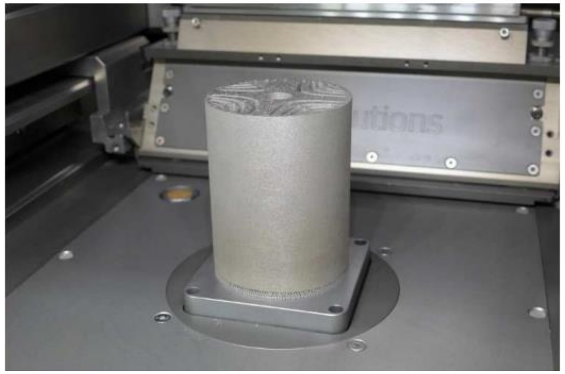
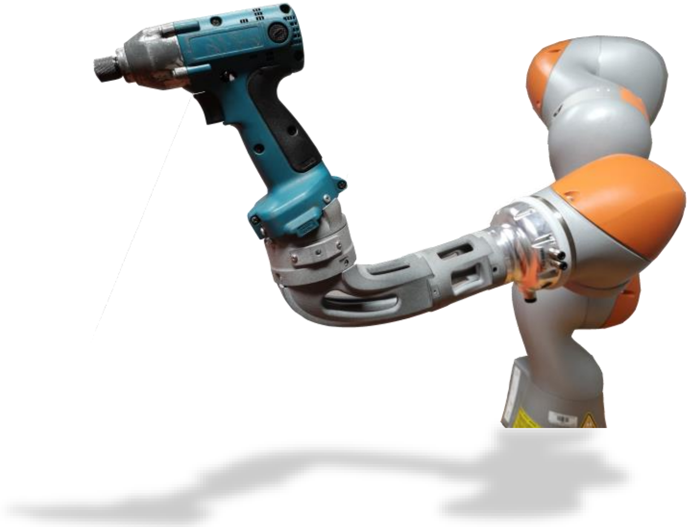
Additive manufacturing in electrical engineering



Miroslav Novak



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

R2P2 project

The strategic objective is to step up the development of the excellent research in the field of interactive, sensible autonomous robotic systems based on additive manufacturing and using smart materials based on nanopolymers.

The competitiveness of research in this area through staff and student exchanges, expert visits and participation at conferences.

The implementation of international scientific projects or contacts, to lead to the creation of new project ideas.

The organization of expert seminars, workshops, PhD forums and international conferences.

The transfer of knowledge from leading research centres to the specialist workplaces at TUL.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

Contacts

Prof. Ing. Aleš Richter, CSc.
ales.richter@tul.cz
https://www.tul.cz/en/

Dr. Francois Pigache
pigache@laplace.univ-tlse.fr
https://www.inp-toulouse.fr/en/

Prof. Nestor Arana-Arexolaleiba
pigache@laplace.univ-tlse.fr
https://www.mondragon.edu/en/

Prof. Dimitris Chrysostomou
dimi@mp.aau.dk
https://www.en.aau.dk/

Prof. Georges Zissis, PhD.
georges.zissis@laplace.univ-tlse.fr
https://www.univ-tlse3.fr/

http://r2p2.eu/

R2P2 project

R2P2 project

This project has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement No. 857061.

Agenda

- Usage (casings, testing fixtures, components = connectors, magnetic materials, PCB…)
- Required parameters (flammability, conductivity, thermal conductivity, mechanical properties, environmental immunity, magnetic parameters…)
- Accessible technologies in TUL

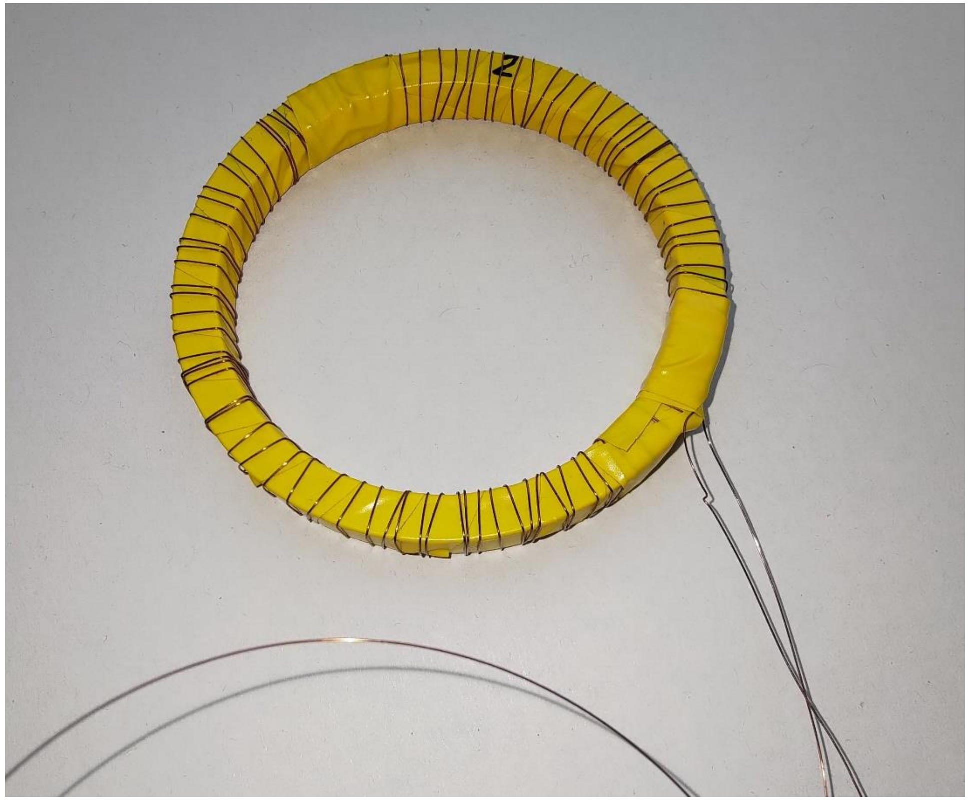
Focus:

- **Electronic enclosures**/insulation part of components
- **Magnetic materials**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

Annotation

3D printing is commonly used for prototyping. A lot today at TUL as well. The aim of the seminar is to remind you of the pitfalls for its use in electronics. Mainly used as covers for electronic products. The second area is the use of 3d printing for ferromagnetic materials. Compared to conventional technologies, 3D printing lags behind in methods of reducing volumetric conductivity, i.e. eddy losses. Some solutions will be presented.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

Usage

On-demand production
Prototyping or small lots

There is a lot of scopes for the designers to come up with **innovative ideas** instead of using the same traditional designs due to the complexity of new and efficient designs. SLS and MJF technologies are good even for **complex designs** and also for batch production which used to be a drawback of AM earlier. A good batch size of electronic casings, breadboards etc can be produced very fast with AM, compared to conventional processes.

For **faster prototyping**
ideal for creating quick prototypes. Printing parts with Multi jet fusion (MJF) is a relatively budget-friendly option often chosen for prototyping.

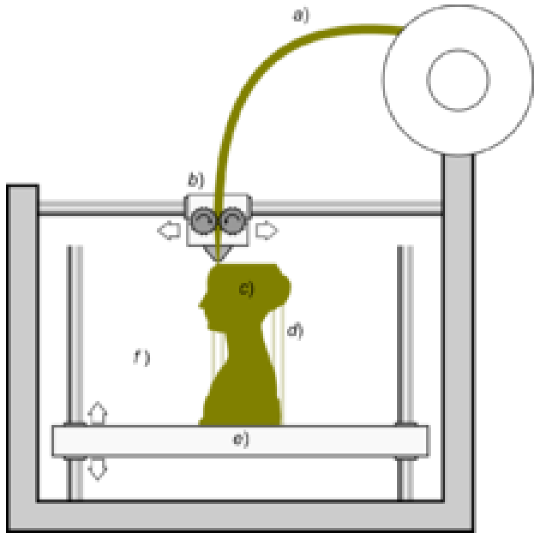
Fused deposition modeling, the most accessible form of additive manufacturing, is another viable alternative. FDM is the cheapest and best technology for prototyping due to its simplicity in usage and the cheaper build material.

To have **new materials** to experiment with
Electronic products like PCBs mainly depend on two types of materials: an insulating dielectric substrate and conductive elements. Newer polymer materials with low dielectric constant and semiconducting polymer materials, both with adjustable electronic properties, are being adapted for use in recent times.

To get parts with a good surface finish
Technologies like SLA or Carbon DLS use resin materials and are fluidic in nature and offer a good surface finish. They offer properties like flexibility and water resistance which are a valuable addition to modern electronics like foldable phones and water resistant gear.

TECHNICAL UNIVERSITY OF LIBEREC www.tul.cz
INP TOULOUSE
MONDRAGON UNIBERTSITATEA
Université Paul Sabatier TOULOUSE III
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

Plastics AM technologies



Material Jetting
As jet printer, por waxes, thermoplastic materials, metals

Material extrusion/ fuse deposition modeling (FDM)
Fusing beads of filament and immediately harden to form layers

Stereolithography (SLA)
Layer by layer photo-polymerization of liquid resin
Materials : PP-types, ABS-types and transparent resin
Advantages : precision and fine surface

Selective Laser Sintering (SLS)
Layer by layer sintering (partial fusion) of plastics powder
Materials : PAGlassFilled, PAAluminiumFilled, PA 2241FR (flame retardant), PrimeCast
Durability, high-performance mechanical or thermal properties

…

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

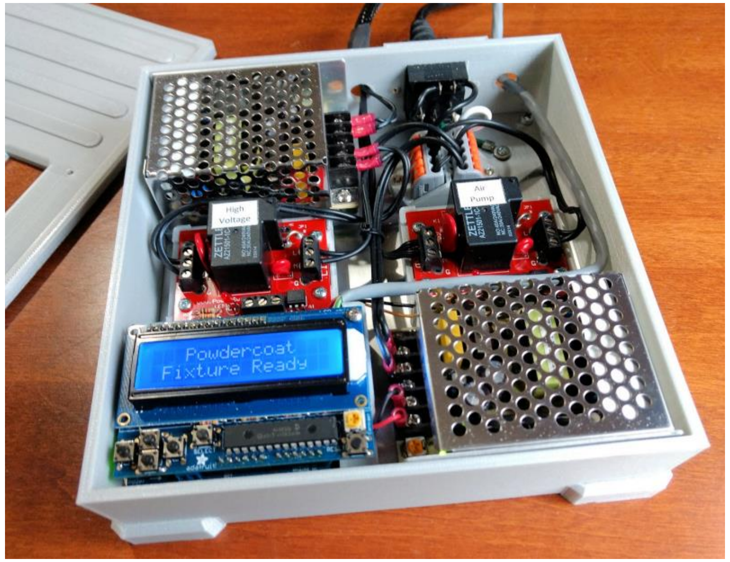
Enclosures

Pros:
Cost-efficient alternative for the small and medium series production of plastic housings
Shape freedom

Cons:
Certification (flammability, insulation properties), tests are necessary – **very expensive** = overall profit is negative
Properties depends not only on material but also on construction (thickness of walls, homogeneity, surface properties) – extended experiences needed – difficult to guarantee = need for tests
Reproducibility – material and technological parameters, printer condition

https://www.eos.info/en/all-3d-printing-applications/production-and-industry/electronical-components/plastic-housings

Flammability – ABS, PLA, PET-G are moderately flammable (HB-V2 - UL94)
https://www.youtube.com/watch?v=a7l0Aaysy_8



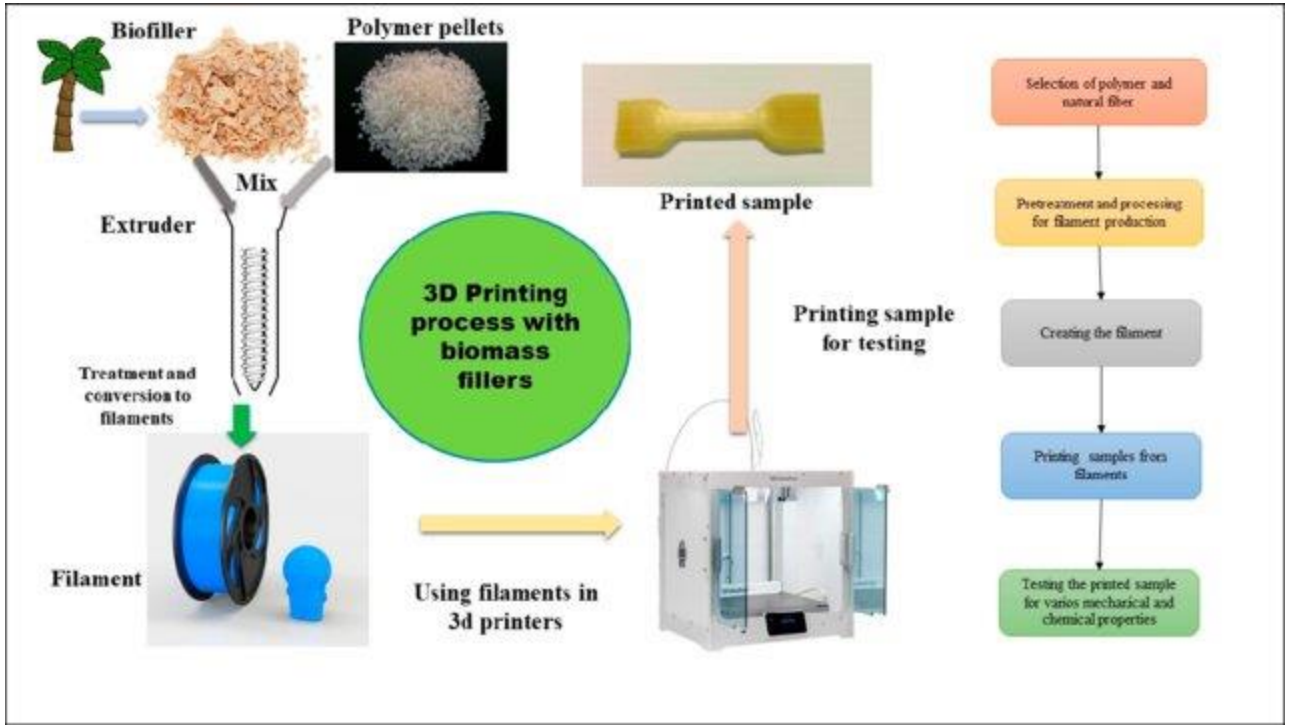
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

Fillers

Carbon/carbon nanotubes, glass, basalt, talc, …

3D printing has limited options for using fillers **<10% wt**

= They do not reach the mechanical and flammability parameters of conventionally processed plastics (injection, extrusion, blowing)

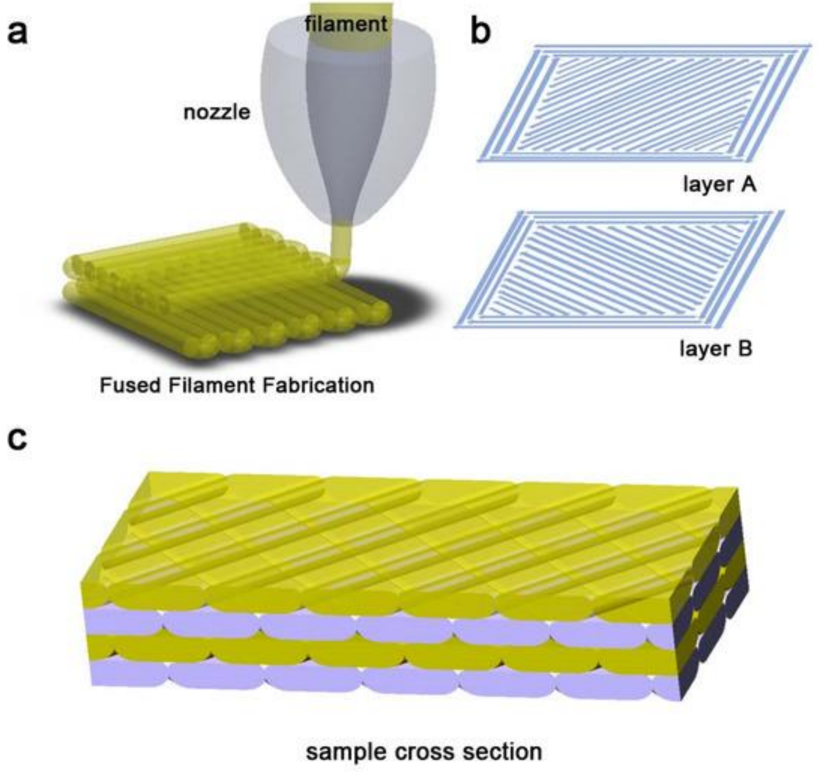


TECHNICAL UNIVERSITY OF LIBEREC www.tul.cz
INP TOULOUSE
MONDRAGON UNIBERTSITATEA
Université Paul Sabatier TOULOUSE III
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

Electrical parameters

Permittivity: 2.4 – 3.5 (PET-G); 2.6-3.2 (PLA); 0.5 (ABS)
Dielectric strength: 10-30 kV/mm (PET-G); 30-60 (PLA)
Resistivity: 10^18-10^19 Ohm.m (PET-G); 10^13-10^14 (PLA); 10^12 (ABS)

Problem – porosity due to 3D print
Is possible to guarantee thickness?
Water/pollution absorption
Surface roughness – surface resistivity problems (env. dirt categories)
http://poseidon2.feld.cvut.cz/conf/poster/proceedings/Poster_2018/Section_PE/PE_043_Vesely.pdf



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

Suitability

LV – cause there is no special requirements on safety

be careful with application with risk of hi temperatures (power NTC, battery, power converters …)

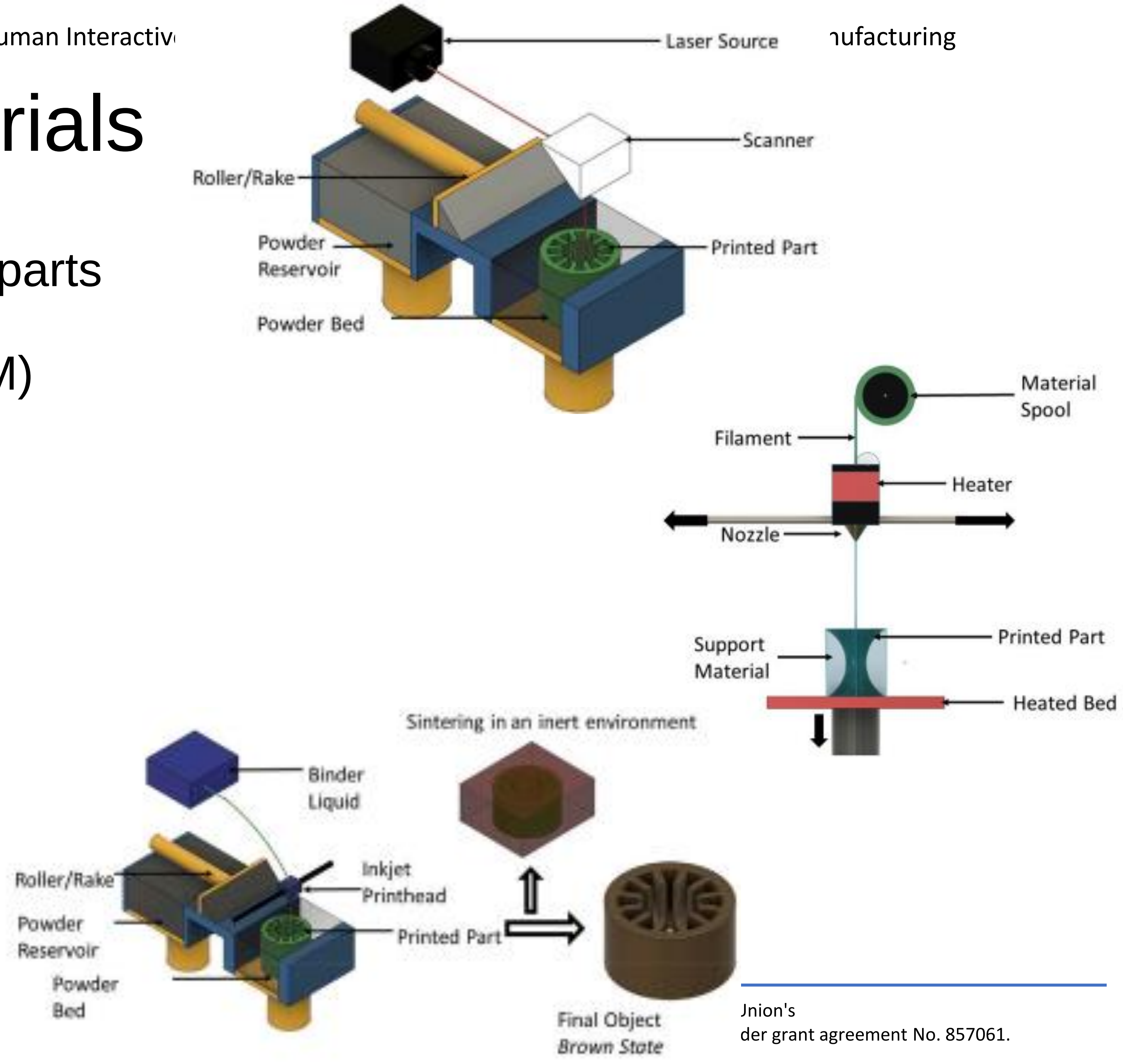
MV/HV – certification barrier = expensive

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

Soft magnetic materials

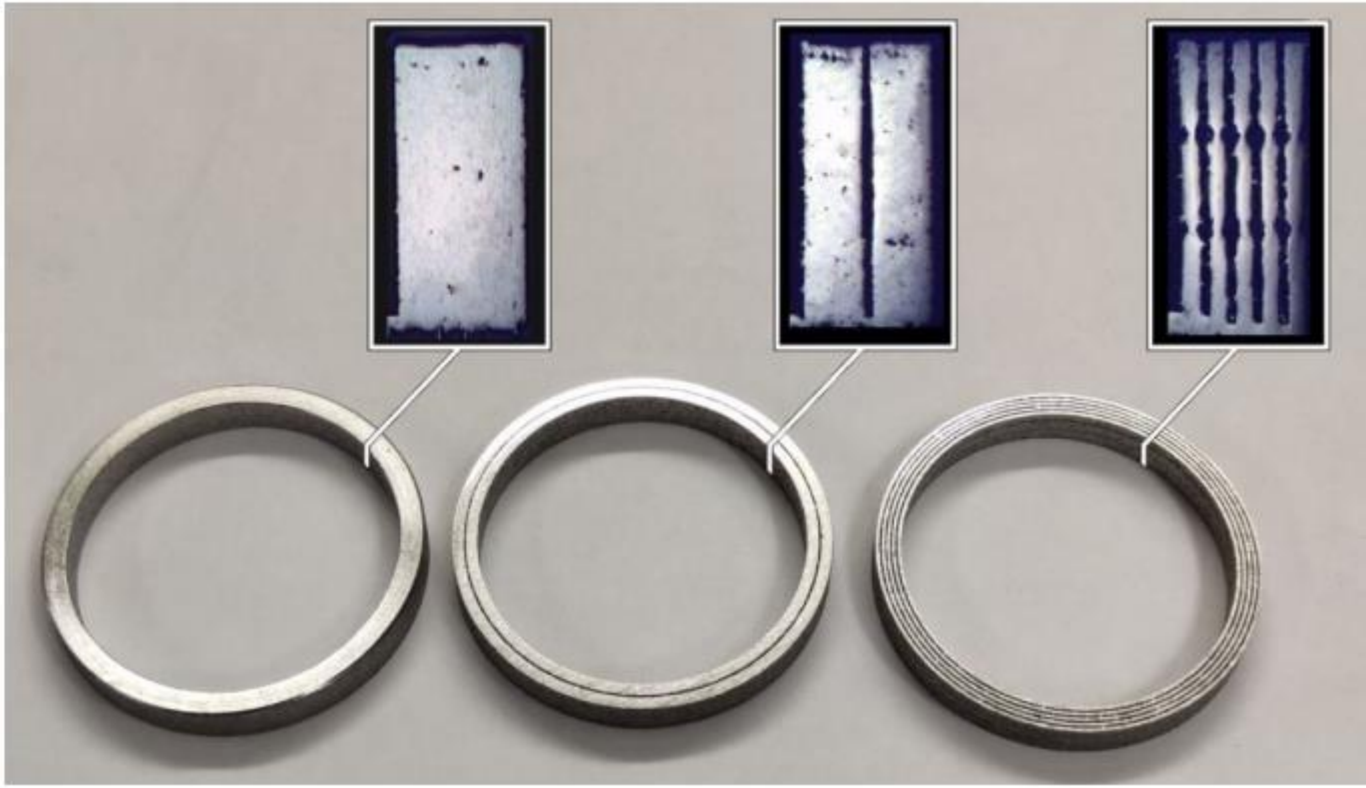
Additive manufacturing of metal parts
Selective laser melting (SLM)
Fused deposition modeling (FDM)
Binder jet technology (BJT)

doi:[10.1016/j.mtphys.2020.100255](https://doi.org/10.1016/j.mtphys.2020.100255)



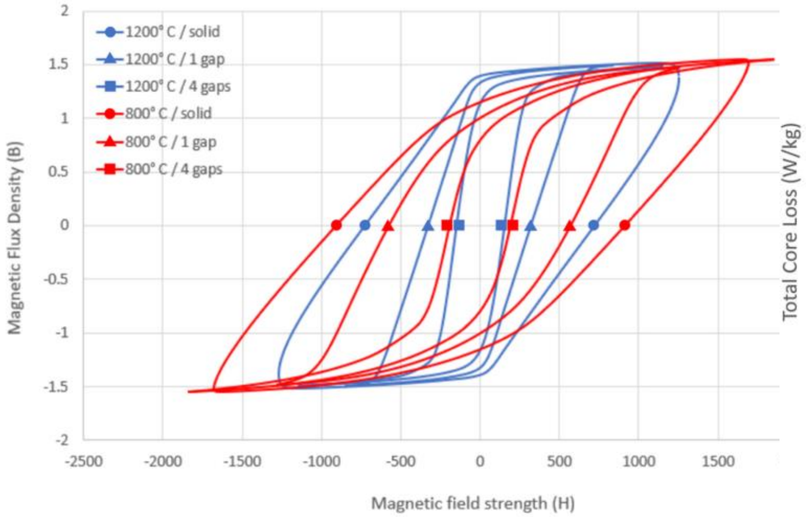
Jnion's
der grant agreement No. 857061.

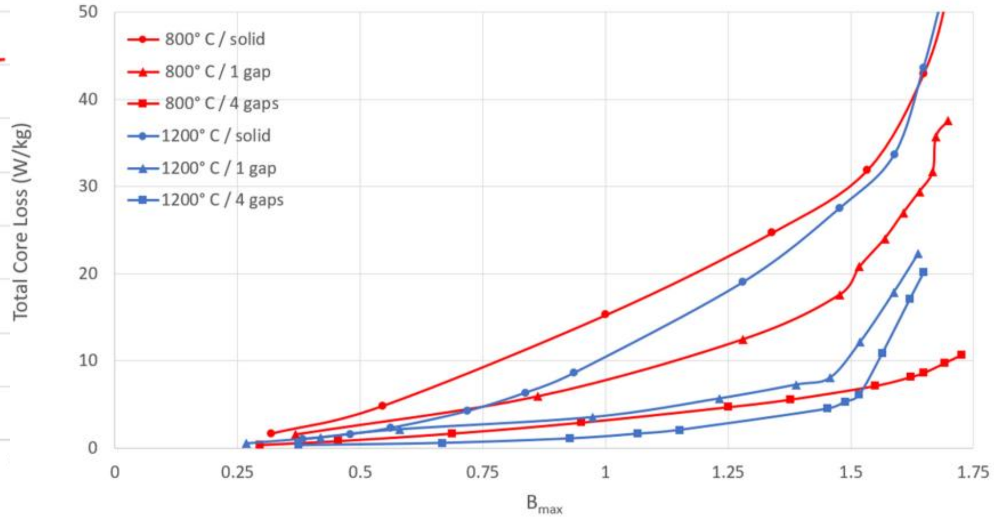
Eddy currents



Plating simulation
Printing gaps – resolution SLM 25-30 um, = gaps 0.1-0.4 mm, far worst filling factor
Printing intermetallic layers, oxide layers, phosphating = much better but need special printing procedure

Losses still fare worst then plating
doi:[10.3390/en14051241](https://doi.org/10.3390/en14051241)





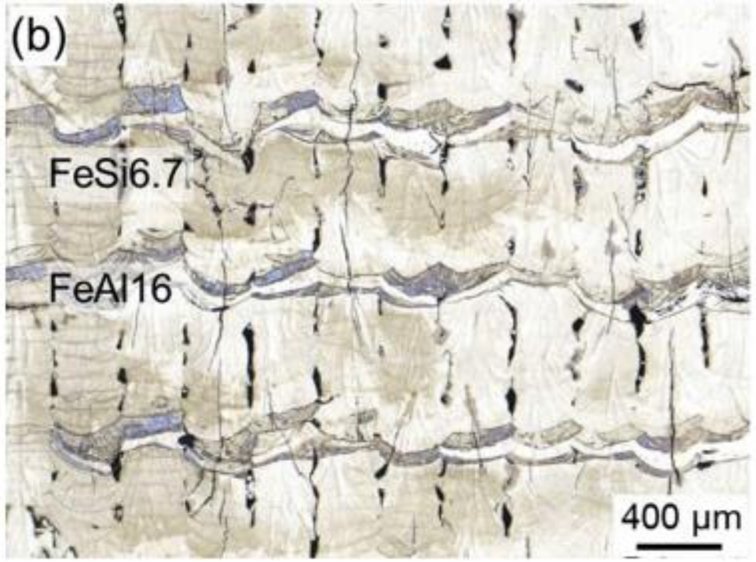
TECHNICAL UNIVERSITY OF LIBEREC www.tul.cz INP TOULOUSE MONDRAGON UNIBERTSITATEA Université Paul Sabatier TOULOUSE III

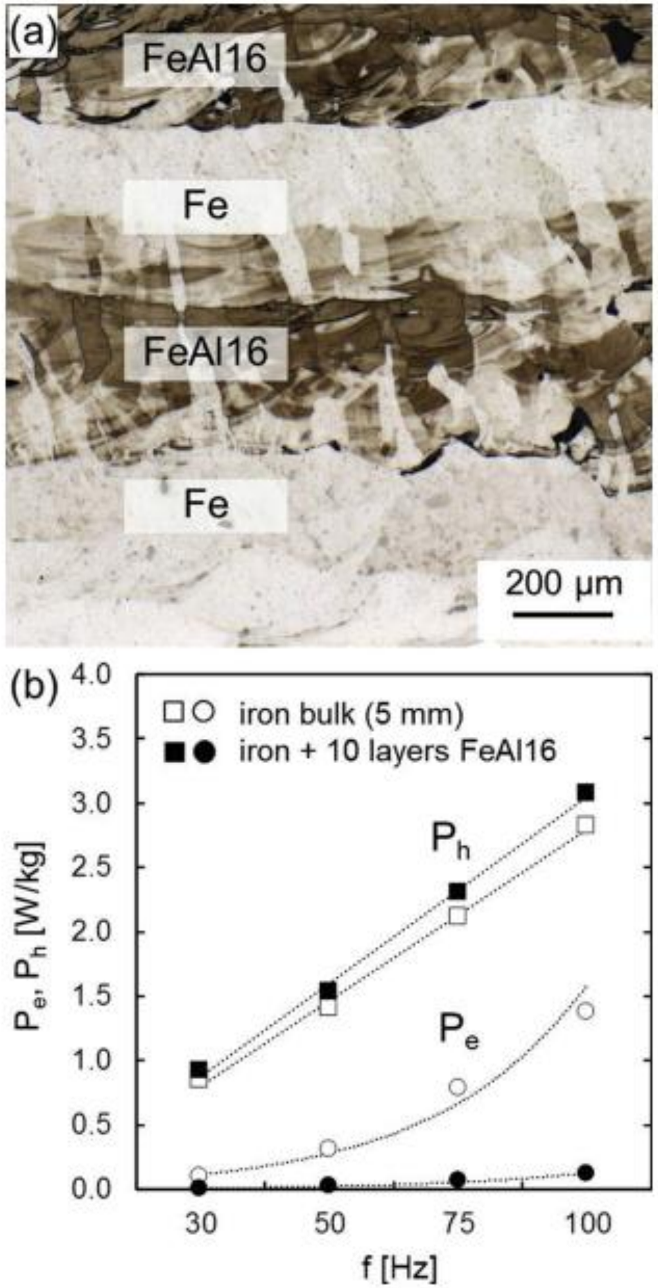
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

Eddy currents

intermetallic layers are promising
even with combination with gaps

doi:[10.1016/j.addma.2019.02.021](https://doi.org/10.1016/j.addma.2019.02.021)



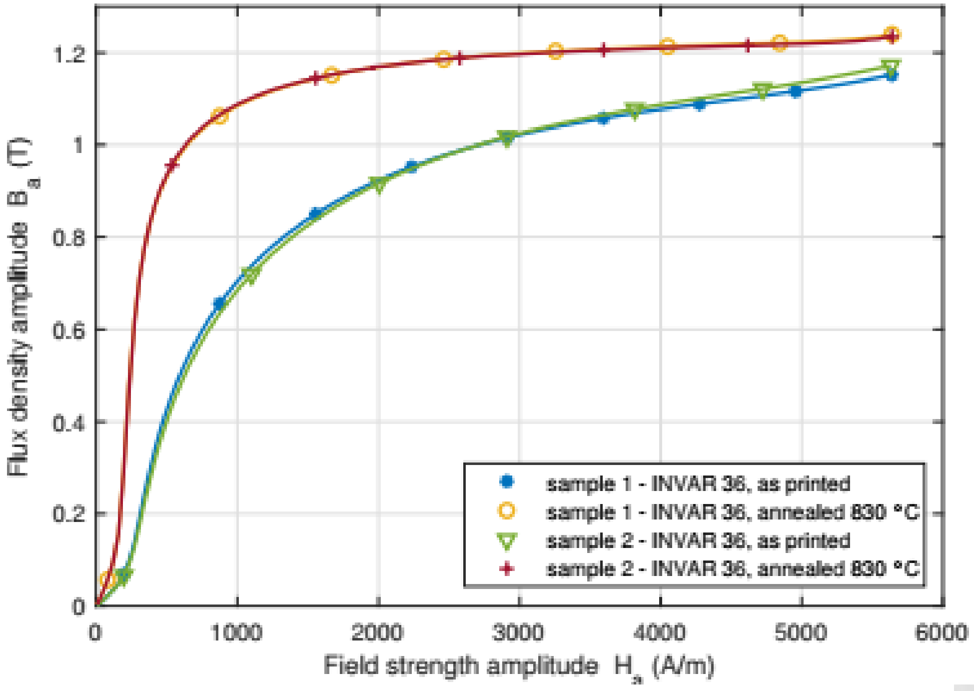


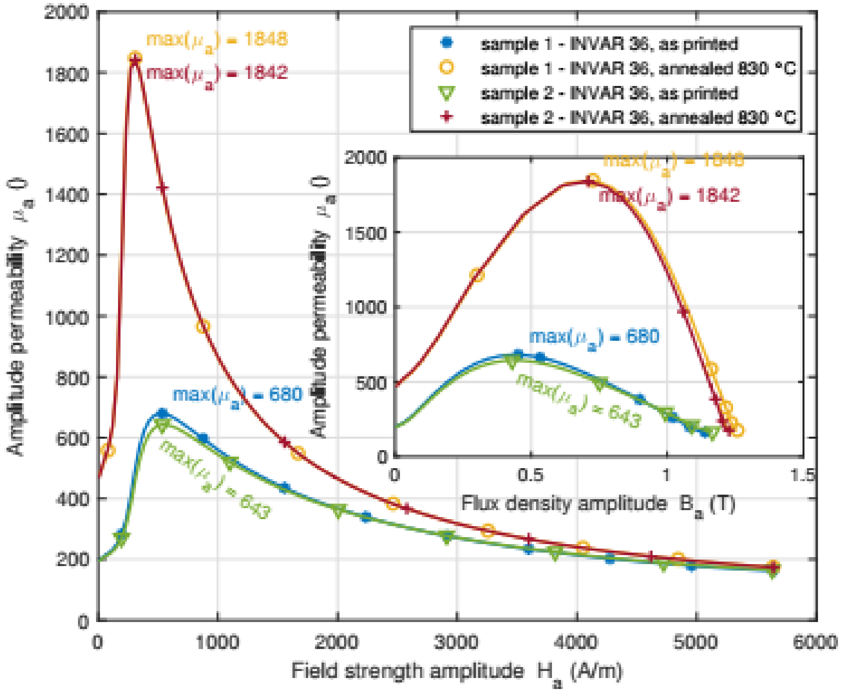
This project has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement No. 857061.

Heat treatmen

SLM, DFM creates a lot of mechanical **stress** and inhomogeneities in material
= **crystallographic disorders**
= deterioration of magnetic properties
= proper **heat treatment** is necessary

Improves permeability
Coercive force
Losses





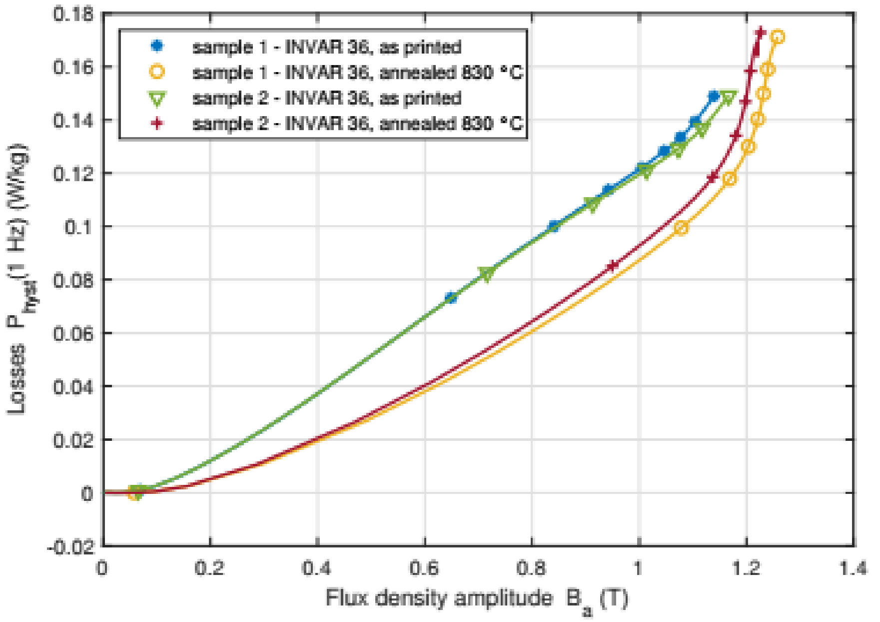


Fig. 7. Comparison of magnetizing losses at 1 Hz

Availability at TUL

TULab

- Dragonfly – PCB (Ag - extremely expensive, poor mechanical properties)

https://www.nano-di.com/resources/blog/the-ultimate-additive-manufacturing-for-electronics-use-case-round-up

- Prusa i3 MK3S+
- Trilab DeltiQ Plus
- Creality CR-10 Max.

NATIONAL CENTRE FOR INDUSTRIAL 3D PRINTING

- SLM 280 HL – metal printing
- Object Connex 500 – PolyJet matrix
- Stratasys 750 – PolyJet matrix
- Stratasys Fortus 450mc – thermoplastic
- HP Jet Fusion 4200 – thermoplastic

And many more at other departments

TECHNICAL UNIVERSITY OF LIBEREC www.tul.cz INP TOULOUSE MONDRAGON UNIBERTSITATEA Université Paul Sabatier TOULOUSE III
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857061.

Thank you for your attention.

http://r2p2.eu/

R2P2 project

R2P2 project

This project has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement No. 857061.