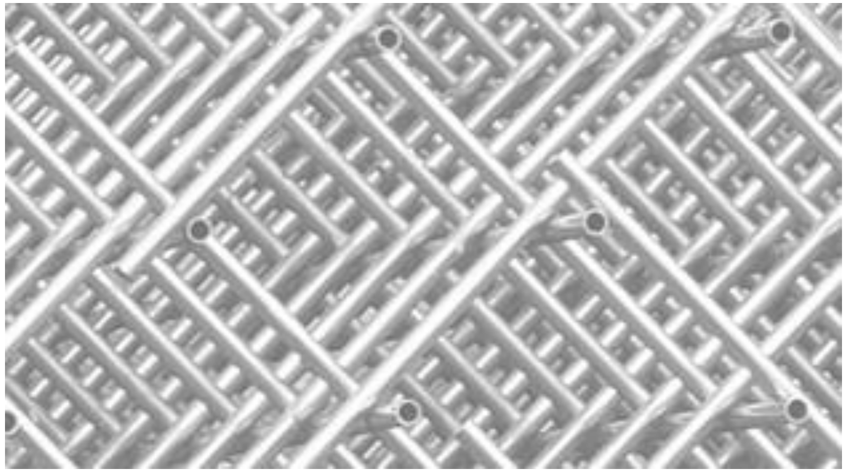
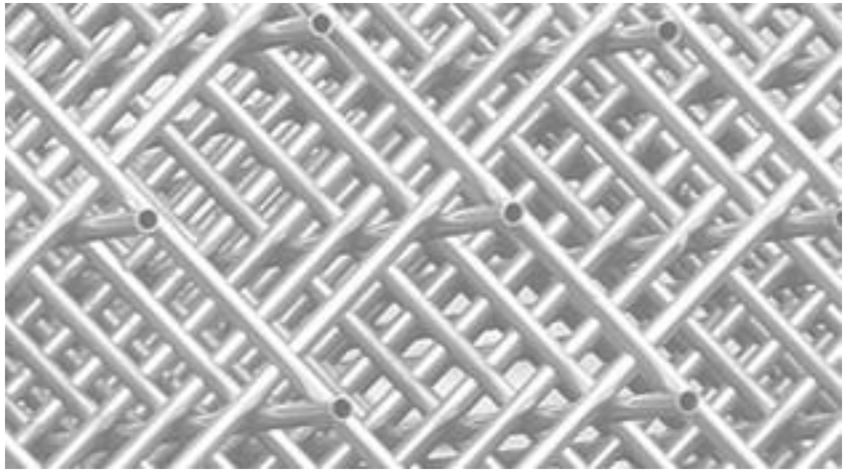
Lightme

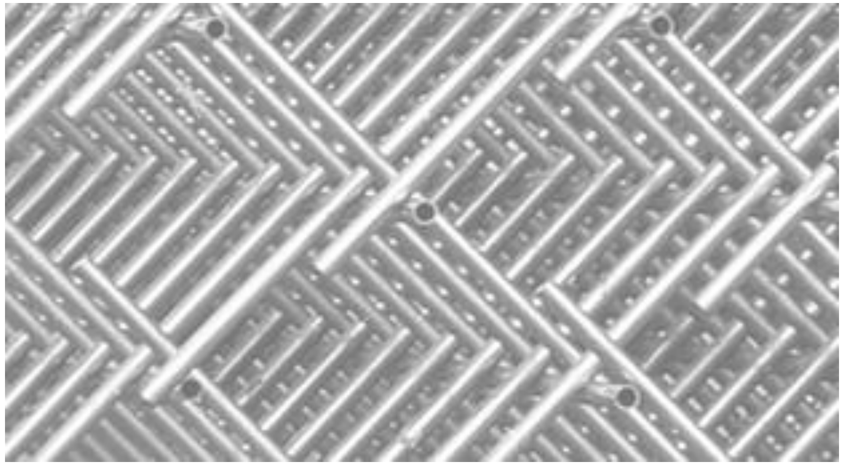
11-12 May 2023

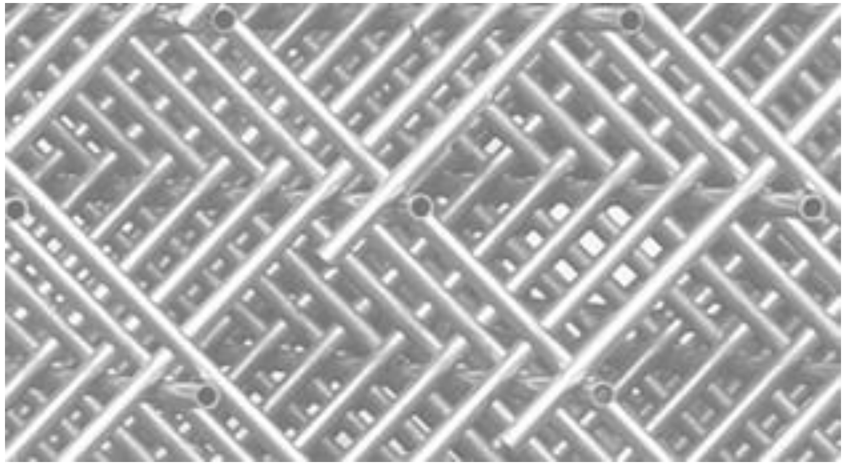




Thermoplastic selection for aluminium replacement in electric and electronic devices made by additive manufacturing.

Joamin Gonzalez-Gutierrez
Luxembourg Institute of Science and Technology





MULTHEM
Multi Material Additive Manufacturing for Lightweight and Thermal Management

European Commission
Horizon 2020
European Union funding
for Research & Innovation

Visit us at: multhem.eu

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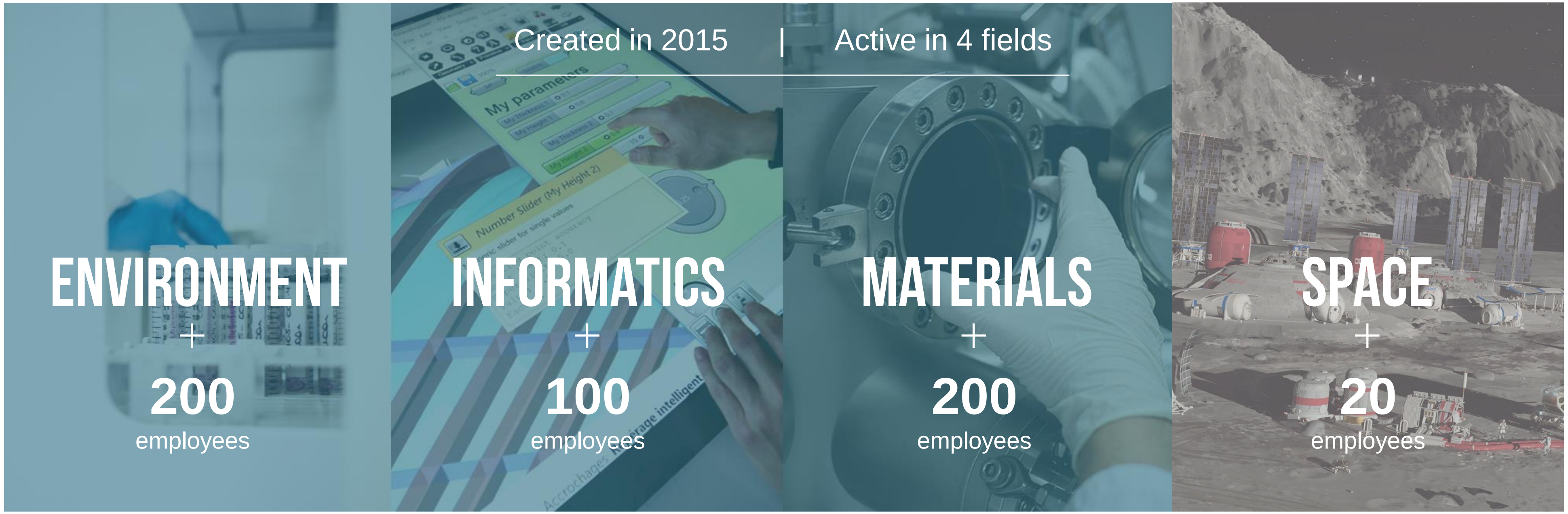
What we do?



This project has received funding from the European Union’s Horizon Europe Research & Innovation programme 2021 -2027 under grant agreement number:101091495

Visit us at: multhem.eu

MULTHEM
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Where are we?

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01
Introduction

MULTHEM
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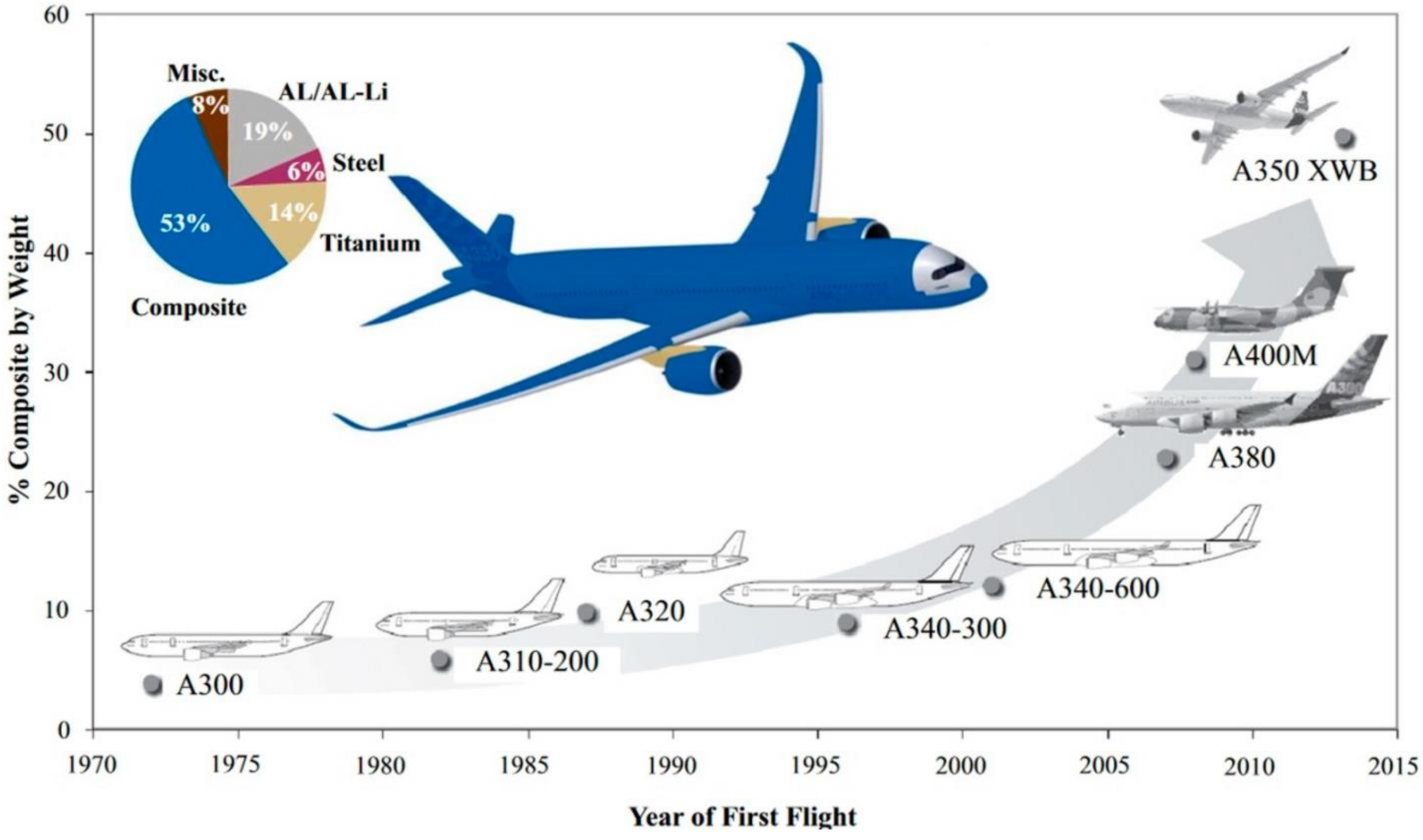
Lightme

Metal replacement

A very common practice for weight reduction

- General trend is using more & more composite materials
  - Example: Airbus planes



Xu et al. 2018, *Advanced Composites and Hybrid Materials* **vol 1**, p. 460–477

Drawback of metal replacement

Composites are thermal insulators

- For electric & electronic devices this is a problem
  - Can cause malfunctions!

- MULTHEM project aims at replacing aluminium by composites in

Electric motor housing
https://www.empcasting.com/electric-drive-motor-housing.html

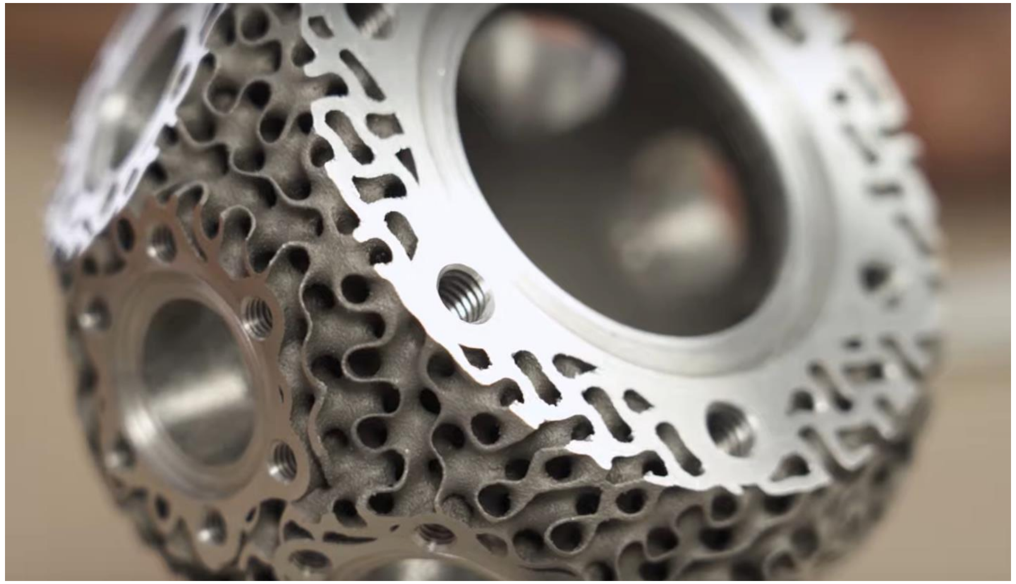
Avionics power electronic housing
https://www.militaryaerospace.com/computers/article/16720110/rugged-intelligent-power-control-device-for-vetronics-and-avionics-introduced-by-ddc

Battery case for e-bike
https://fr.aliexpress.com/store/4989531?spm=a2g0o.detail.1000007.1.e0fe7c1b61Y7Qa

Further lightweighting

Use additive manufacturing

- Complex shapes to enhance heat dissipation
- Use thermoplastic composites with carbon fibres
    - higher conductivity & materials are available

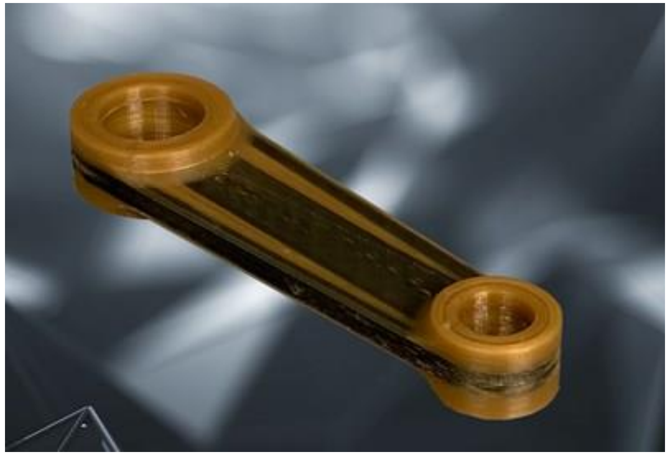


Gyroid structures on the surface

https://youtu.be/1G4wyjeMjPk

Short carbon fibre

https://www.jweimolding.com/carbon-fiber-reinforced-thermoplastic-compounds-for-high-temperature-applications/



Continuous carbon fibre

https://www.compositesworld.com/news/asp-tech-solutions-is-renamed-to-venox-systems

How 3D parameters affect the thermal conductivity?

02 Materials & Methods

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Material selection

Based on thermal & mechanical requirements

- 4 thermoplastics with short carbon fibres were purchased

PEKK-CF
E = 9125 MPa
HDT = 285 °C
ρ = 1.33 g/cm^3

PEI-CF
E = 4685 MPa
HDT = 200 °C
ρ = 1.27 g/cm^3

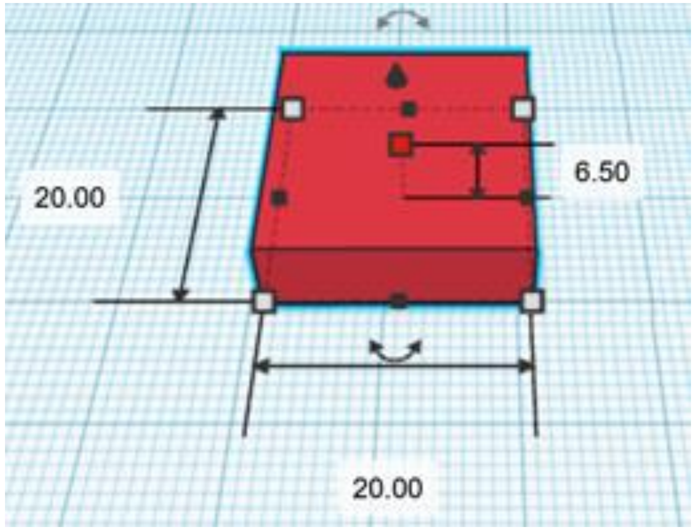
PC-CF
E = 6390 MPa
HDT = 144 °C
ρ = 1.26 g/cm^3

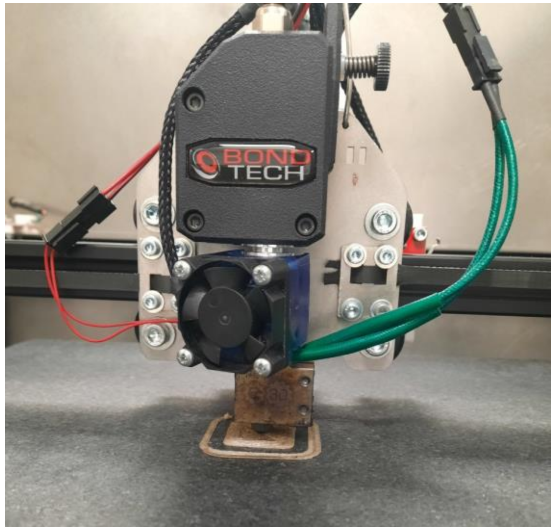
PA6-CF
E = 5500 MPa
HDT = 140 °C
ρ = 1.21 g/cm^3

Fused filament fabrication

3D printed prisms for hot disk thermal conductivity

- Dimensions 20 mm x 20 mm x 6.5 mm
- Direct extrusion printer
- Maximum recommended extrusion temperature for each material
- Extrusion multiplier from 110 % to percentage where pores were visible





Thermal conductivity

Hot disk method

- Polish surface of 3D printed parts for good contact
- Adjusted parameters for each material to minimize warnings

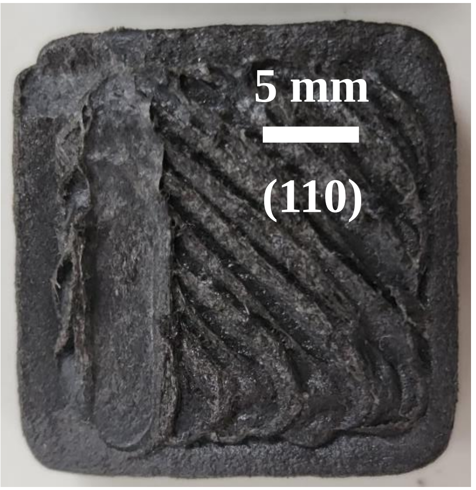

Hot Disk Thermal Constants Analyzer

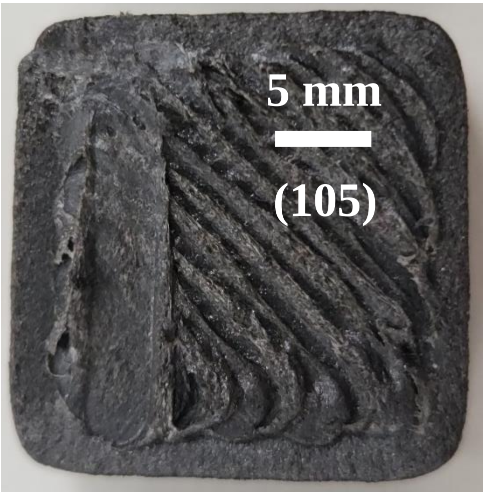

Hot Disk
Kapton sensor

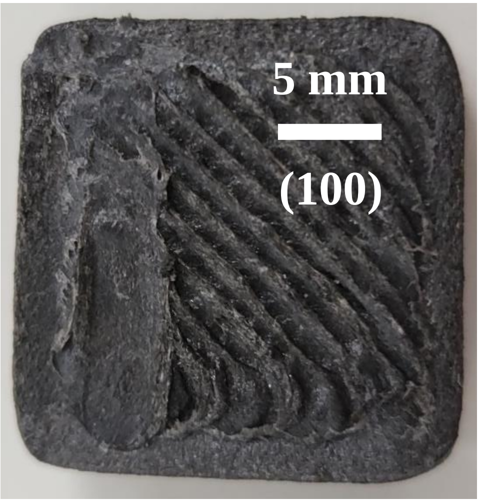
https://www.ortonceramic.com/hot-disk-transient-plane-source-tps

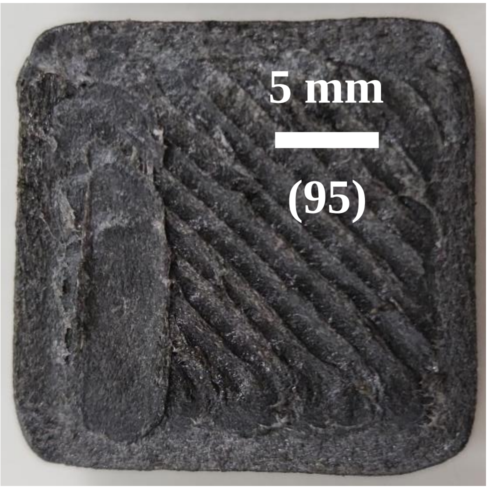
03 Results

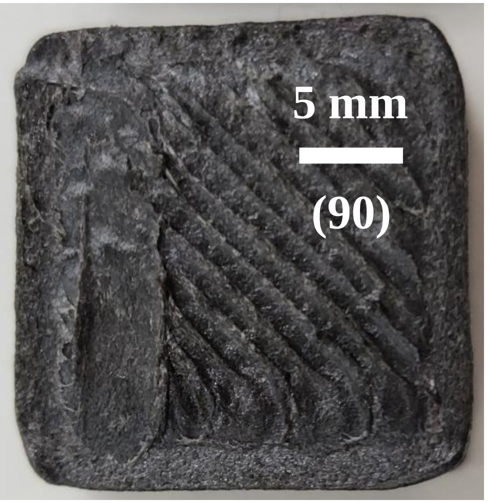
Printing results – PEKK - CF

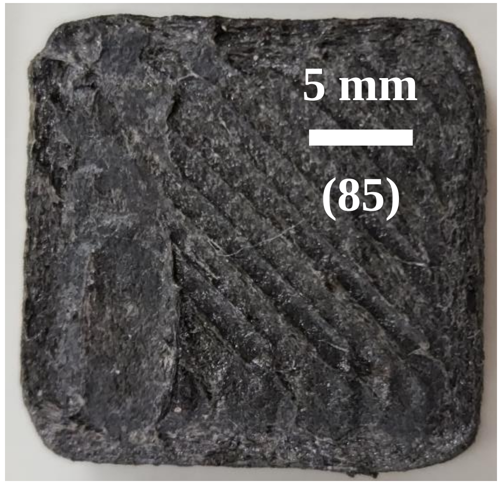


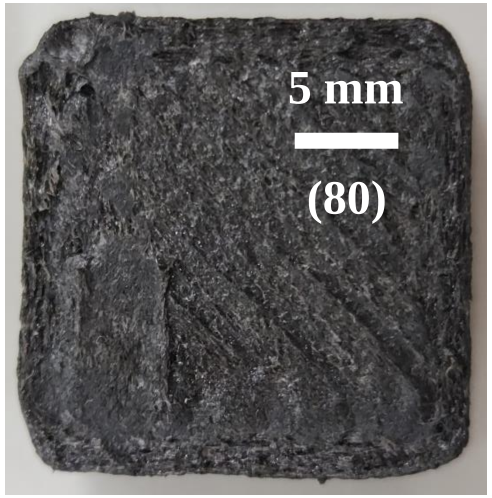










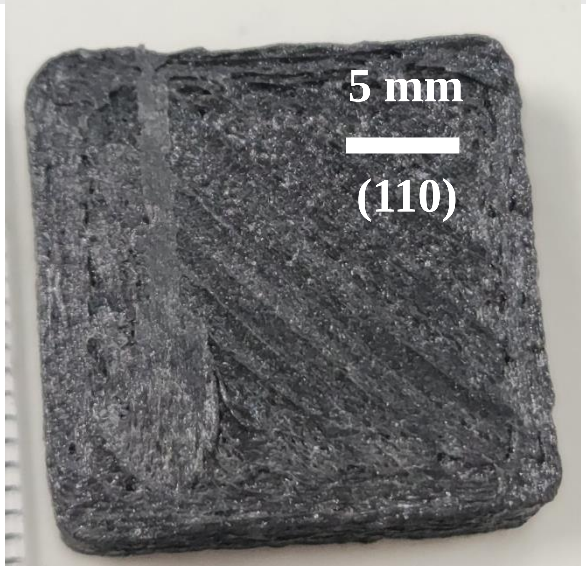


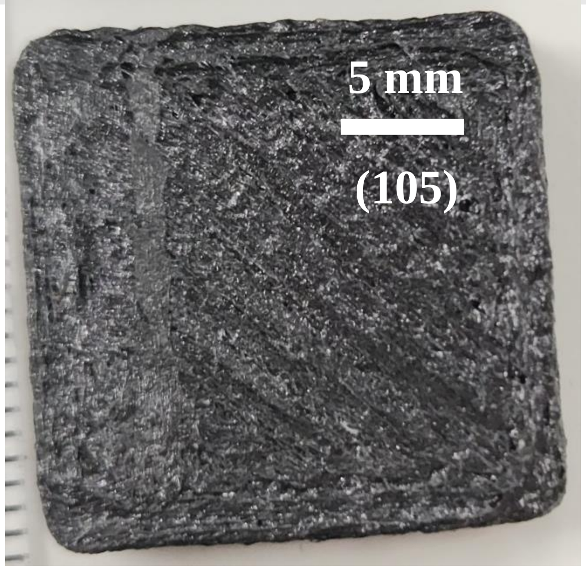
<u>Printing conditions</u>:

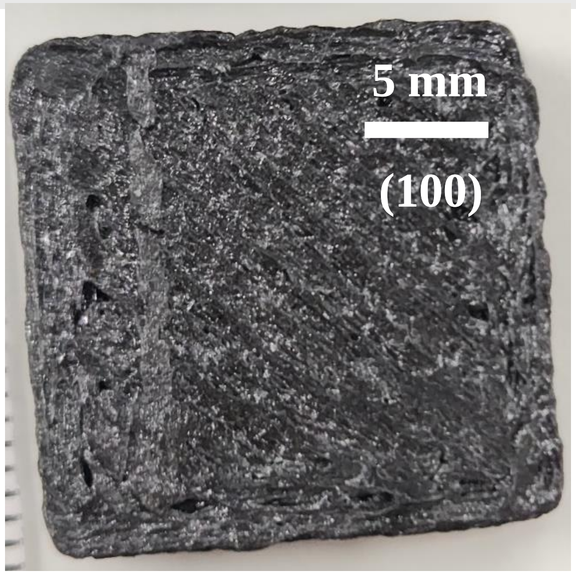
Nozzle temp: 390 °C

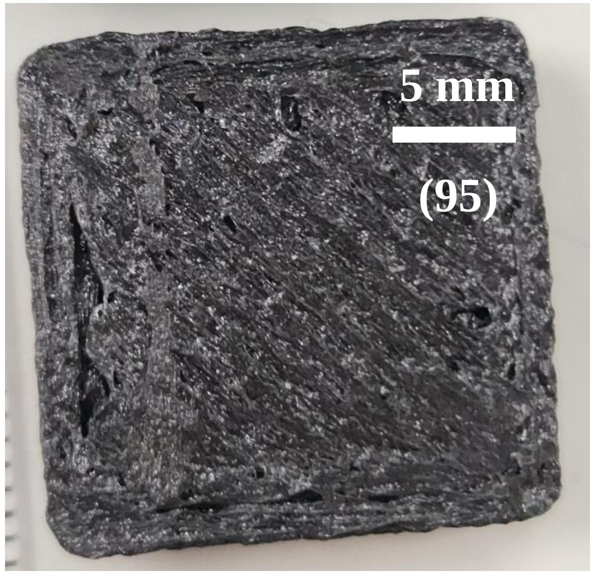
Bed temp.: 120 °C

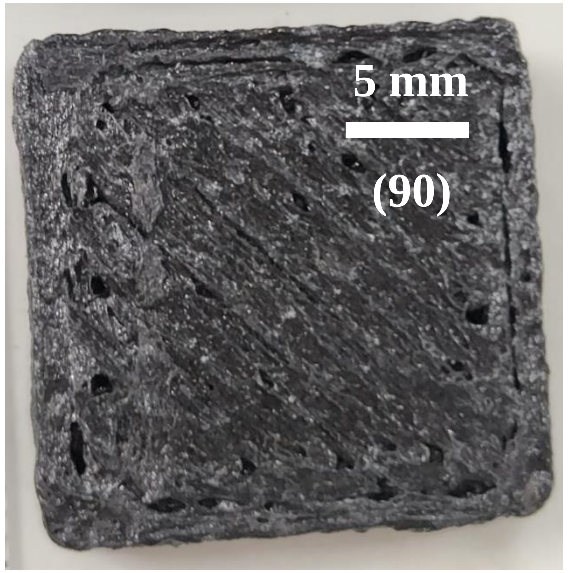
Printing results – PEI - CF









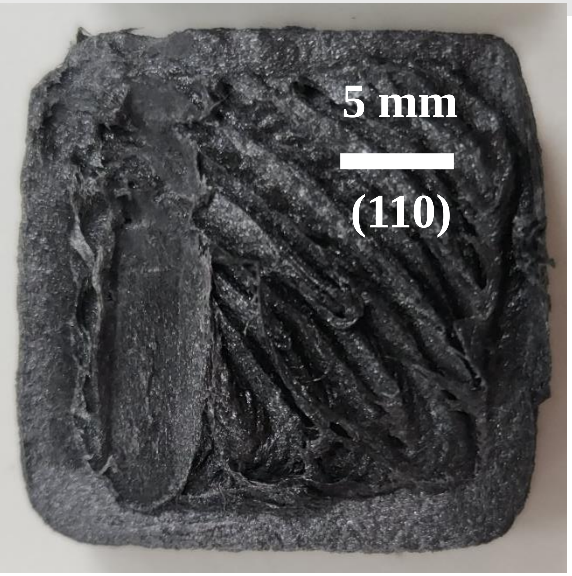


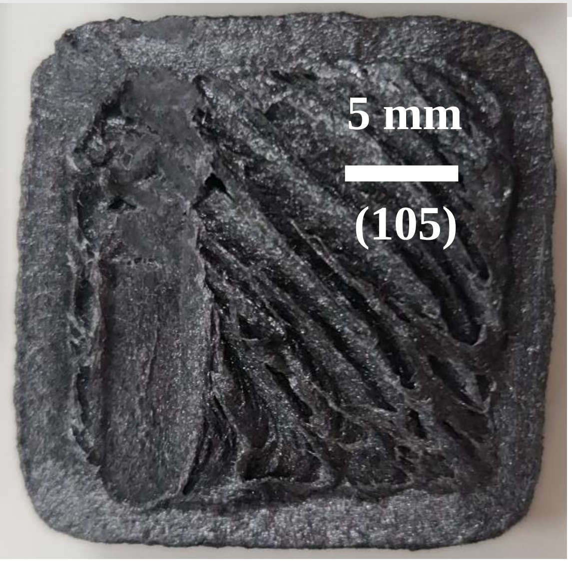
Printing conditions:

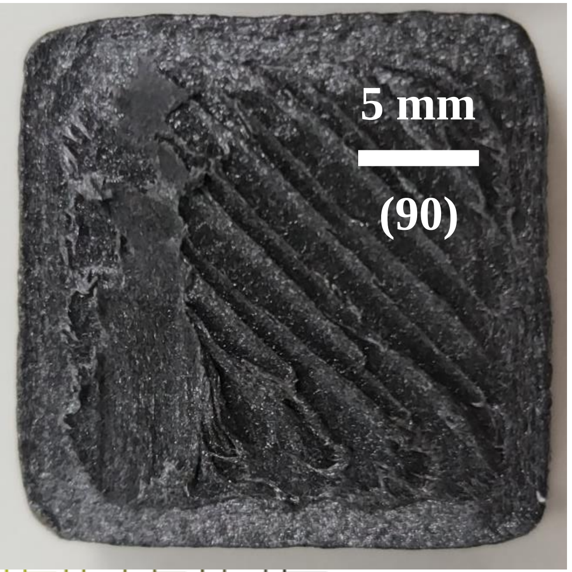
Nozzle temp: 390 °C

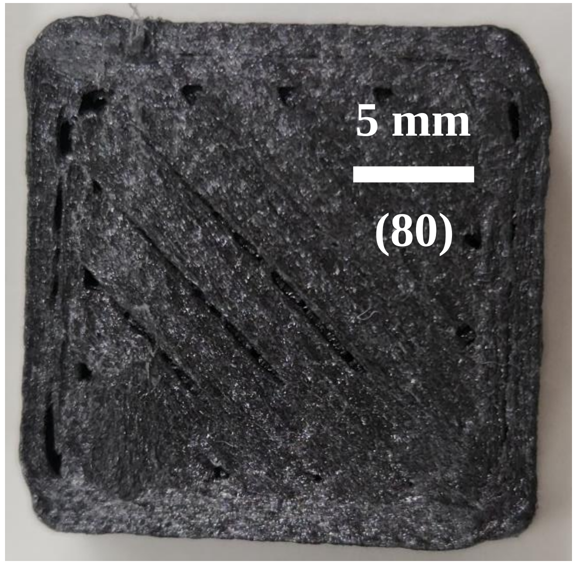
Bed temp.: 120 °C

Printing results – PC - CF







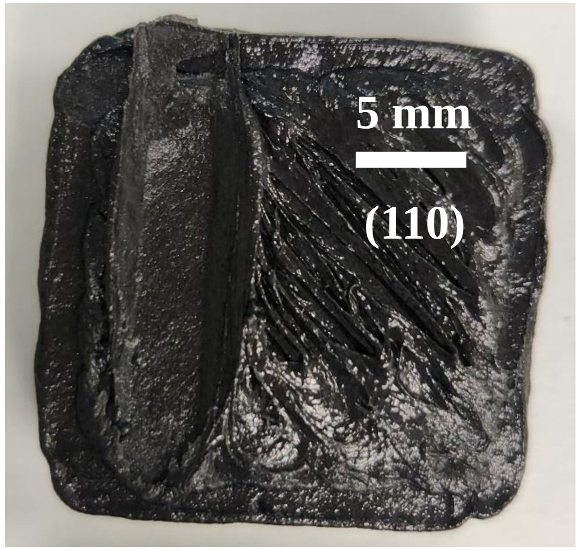


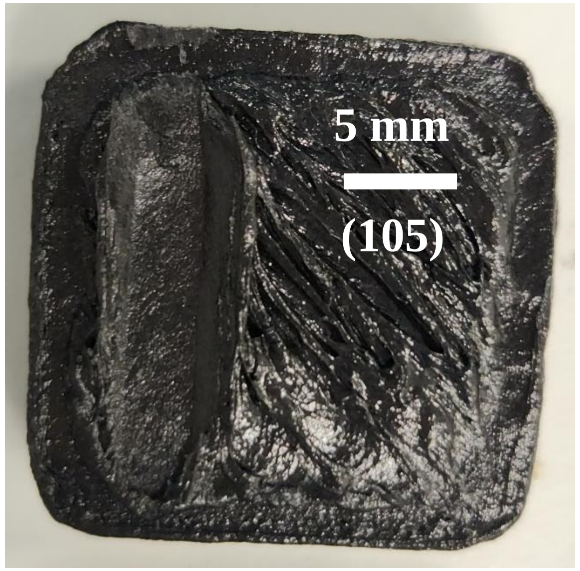
<u>Printing conditions</u>:

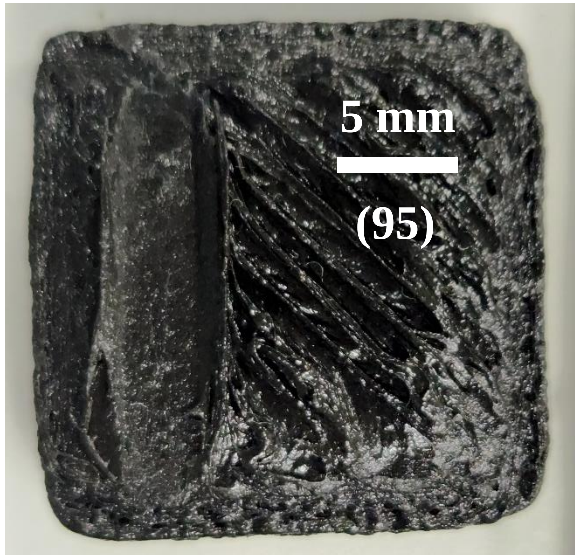
Nozzle temp: 290 °C

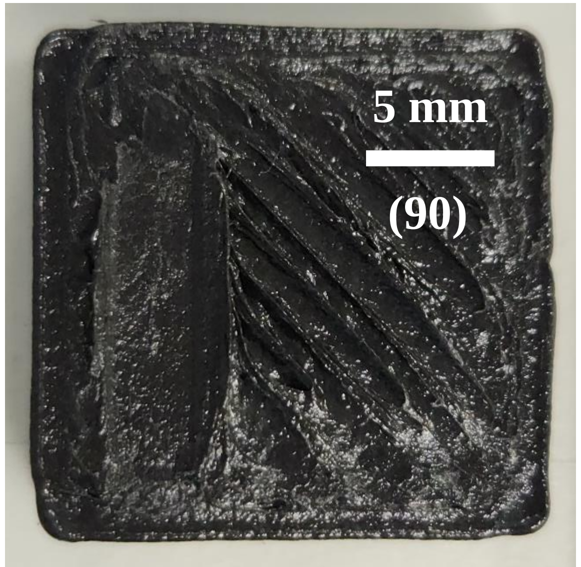
Bed temp.: 120 °C

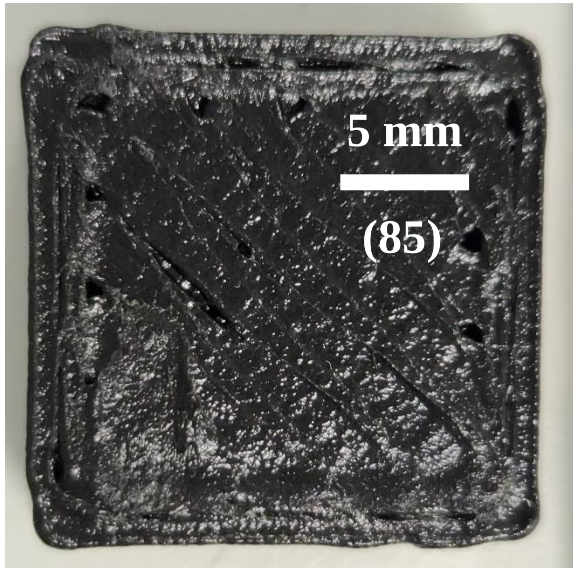
Printing results – PA6- CF









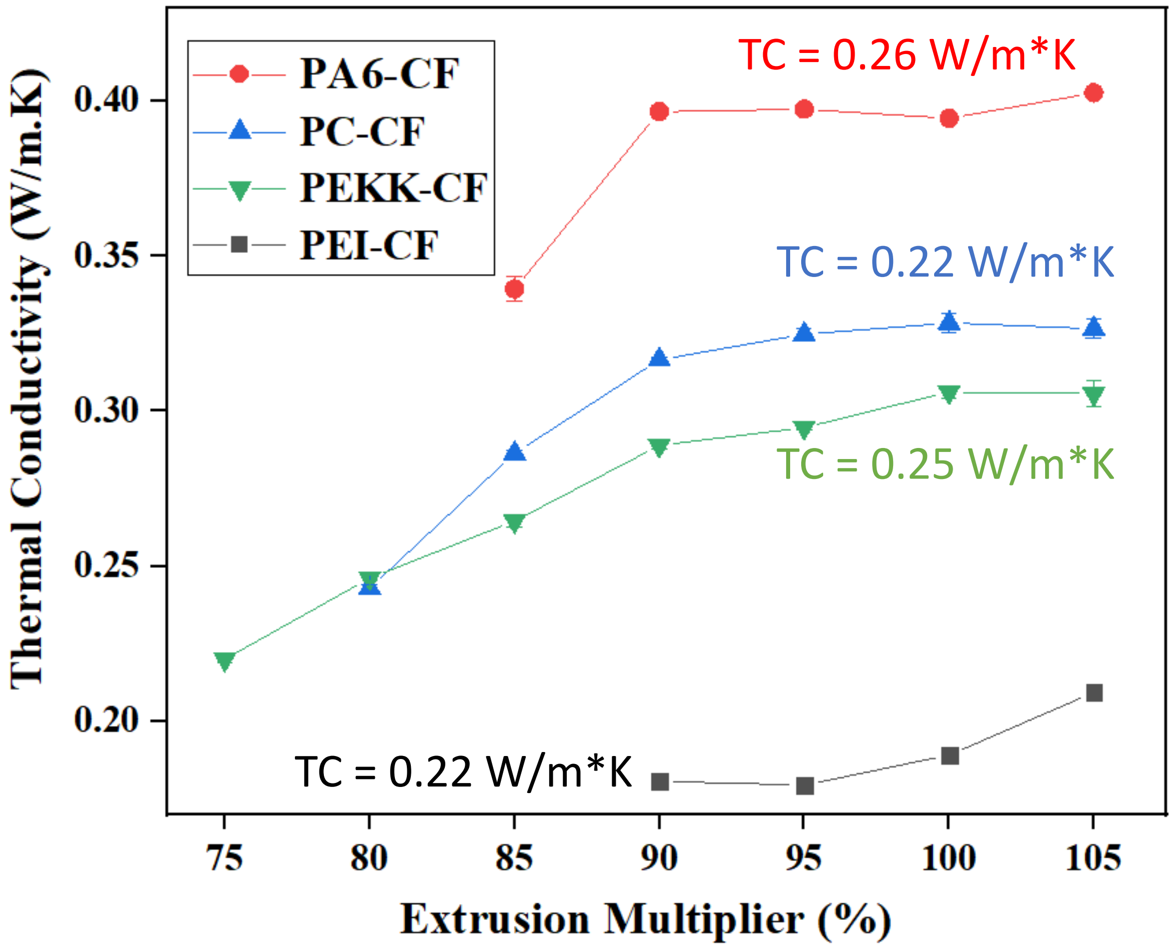


<u>Printing conditions</u>:

Nozzle temp: 260 °C

Bed temp.: 90 °C

Thermal conductivity results



Thermal conductivity

- Increases with extrusion multiplier (EM)
- Most likely related to porosity
- Highest PA6-CF → maybe more fibre content
- Lowest PEI-CF → might need higher EM & higher nozzle temperature

04 Conclusions & Future work

Conclusions

For each material tested

- Was printable in the range of recommended conditions
- Visible porosity appears at different extrusion multiplier values
  - PEKK at 75%
  - PEI at 90%
  - PC at 80%
  - PA6 at 85%
  - Most likely related to viscosity of composite

- Thermal conductivity increases with extrusion multiplier
- Higher for PA6-CF
- Lower for PEI-CF

Future work

Quantify porosity & fibre content of specimens

- Micro computed tomography
- Density measurements

Vary other 3D printing parameters

- Layer height
- Nozzle diameter
- Printing orientation & temperature

Develop new materials

- Higher thermal conductivity (>1 W/m*K) & still printable
- Combine with continuous carbon fibres

Acknowledgements

Co-authors

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- Gabriel Foyer – Thales Research and Technology (FR)
- Tessa ten Cate – Brightlands Materials Center (NL)

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Thank you for your attention!

Questions?

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