INDUCED ANISOTROPY IN POLYMER NANOCOMPOSITES BY FUSED FILAMENT FABRICATION

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ICCM 2023
July 30th – Aug 4th, 2023

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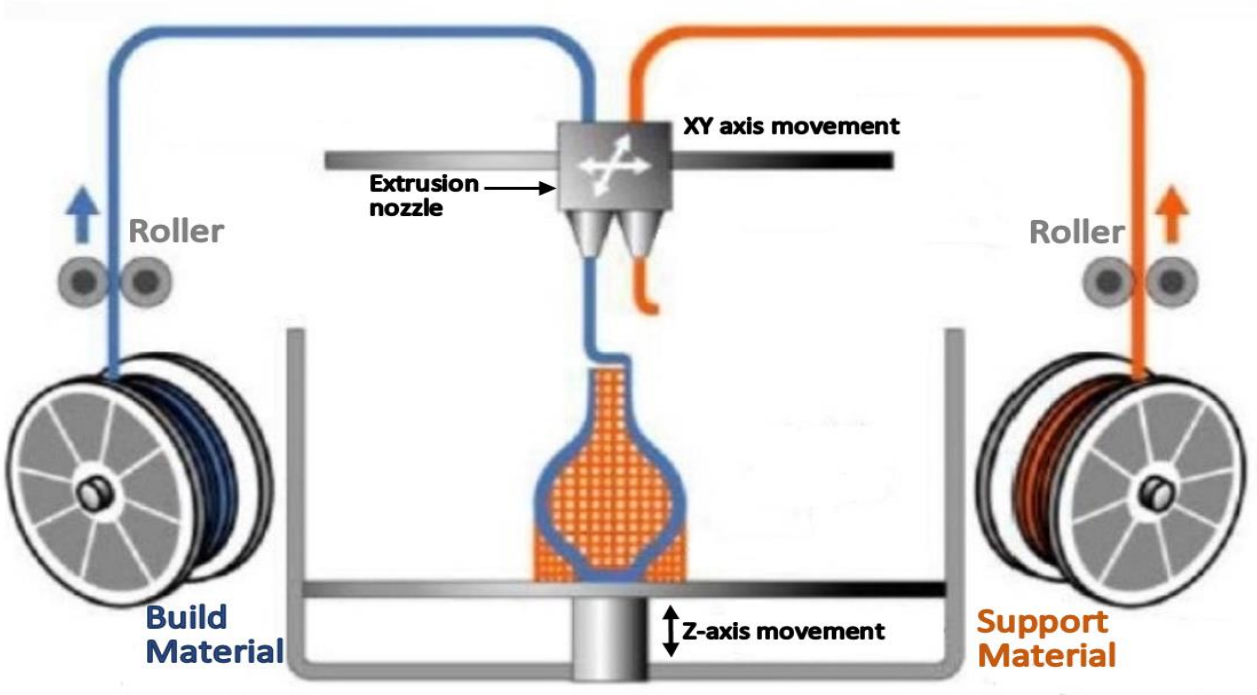
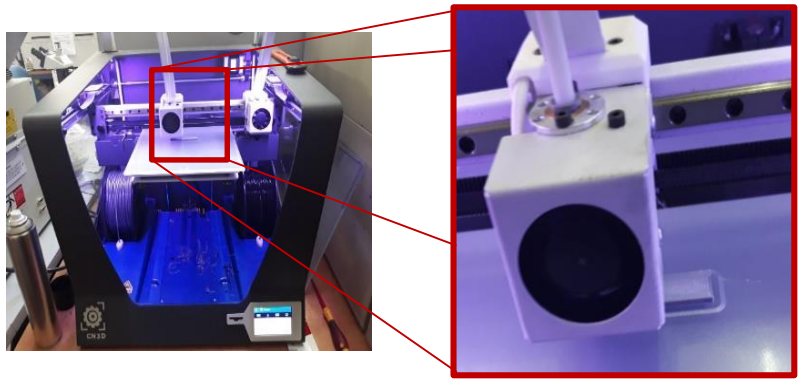
הפקולטה להנדסה ע"ש איבי ואלדר פליישמן אוניברסיטת תל-אביב

Outline

- The principles of Fused Filament Fabrication (FFF) and how can we use them
- Morphological effects of Fused Filament Fabrication (FFF) on nanocomposites
- Induced anisotropy in PLA/nanocarbons 3D printed composites:
  - Mechanical – for bio-mimicry
  - Electrical – for “materials as devices”

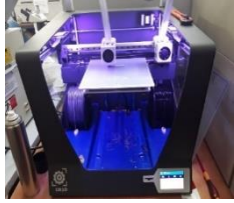
The principals of Fused Filament Fabrication





3D printing of thermoplastic composites

The principals of Fused Filament Fabrication

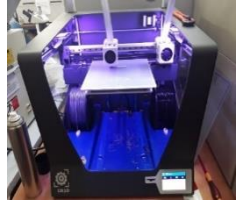


- Materials Parameters:
  - Printing temperature (affected by polymer Tm)
  - Build plate temperature (affected by polymer Tg)

- Product Quality Parameters:
  - Printing speed (faster vs. more precise)
  - Layer thickness (better resolution vs. faster printing, voids)
  - Air gaps (faster & more precise vs. voids)

- Printing Progress Parameters:
  - Building orientation
  - Raster angle
  - Infill percentage
  - Infill pattern

The principals of Fused Filament Fabrication



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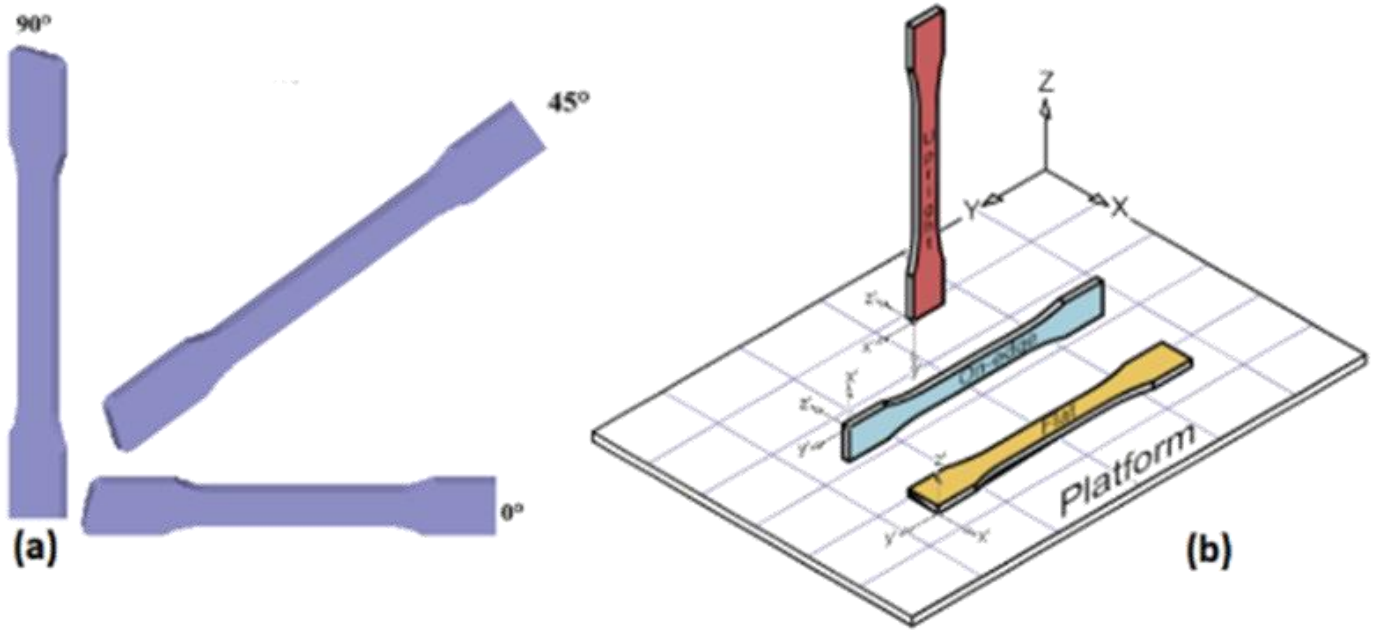

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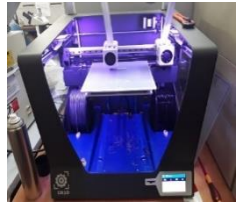

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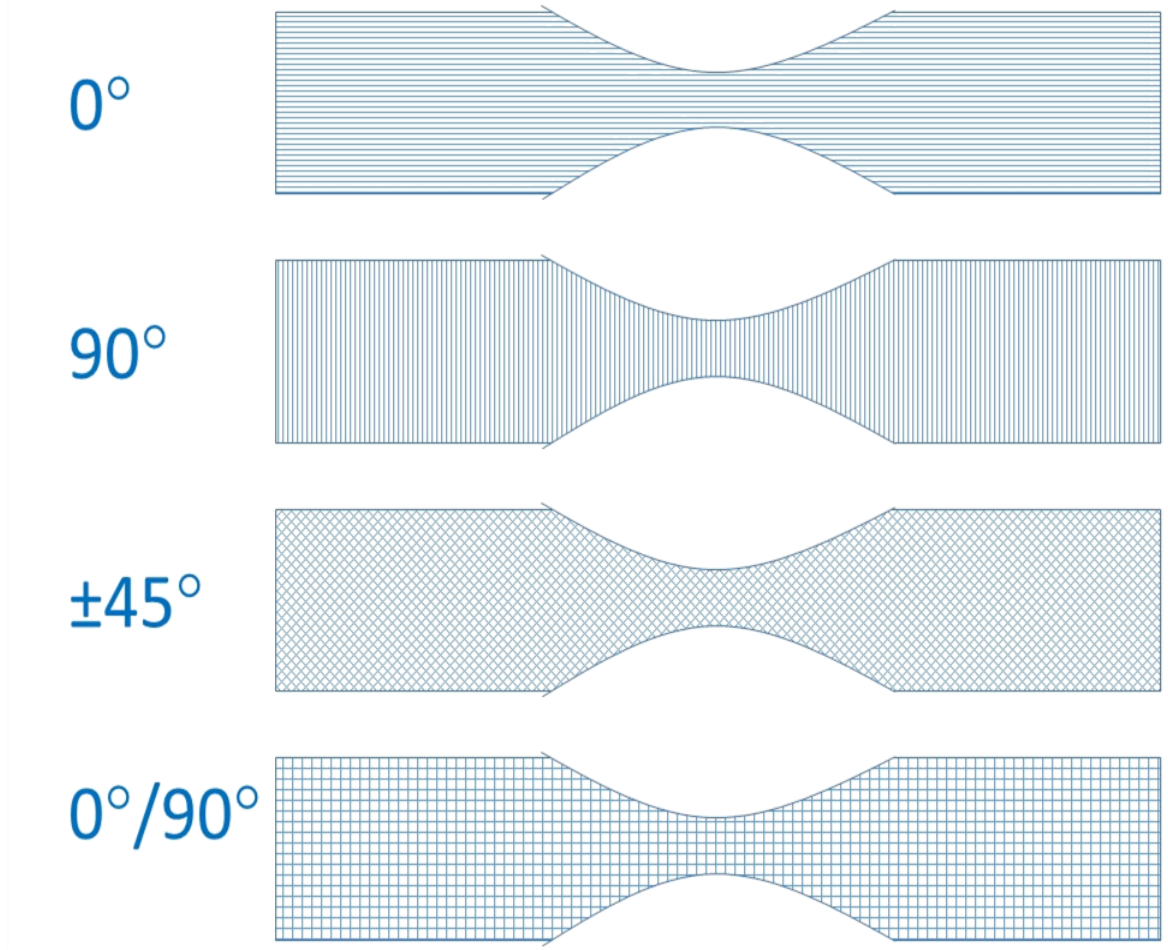

Bouzaglou, O. et al. *Polymers* 2023, **15**, 2280.

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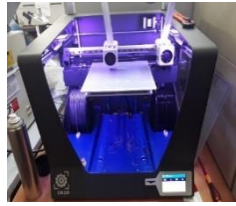

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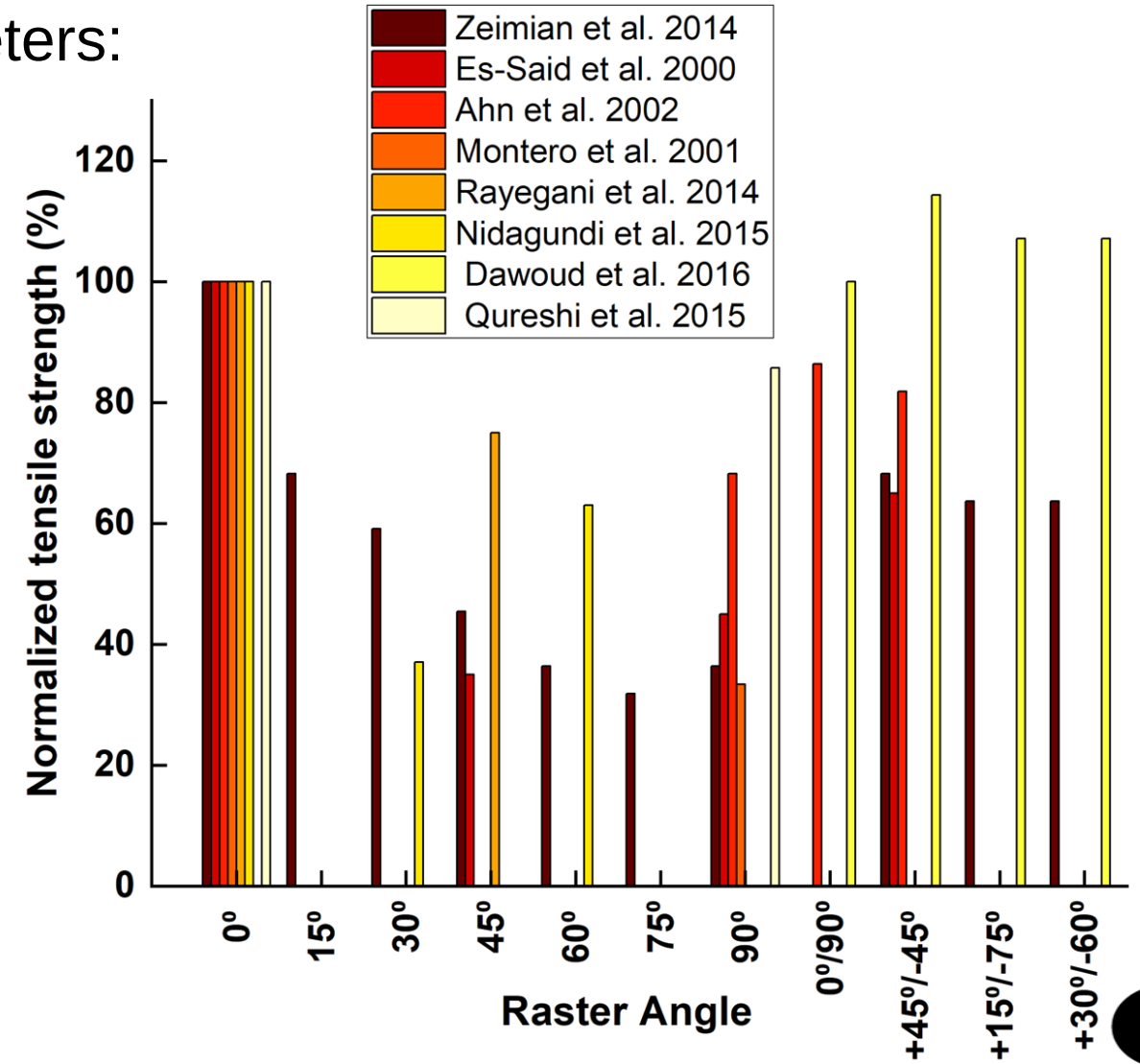

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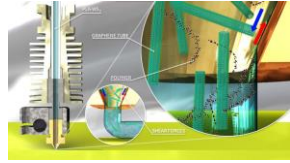
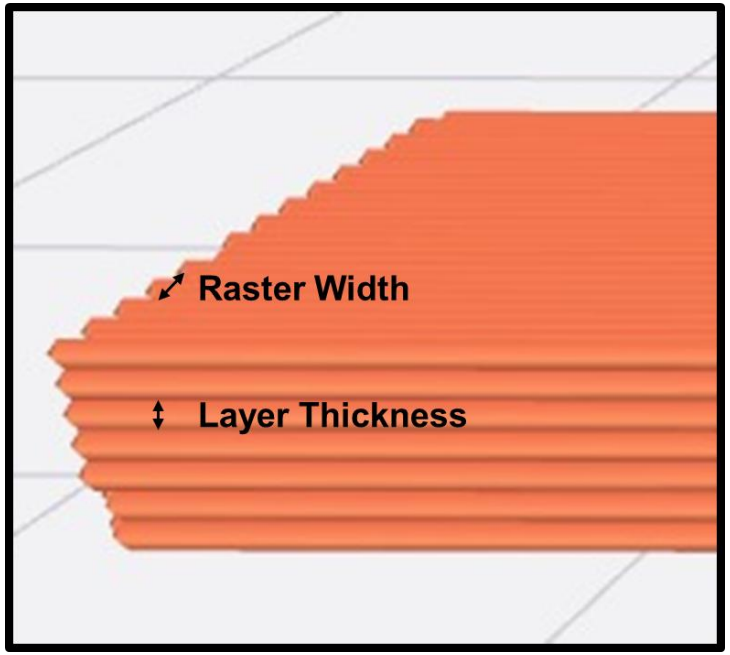
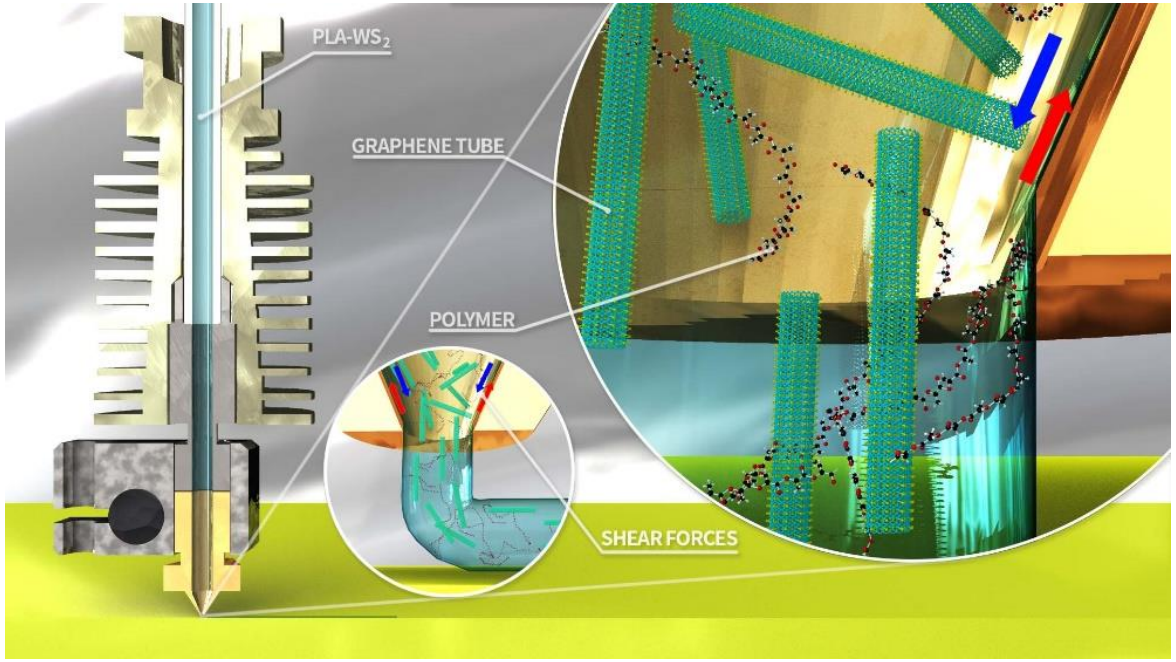


The effect of FFF on nanocomposites

- Product Quality Parameters:
  - Layer Thickness





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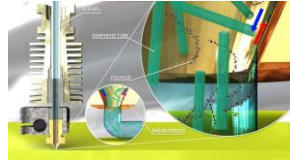

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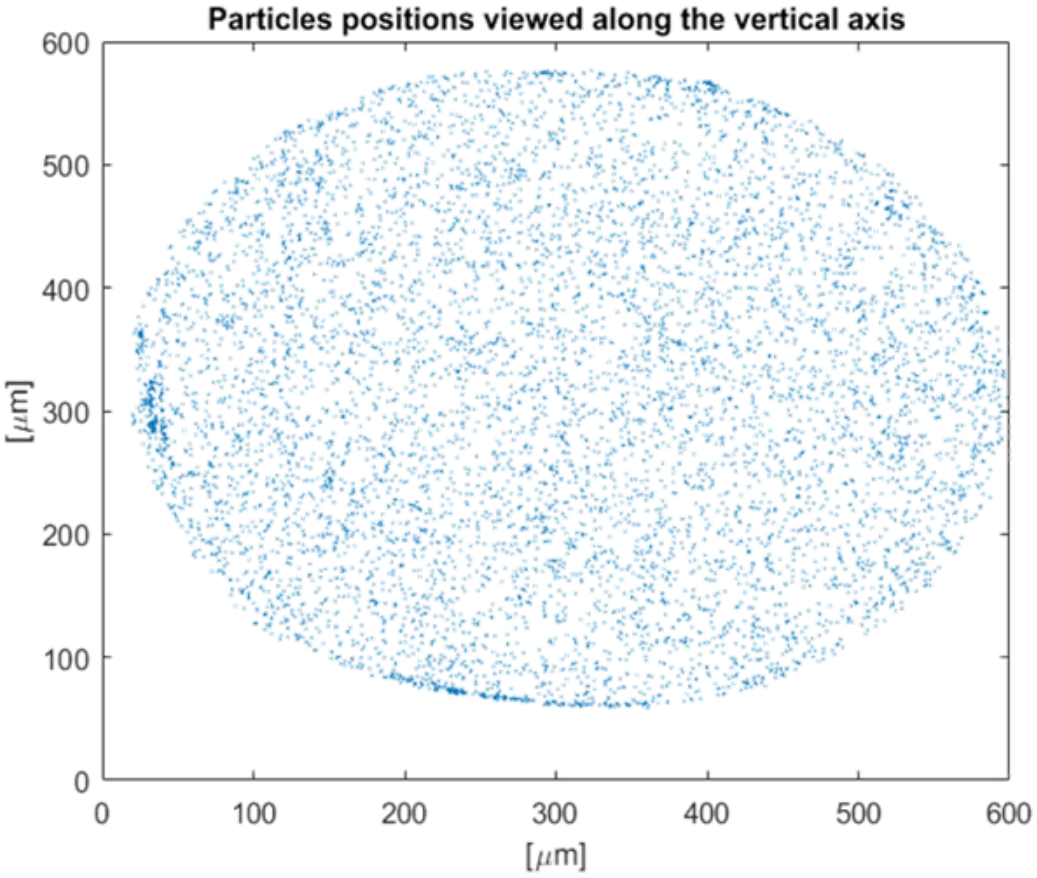

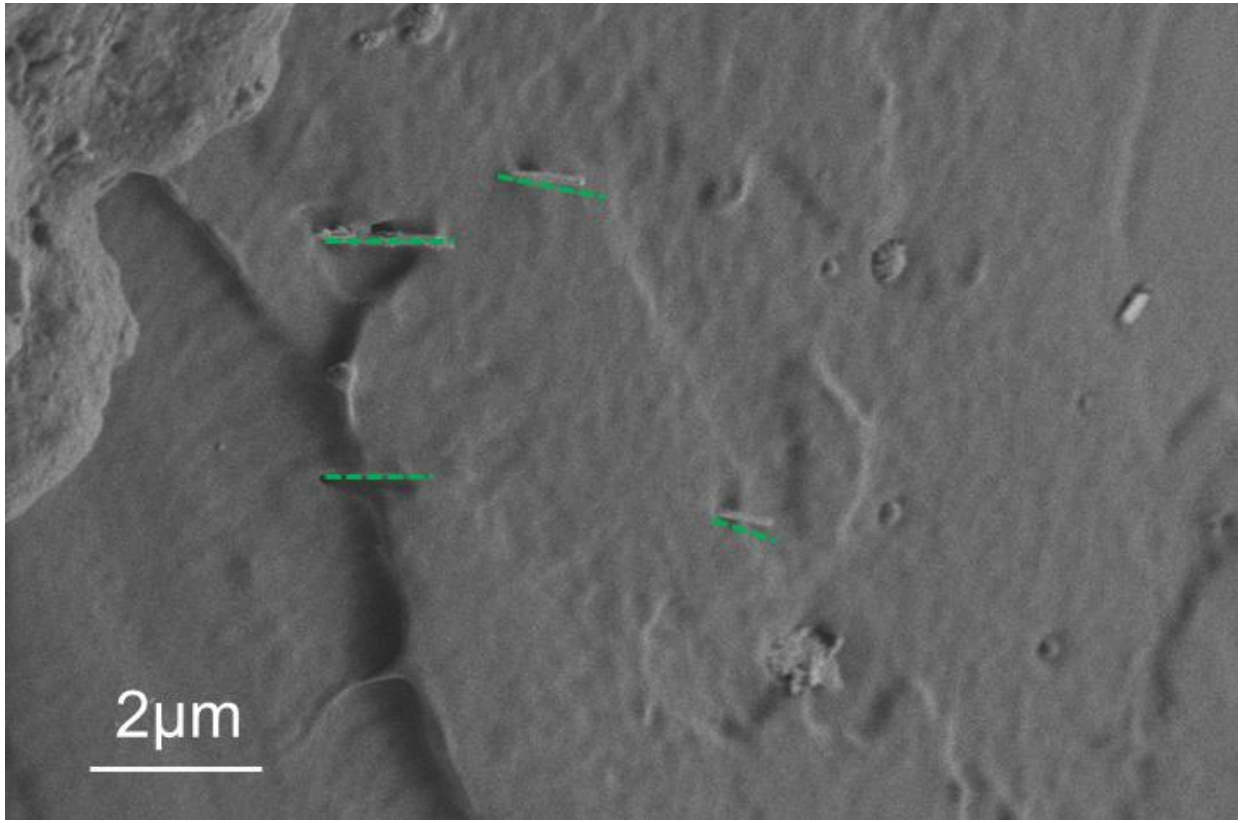

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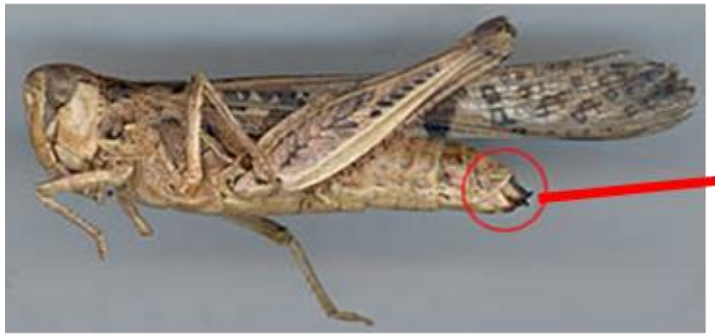
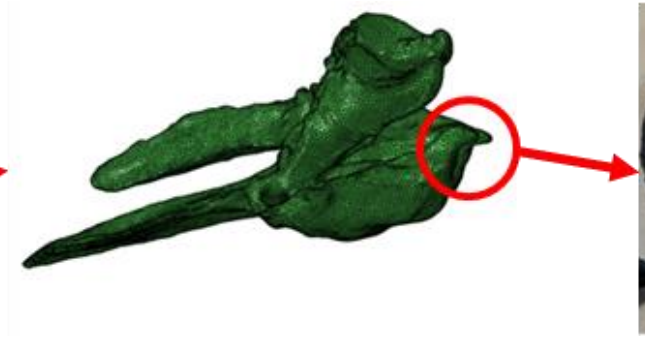
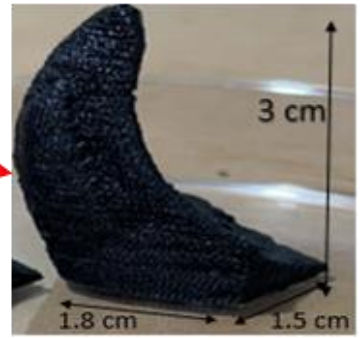
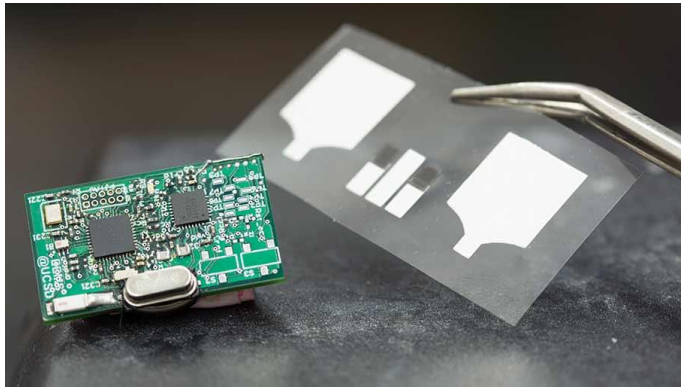
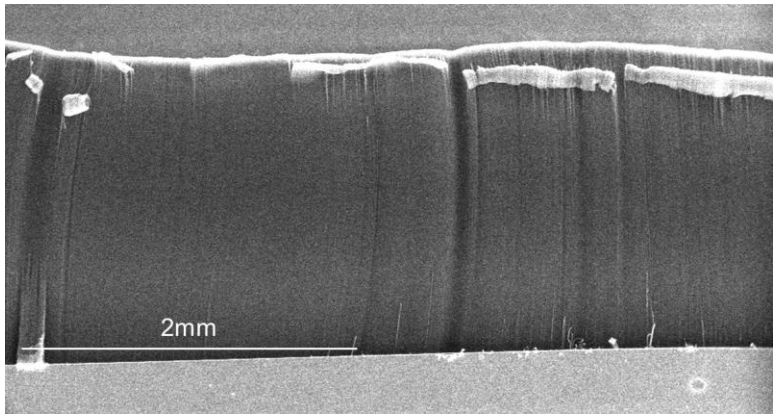
It’s not a bug











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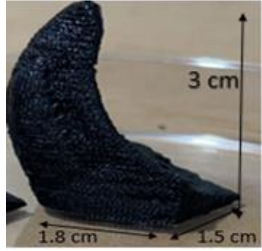
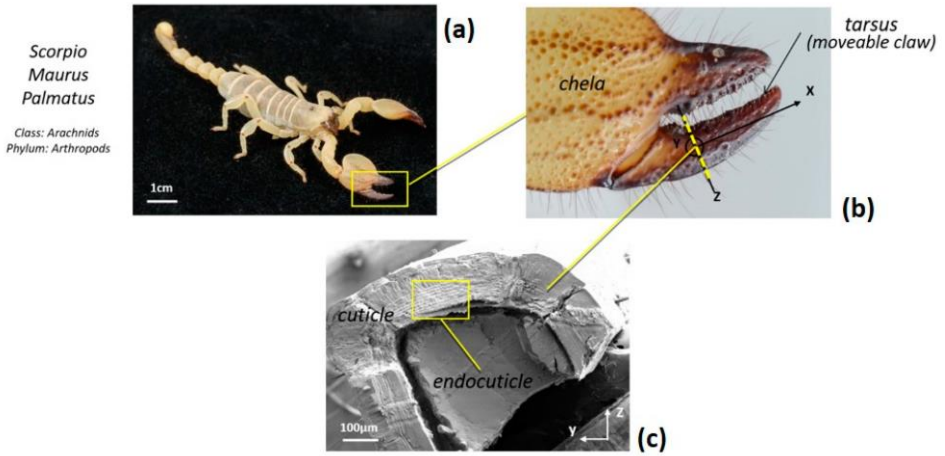
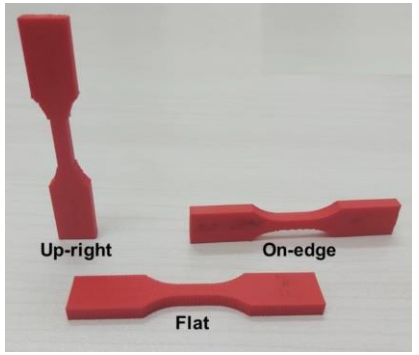
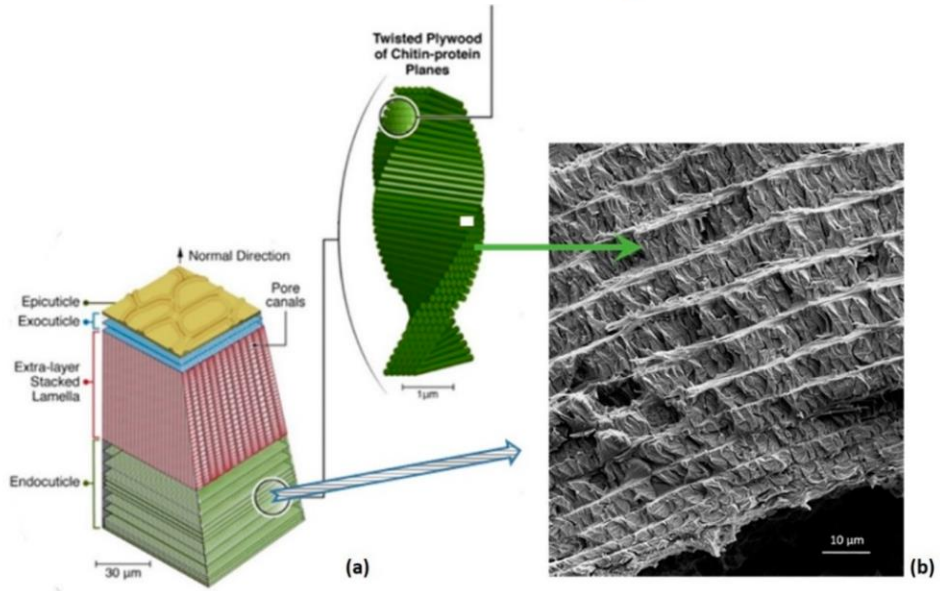
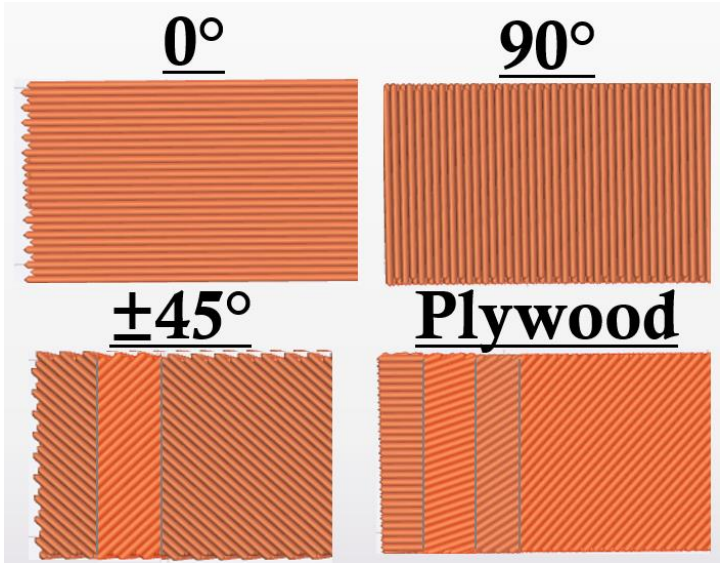
Induced anisotropy for bio-mimicry

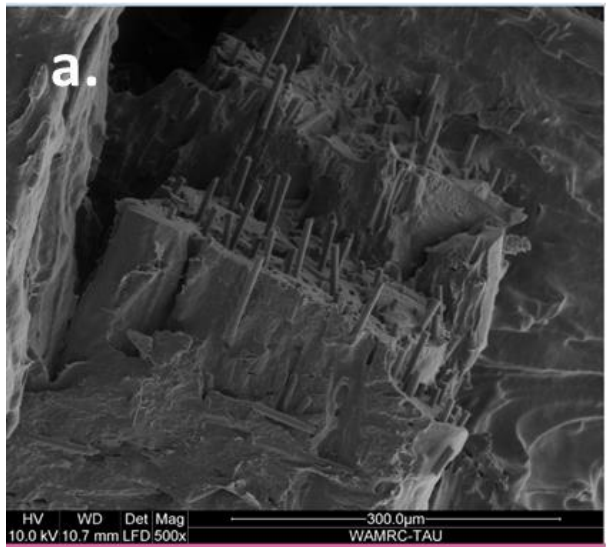












H.D. Wagner / Materials 2021, 14, 6855

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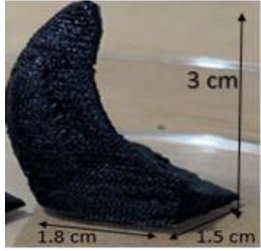

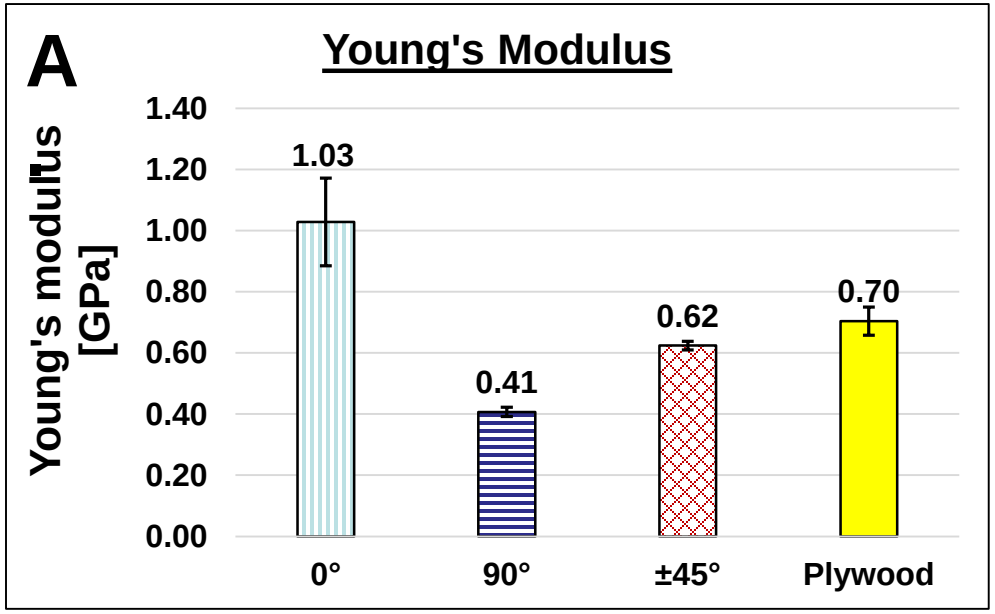

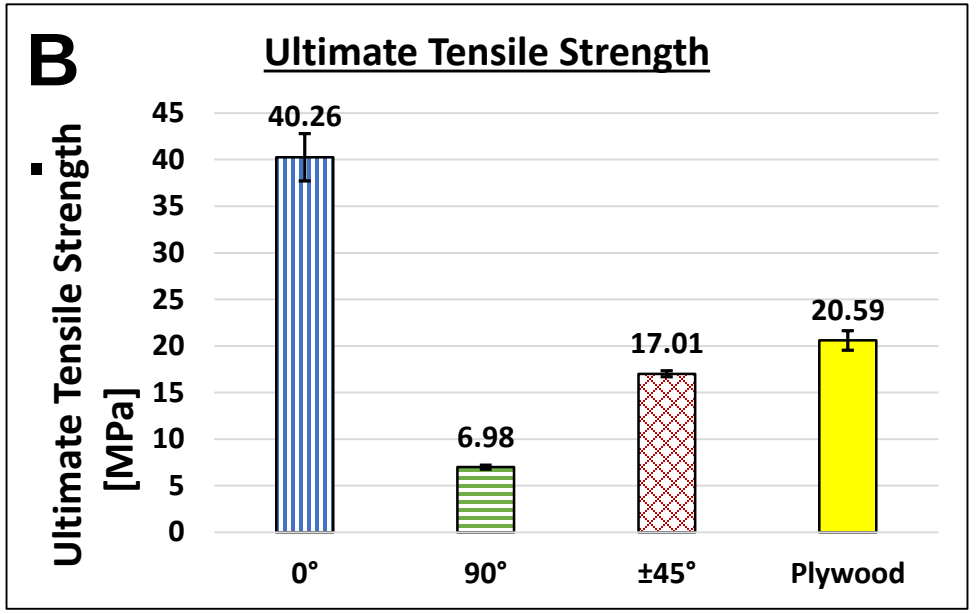

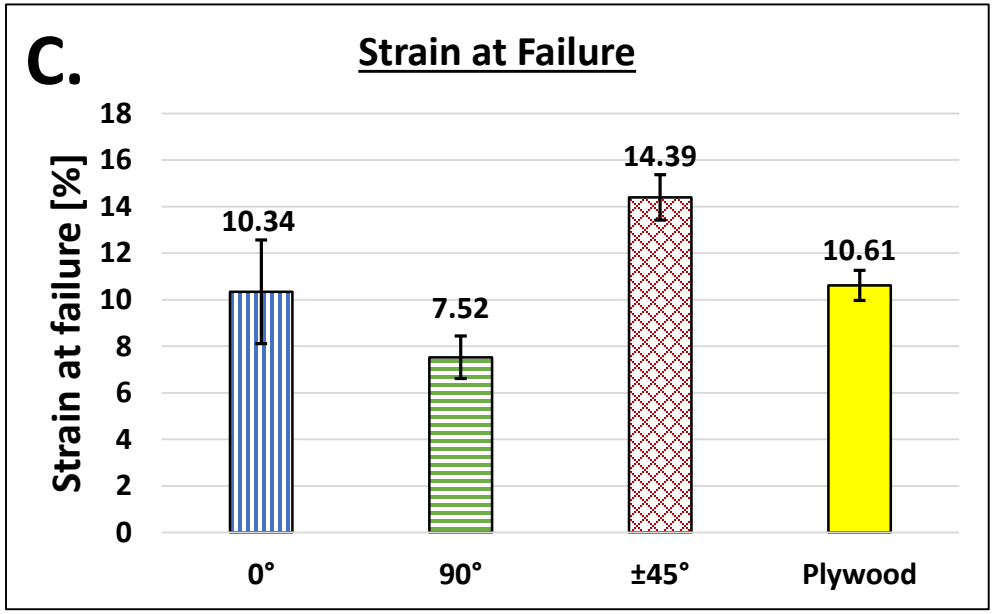

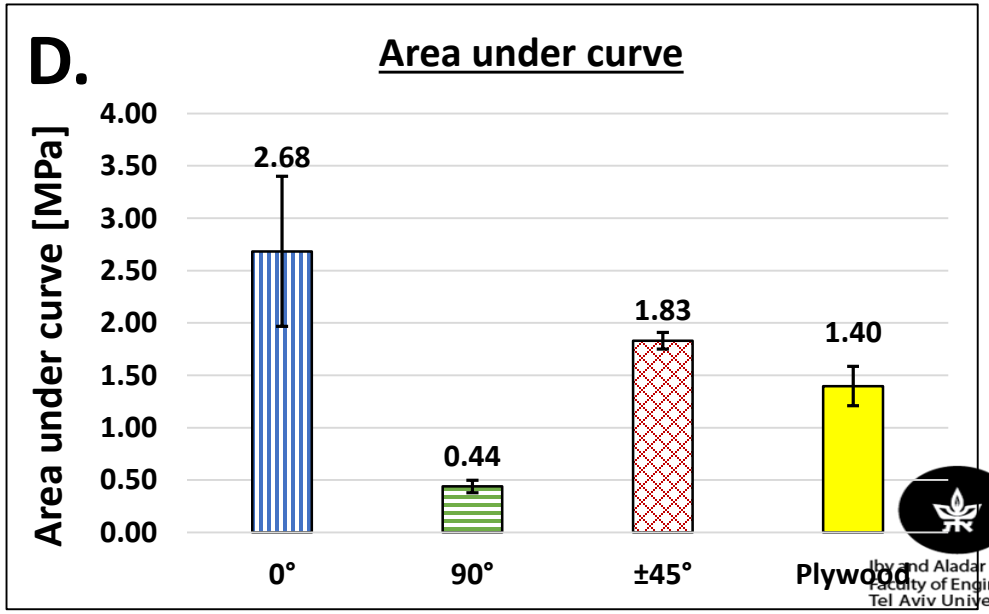

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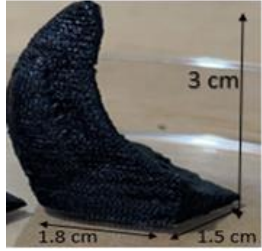

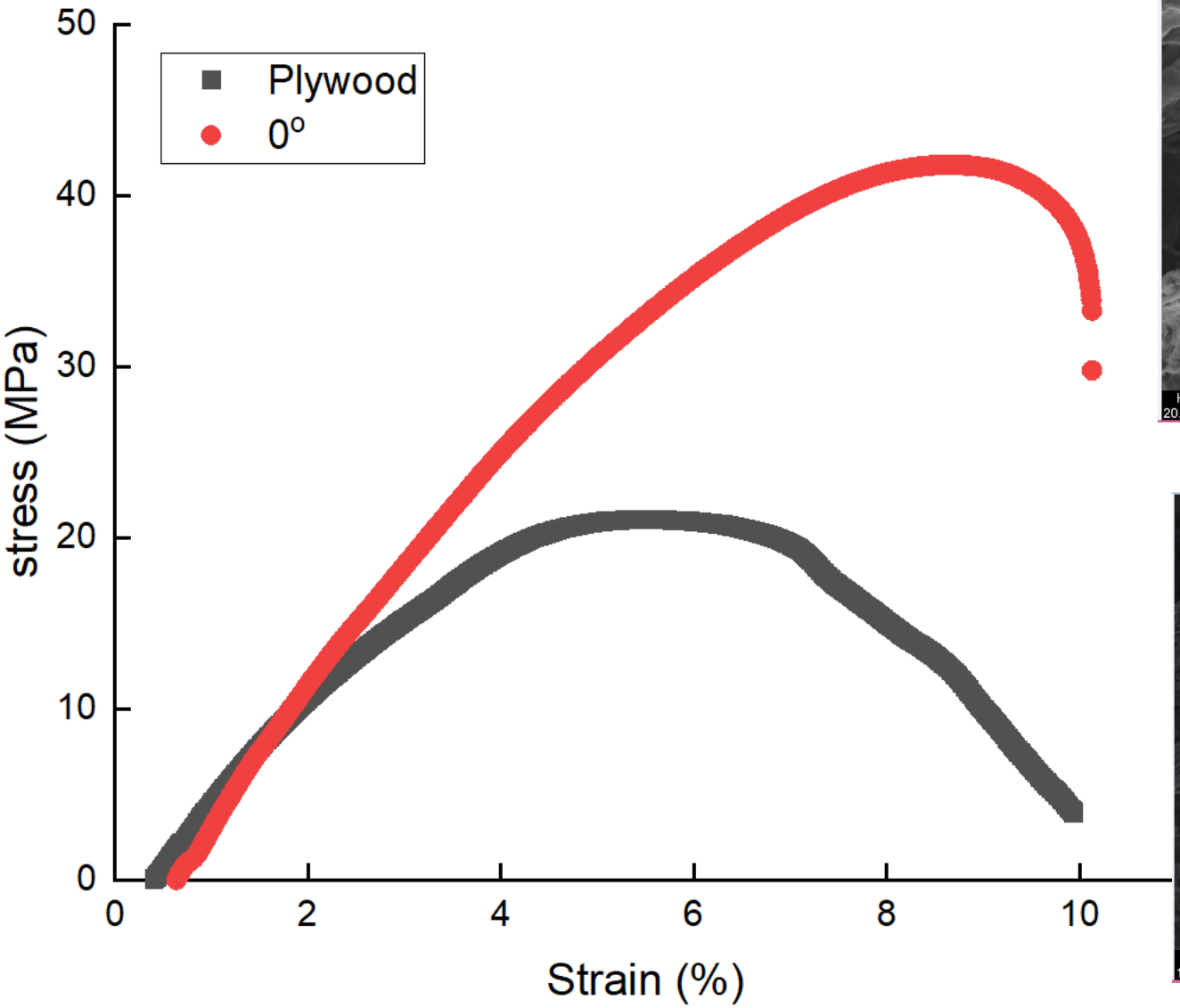

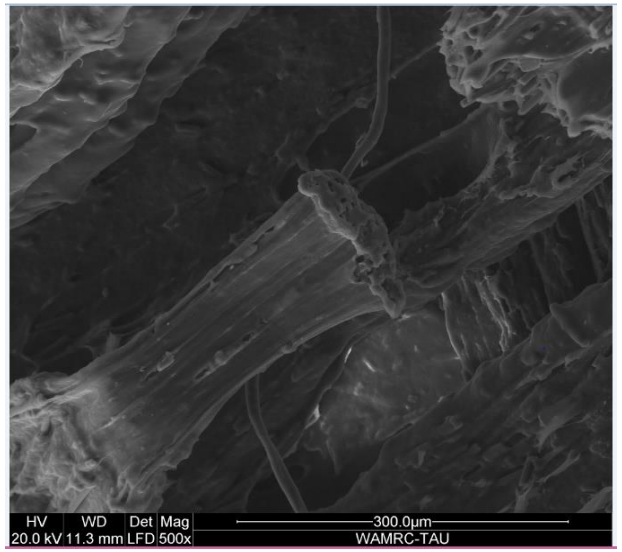

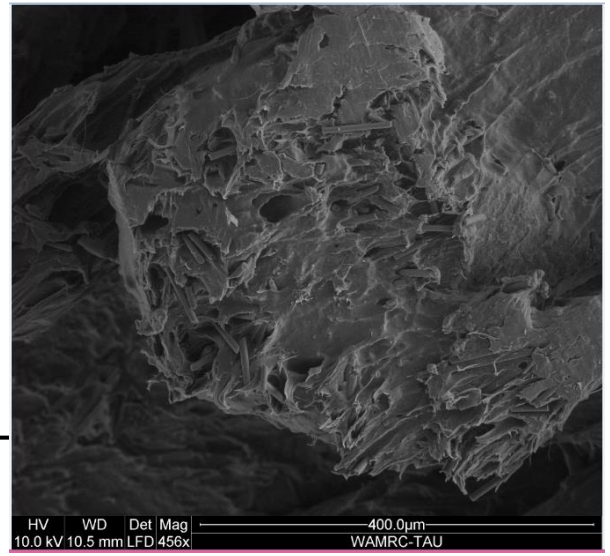

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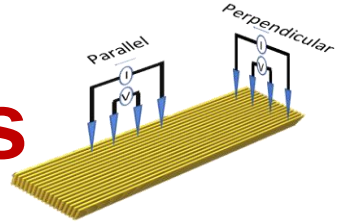
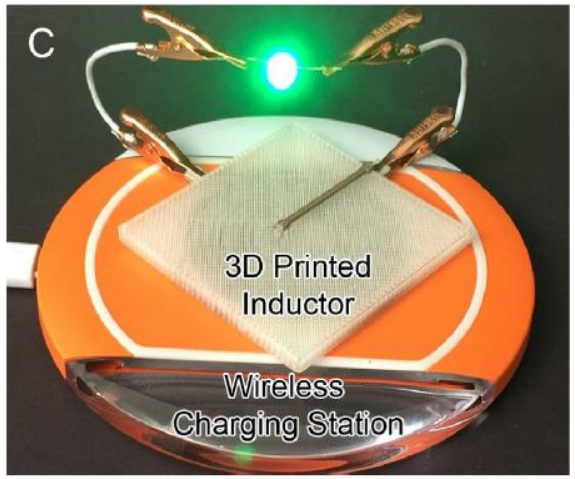
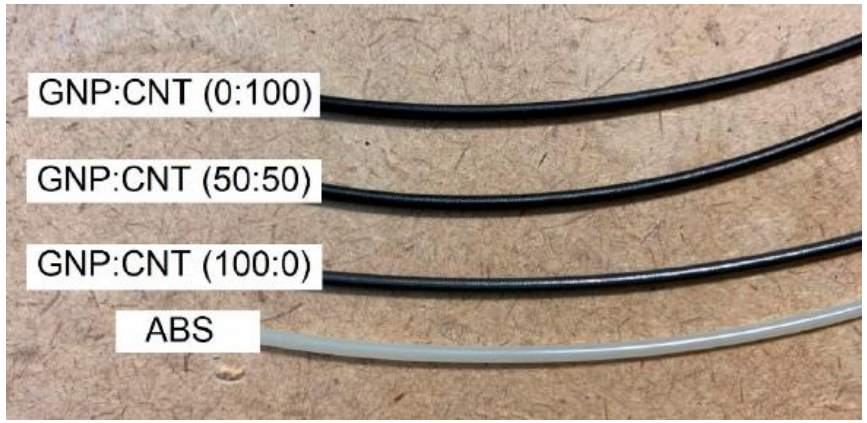
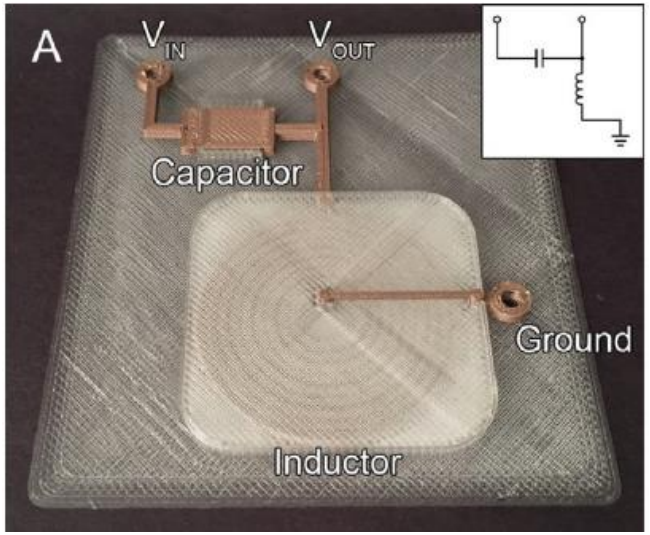
The need for 3D printable conductive polymers



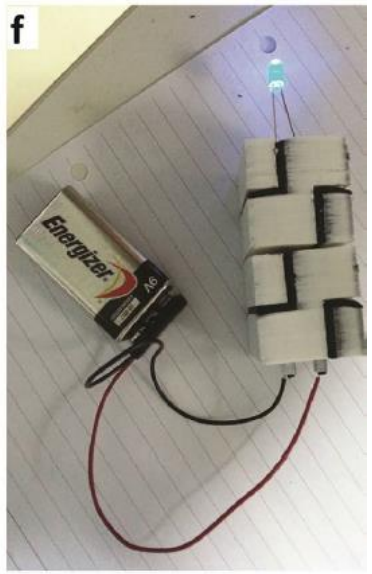




*S. Dul et al. Polymers **2020**, 12, 101; doi:10.3390/polym12010101*



P.F. Flowers et al. / Additive Manufacturing 18 (2017) 156–163



S.W. Kwok et al. / Applied Materials Today 9 (2017) 167–175

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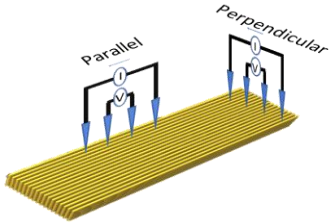
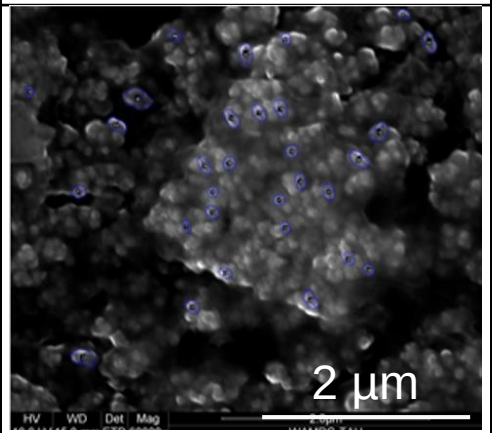
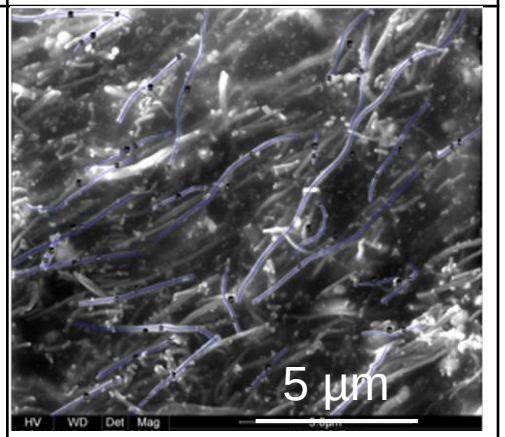


The system

		
The filler	Carbon Black (CB)	Graphene (Gn)
Wt. %	27%	12.7%
Aspect ratio	1.60±0.61	23.73±13.91≤
Visual		

Karutzero Y. et al. *in preparation*

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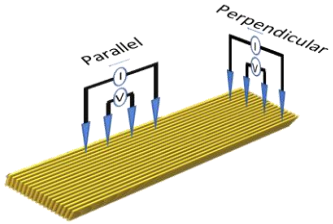
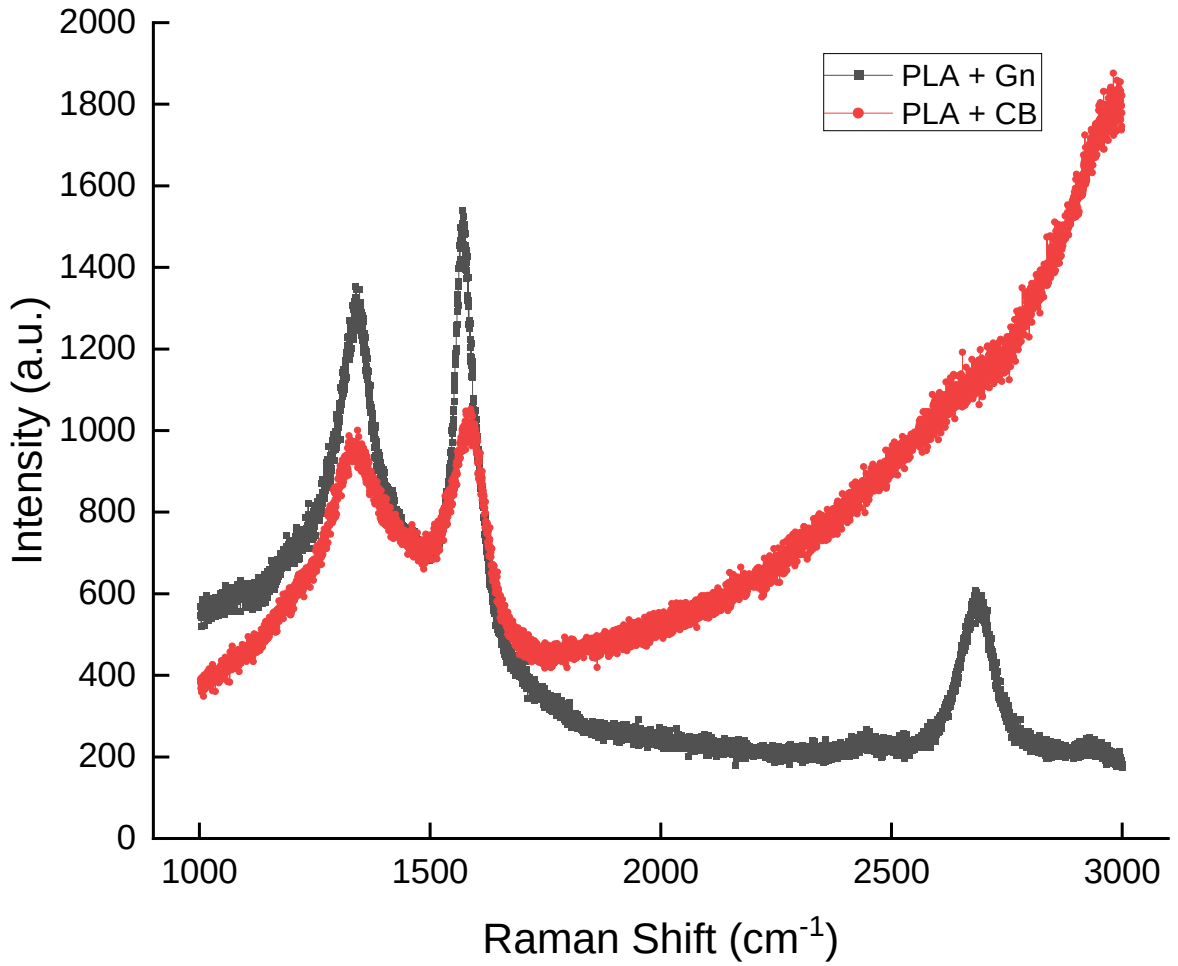
The system





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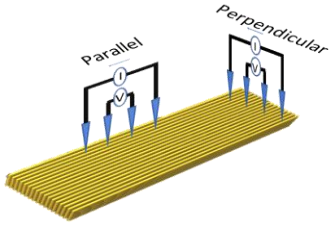
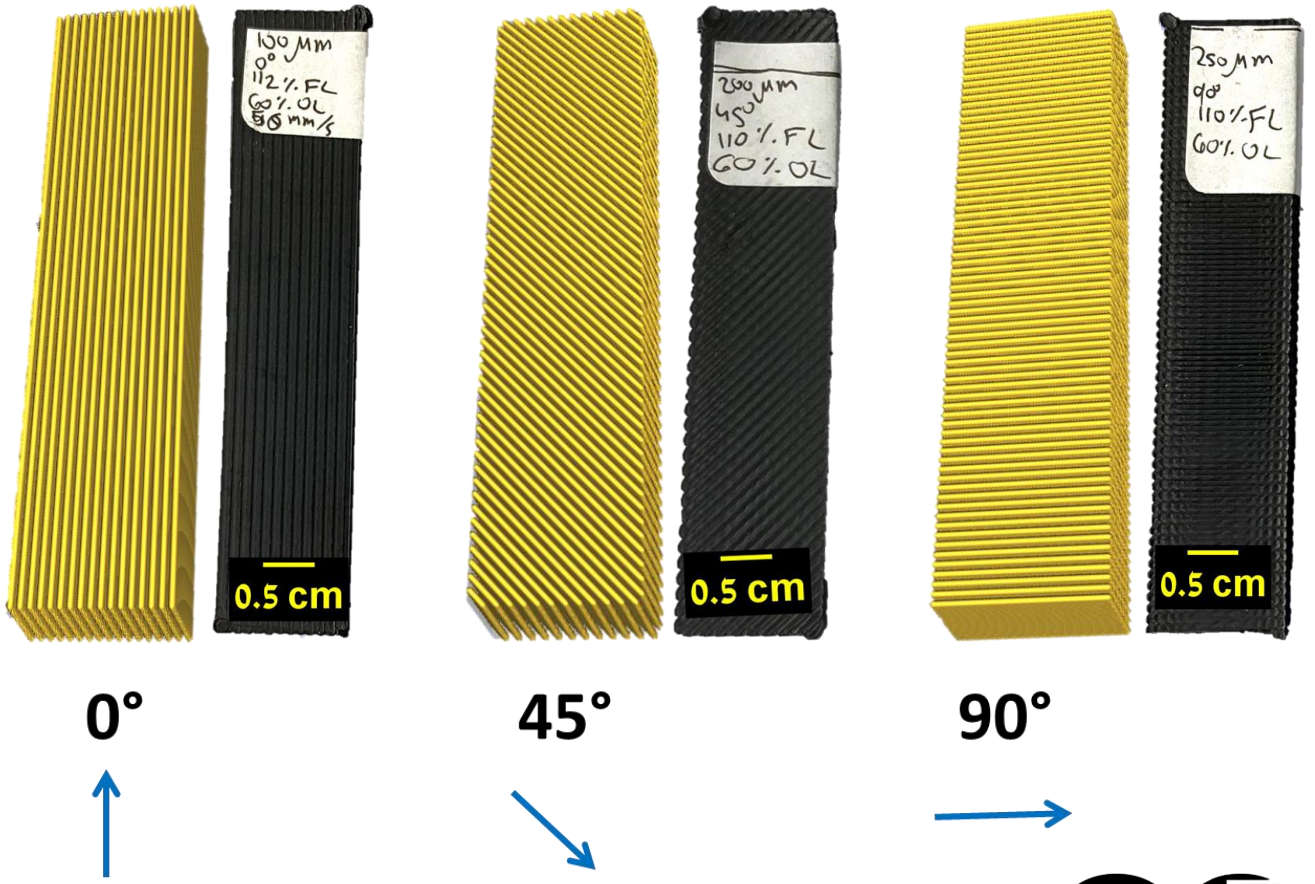


The system

- 3 different line directions: 0 °, 45 °, 90 °.
- 2 different layer heights: 100µm, 250µm



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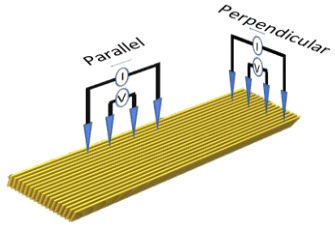
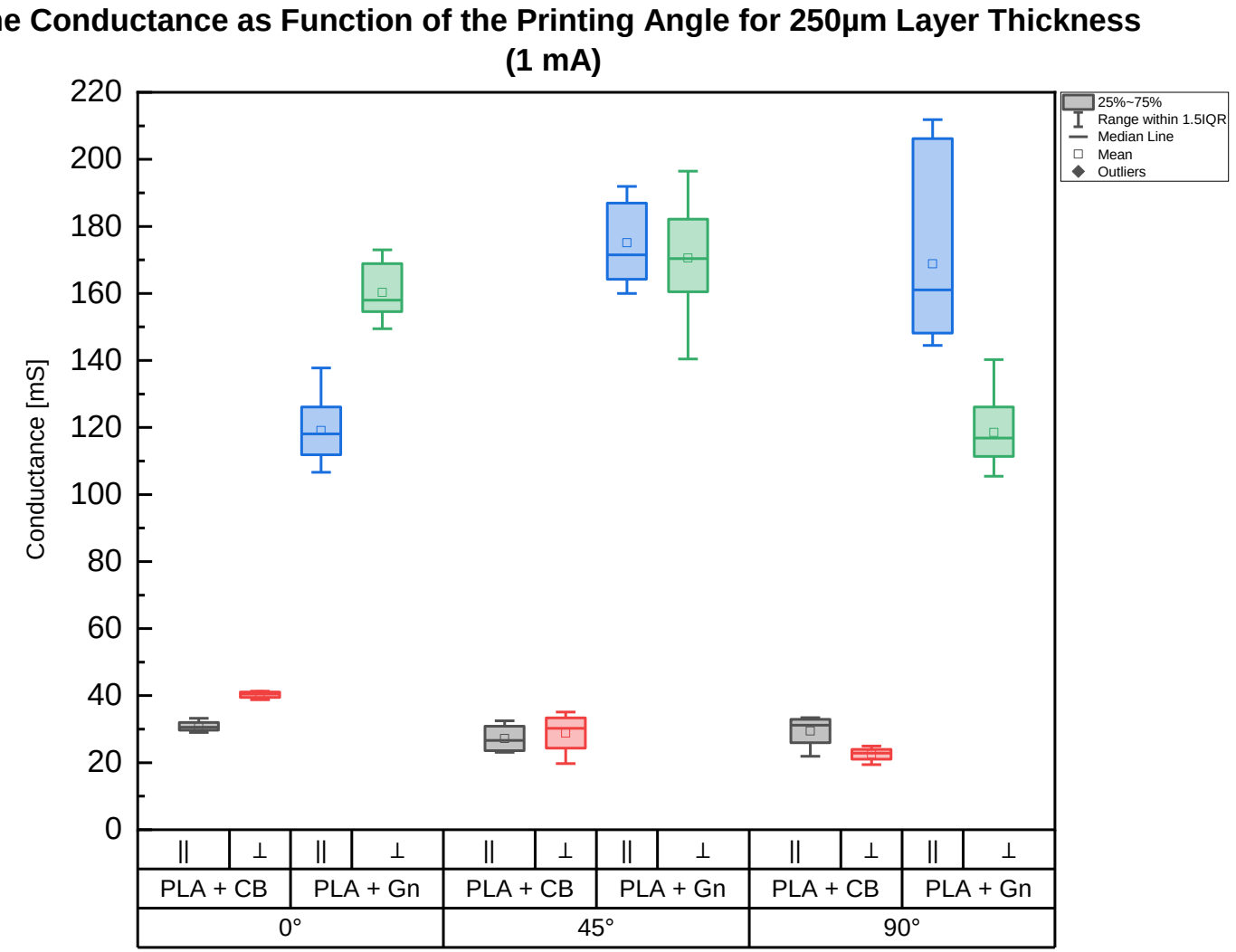
Anisotropy dependence on nanoparticle morphology





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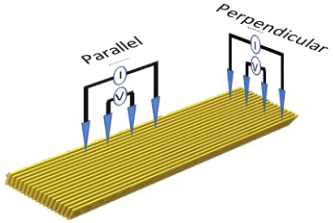
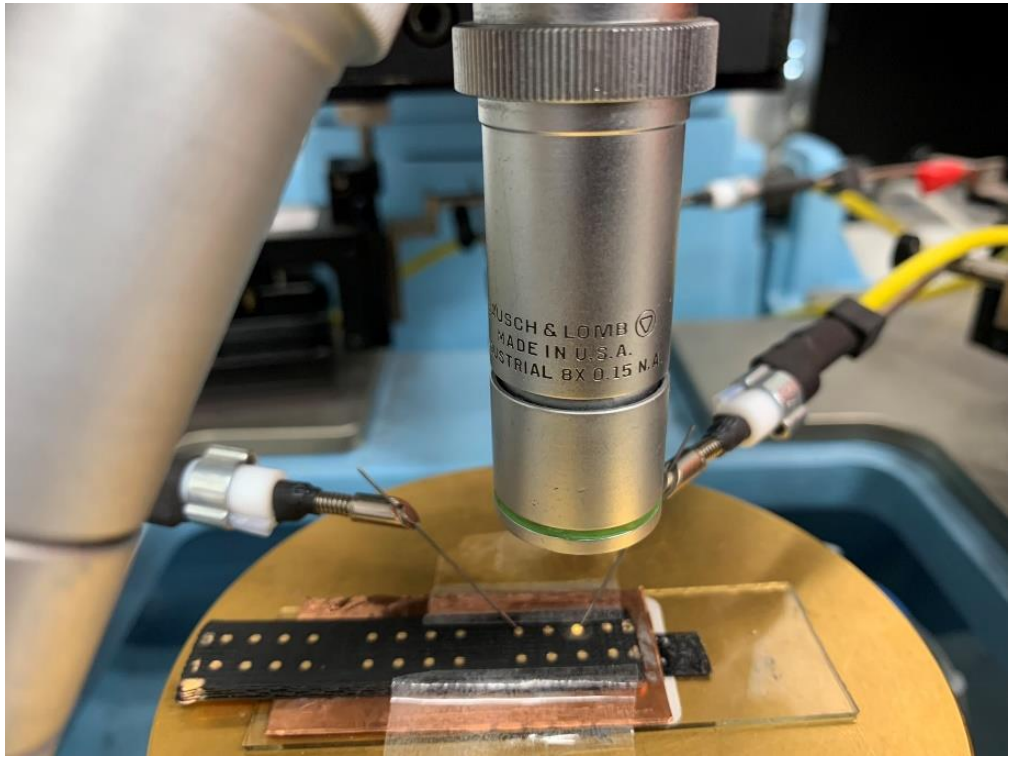
Anisotropy dependence on Printing Parameters





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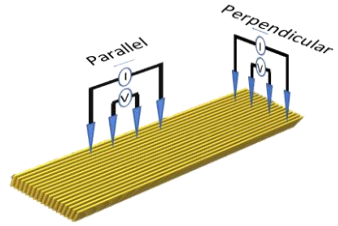
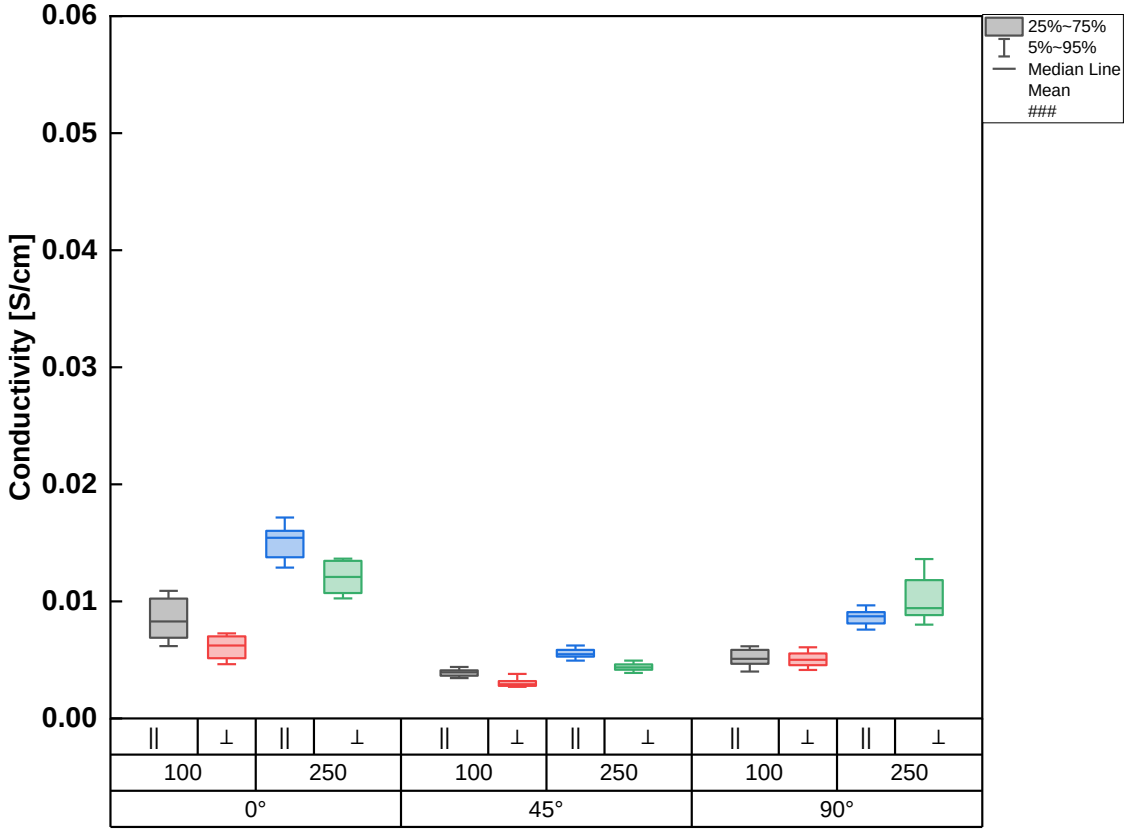
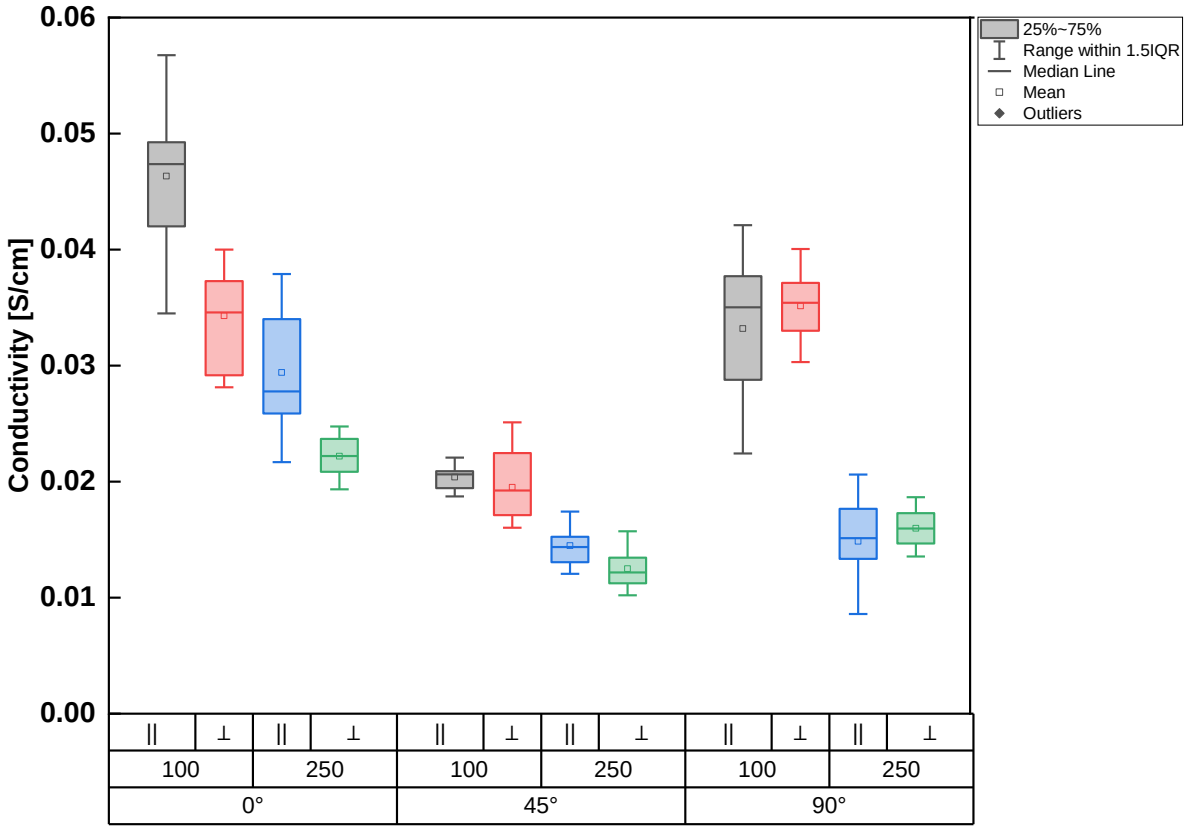
Surface conductivity affected by printing parameters



PLA/CB



PLA/Gn



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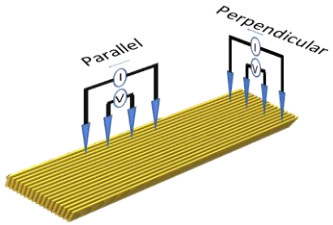
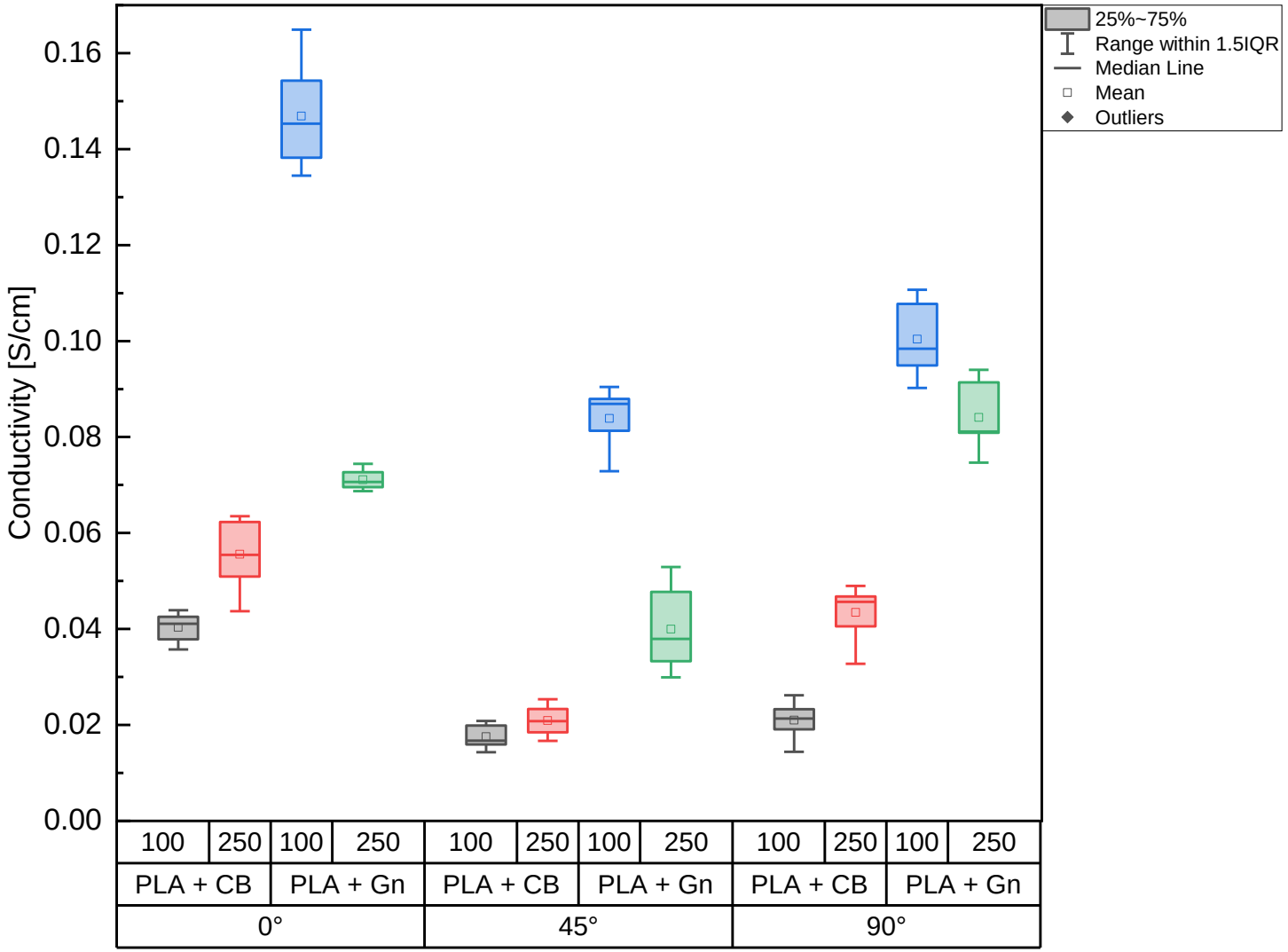
Volumetric conductivity affected by printing parameters





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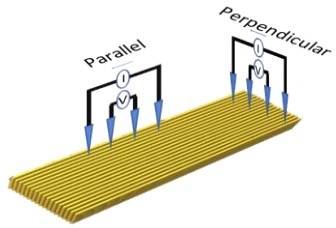
Morphologic explanation to electrical anisotropy



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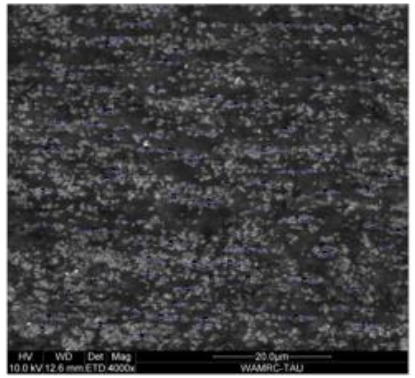	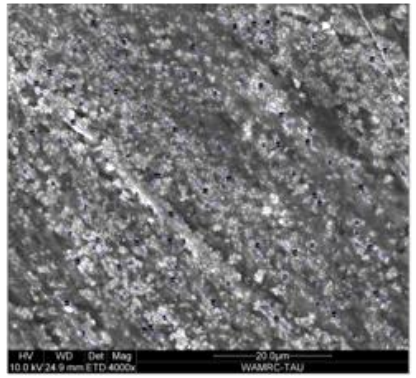	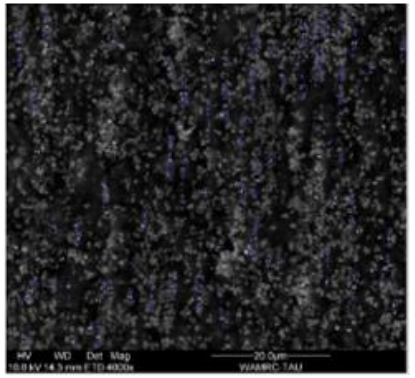	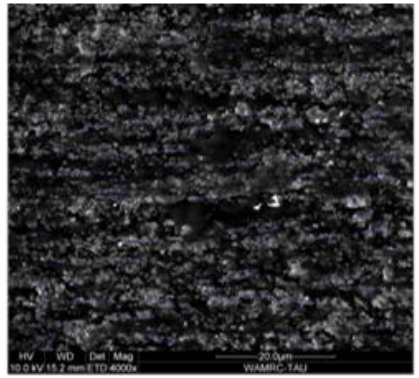
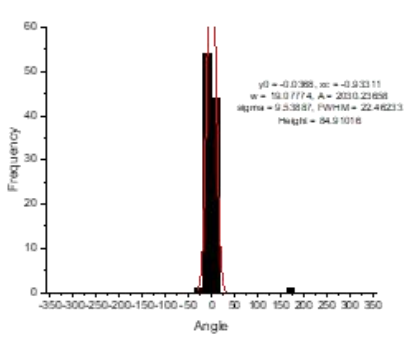	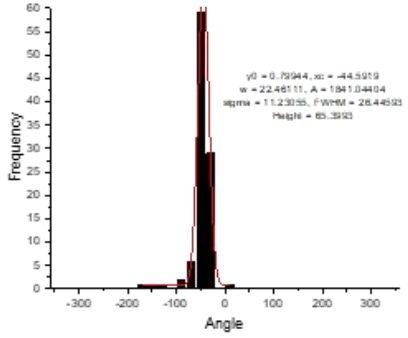	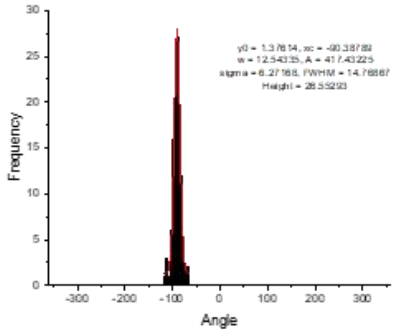	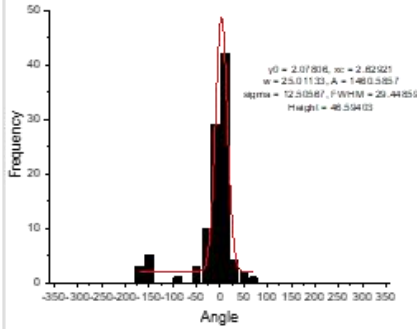
-0.93±9.54°	-44.59.39±11.23°	-90.39±6.27°	2.63±12.51°
+1.02%	-0.91%	+0.43%	+2.90%

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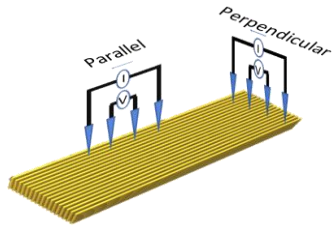
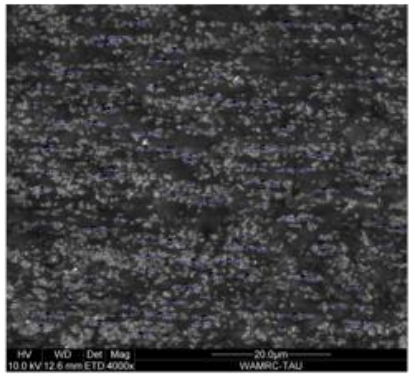
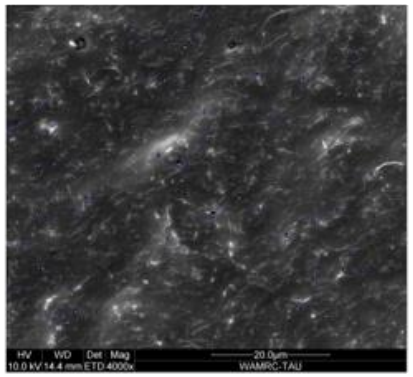
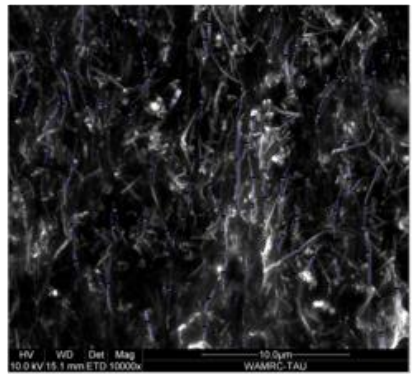
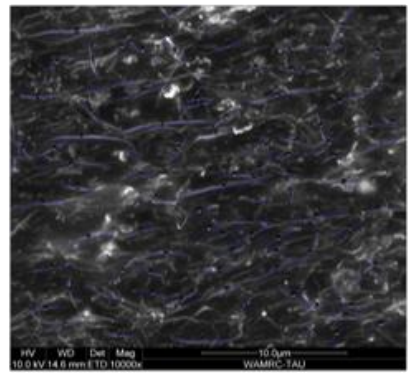
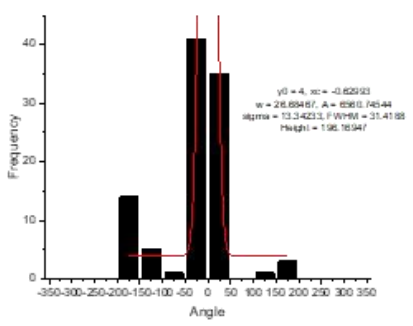
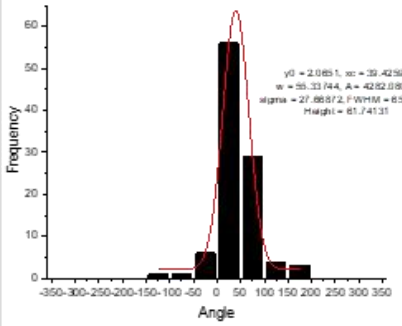
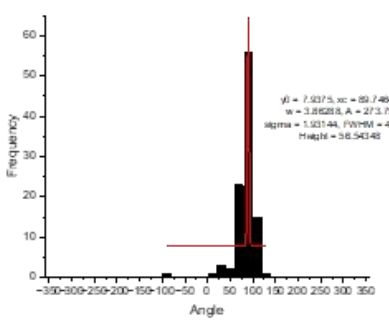
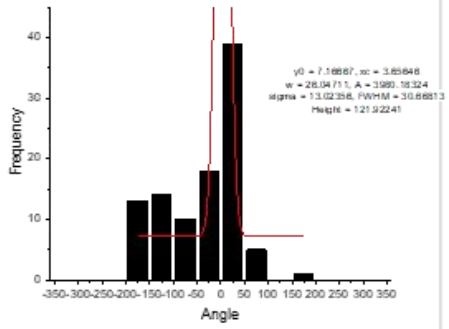
Morphologic explanation to electrical anisotropy



PLA_Gn_100_0	PLA_Gn_250_45	PLA_Gn_100_90	PLA_Gn_250_0
			
			
-0.63±13.34°	39.43±27.67°	89.75±1.93°	3.66±13.02°
+0.69%	-6.14%	-0.28%	+4.03%

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Conclusions

- FFF is a highly versatile fabrication technique, capable of inducing anisotropy.
  - Mechanical properties of FFF fabricated materials somewhat resemble those of micro-composites – even in pure materials.

- FFF of nanocomposites affects the dispersion and alignment of the nanoparticles within the matrix – allowing another degree of control in the design.

- The effect of FFF on the nanoparticles in the nanocomposite depends on the morphology of the nanoparticles.

And we haven’t discussed hybrids yet

Acknowledgments

- My Group:
  - Lev Rovinsky
  - Raz Samira
  - Yael Karutzero
  - Ofek Golan
  - Keren Sobol
  - Nicole Gorodeski

- Past students
  - Andrey Bannich
  - Hila Shalom
  - Shira Hadar
  - Moran Ben-Basat
  - Ouri Buzaglo
  - Lior Barginski
  - Omri Shulman

- Collaborators:
  - Prof. Reshef Tenne (WIS)
  - Prof. Daniel Nessim (BIU)
  - Dr. Chris Arnush (BGU)
  - Prof. Dov Sherman (TAU)
  - Dr. Irina Guzman (NRC Soreq)
  - Prof. Matthew Grayson (NU)

- Fundings:

רשות החדשנות
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