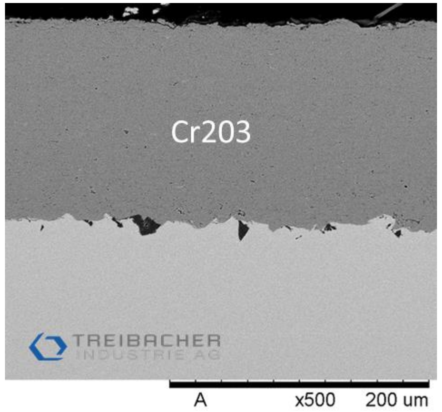
Bio-coatings for medical implants

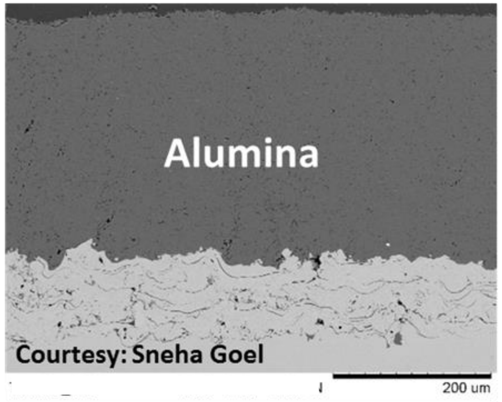
Thermal barrier coatings

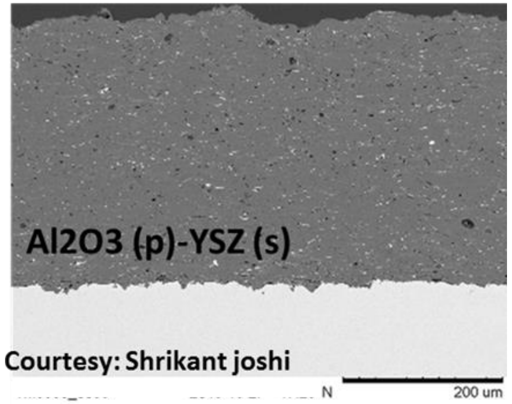
Coatings for tribological applications











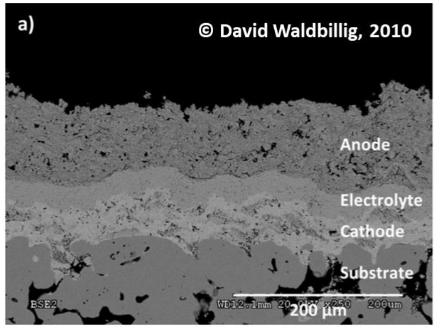
Semiconductor industry

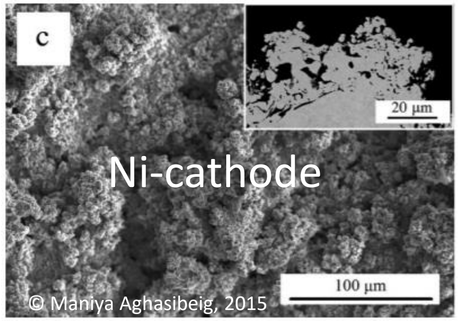
Solid oxide fuel cells

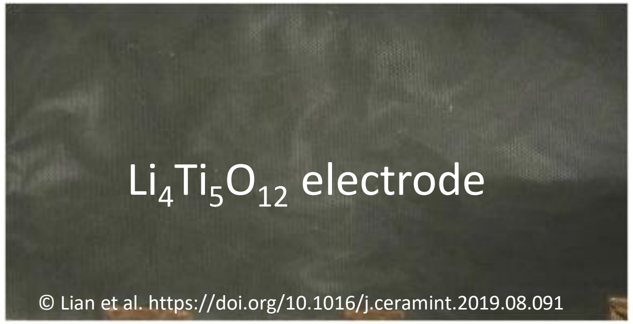
Hydrogen production

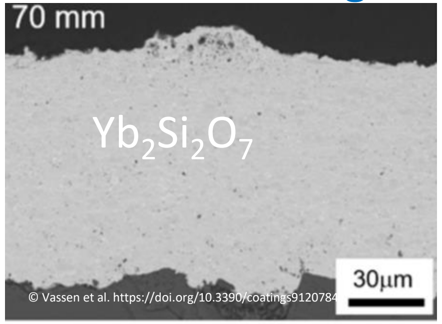
Li-ion batteries

Environmental barrier coatings



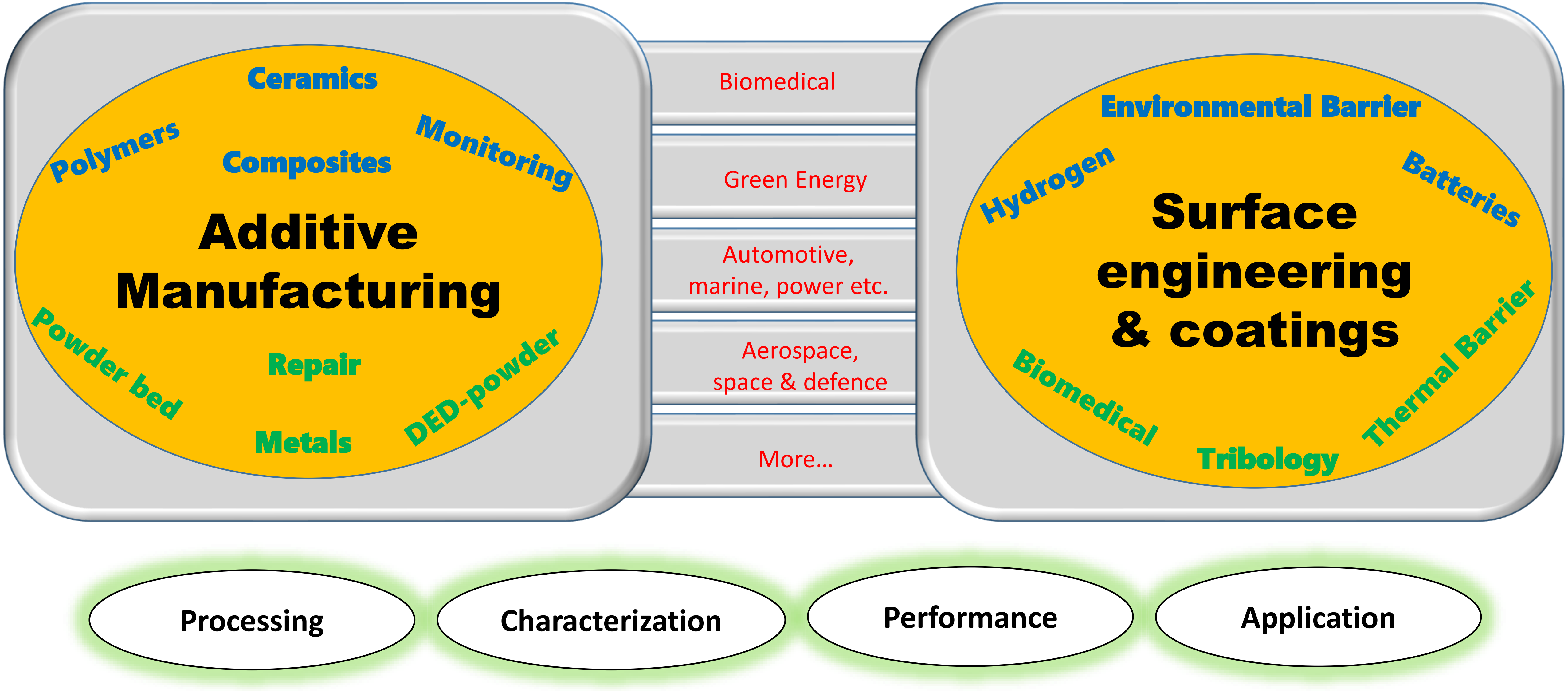






and many more…

Summarizing my research: current focus and future ambition



Stay safe, healthy and happy!

Thanks!!