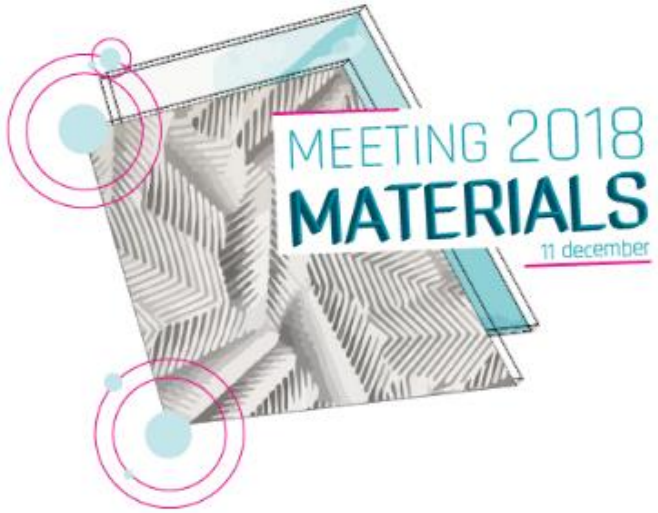
Brightlands
Materials Center

“Challenges and opportunities in FDM printing of electrically conductive thermoplastics”

Andrea Gasperini, Scientist

December 11th, Noordwijkerhout, The Netherlands



TNO innovation for life provincie limburg

Brightlands Materials Center

- Inspiring Innovations in Plastics
- Research center running own R&D program
- Public-private partnership founded by TNO and Province of Limburg in 2015
- Focus on innovations in polymeric materials
- R&D driven by application challenges, supported by academic knowledge
- Shared Innovation model: Collaboration in shared R&D leading to shorter time-to-market

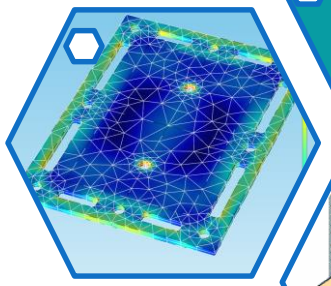
Additive Manufacturing

Sustainable Buildings

Lightweight Automotive

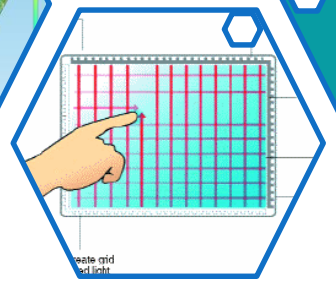
TNO innovation for life provincie limburg

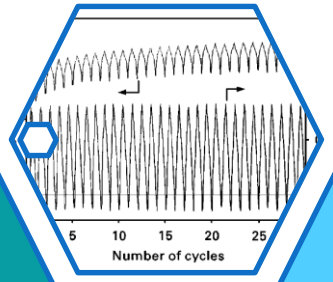
AM activities at Brightlands Materials Center



Load history monitoring
FDM

Structural integrity monitoring
FDM





Porous materials
SLA

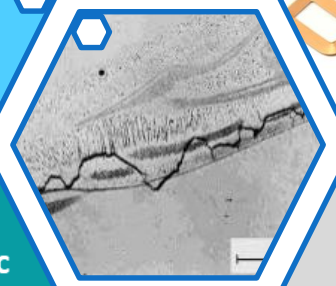
Integrated pressure sensors
FDM

Process Optimization
SLS

3D Printed Thermoplastic composite
FDM

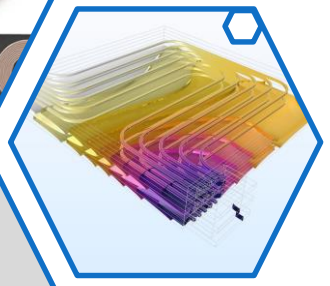
Complex Shape Antennas

Particles alignment in SLA



Light emitting elements
SLA

Thermal conductivity
FDM



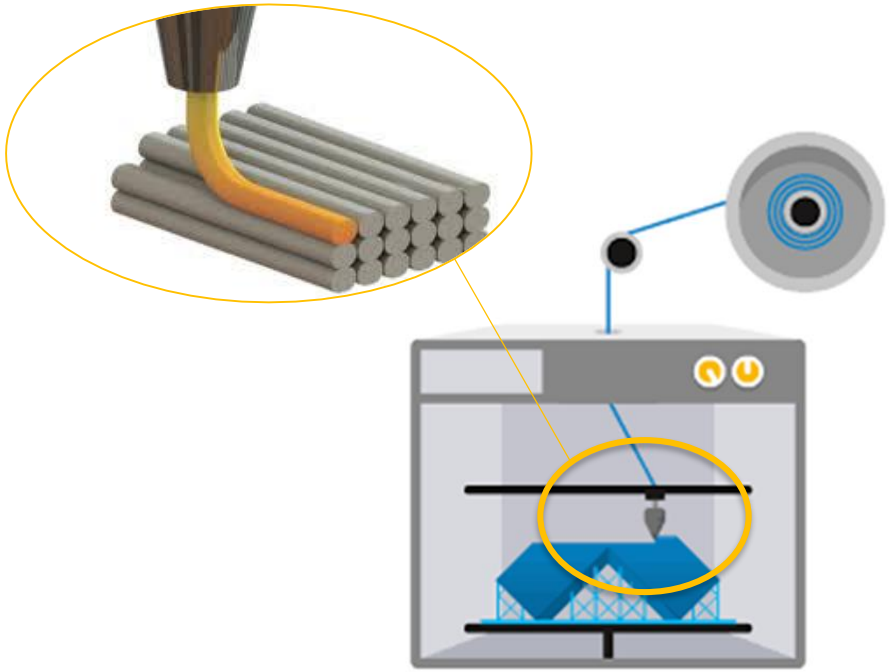
Multimaterial Dental
SLA

“Challenges and opportunities in FDM printing of electrically conductive thermoplastics”

- *Outline*
  - *Use of Additive Manufacturing in industry*
  - *Motivation*
  - *Fused deposition modeling of composites at BMC*
    - *Short fiber FDM*
    - *Continuous fiber FDM*
    - *Functional properties - sensing*
  - *Outlook*

Key Benefits of Additive Manufacturing Create Opportunities

Fused deposition Modeling (FDM)



Advantages

- Design
- Freedom
- On Demand — Just Made Locally
- Customization — customized

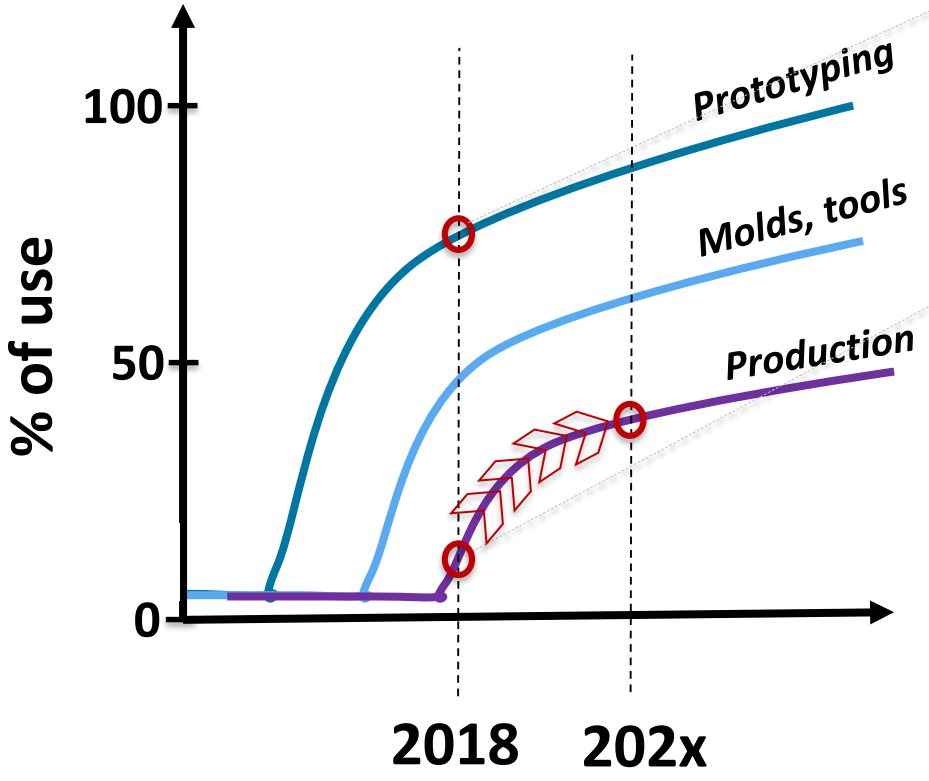
Benefits

- unique ***complex products***
- embedding
- lighter and stronger
- ***less assembly steps***

- local manufacturing
- impact on ***logistics and storage***
- no need for tool production

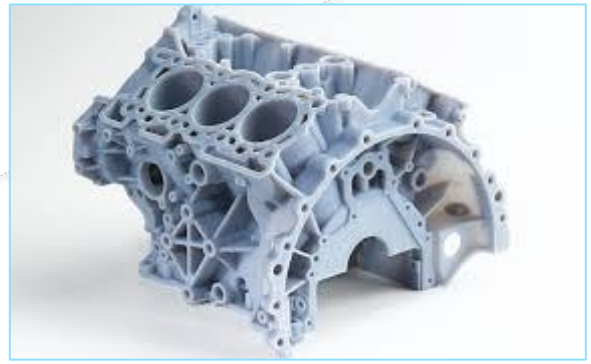
- no additional cost
- short time to market
- ***fast change-over cycles***

Use of AM in industry



Prototyping/tooling

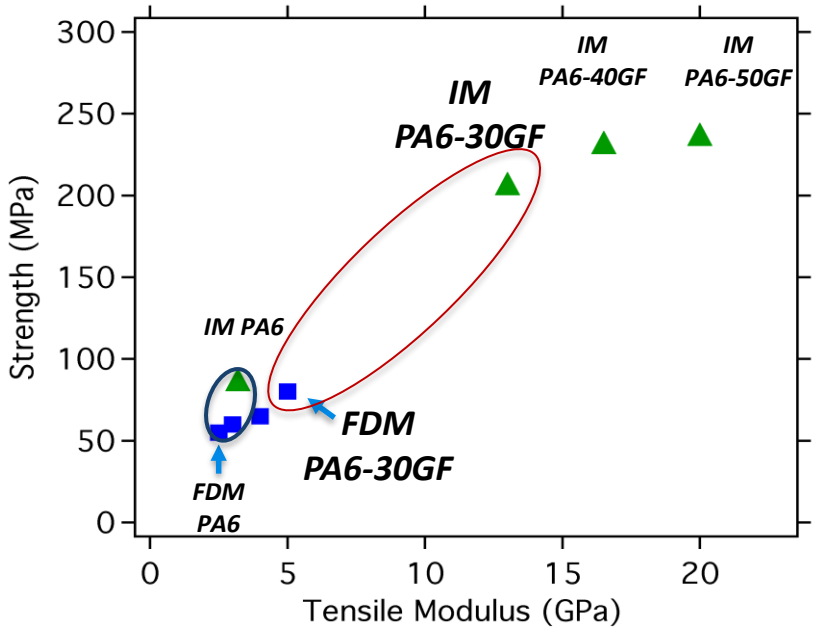
Monomaterial
Visual inspections
Jigs/fixtures



Low volume production

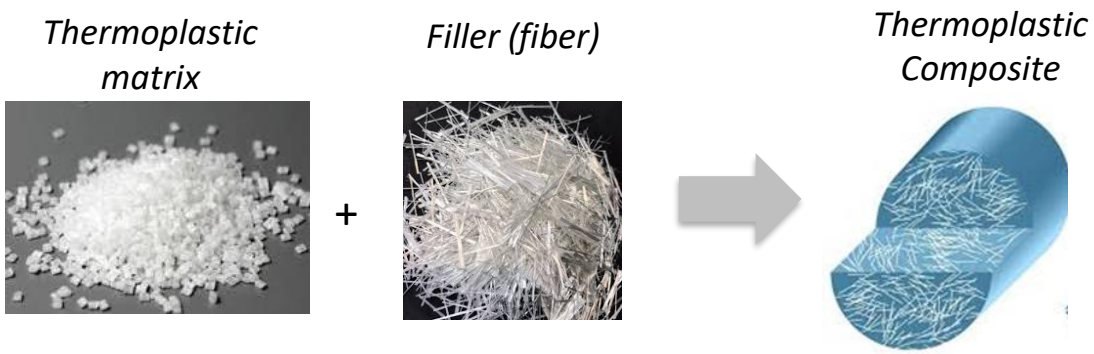
2000 parts/year
High accuracy
High reliability
Metal!

FDM of composites

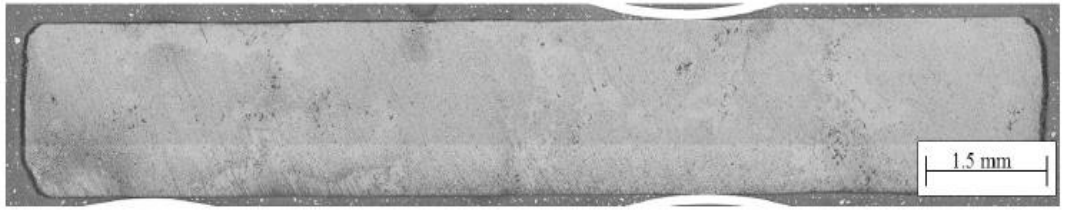


Focus at Brightlands Materials Center:

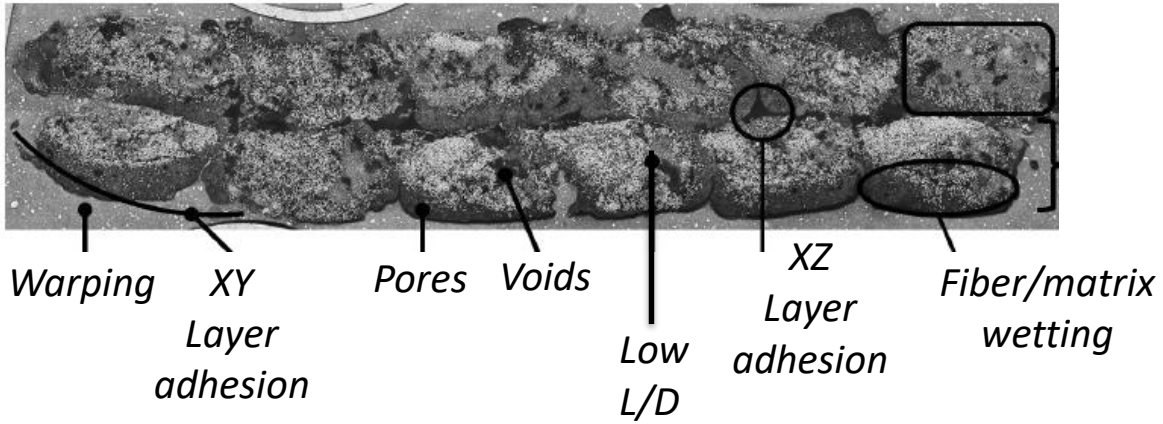
- ✓ Fillers nature's influence **on Interlayer adhesion**
- ✓ Increase **L/D in printed parts**
- ✓ How filler influence internal microstructure (**voids**)



- Injection molding



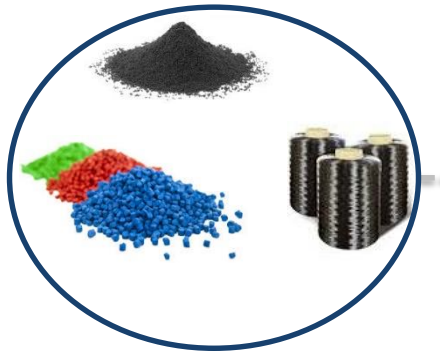
- FDM



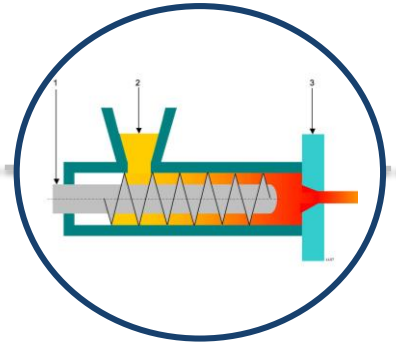
M. Domm et al. ***2017***

From material formulation to 3D parts characterization

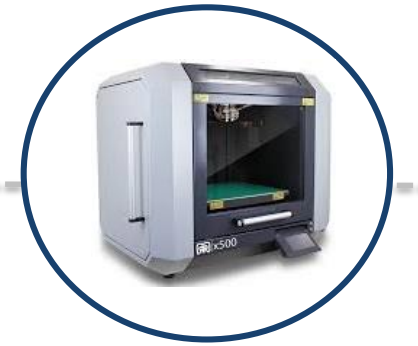
Materials selection



Materials “interaction”



FDM Processing



Part characterization

Materials characterization

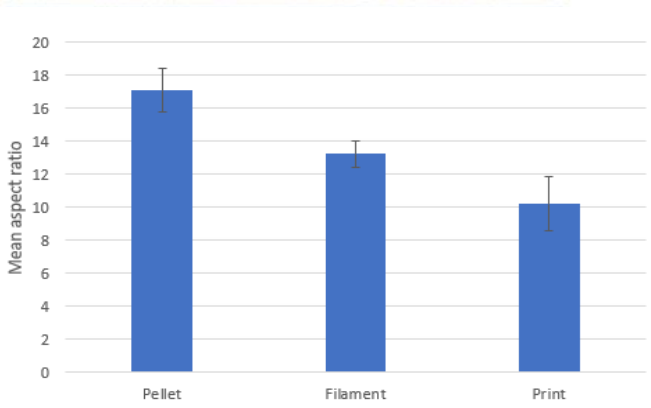
Composition development

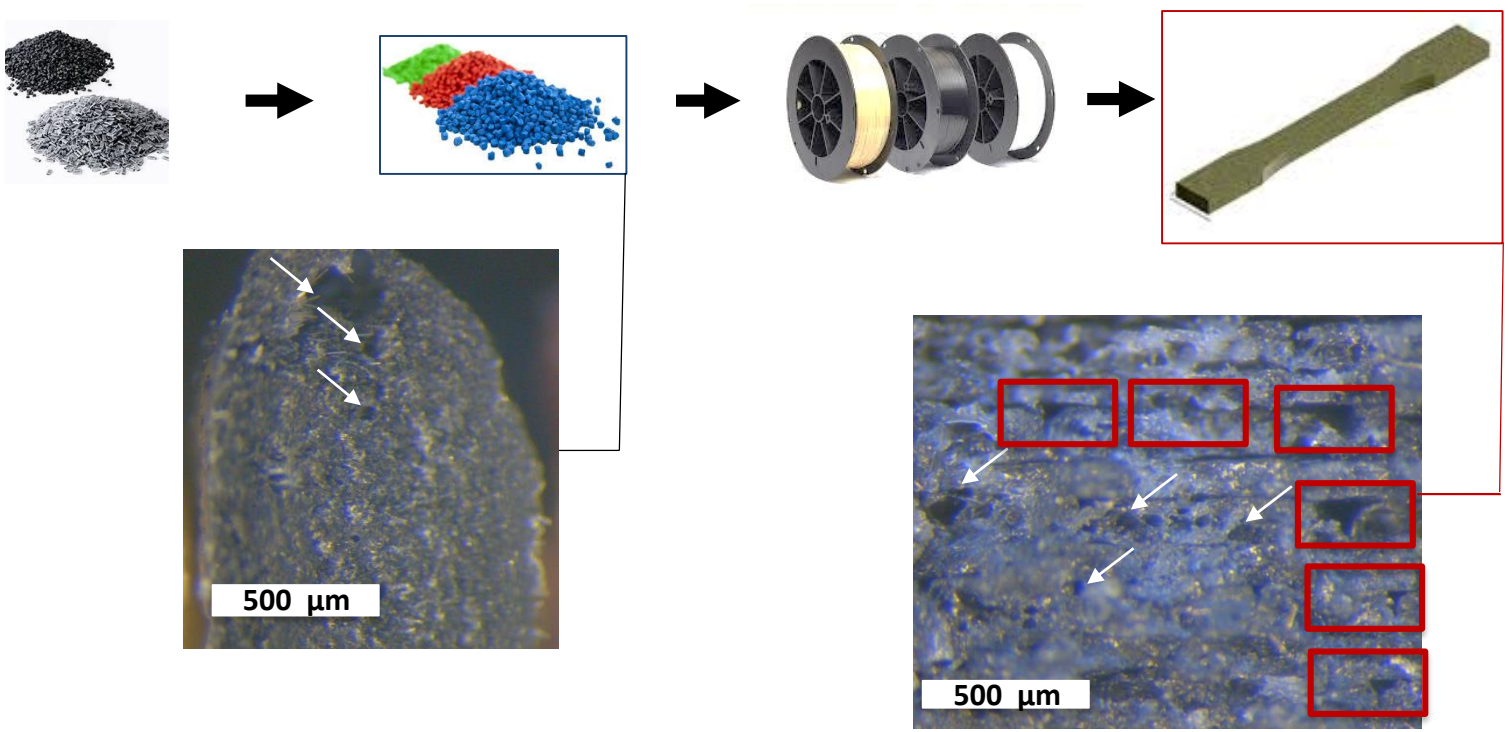
Processing parameters

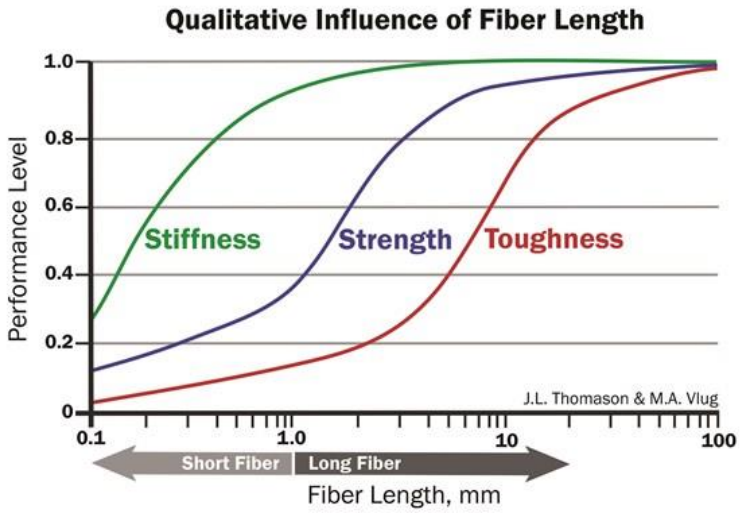
Mechanical properties

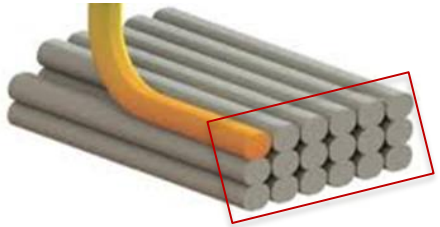
Modelling and Simulation

FDM of Short fiber composites





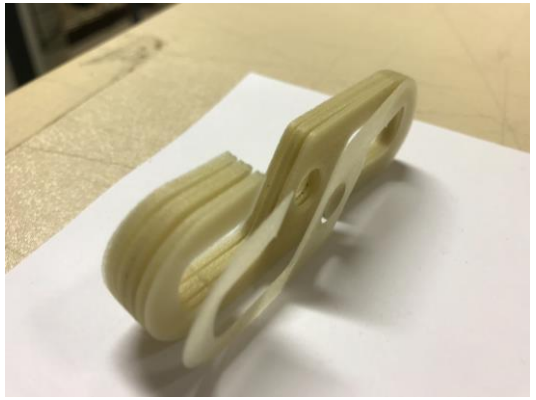




Material preparation challenges

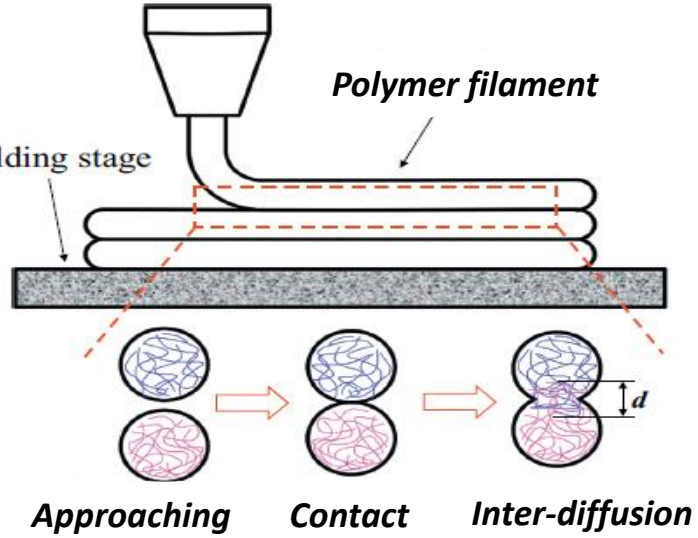
- Keep ***high L/D ratio*** until final printed part
- Reduce ***internal layer voids*** already during compounding
- Reduce ***interlayers voids***

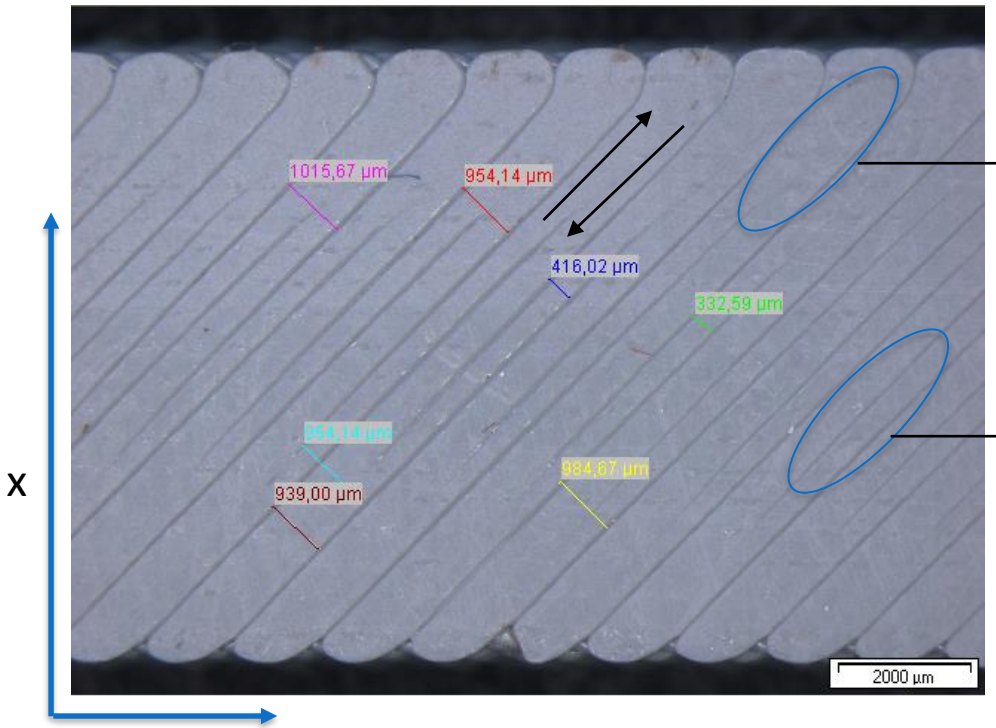
Interlayer adhesion

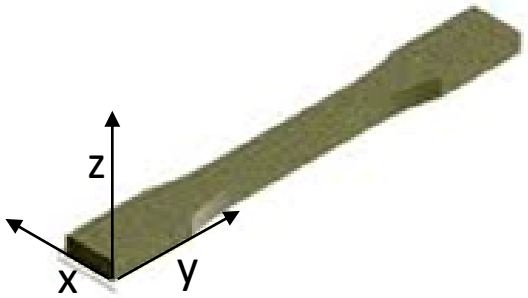


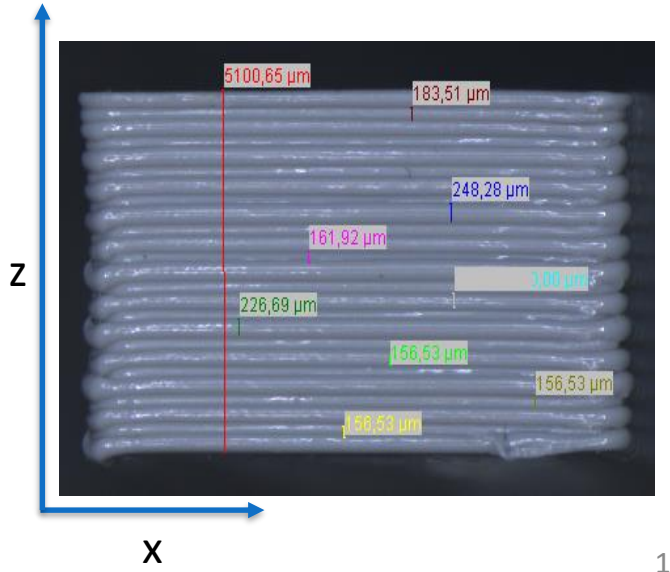
Molecular diffusion

- Time
- Temperature
- Molecular weight





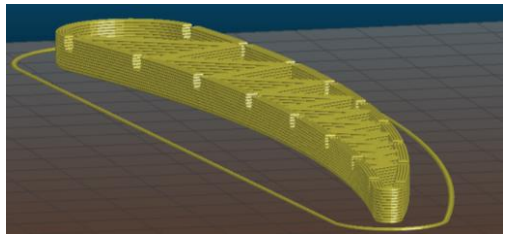


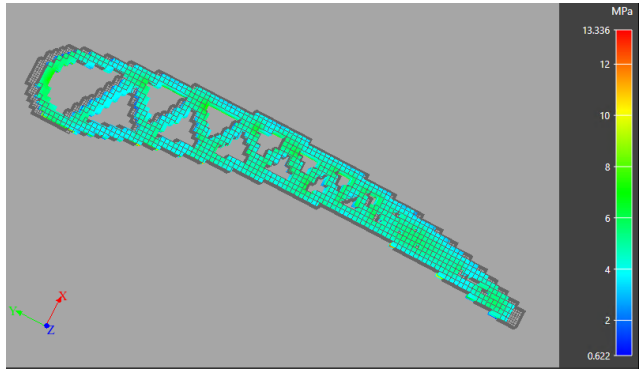


Stress evolution *vs* printing path

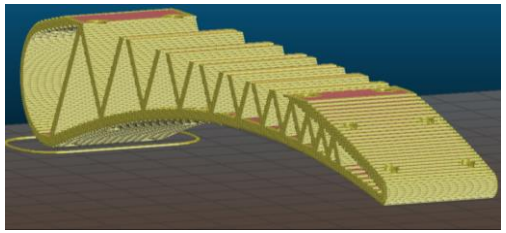
Input | *Output*

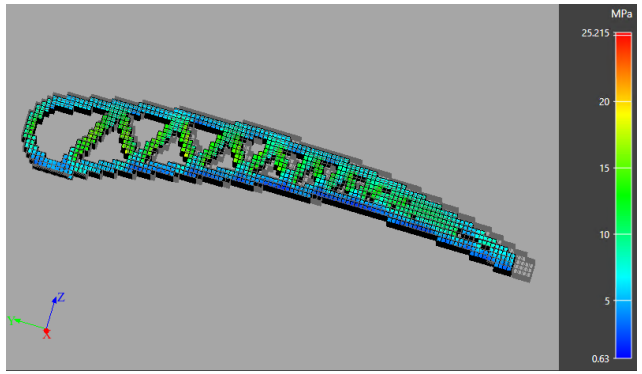
"Edge on" orientation





"Face on" orientation





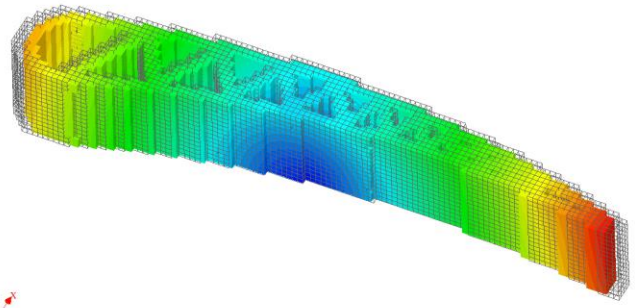
Materials composition

FDM printing path

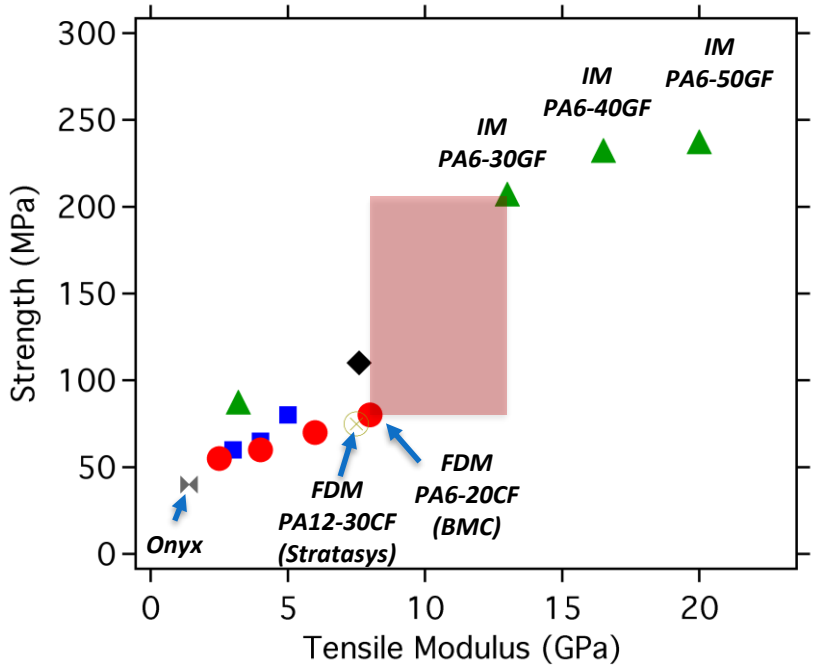
Processing conditions

Digimat

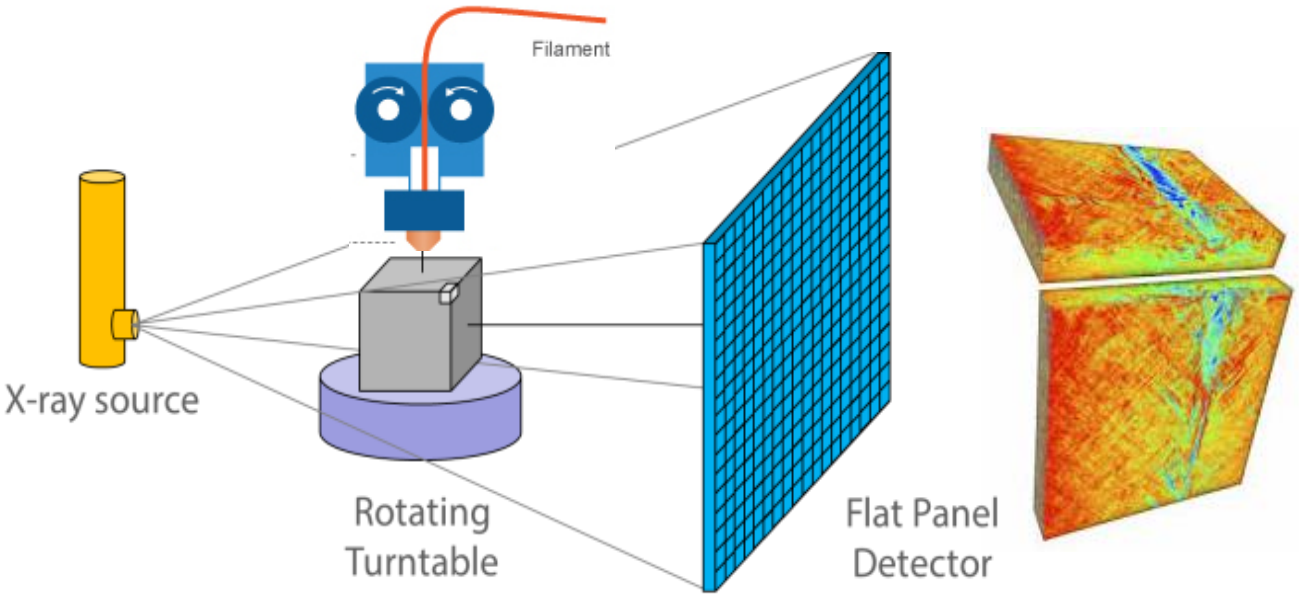
Toolpath optimization
Warpage prediction
Shrinkage



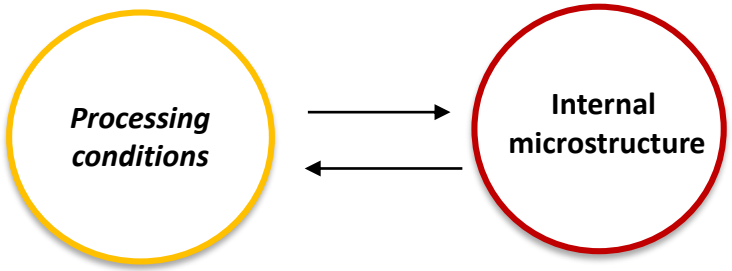
M-Eranet – “Reliable-GF-3D”



Real time X-Ray CT during FDM printing



Partners



Feedback loop

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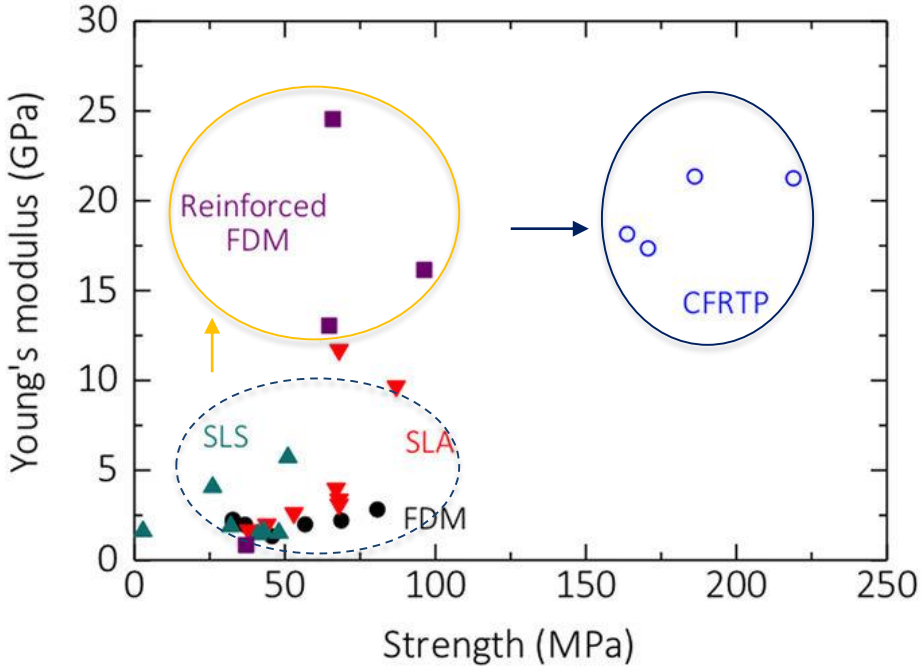
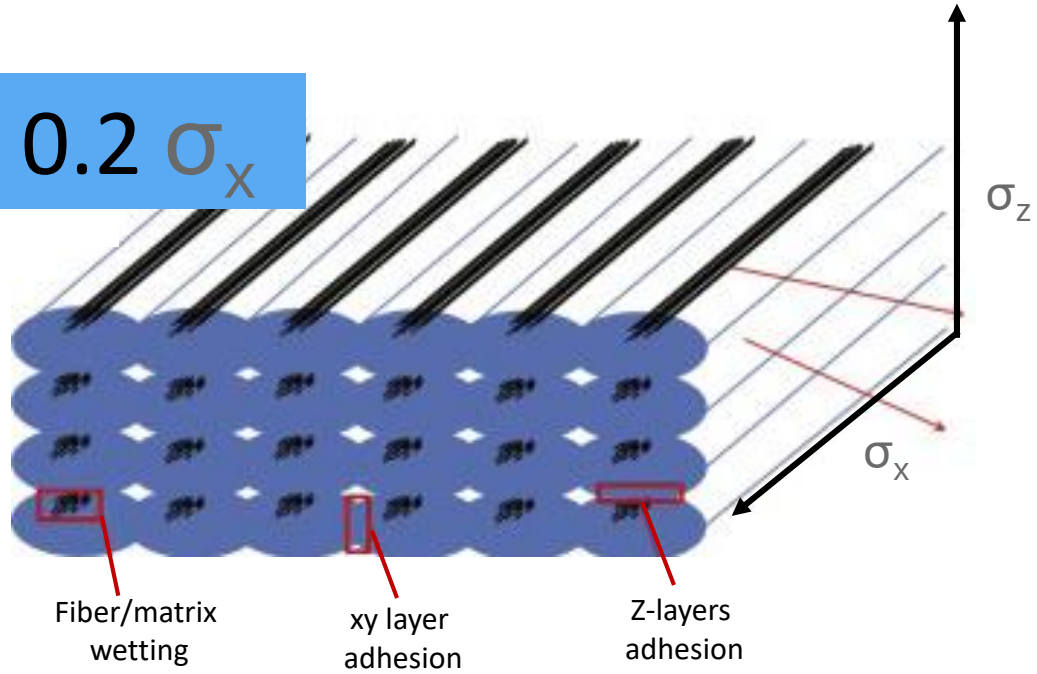
Mechanical properties of 3D printed continuous carbon fibers



Continuous fiber filament

Anisoprint Composer Printer

$\sigma_z = 0.2\ \sigma_x$



Material preparation challenges

- Anisotropy in stress transfer directions
- Reduce ***interlayers voids***
- *Increase* ***fiber volume (< 20%)***

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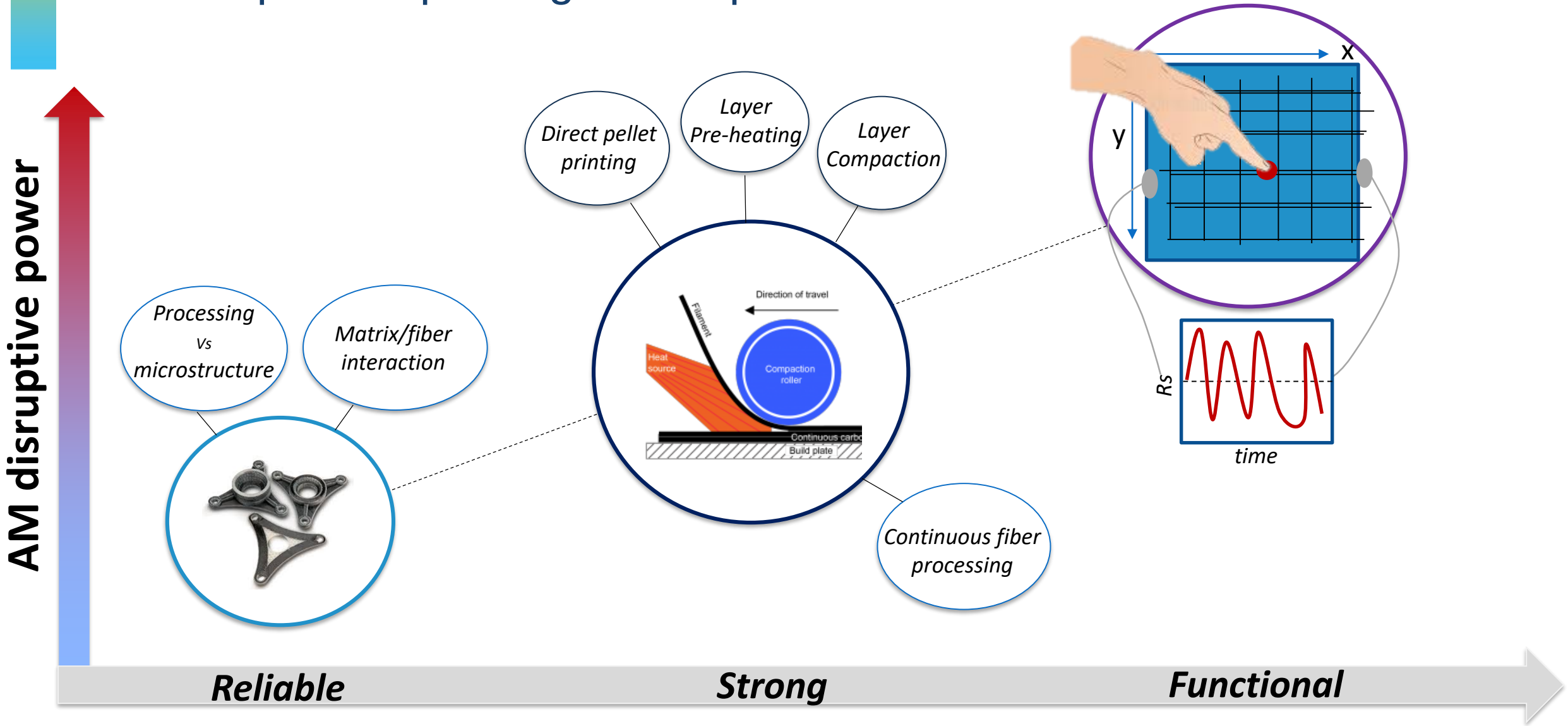
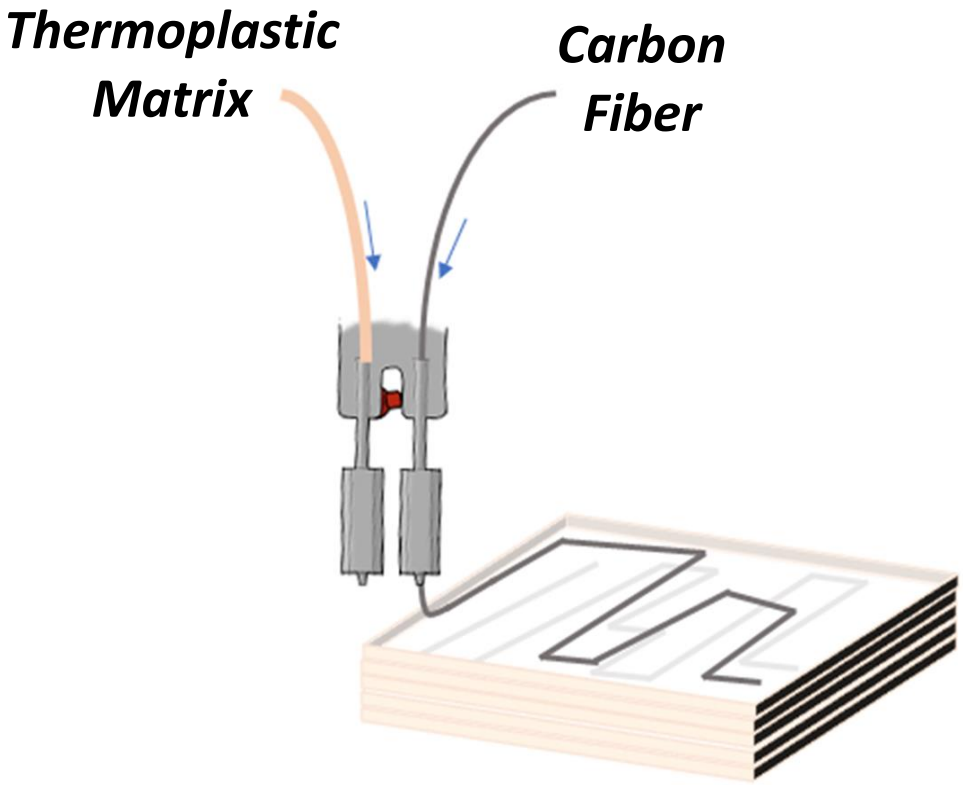
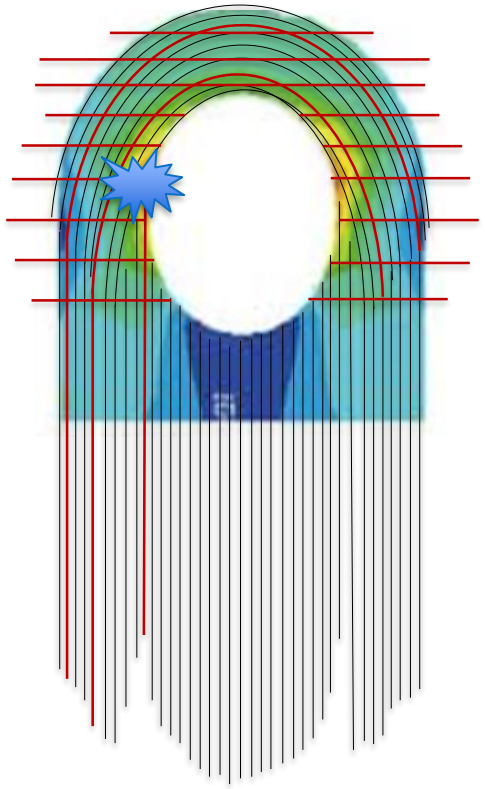
Roadmap in 3D printing of composites

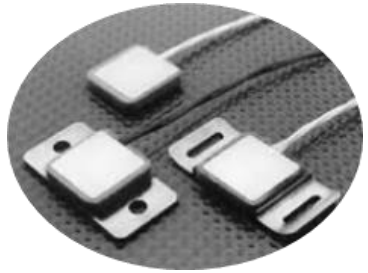


3D Printing of continuous fiber



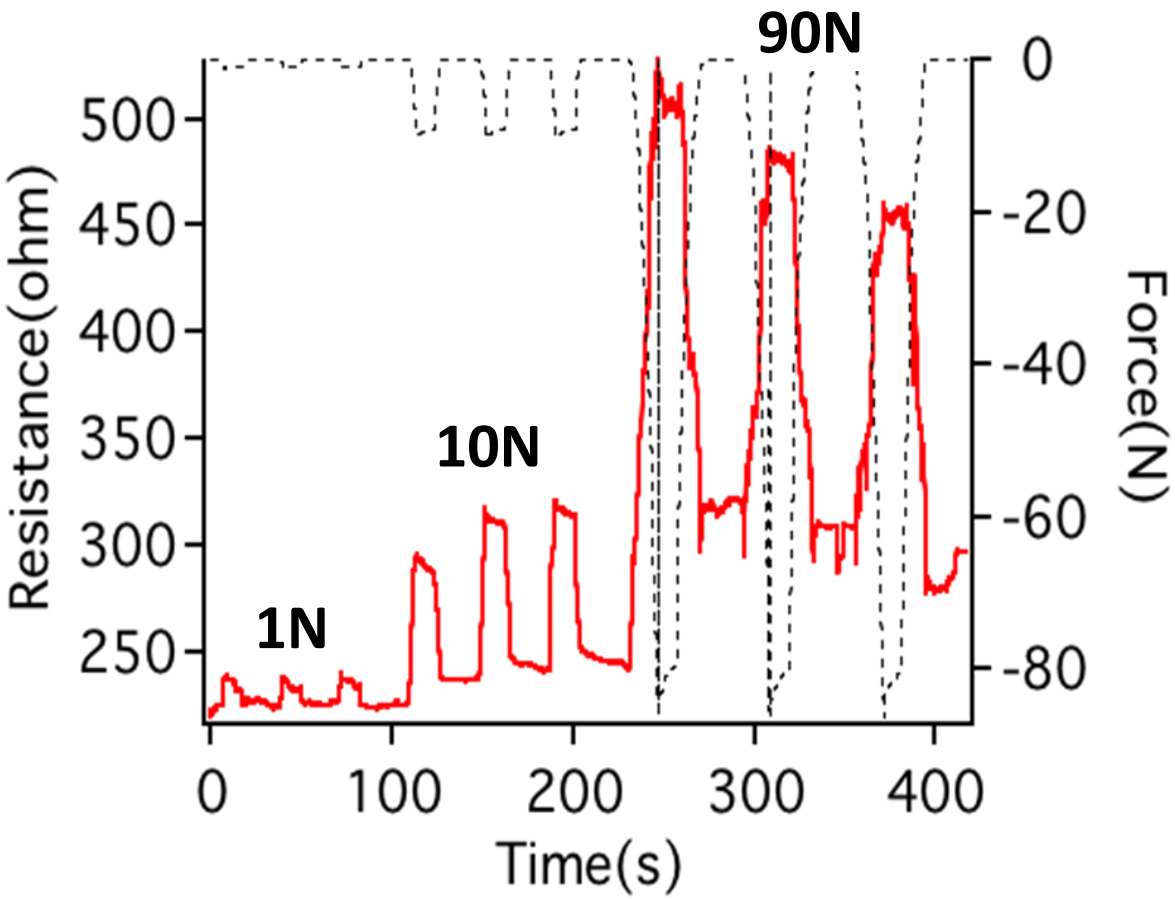


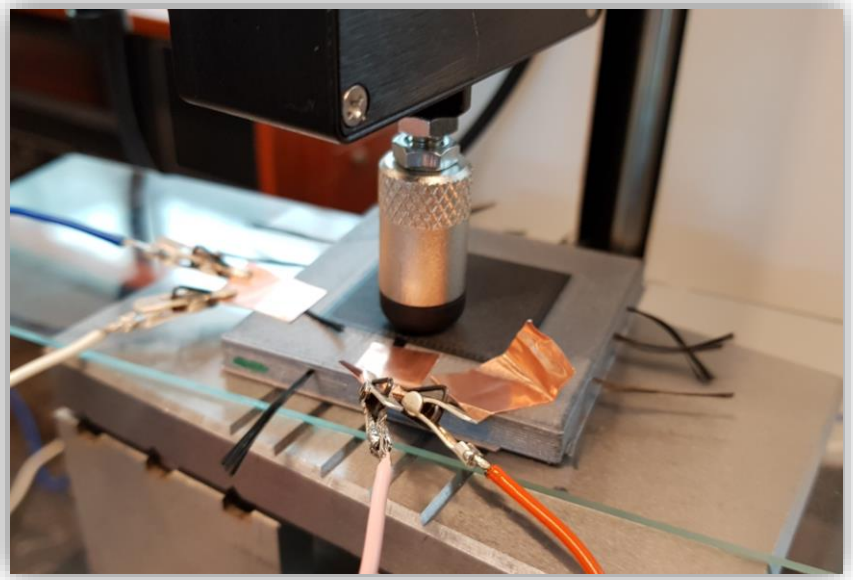
vs

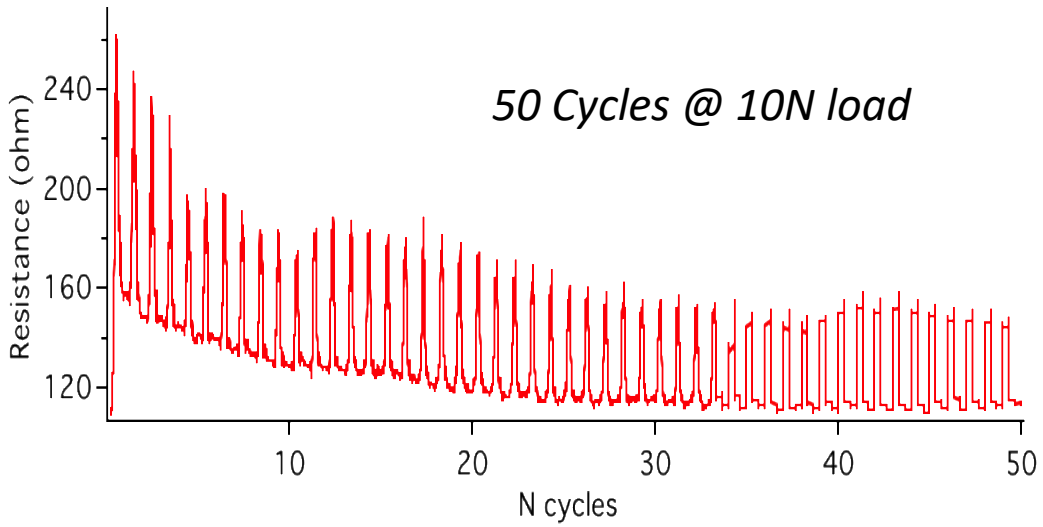


3D printing of self-monitoring composites in which continuous fibers act as reinforcement and as fully integrated sensing elements

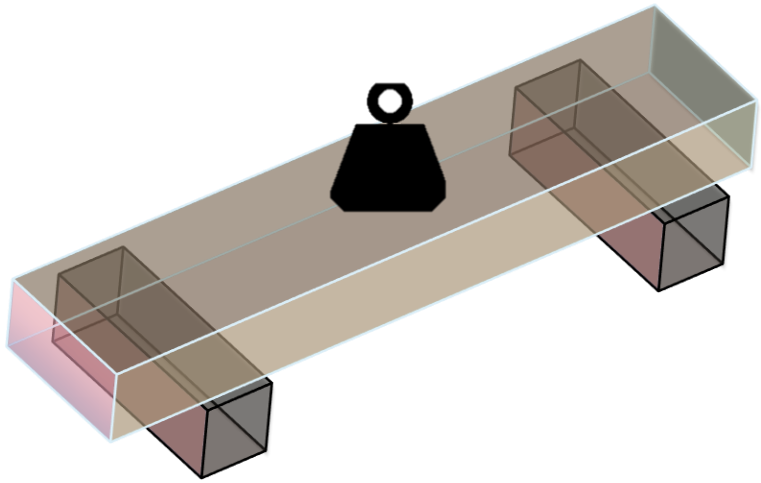
Pressure sensors

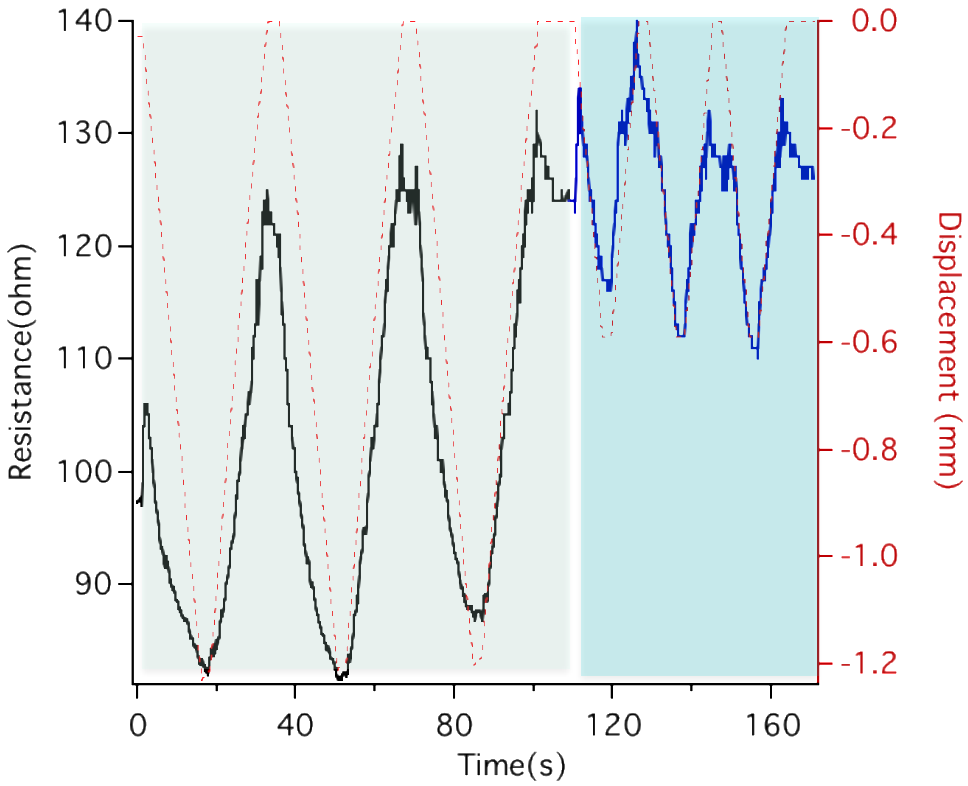


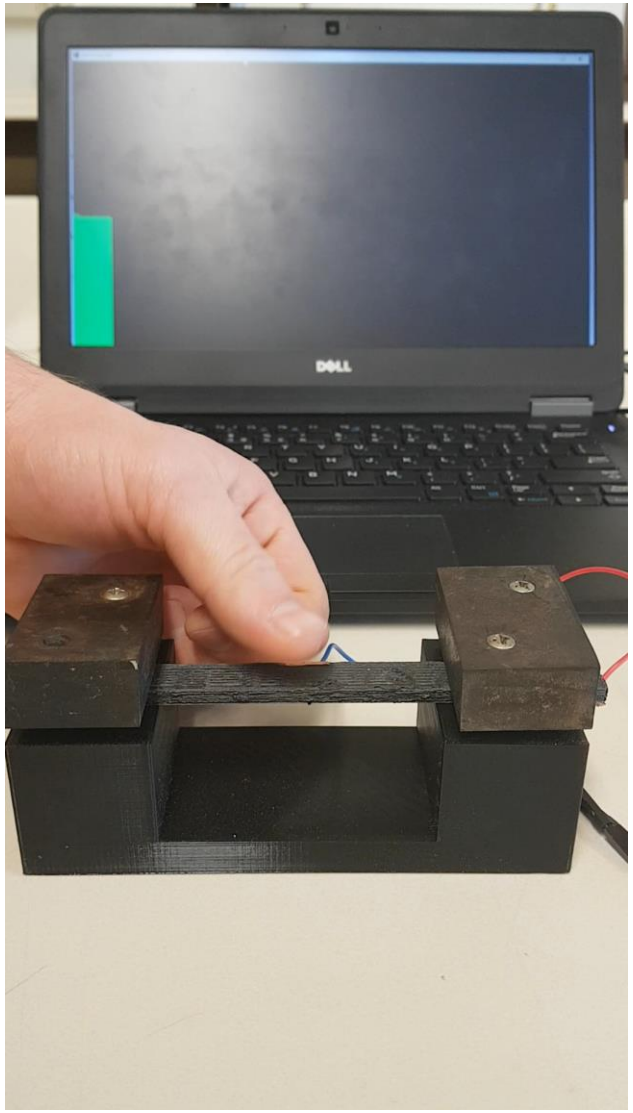




Flexural sensor







Resistance change

Vs

Beam bending radius

Outlook

Directions

- Increase wt% fillers
- Formulation-microstructure
- Self-sensing composites
- Advanced FDM processing
- Long/continuous fiber

Challenges

- Low L/D
- Z-layer adhesion
- Voids
- Fiber/matrix wetting
- Strength anisotropy

Opportunities

- Functional prototypes
- Products with New Functionalities (sensing)

Brightlands Materials Center

Thank You for Your Attention

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