Influence of Shear Flows and Long Chain Branching on the Rheological and Electrical Properties of Polypropylene/Carbon nanotube Composites

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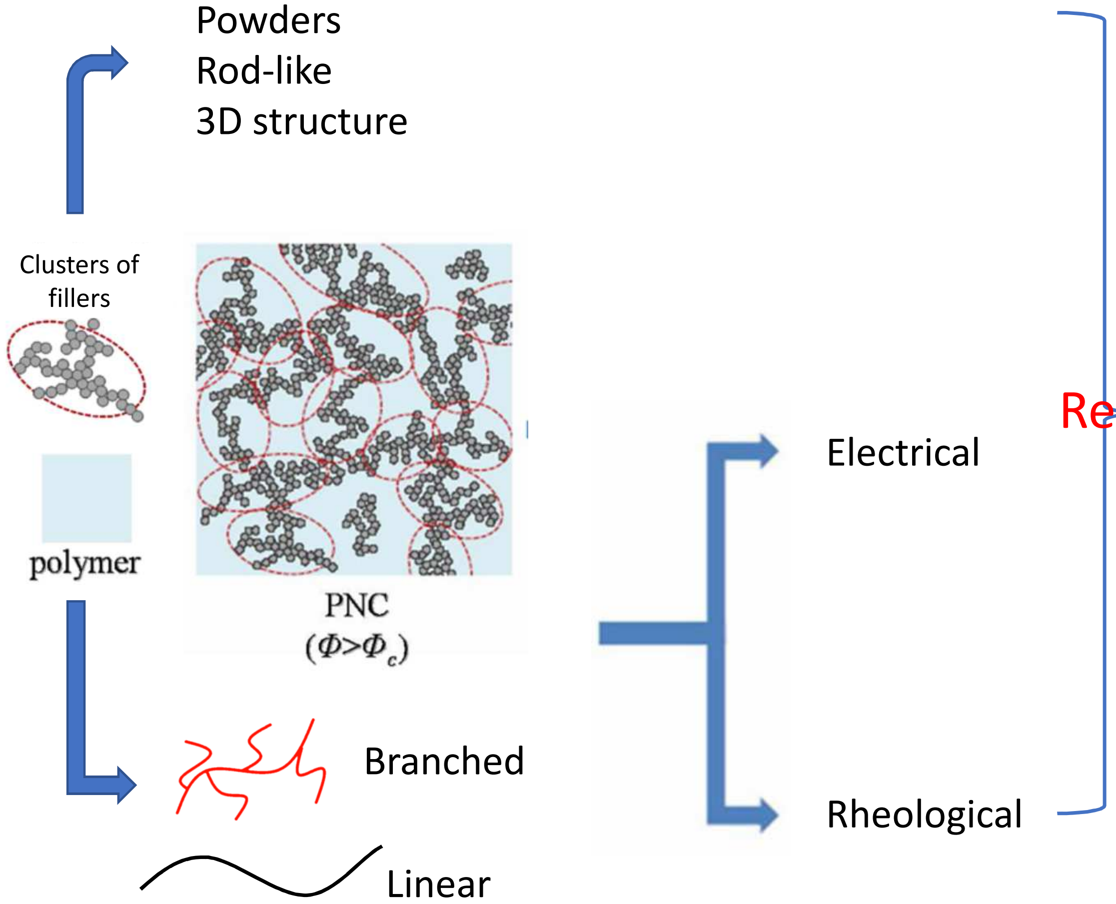
Background



Powders
Rod-like
3D structure

Branched

Linear

Electrical

Rheological

Relationships between them???

Background: Rheological Percolation

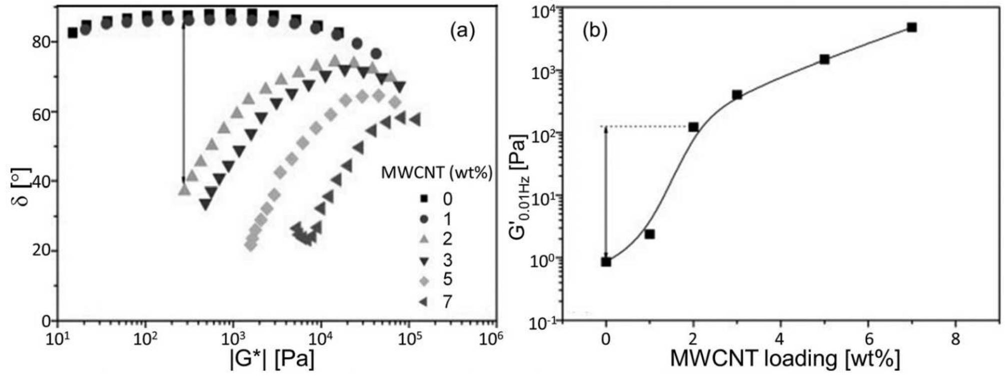


FIG. 1. (a) van Gurp–Palmen plot and (b) $G'(\omega,\varphi)$ measured at 0.01 Hz as a function of MWCNT loading for PBT nanocomposite melts at 240 °C [Wu *et al.* (2007b)].

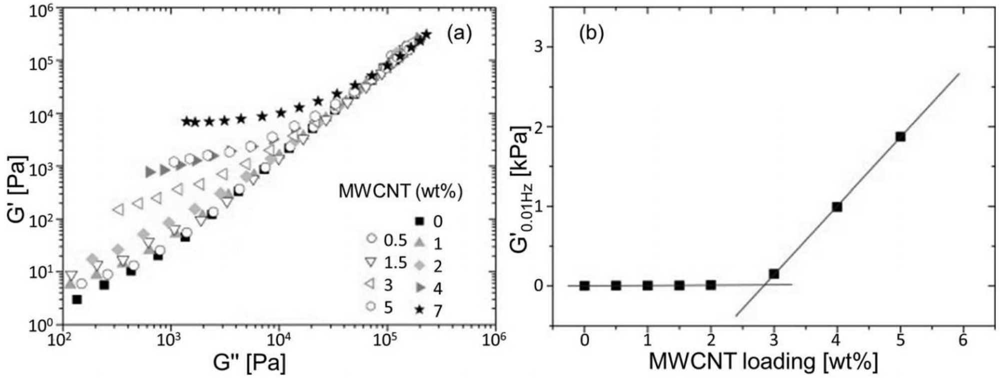
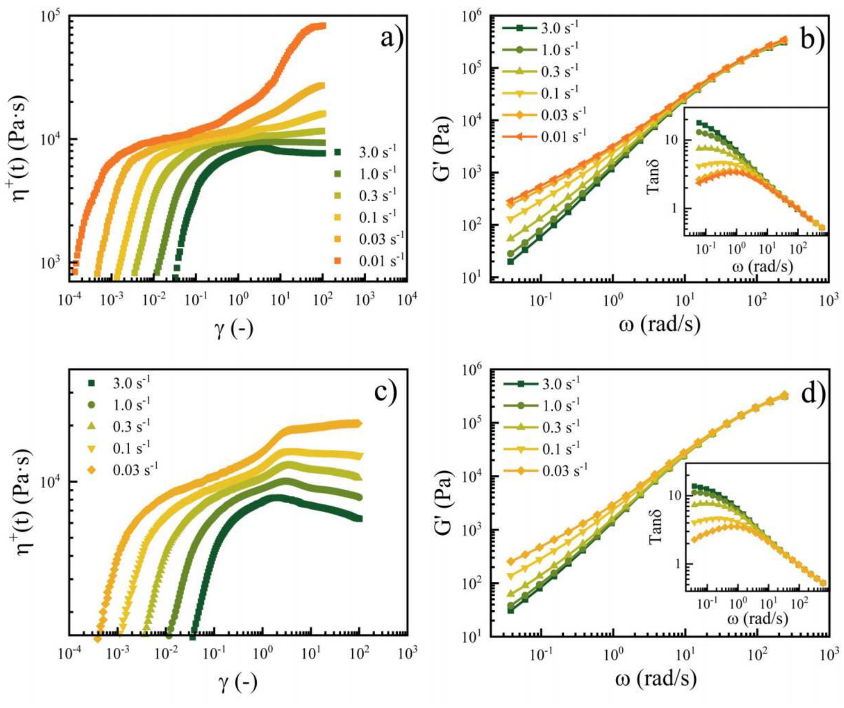


FIG. 3. (a) Han plots for carboxylic MWCNTs filled polylactide melts and (b) $G'(\omega,\varphi)$ measured at 0.01 Hz as a function of MWCNT loading [Wu *et al.* (2008)].

Yihu Song *and* Qiang Zheng , "Linear rheology of nanofilled polymers", Journal of Rheology 59, 155-191 (2015) https://doi.org/10.1122/1.4903312

Background: Impacts to the percolation



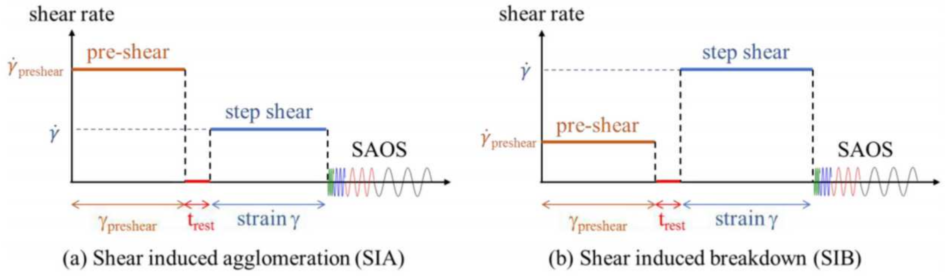
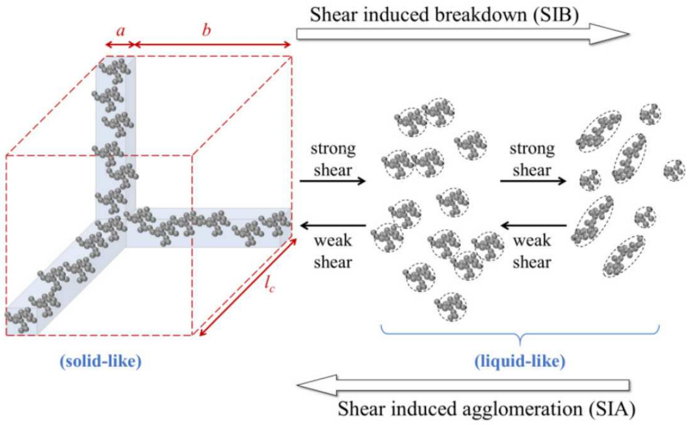


FIG. 1. Schematics of two shear protocols: (a) SIA and (b) SIB.



Benke Li, Ying Guo, Paul Steeman, Markus Bulters, *and* Wei Yu , "Shear-induced breakdown and agglomeration in nanoparticles filled polymer: The shift of phase boundary and kinetics", Journal of Rheology 65, 291 309 (2021) https://doi.org/10.1122/8.0000032

Background: Impacts to the percolation

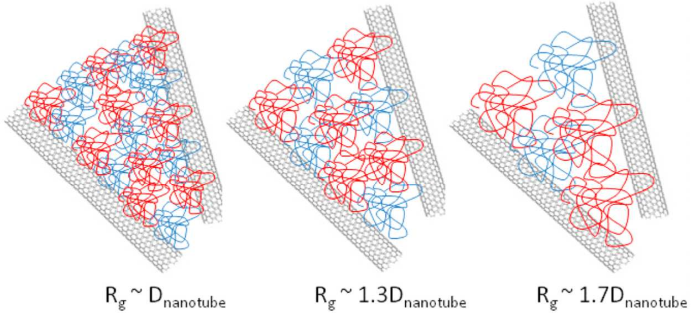


Figure 15. Scheme showing the possible differences in the interaction between macromolecules and CNTs as a function of molecular size (based on M_w values).

Table 1. Molecular and Melt Linear Viscoelastic Features (T = 140 °C) of the Neat Polyethylene Matrices and the Nanocomposites Studied[a]

					η_0 (kPa s)		J_e^0 (mPa^{-1})	
sample	SCB CH_3/1000C	M_w kg mol^{-1}	M_w/M_n	M_z kg mol^{-1}	neat	CNT	neat	CNT
PE1	10.7	113	2.1	225	14.0	900	0.065	3.32
PE2	0	185	2.2	370	60.0	425	0.64	4.95
PE3	4.4	326	37.4	1990	1020	1460	2.30	2.96

[a] SCB: Short chain branching content. M_w: weight-average molecular weight M_z: z-average molecular weight. η_0: zero shear melt viscosity. J_e^0: linear steady-state recoverable compliance.

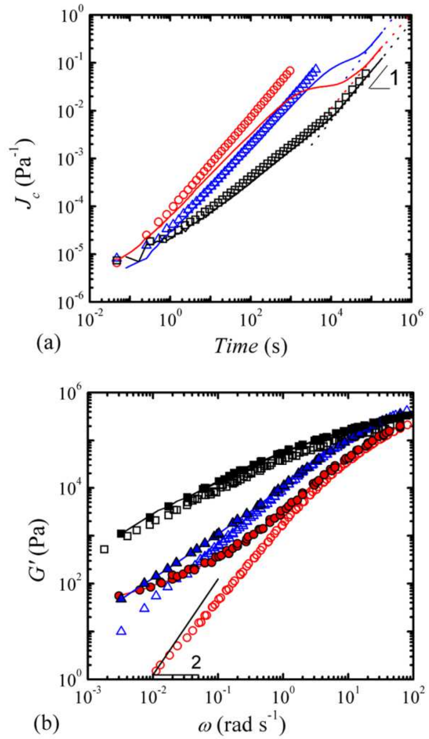
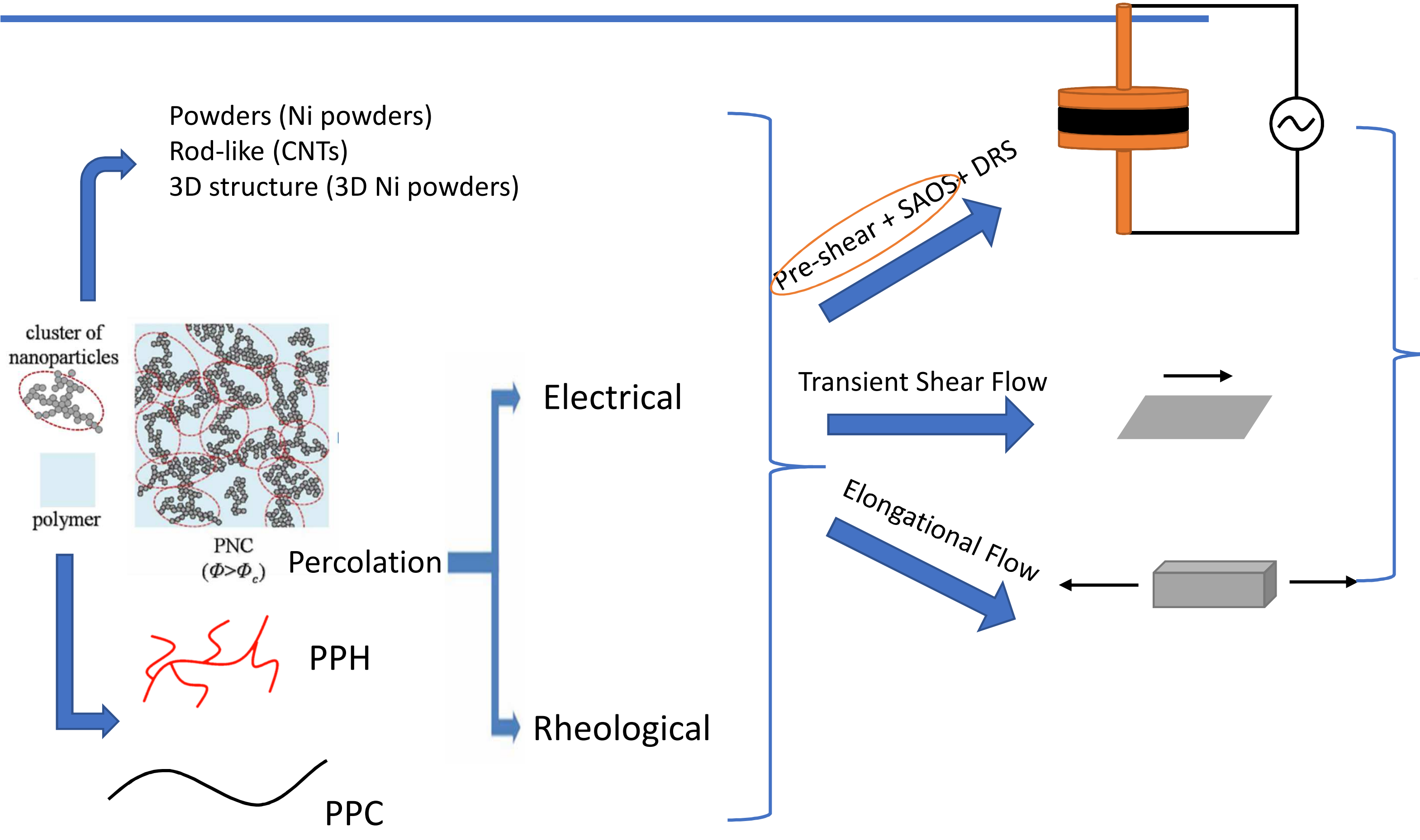


Figure 6. (a) Shear creep compliance, J_c, as a function of creep time for the neat materials (open symbols) and the nanocomposites (lines) at a shear stress of τ_0 = 6.25−50 Pa and T = 140 °C; (b) Dynamic modulus, G', versus angular frequency, ω, of the neat materials (open symbols) and the nanocomposites (close symbols and lines) at T = 140 °C (three independent measurements for each sample are plotted). (red ●, ○) PE1, (blue ▲, △) PE2 and (■, □) PE3.

Juan Francisco Vega, Yudith da Silva, Ernesto Vicente-Alique, Rafael Núñez-Ramírez, Mariselis Trujillo, María Luisa Arnal, Alejandro J. Müller, Philippe Dubois, and Javier Martínez-Salazar, *Macromolecules* **2014** *47* (16), 5668-5681, DOI: 10.1021/ma501269g

Strategies and Methods



Powders (Ni powders)
Rod-like (CNTs)
3D structure (3D Ni powders)

Percolation

PPH

PPC

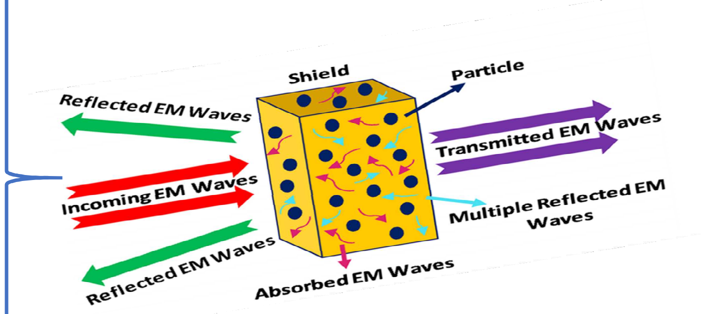
Electrical

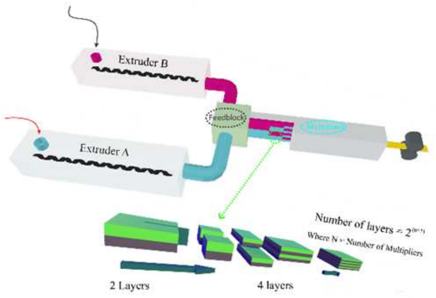
Rheological

Pre-shear + SAOS+ DRS

Transient Shear Flow

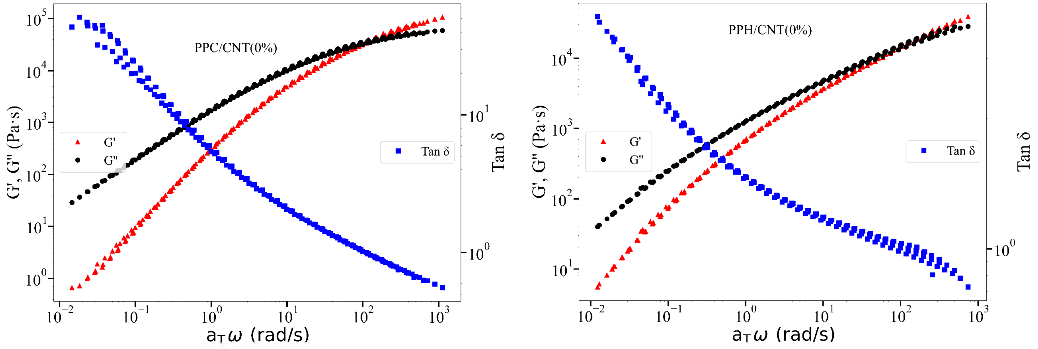
Elongational Flow



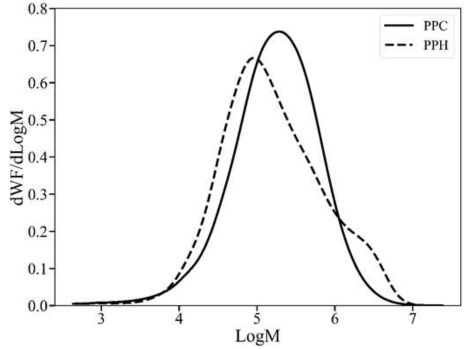


Results: Comparation of PPC and PPH

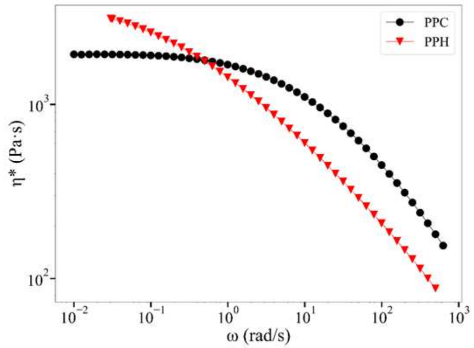
Master Curves of PPC and PPH



SEC

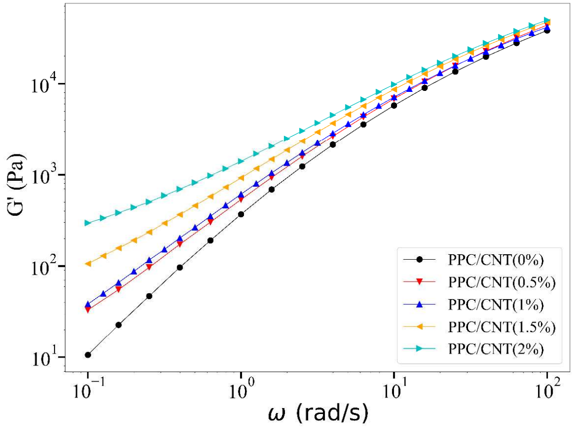


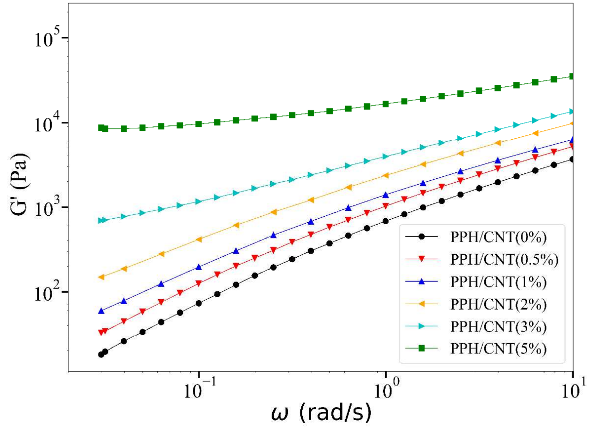
Complex Viscosity

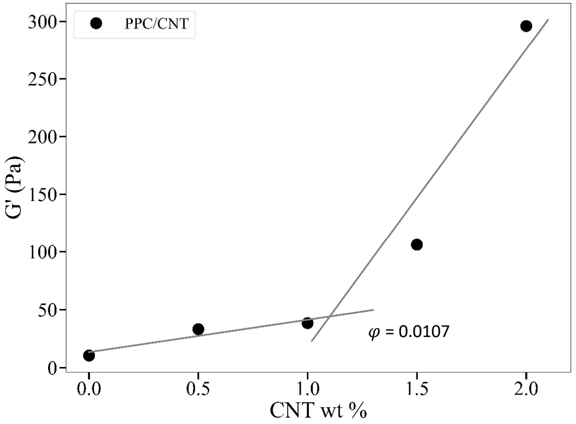


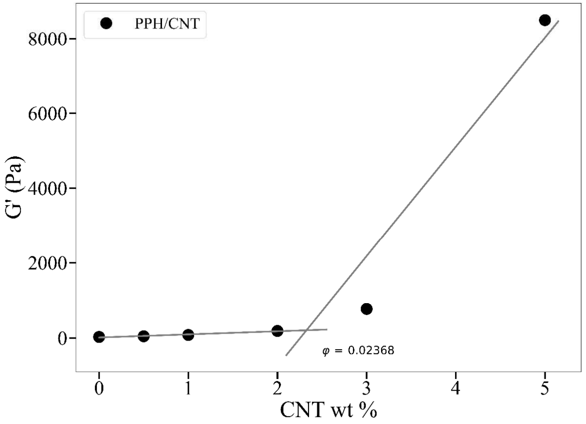
Polymer	M_w(kg/mol)	M_w/M_n	LCBf/1000C	η_0(pa.s)	G_N^0 (pa)	M_e (g/mol)	τ_{rep} (s)
PPC	355	6.9	0	1.98×10^3	2.8×10^5	4471	~0.10
PPH	475	9.8	0.021	4.20×10^3	4.73×10^6	253	~5.03

Results: Pecolation of PPC and PPH at 200 ºC

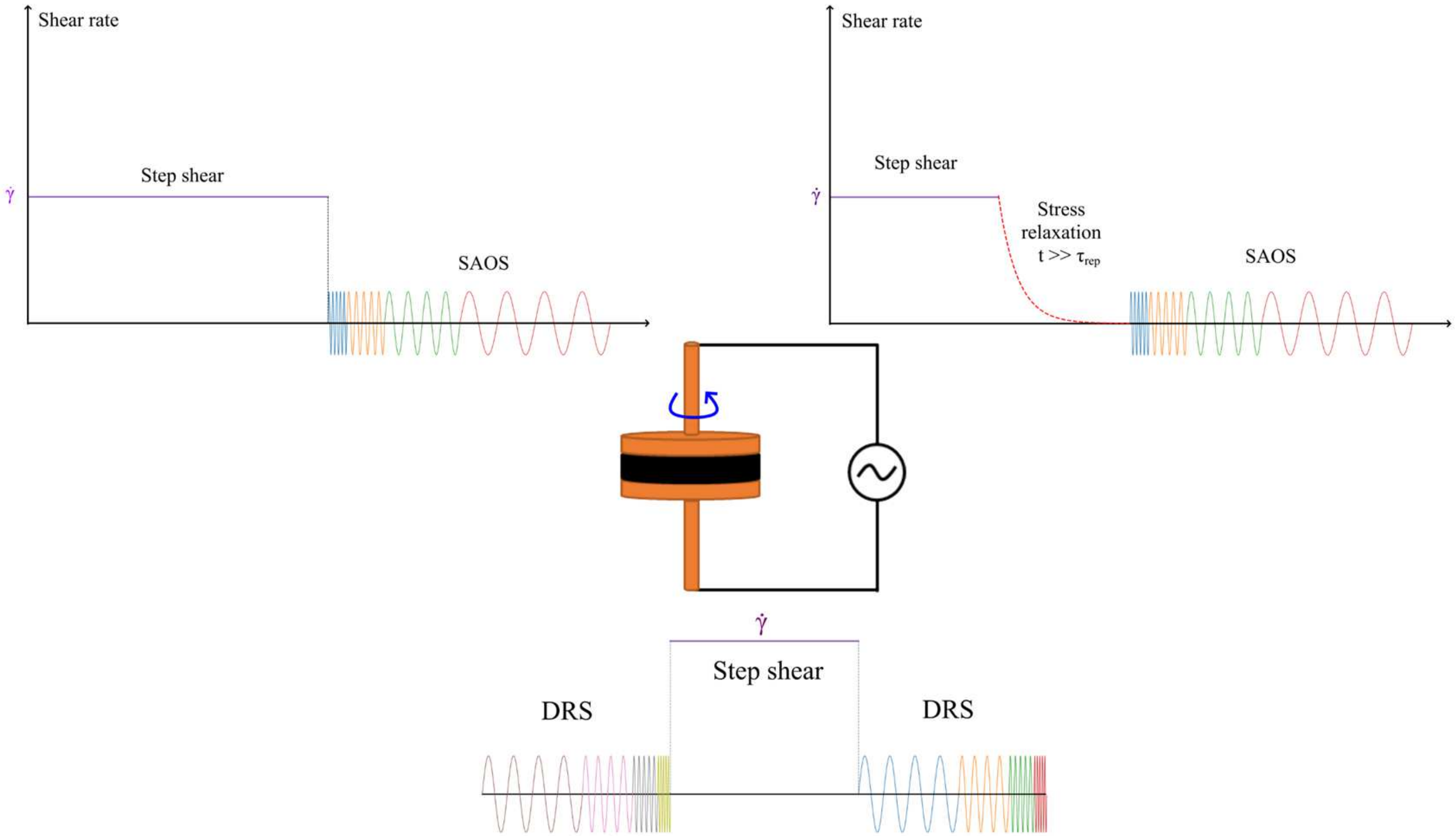








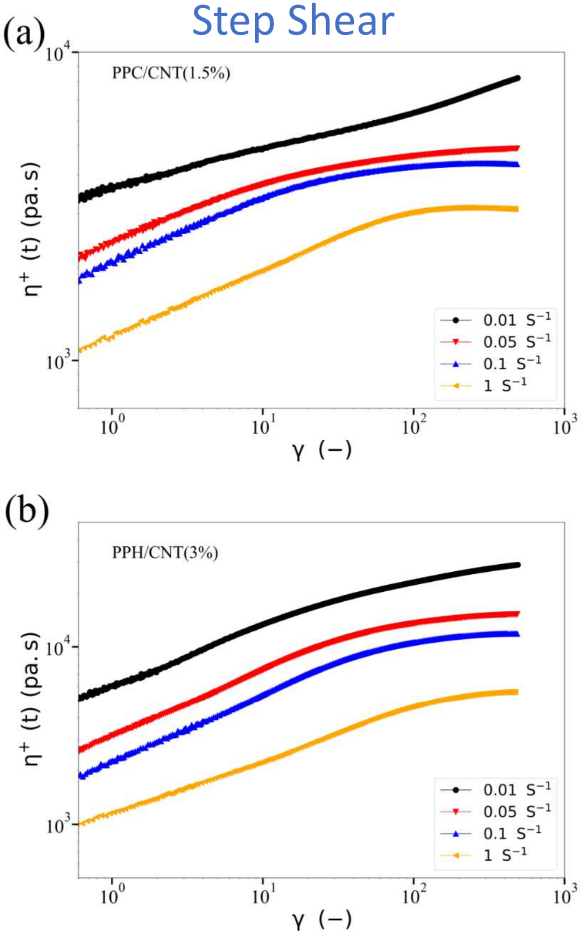
Pre-shear Protocols



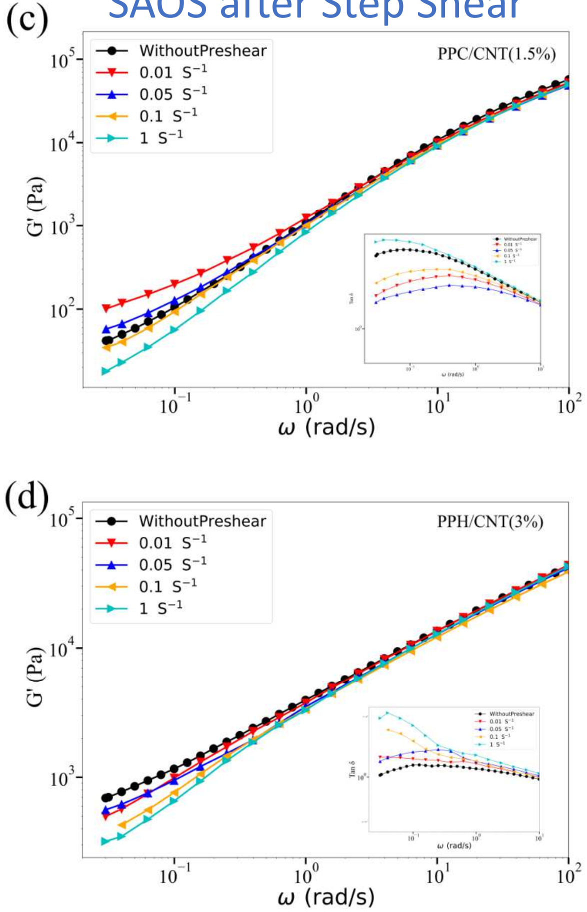
Results: Liquid-solid transition after a pre-shear

The samples with filler fraction higher than the percolation

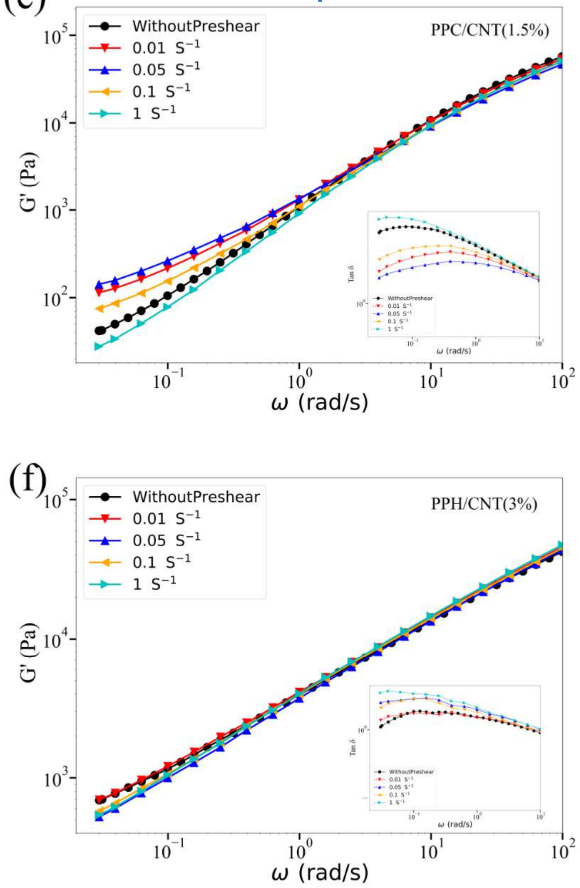
Step Shear



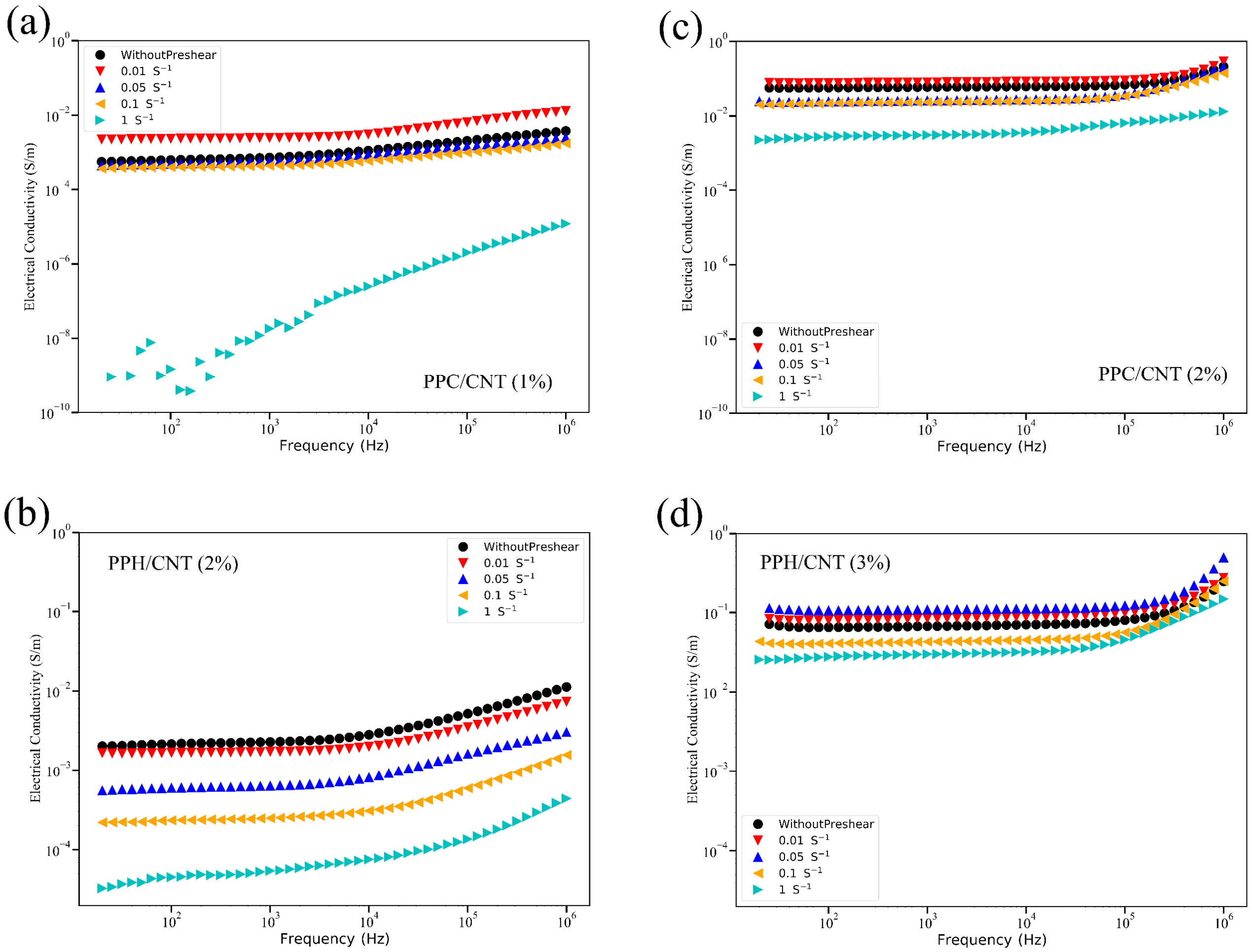
SAOS after Step Shear



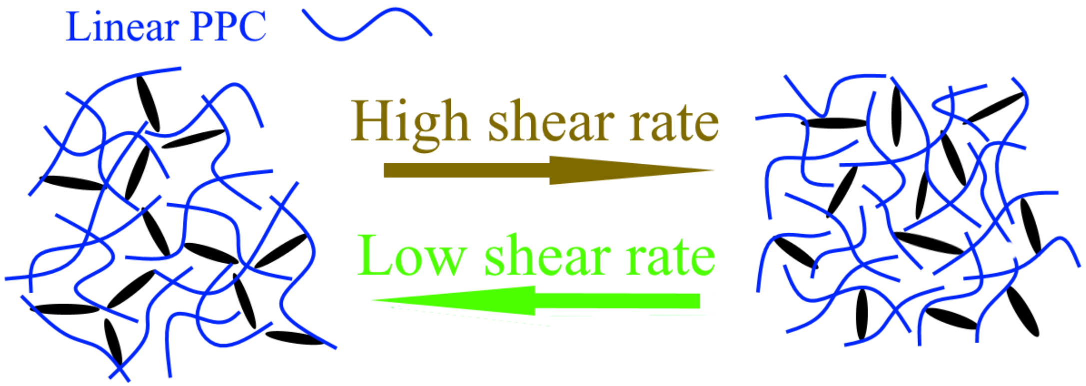
SASO after Step Shear and Relaxation



Results: Conductivities after a pre-shear



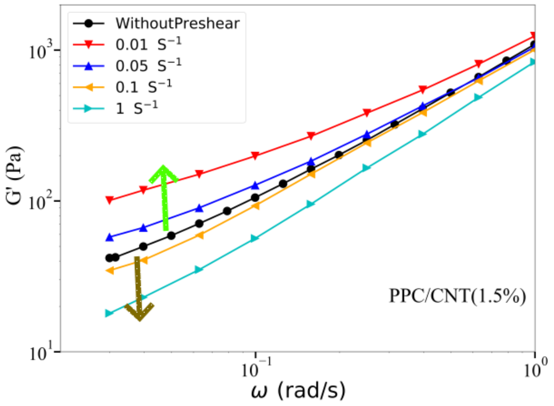
CNT network aggregate and break down



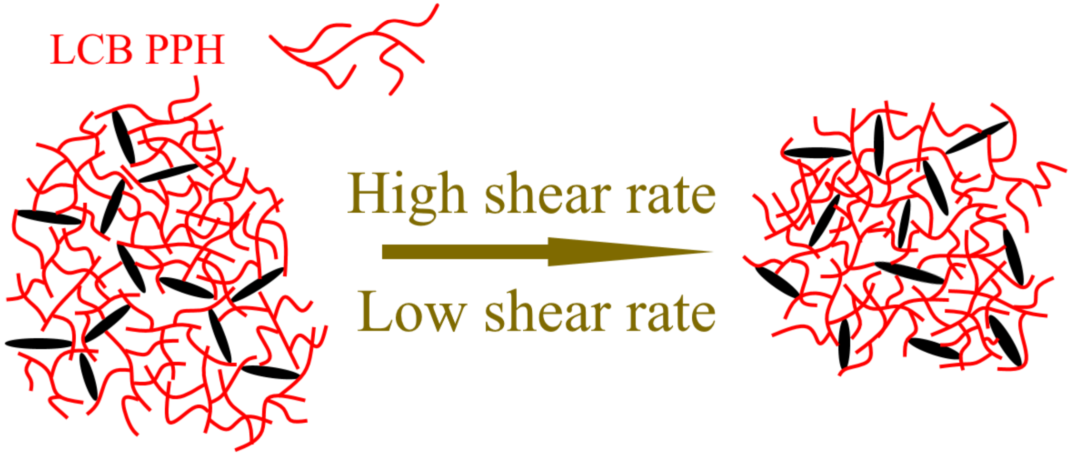
Linear PPC

High shear rate

Low shear rate

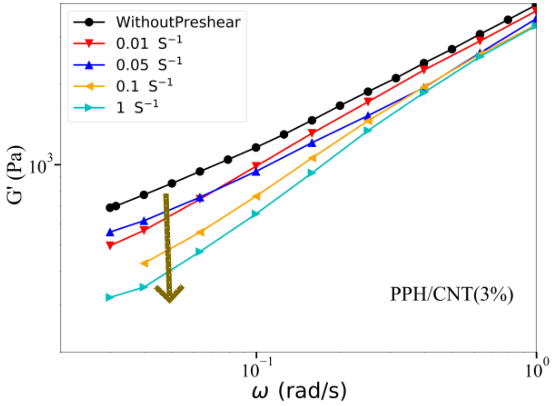


LCB PPH



High shear rate

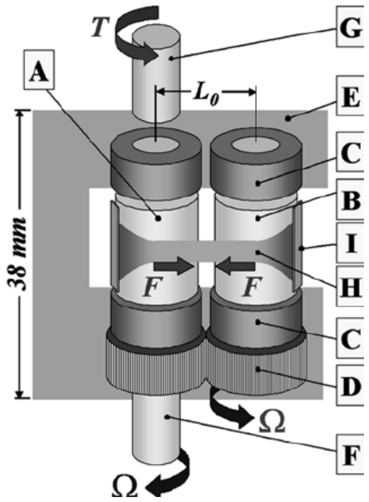
Low shear rate

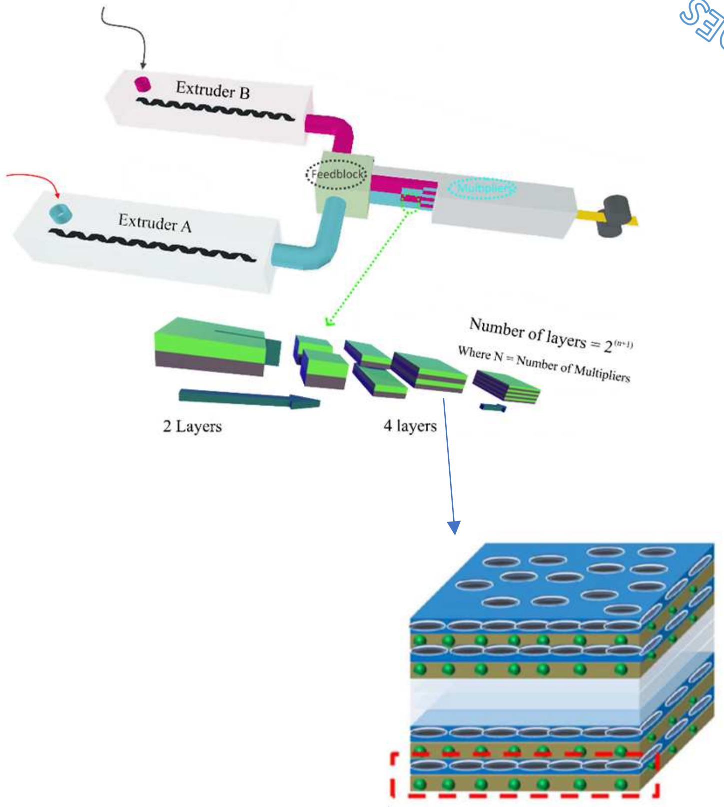


Perspectives

Next steps

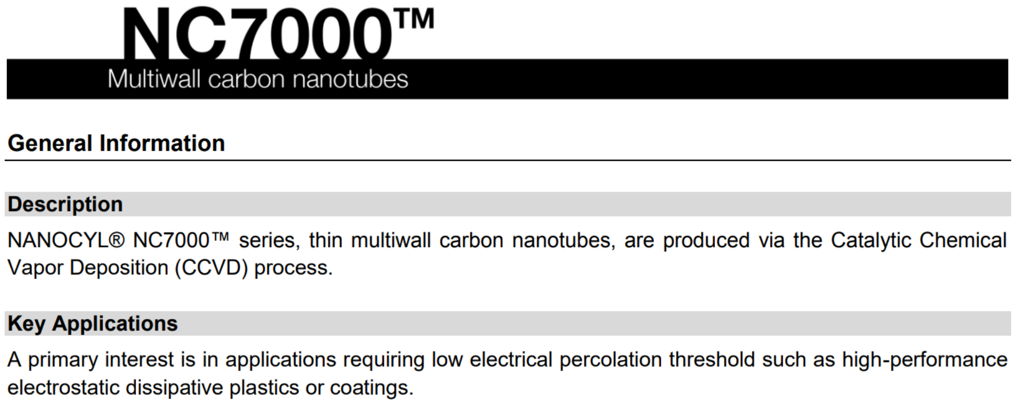
1. Go deeper to analyze the phenomenon.
2. Nonlinear transient rheology on filled polymers
3. Work with different shape of fillers (Micro)
4. Start with co-extrusion





THANK YOU!!!

Appendix



NC7000™

Multiwall carbon nanotubes

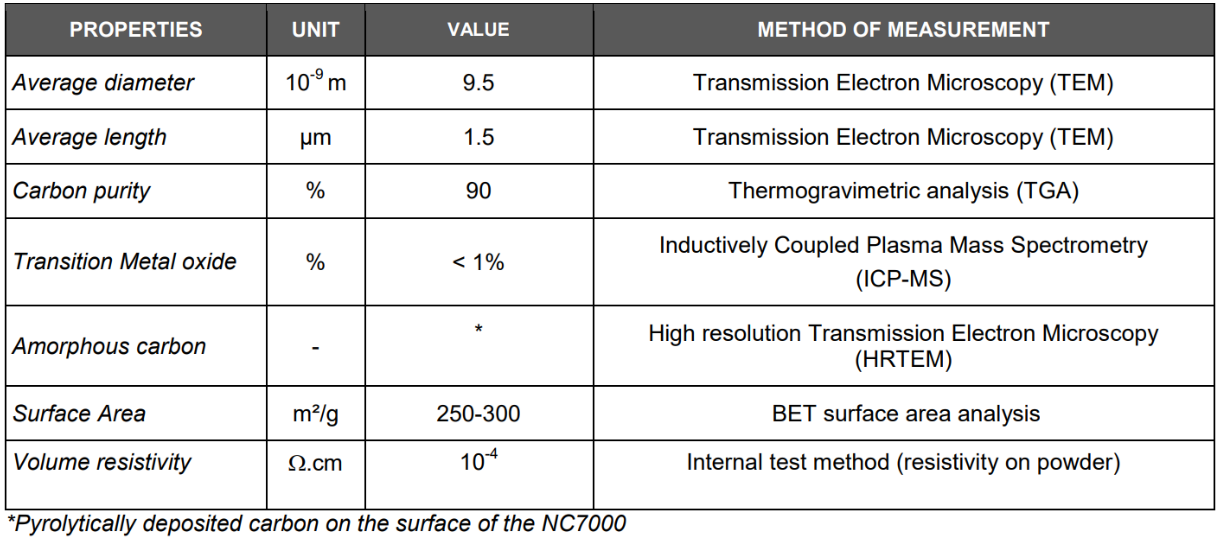
General Information

Description

NANOCYL® NC7000™ series, thin multiwall carbon nanotubes, are produced via the Catalytic Chemical Vapor Deposition (CCVD) process.

Key Applications

A primary interest is in applications requiring low electrical percolation threshold such as high-performance electrostatic dissipative plastics or coatings.



PROPERTIES	UNIT	VALUE	METHOD OF MEASUREMENT
Average diameter	10^{-9} m	9.5	Transmission Electron Microscopy (TEM)
Average length	µm	1.5	Transmission Electron Microscopy (TEM)
Carbon purity	%	90	Thermogravimetric analysis (TGA)
Transition Metal oxide	%	< 1%	Inductively Coupled Plasma Mass Spectrometry (ICP-MS)
Amorphous carbon	-	*	High resolution Transmission Electron Microscopy (HRTEM)
Surface Area	m²/g	250-300	BET surface area analysis
Volume resistivity	Ω.cm	10^{-4}	Internal test method (resistivity on powder)

**Pyrolytically deposited carbon on the surface of the NC7000*