

Industrial-graded epoxy nanocomposites with mechanically dispersed multi-walled carbon nanotubes: static properties

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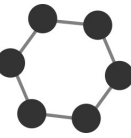
6 Institute for Advanced Study, Princeton, NJ, USA

Nano Rome, 20-23 September
2016 Innovation
Conference & Exhibition



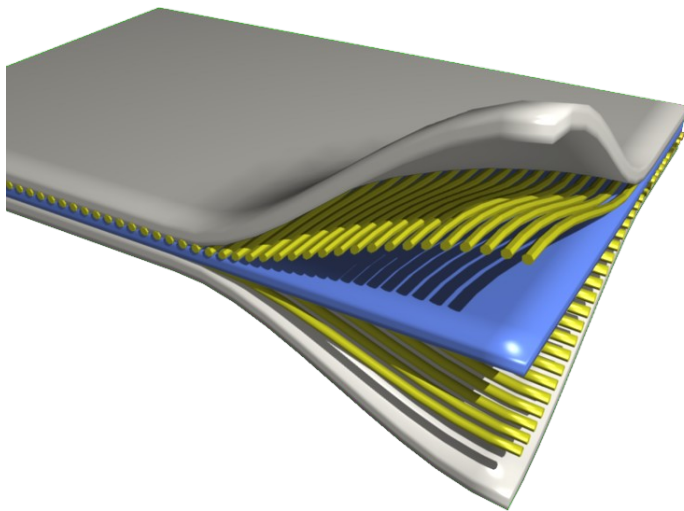
Why nanocomposites?





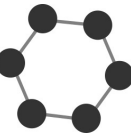
Why nanocomposites?

	Typical carbon fiber properties	Typical matrix properties
Tensile Strength	3900 - 4,900 MPa	40 - 70 MPa
Tensile Modulus	230 - 400 GPa	2 - 3 GPa
Elongation at break	~ 2 %	3 - 6 %

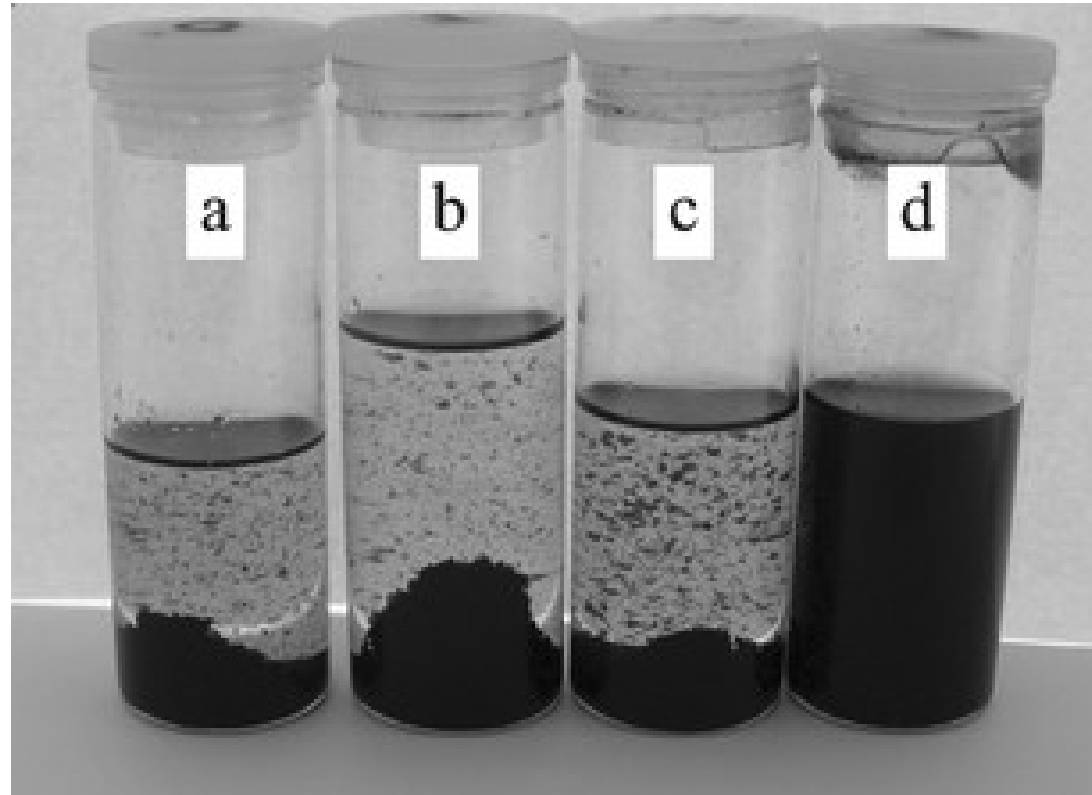


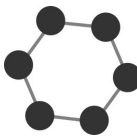


The role of nanoparticles



Efficient dispersion is the key!

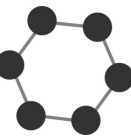




Dispersion techniques

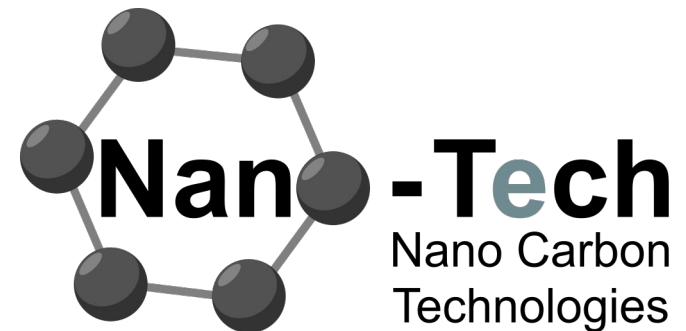
Instruments	Principle of Operation	Adantages	Disavantages
Stirrers (oveheads, magnetic,...)	Low shear rate	Low Cost, Easy to scale up	Low quality dispersion
Mills (3 roll mills, ball mills,...)	High-shear rate / High-energy impacts	Useful for larger batches	Slow, Inefficient, Low quality dispersion
High Pressure homogenizer (microfluidics,..)	High-shear rate	High dispersion efficiency, Easy to scale up	Expensive, Easy to clog
Ultrasonication (bath, probe,...)	Ultrasonic waves	Cost effective for small batches, Good dispersions	Damage to the nanoparticles, Difficult to scale

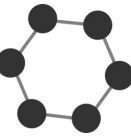
Nano-Tech SpA



“The best materials for the hardest challenges”

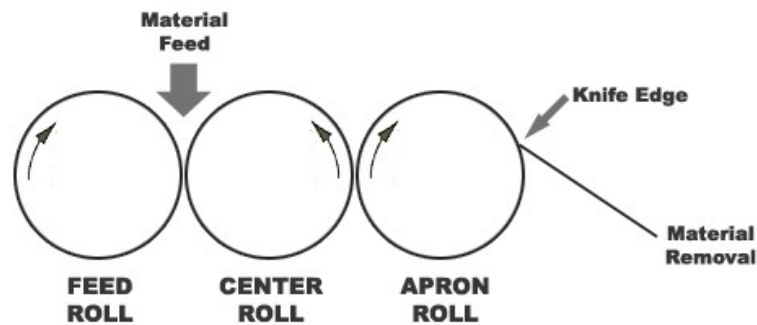
Nano-Tech is an innovative company specializing in nanotechnology applications. We deliver advanced material solutions for industrial leaders who want to grow and go beyond the limits of today's technologies. Our unique expertise set us apart from competitors.





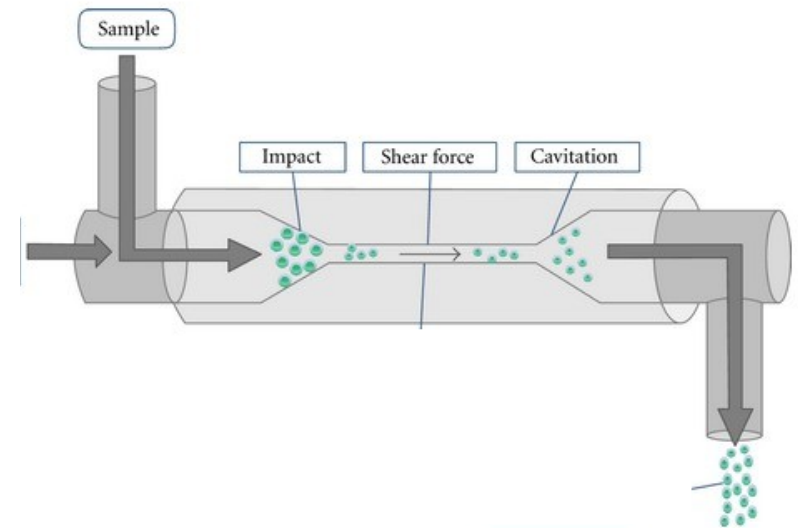
Our Approach

To combine the advantages of multiple techniques in a single device

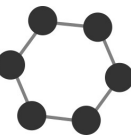


**Mechanical
milling**

+

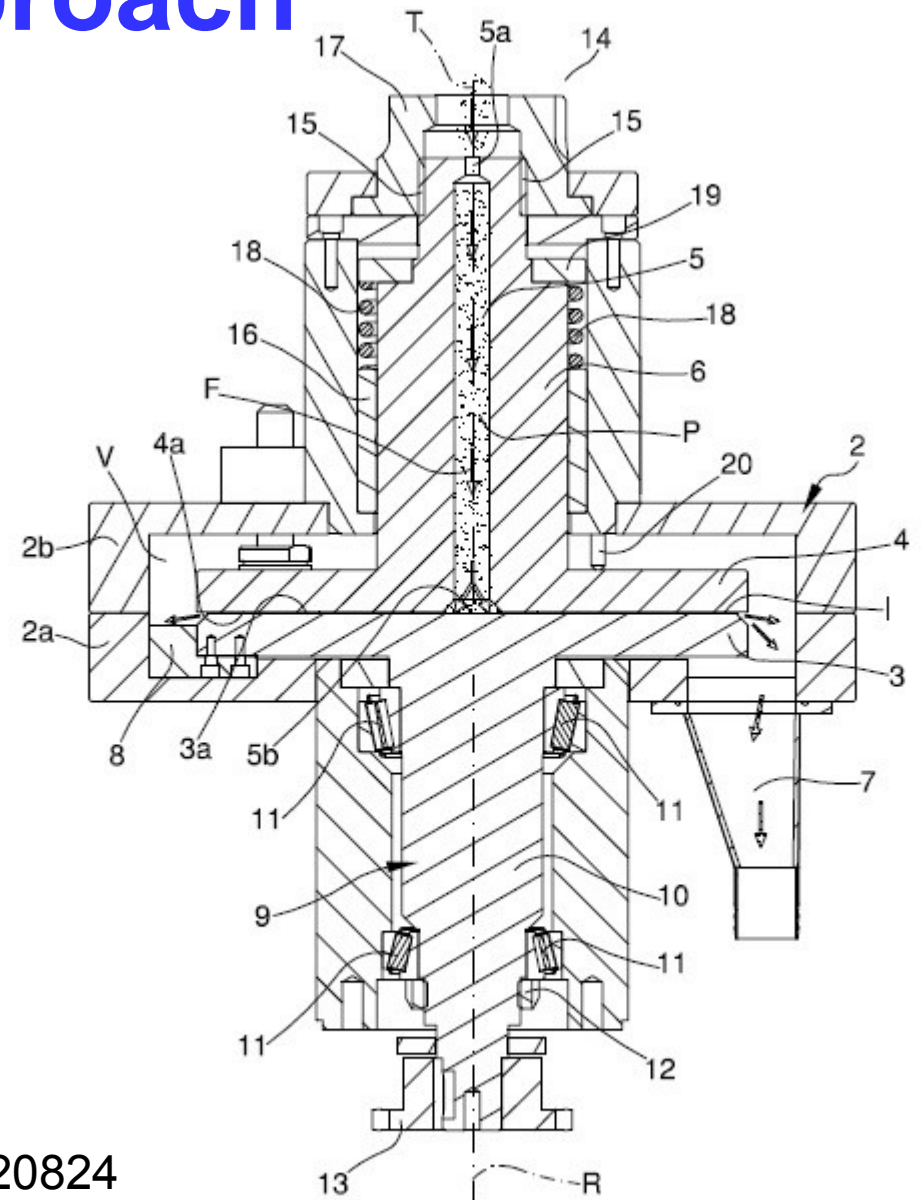


**High-pressure
homogenizer**



Our Approach

The fluid is forced to pass through different surfaces in relative motion with a gap between them from 5 mm to 5 μm , creating therefore a complex 3D motion field.



Patented dispersion technology - patent n. 0001420824

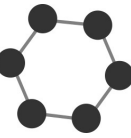




Traction test

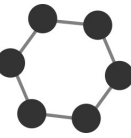


Test in accordance with
ASTM D638



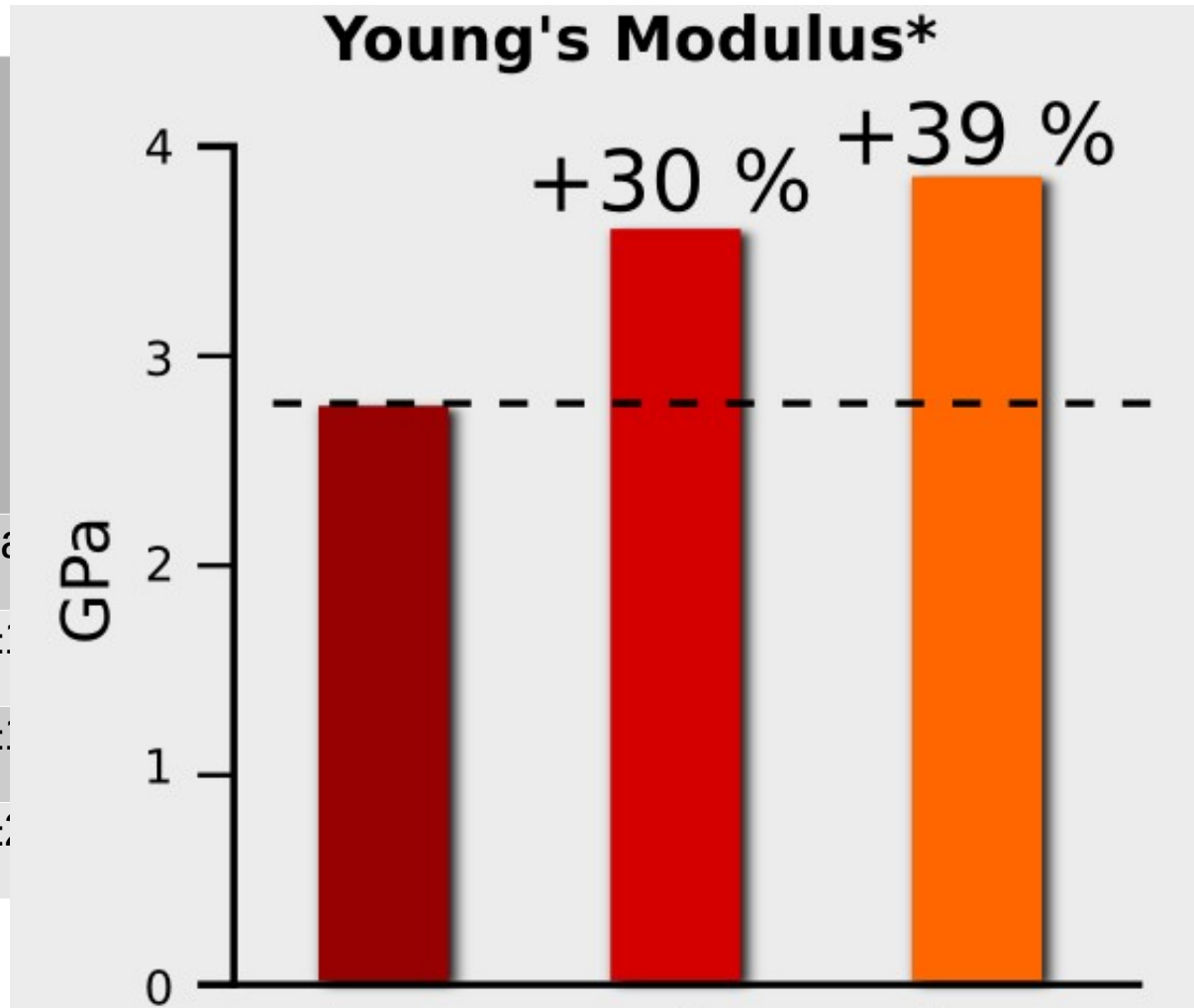
Traction test

CNTs	σ		ϵ Y.P.		ϵ at break		Young's modulus	
phr	MPa	p	%	p	%	p	GPa	p
0.00%	73.9±1.3		4.2±0.1		4.8±0.2		3.3±0.4	
0.10%	73.9±1.7	ns	4.1±0.6	ns	4.7±1.3	ns	3.6±0.4	ns
0.20%	72.0±2.3	ns	3.2±0.2	***	3.3±0.3	***	3.9±0.2	*

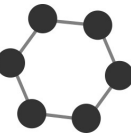


Traction test

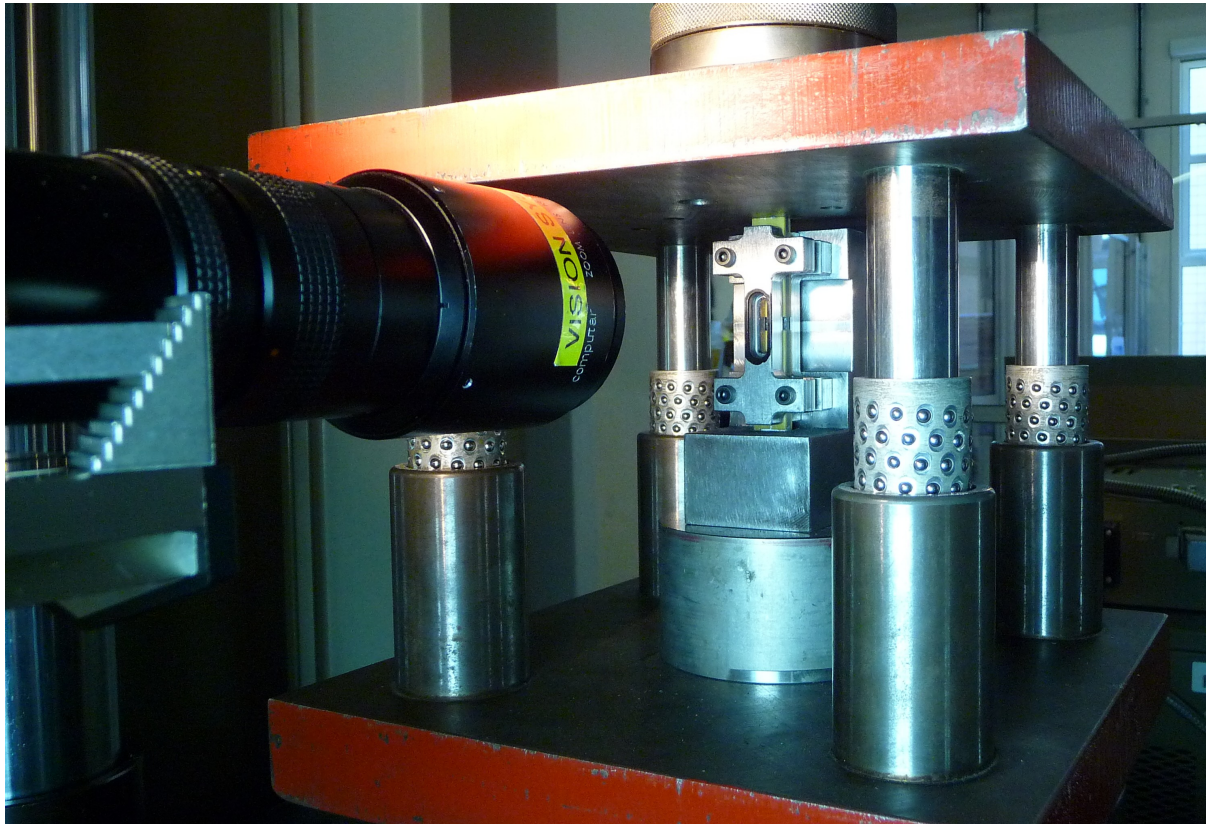
CNTs	σ
phr	MPa
0.00%	73.9±
0.10%	73.9±
0.20%	72.0±



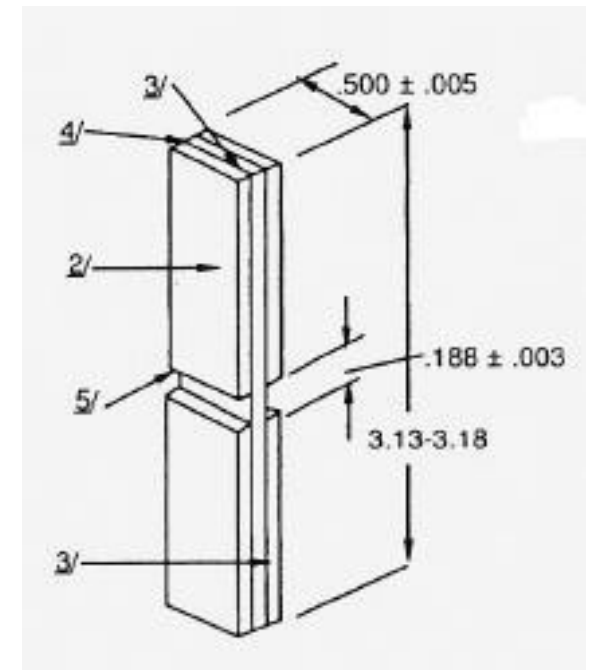
Young's Modulus	p
3±0.4	
6±0.4	ns
9±0.2	*

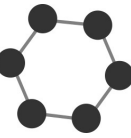


Compression test



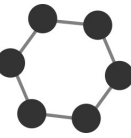
Test in accordance with
ASTM D695 M





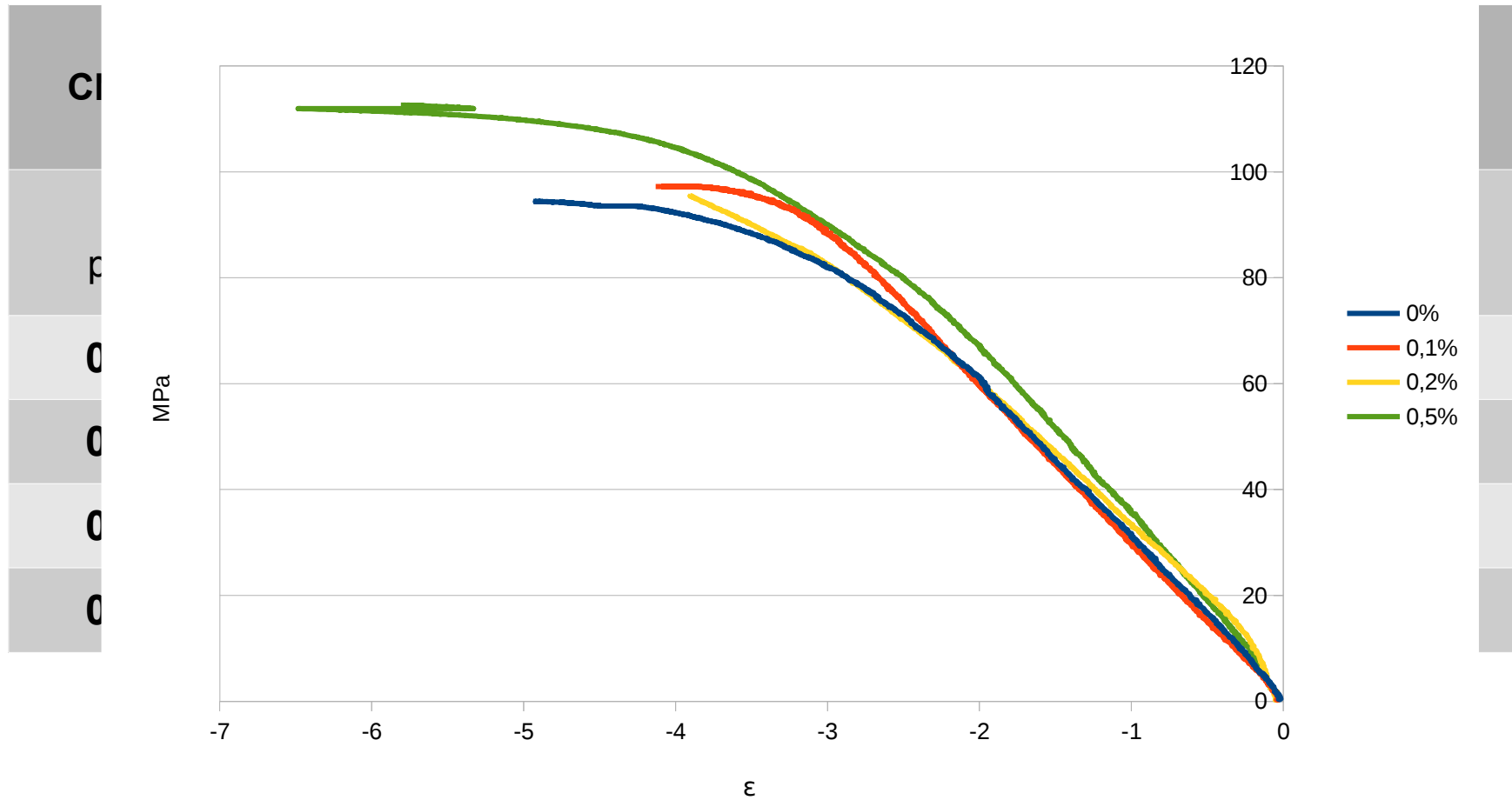
Compression test

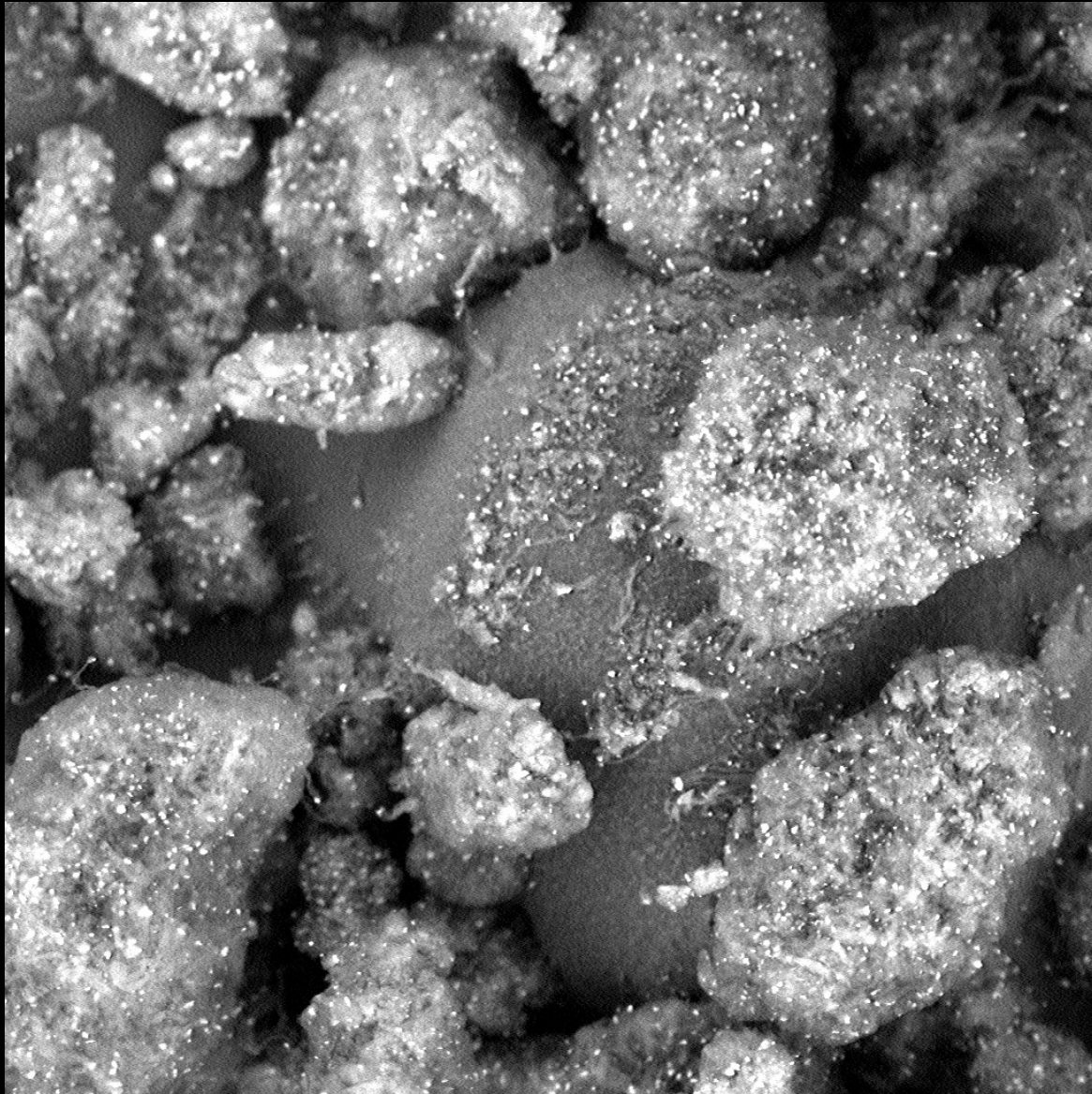
CNTs	σ		ϵ Y.P.		Young's modulus	
phr	MPa	p	%	p	GPa	p
0.0	94.8±4.6		4.9±0.4		2.8±0.2	
0.1	96.6±3.9	ns	3.9±0.7	ns	2.9±0.2	ns
0.2	106.3±3.5	***	3.8±0.7	ns	3.0±0.4	ns
0.5	113.7±3.4	***	6.5±2.1	ns	3.2±0.2	*



Compression test

Compression Test



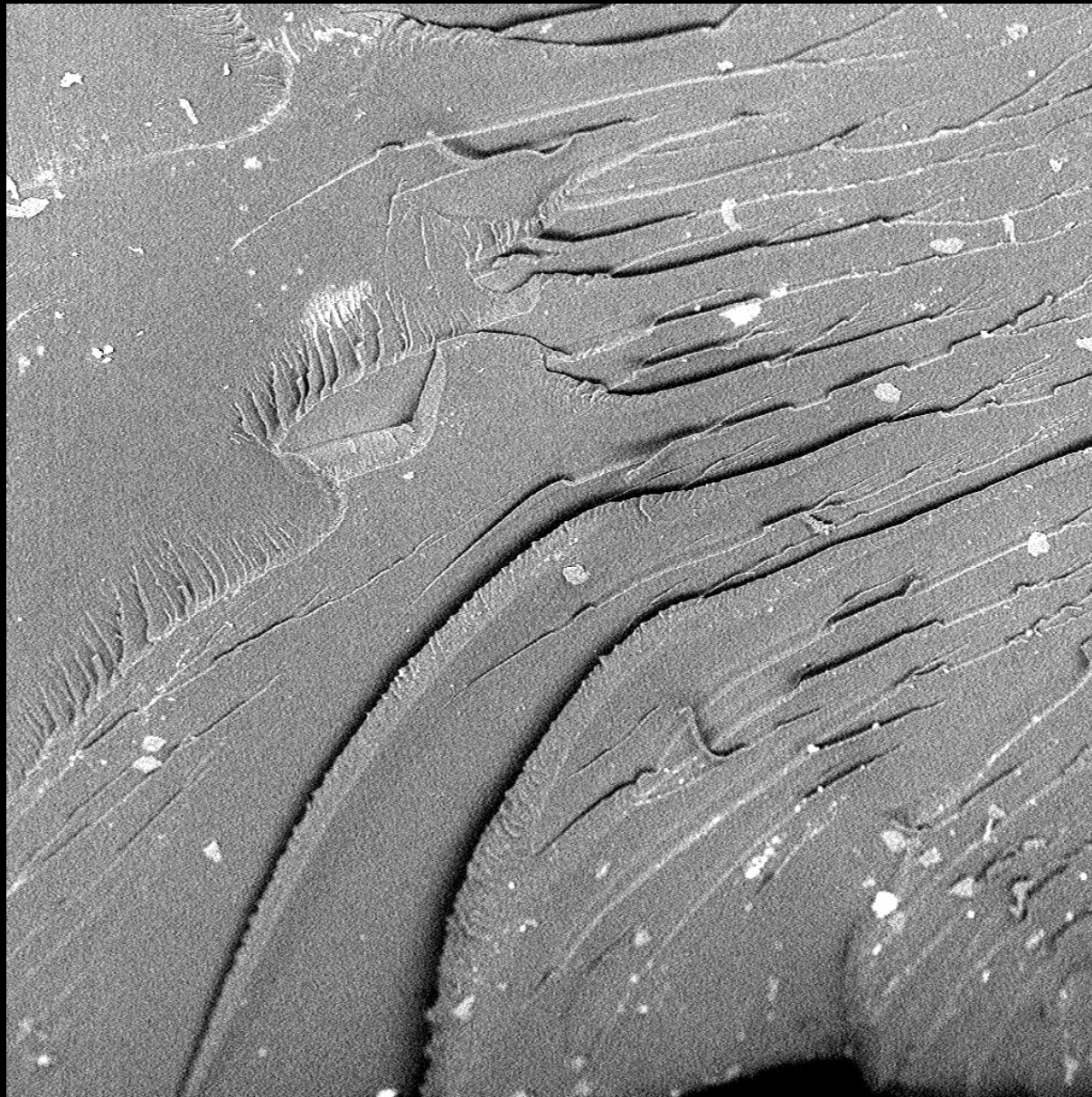


80 μm

980x
277 μm

10kV -Image
BSD Full

MAR 14 2016 11:15
NT_CNT1

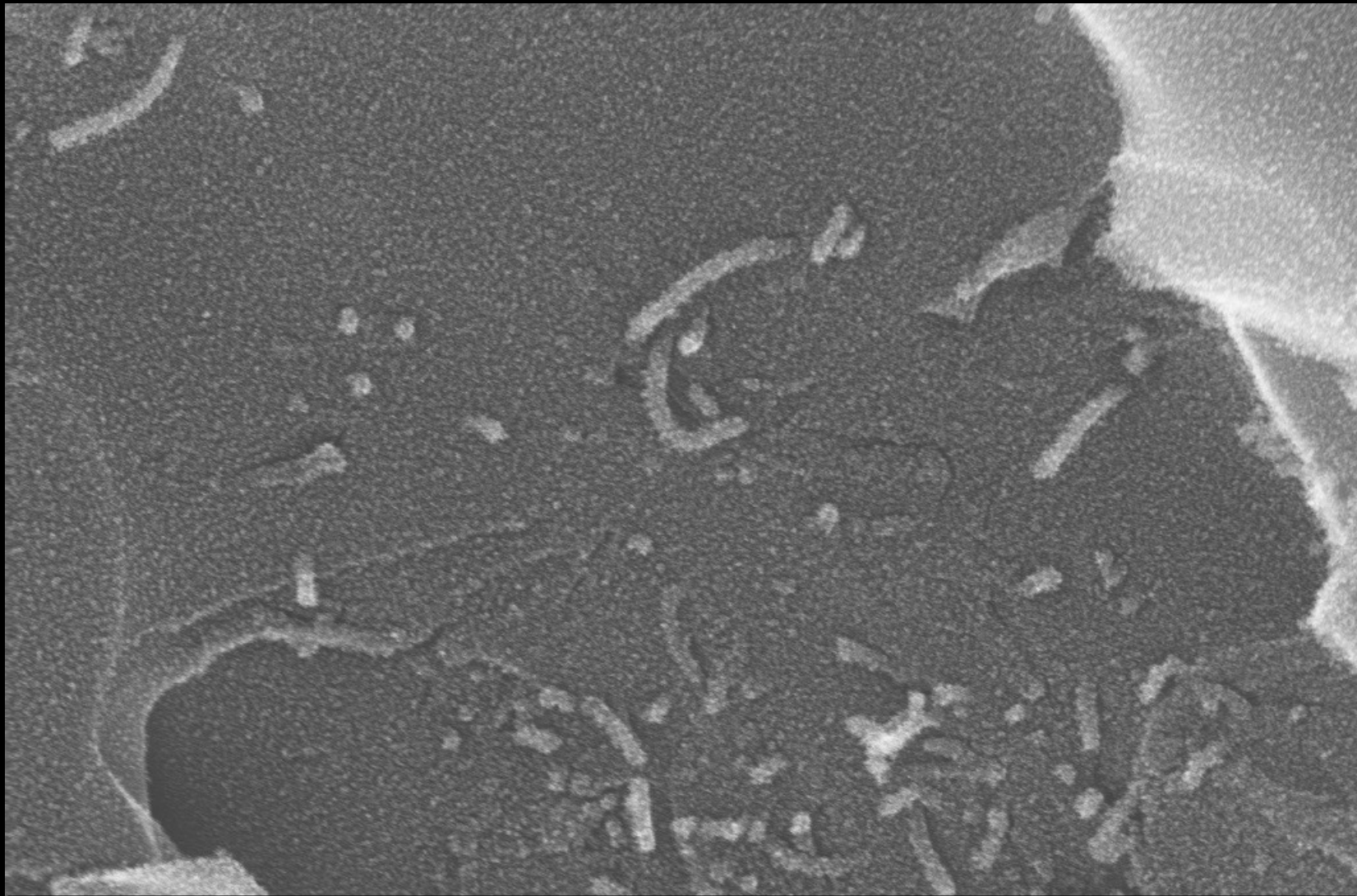


300 μ m

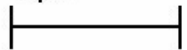
245x
1.11 mm

10kV -Image
BSD Full

FEB 12 2016 12:59
nt_test_NF100



1 μm



EHT = 20.00 kV

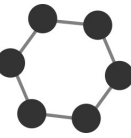
WD = 10.1 mm

Signal A = InLens

Mag = 12.03 K X

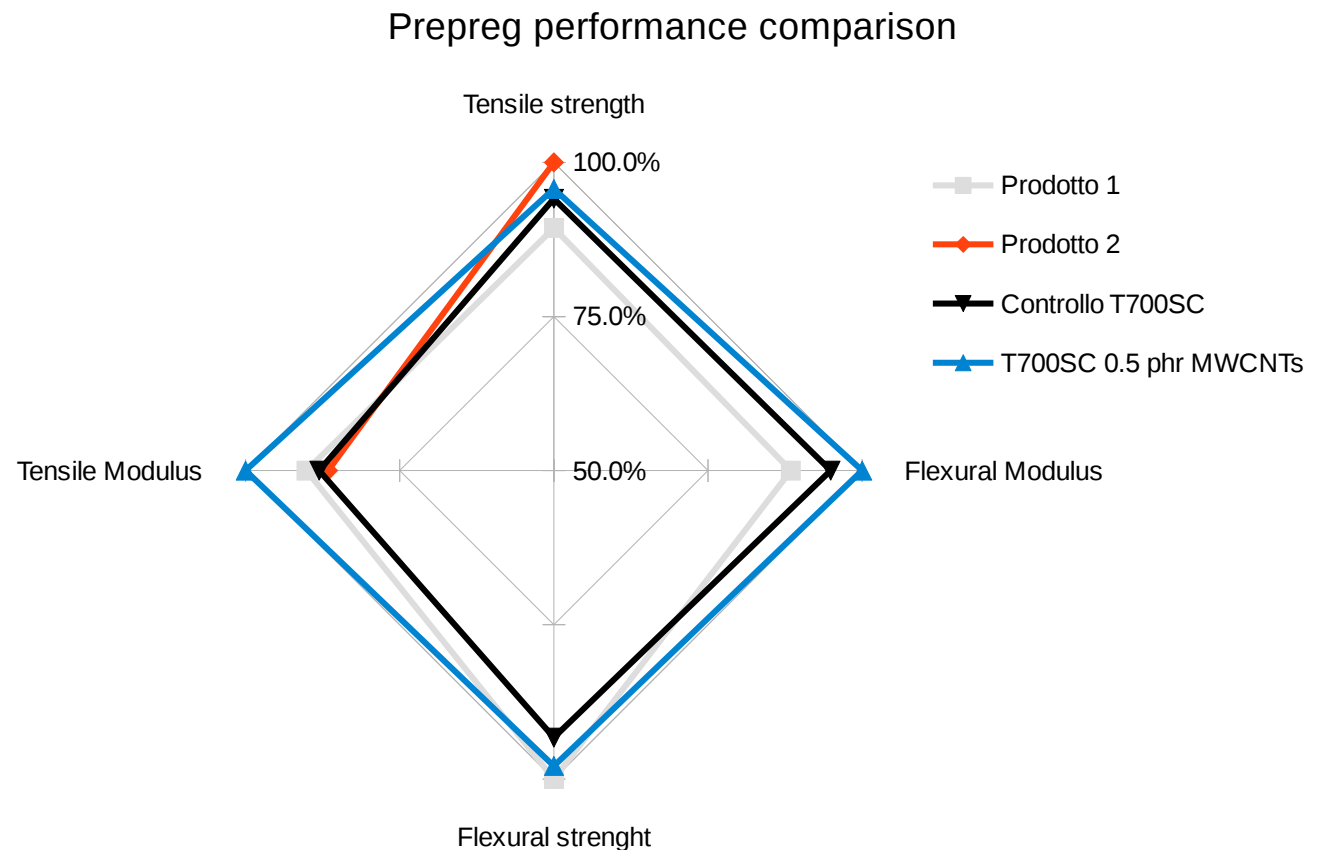




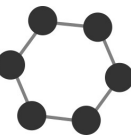


Nano-Engineered resins in CFRP

	Nano-Preg T700SC 0.5 phr MWCNTs
Tensile strength [MPa]	2730
Tensile Modulus [GPa]	150
Flexural strength [MPa]	1640
Flexural Modulus [GPa]	136







Conclusions

- Nano-epoxies with well-dispersed CNTs were successfully fabricated with a new manufacturing technique, and SEM imaging were used to investigate the dispersion
- The tensile and compressive behaviours of pristine resin and CNT-resin with various weight loads of MWCNTs were investigated to identify statistically significant correlations between the output mechanical properties and the composition
- CFRP fabricated using MWCNTs epoxy nanocomposites show improvement in the mechanical performance



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