Universidade Federal do ABC

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nano
Pós Graduação
Nanociências
Materiais Avançados
U F A B C

Workshop on Carbon-based Nanocomposites

Influence of Carbon-based Nanoparticles on the Rheological, Mechanical and Electrical Properties of Polymers

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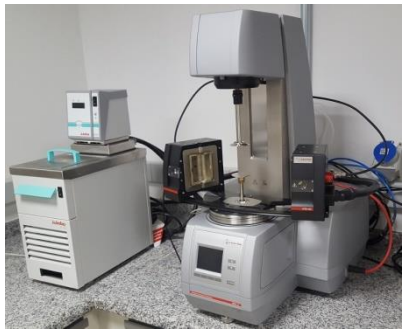
RheoPol – Rheology and Multiphase Polymer Systems

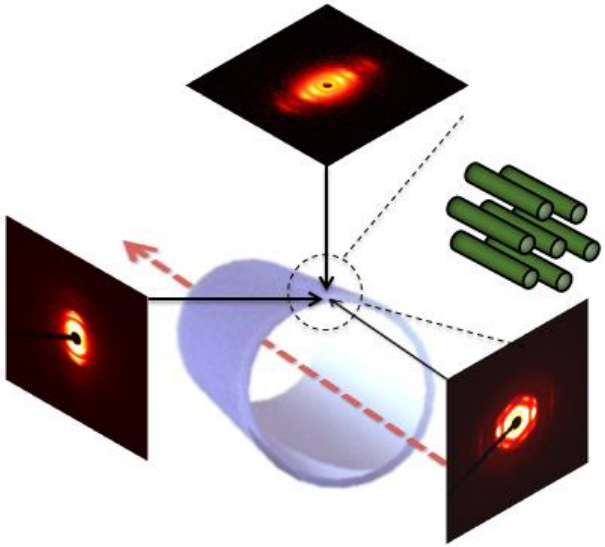
Research Topics:

- ✓ Multiphase polymeric materials
- ✓ Rheology
- ✓ (Nano)composites – graphene, nanotubes, nanofibers, nanoclays
- ✓ Electroactive elastomers
- ✓ Shear thickening materials for armor and impact applications



Research team:

- 4 Doctoral students
- 4 Master's students
- 8 Undergraduate students

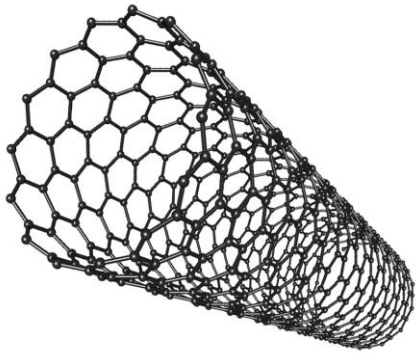


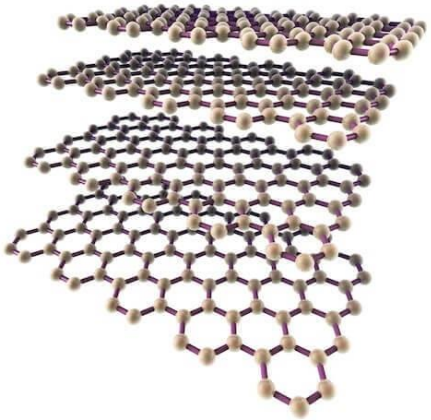
UFABC

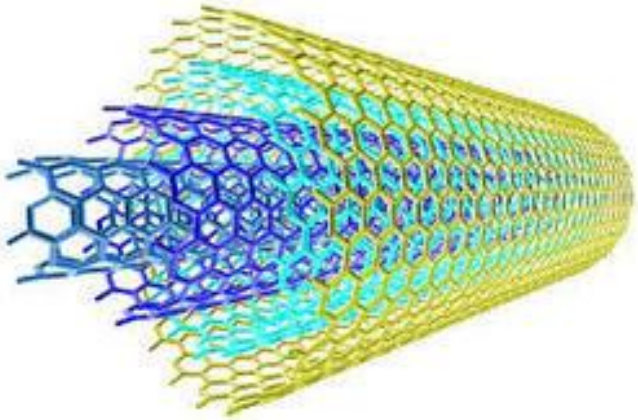
Carbon-based Polymer Nanocomposites

Types of Carbon-based Nanoparticles

- Carbon Nanotubes – SWNTs, MWNTs
- Graphene Nanoplatelets (GNP)
- Graphene Oxide (GO)

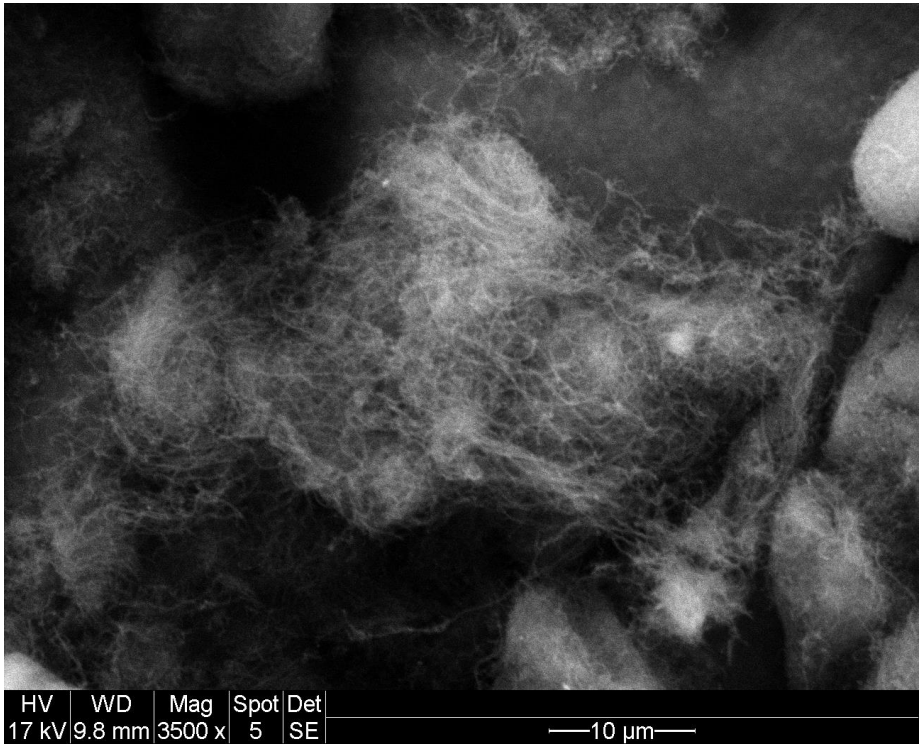


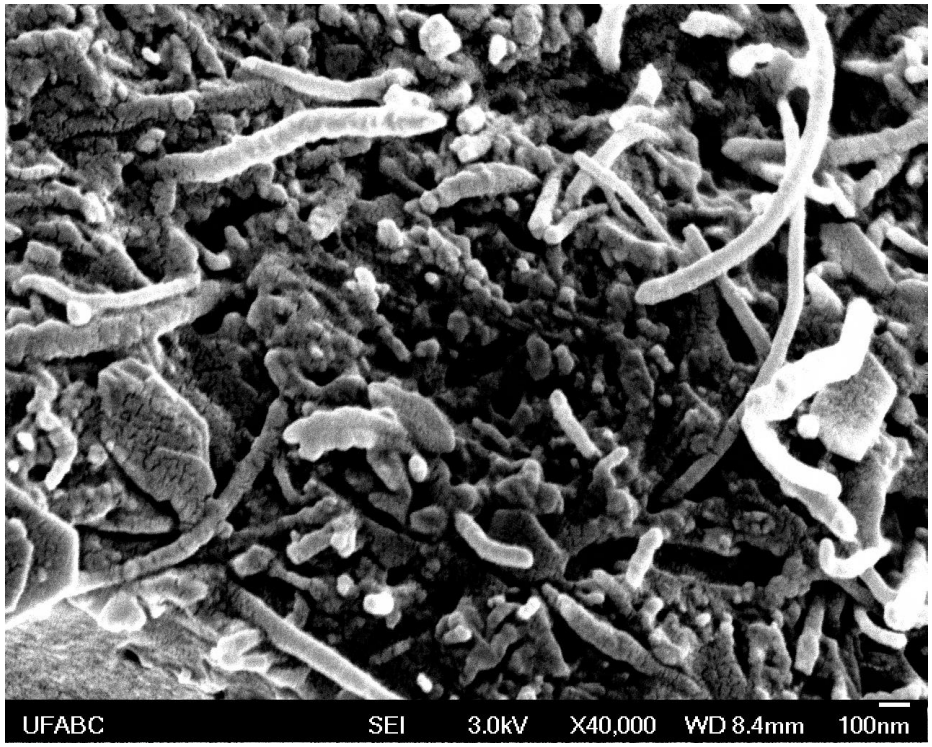




Types of Carbon-based Nanoparticles

- Carbon Nanotubes





Types of Carbon-based Nanoparticles

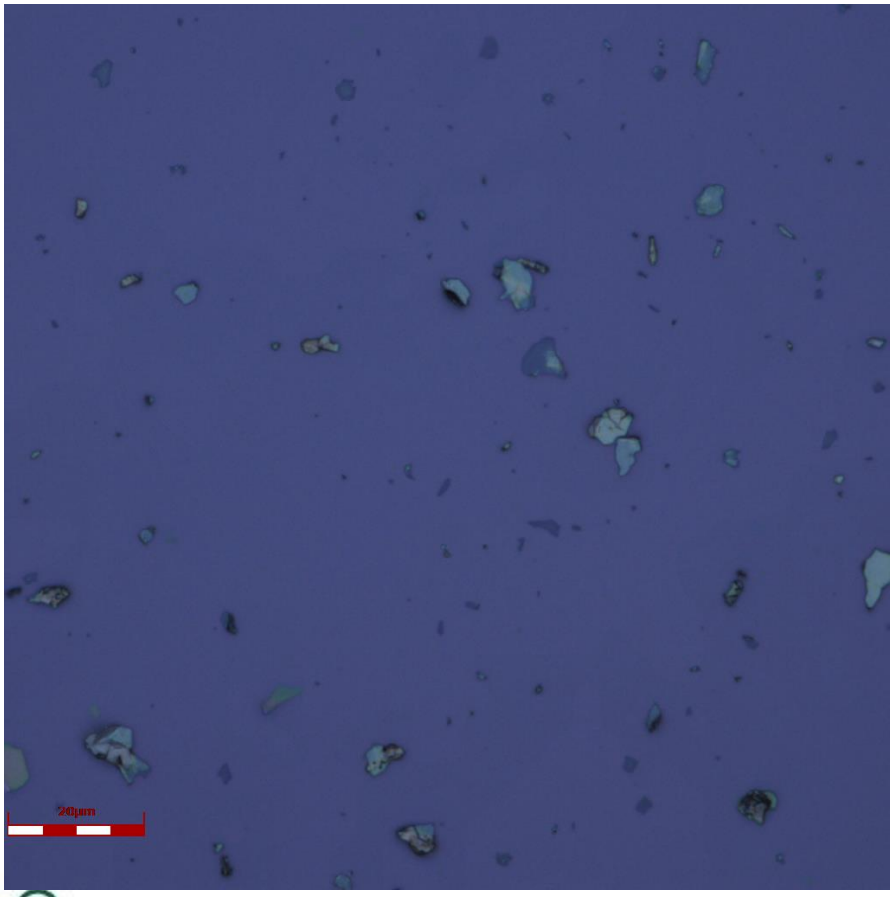
- Graphene and related materials

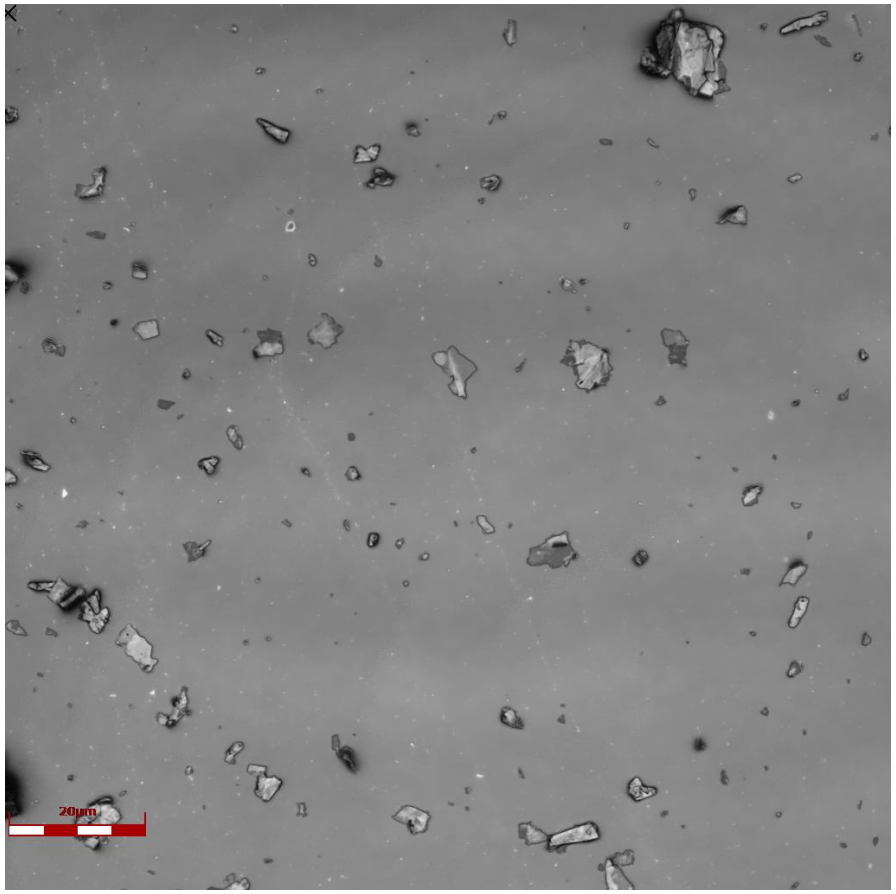
Definitions – ISO (2017):

- Graphene: single layer of carbon atoms;
- Bilayer graphene: two well-defined stacked graphene layers;
- Few-layer graphene: 3 to 10 stacked graphene layers
- Graphene nanoplatelets: thickness between 1 and 3 nm and lateral dimensions ranging from ≈100 nm to 100 μm.

Graphene Nanoplatelets (GNP)

- Optical / Confocal microscopy – Oxidized Si surface

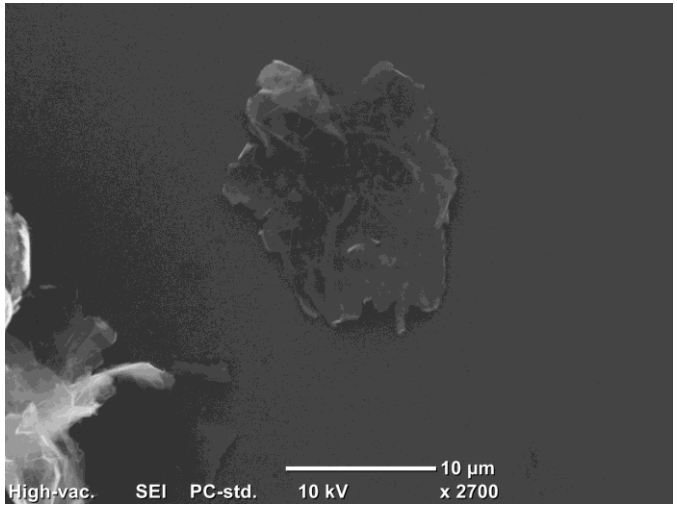


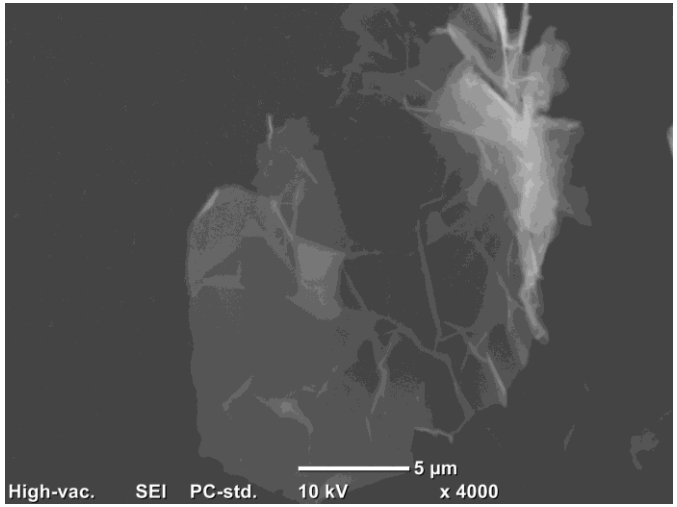


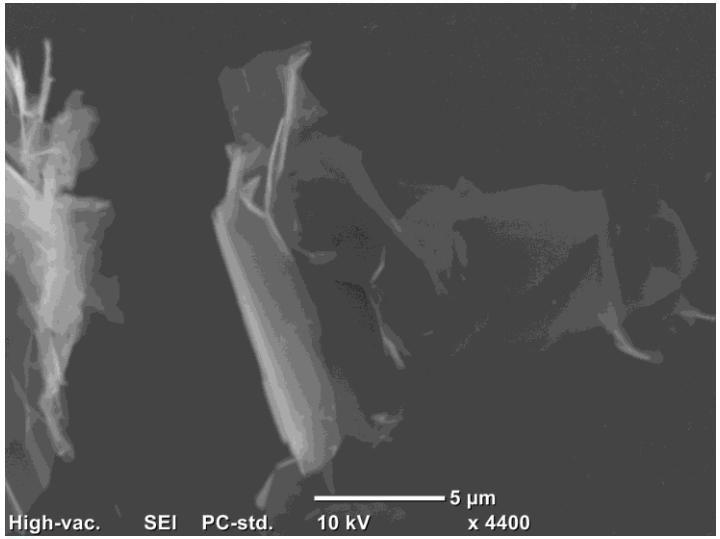
Carbon-based Polymer Nanocomposites

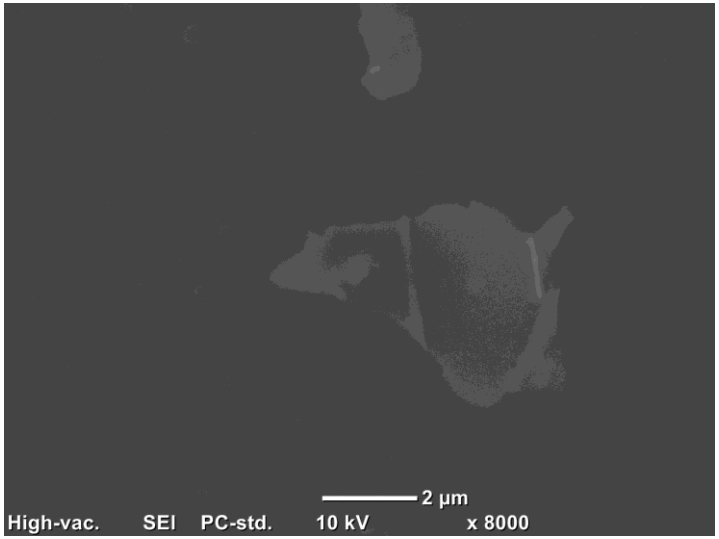
Graphene Nanoplatelets (GNP)

- SEM







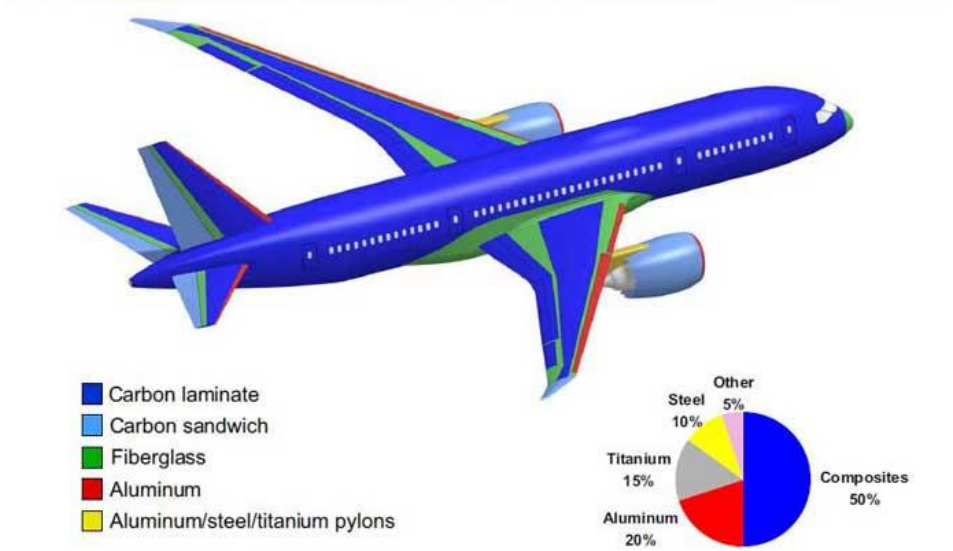


Types of Polymer Matrices

- Epoxy
- Block Copolymers (SEBS)
- Polyolefins (PE, PP)
- Polycarbonate (PC)
- Polytetrafluorethylene (PTFE)

EPOXY NANOCOMPOSITES

Multifunctional (Nano)Composites for Aeronautical Applications



Boeing 787 "Dreamliner"

Saab Gripen

EPOXY NANOCOMPOSITES

Multifunctional (Nano)Composites for Aeronautical Applications

Goals:

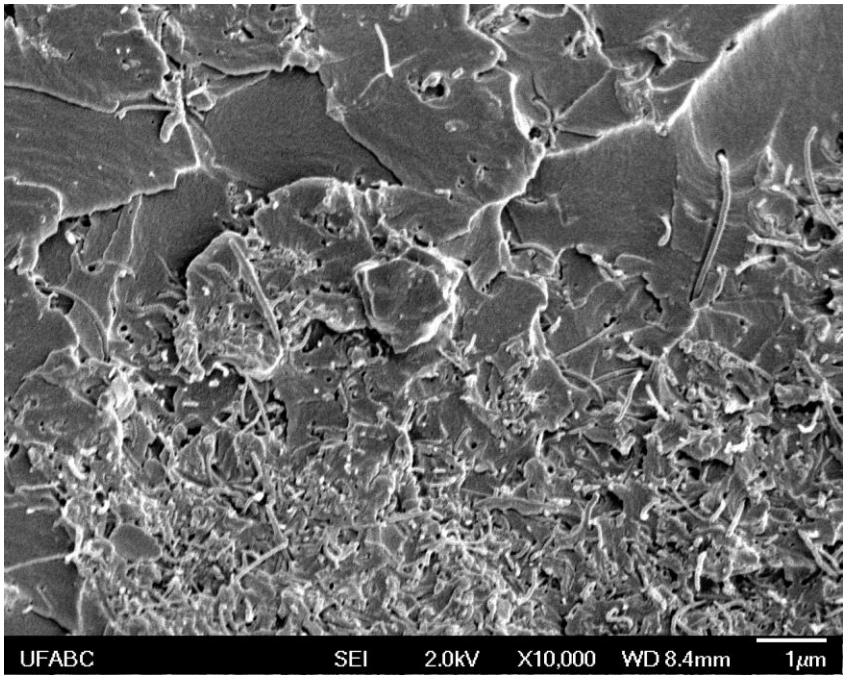
- Improve mechanical performance – strength and damage tolerance
- Weight reduction
- Improve electrical conductivity – lightning strike protection
- Decrease moisture absorption

EPOXY NANOCOMPOSITES

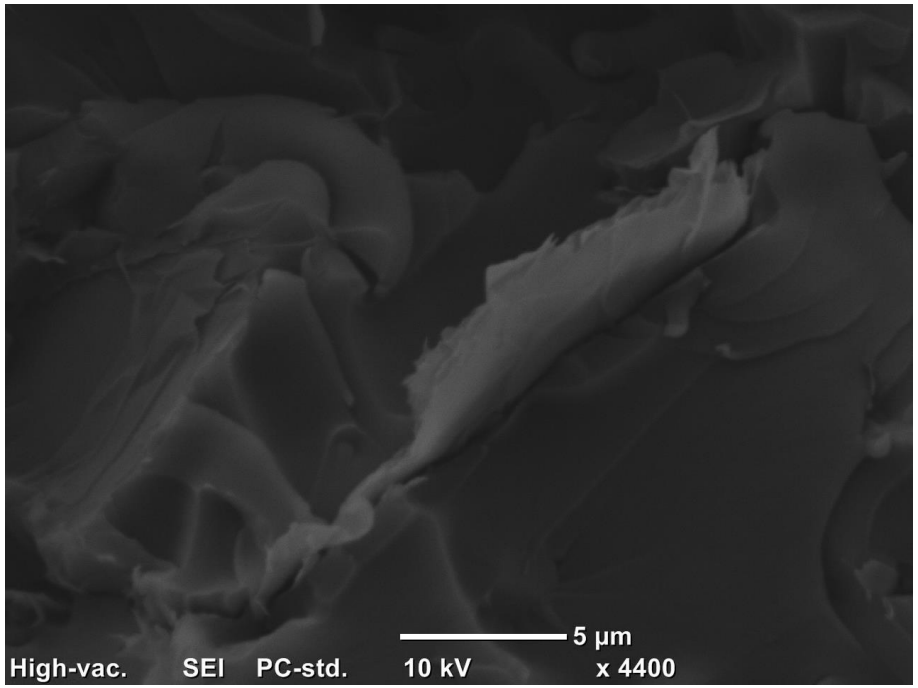
Dispersion Techniques

- Ultrasonic bath
- Ultrasonic probe
- High energy ball milling
- Solvent-assisted dispersion

SEM – Nanocomposites



Epoxy + MWCNT



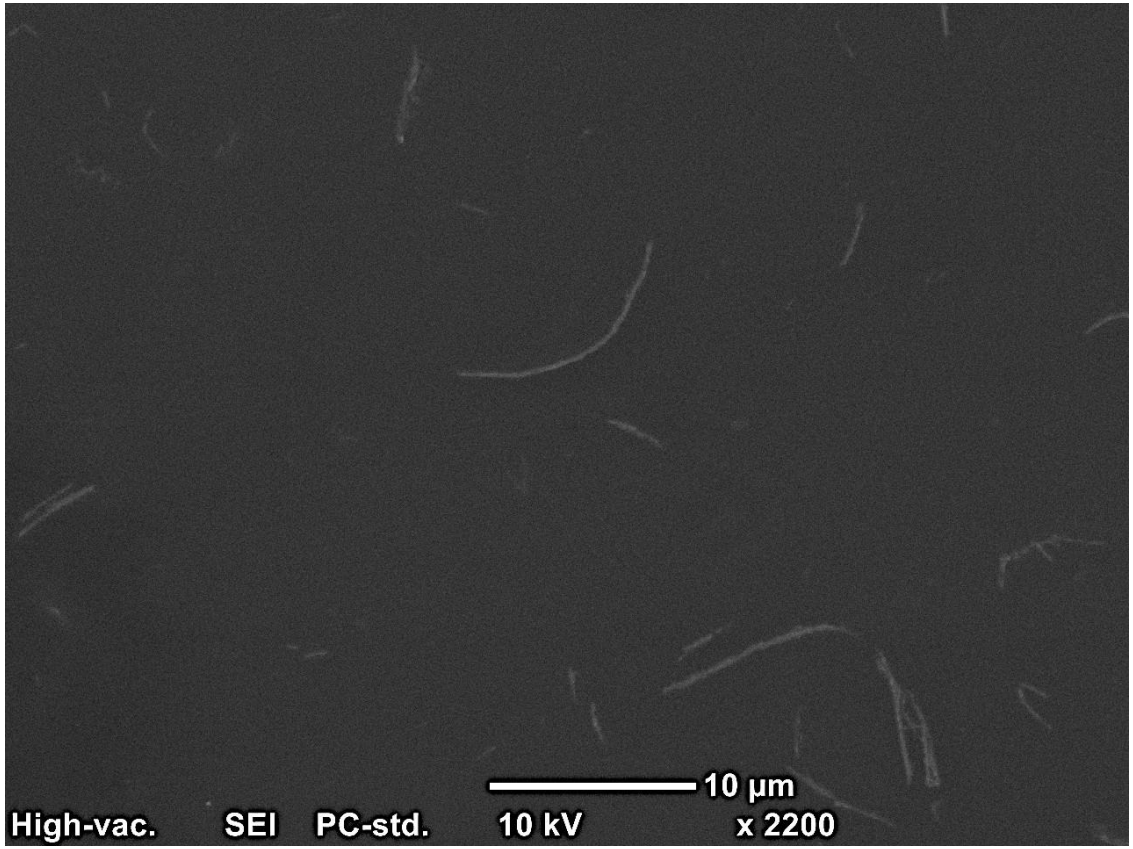
Epoxy + GNP

Ceretti; Carastan, Macromolecular Symposia - 2018.

Moritugui; Carastan - 2018.

SEM – Nanocomposites

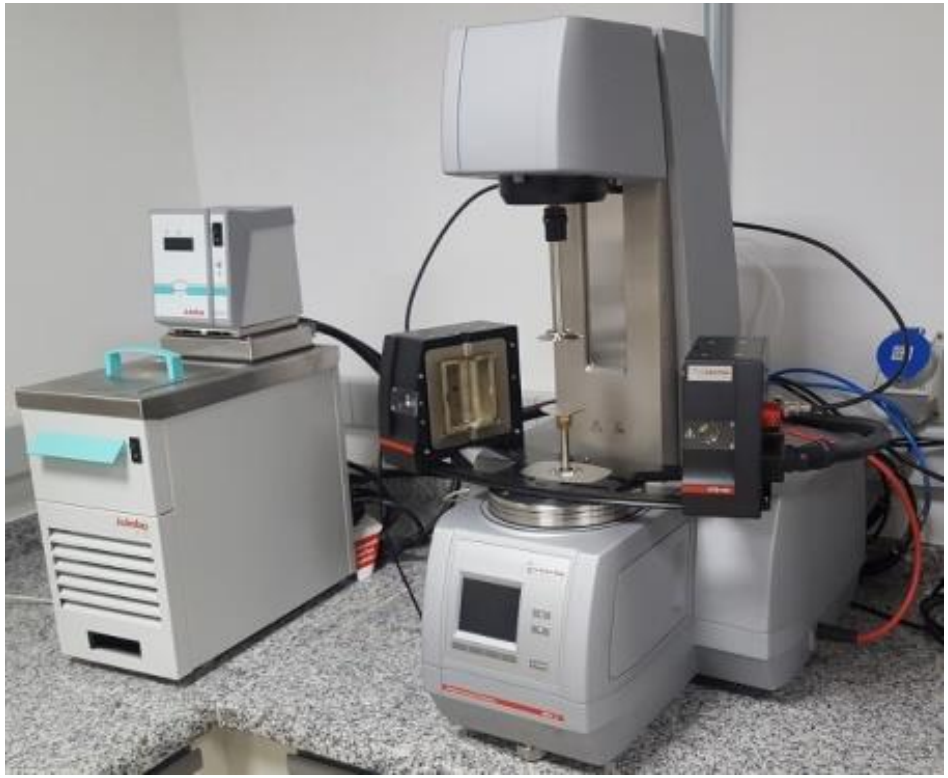
- Polished section for image analysis



Epoxy + GNP

Moritugui; Carastan - 2018.

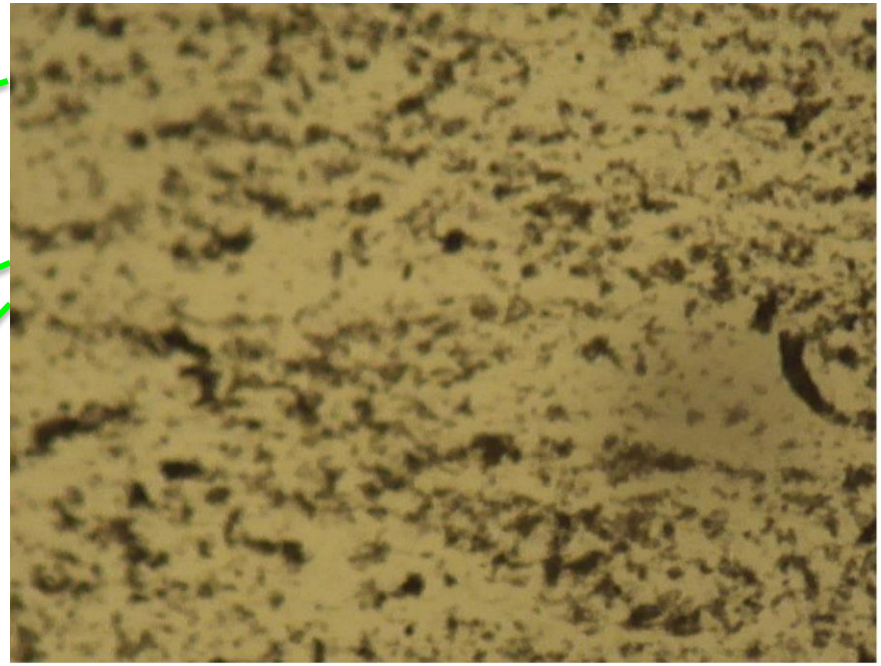
Rheological tests – uncured resin

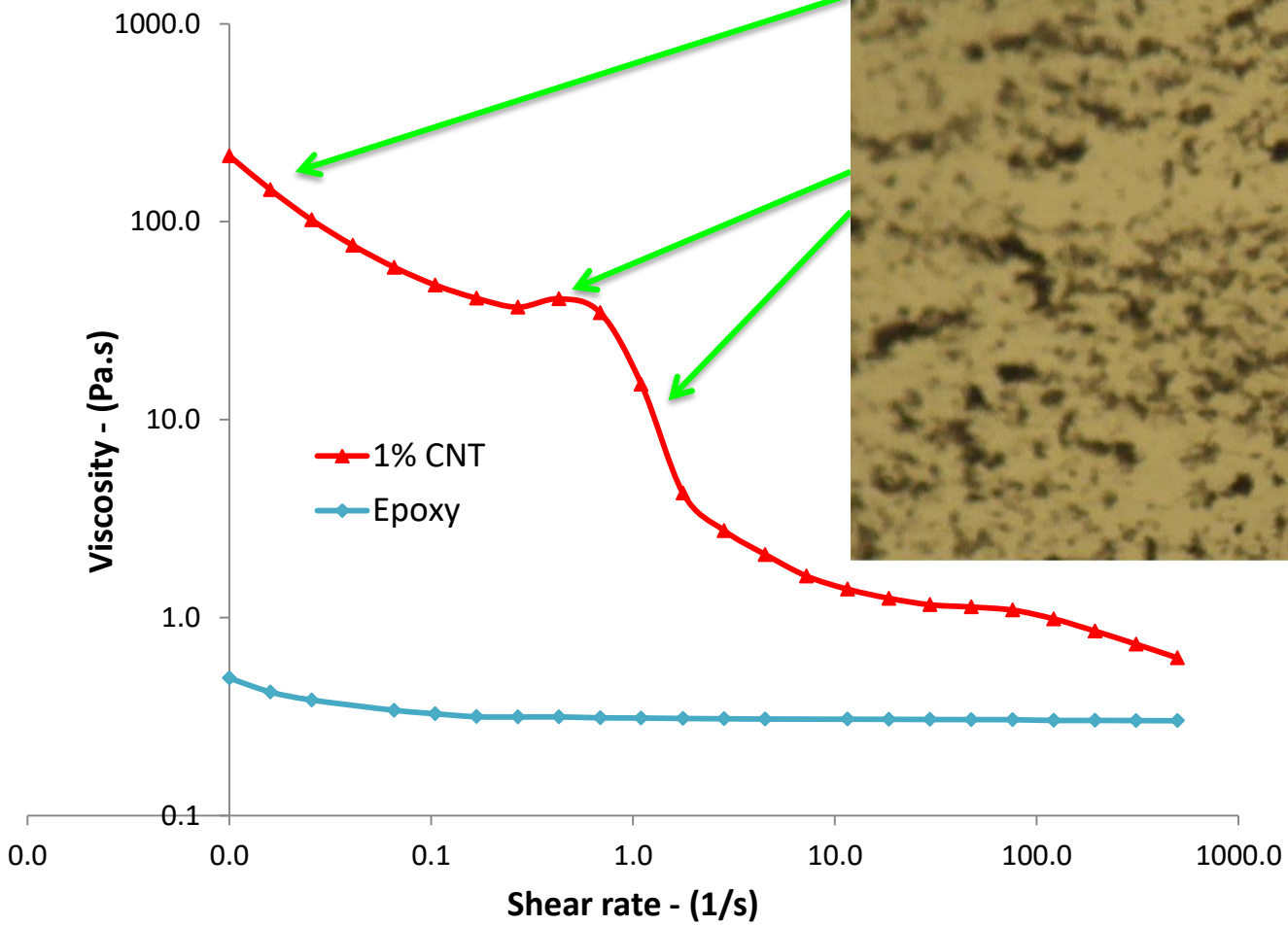


Anton Paar MCR 502 Rotational Rheometer

Rheological tests – uncured resin

MWCNT





Ramalho; Carastan - 2012.

Rheological tests – uncured resin

1 wt% GNP

Ultrasonic probe

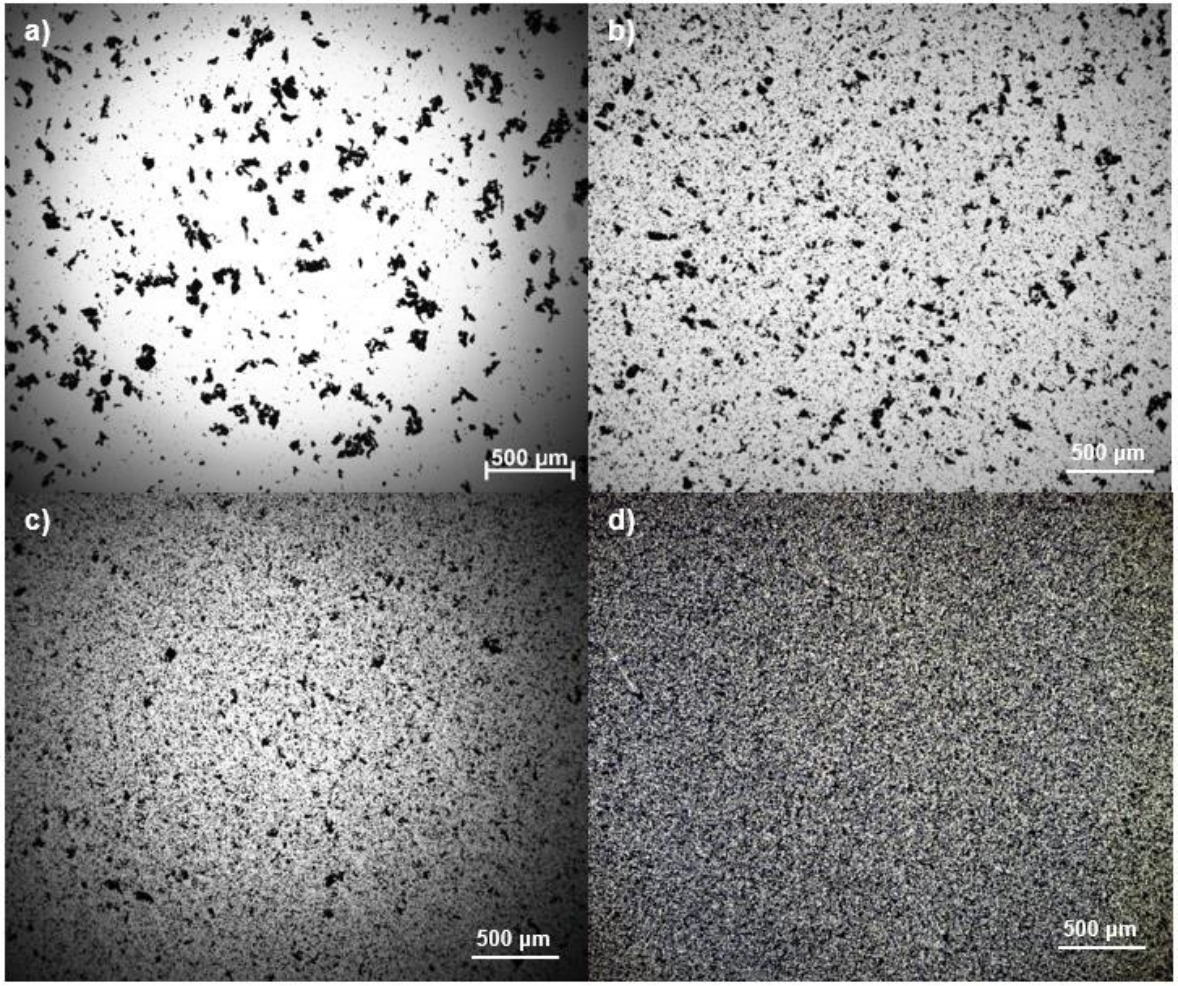
Sonication times:

a) 0 min

b) 2 min

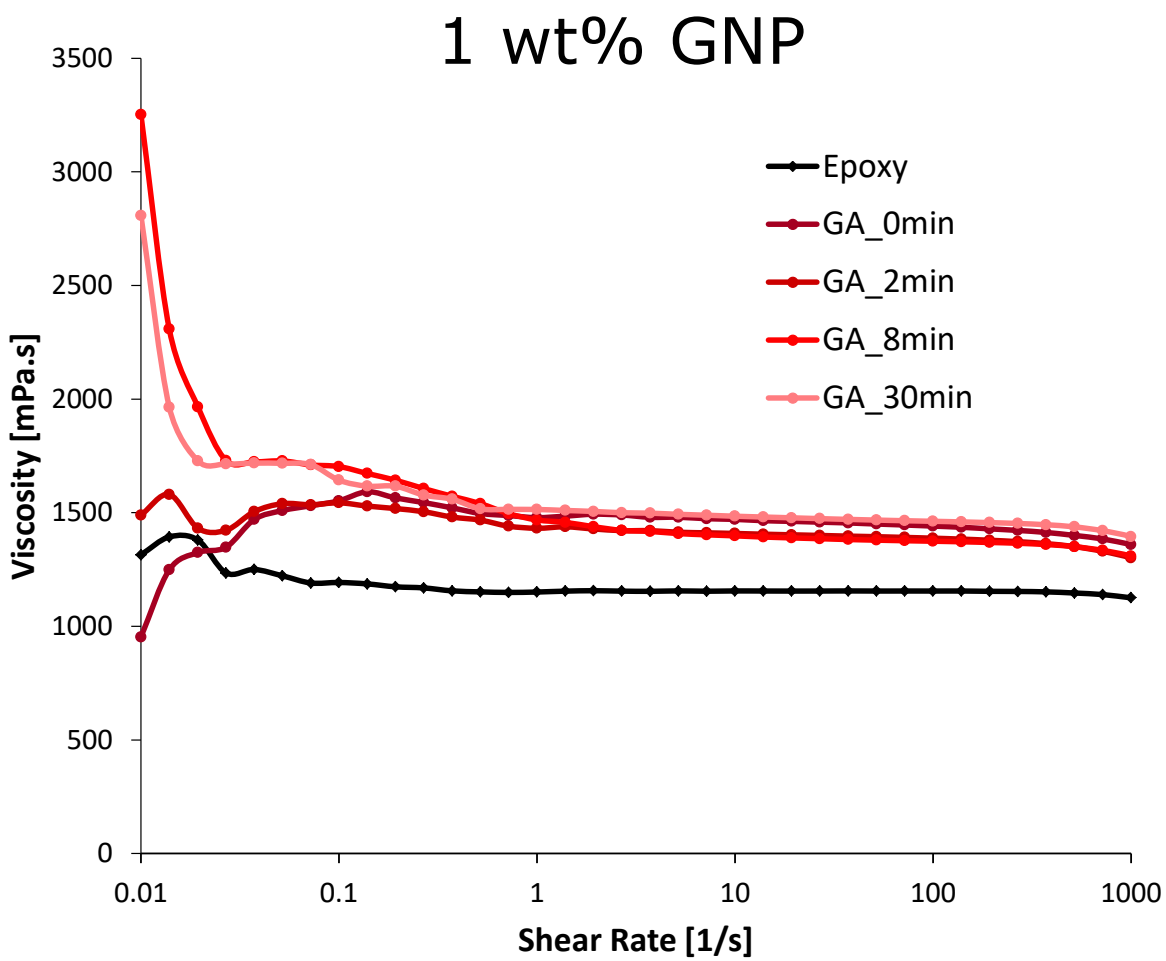
c) 8 min

d) 30 min



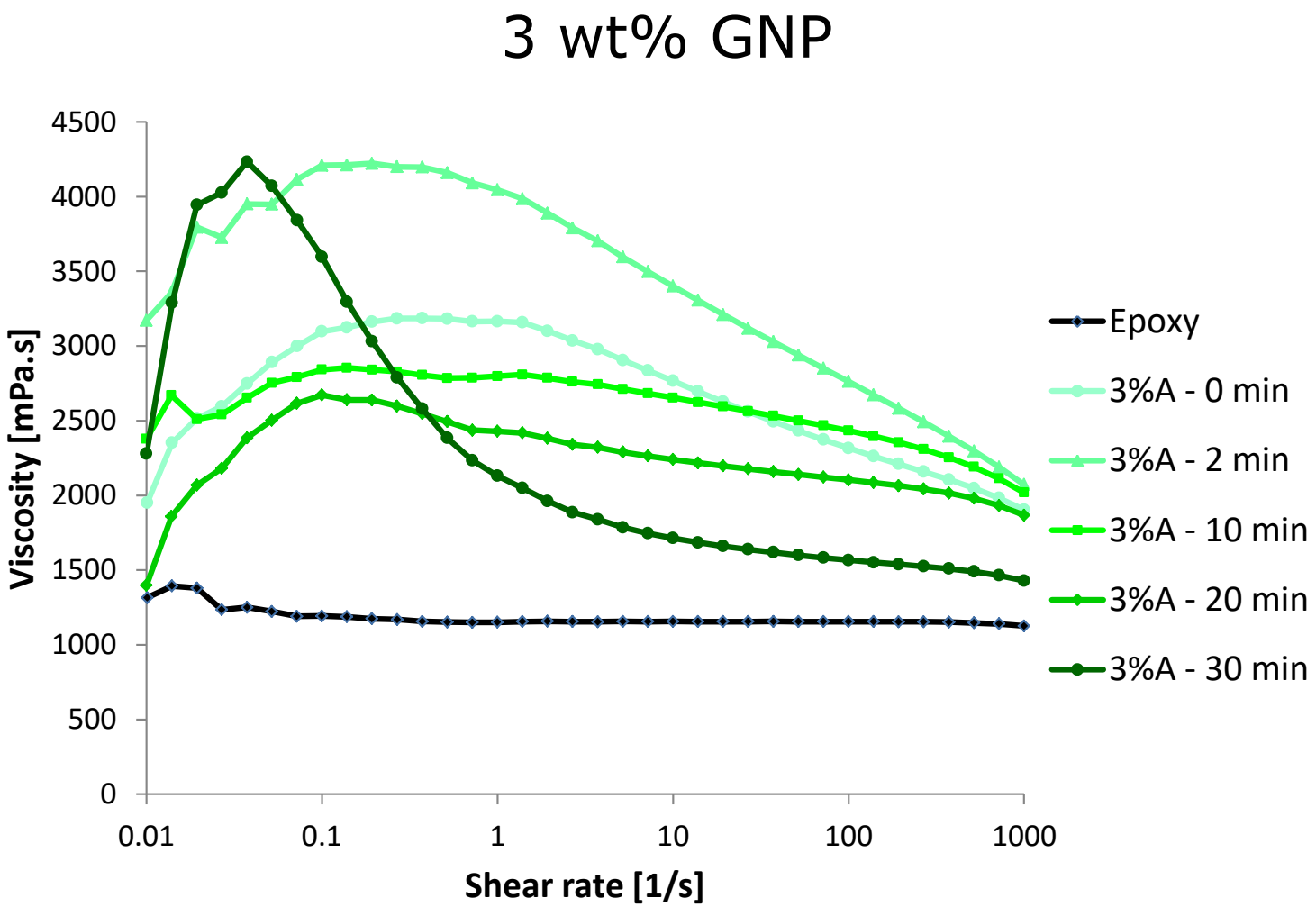
Moritugui; Táboas; Carastan - 2018.

Rheological tests – uncured resin



Moritugui; Carastan - 2018.

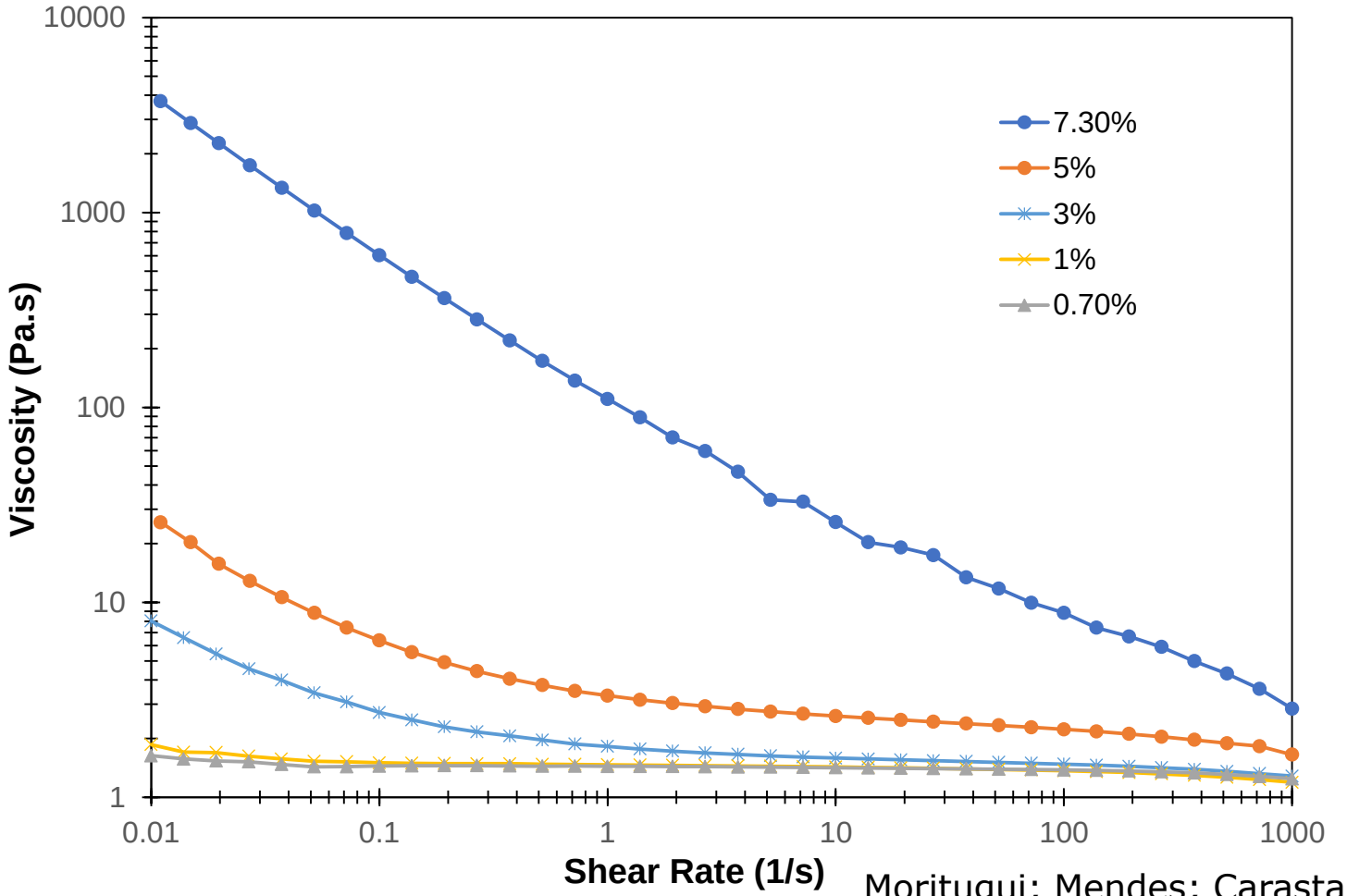
Rheological tests – uncured resin



Moritugui; Carastan - 2018.

Rheological tests – uncured resin

GNP – Effect of concentration

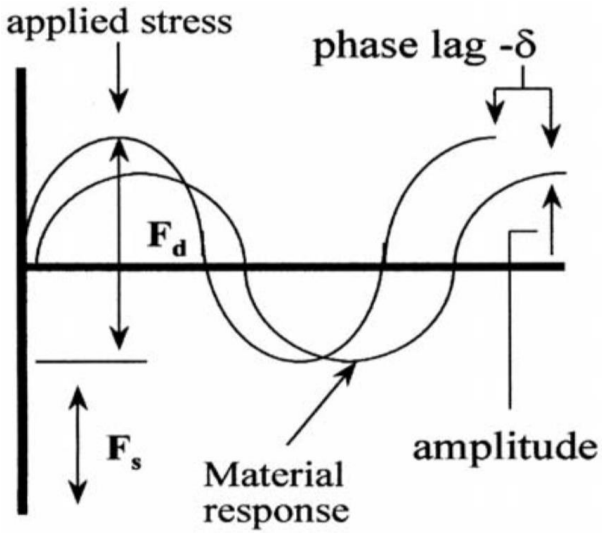


Moritugui; Mendes; Carastan - 2018.

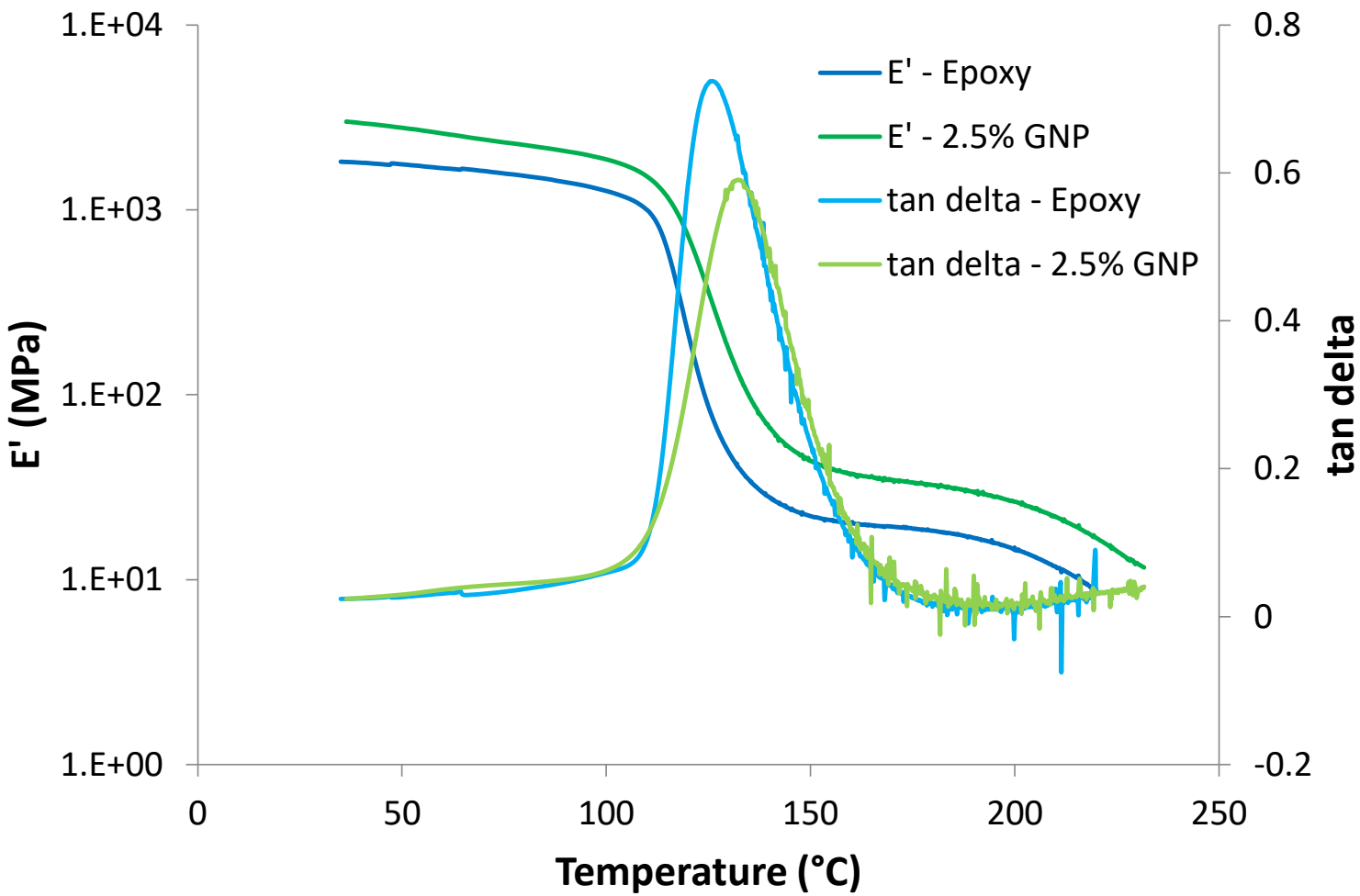
Dynamic-Mechanical Analysis (DMA)

Q800 DMA – TA Instruments

Dual cantilever clamp

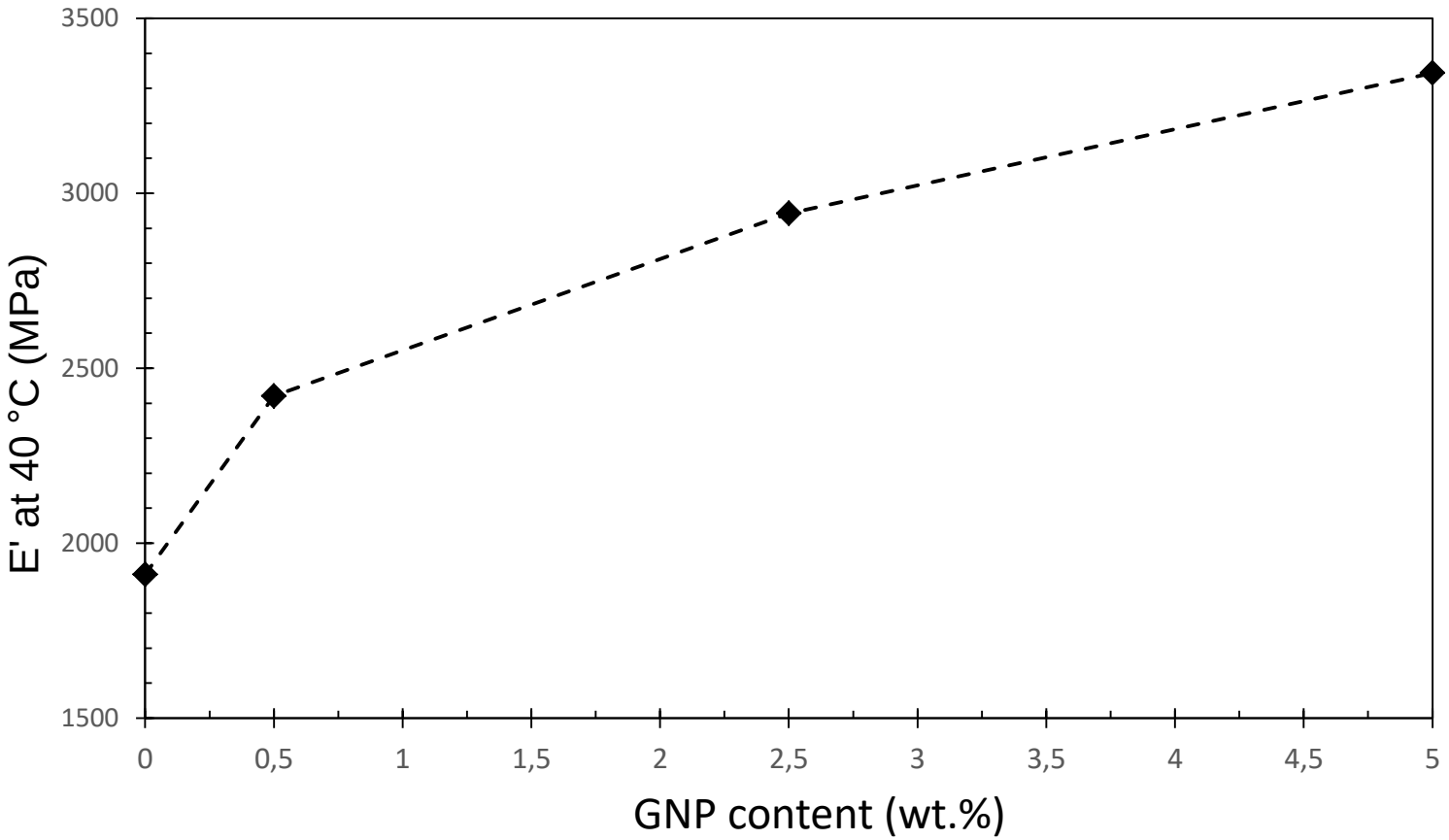


Dynamic-Mechanical Analysis (DMA)



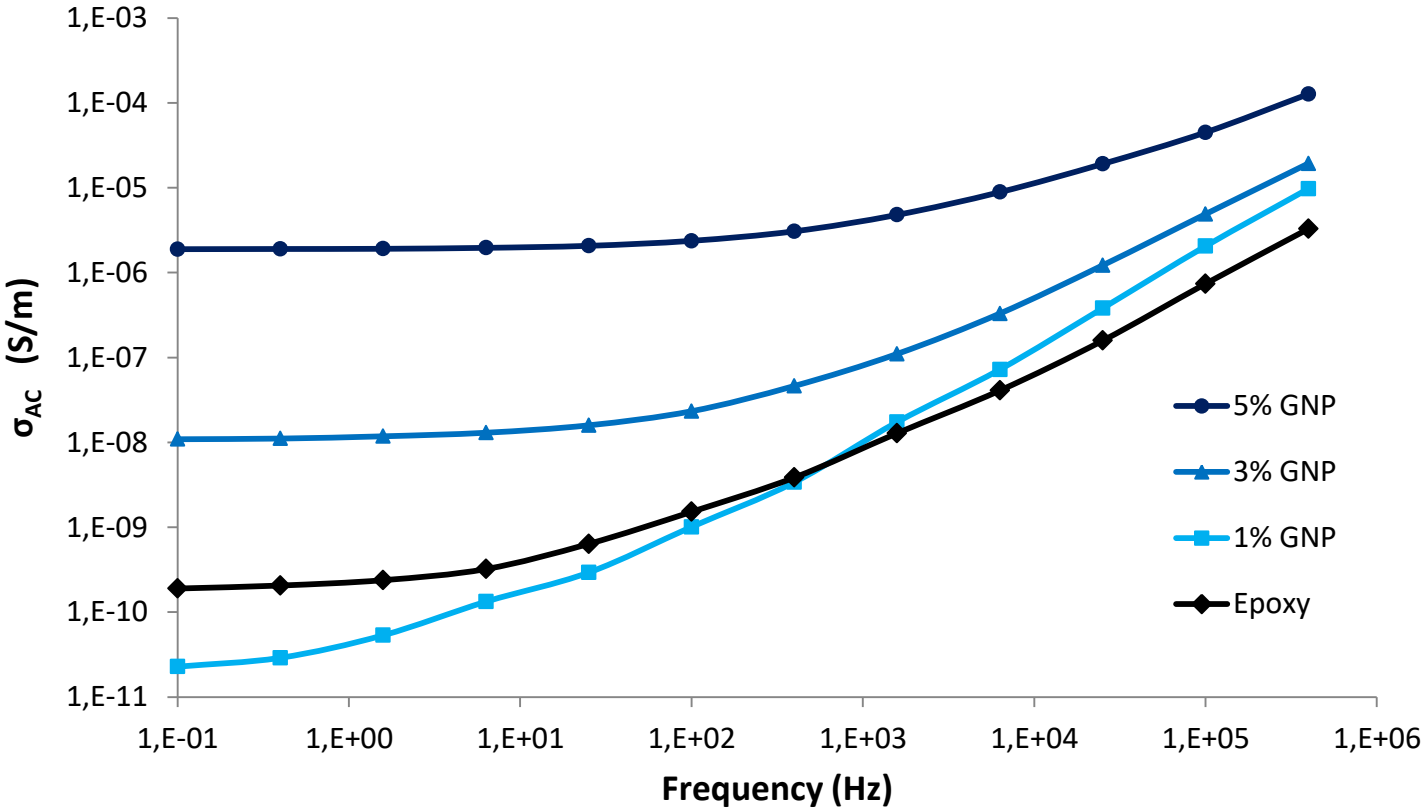
Mendes; Carastan - 2018.

Dynamic-Mechanical Analysis (DMA)



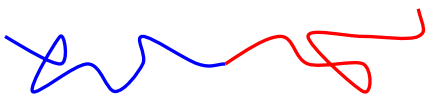
Mendes; Carastan - 2018.

Electrical Properties – Impedance Spectroscopy

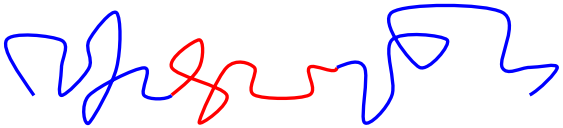


Mendes; Táboas; Carastan - 2018.

Architectures

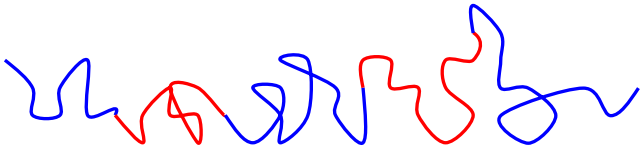


diblock

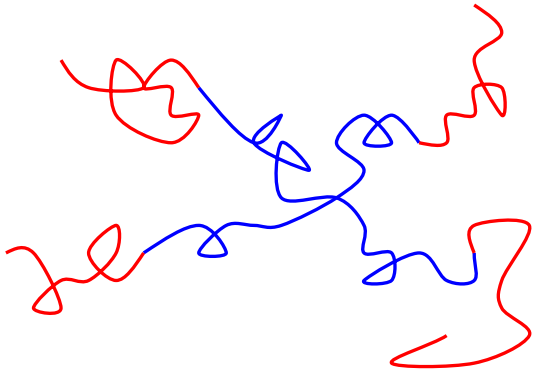


ABA triblock

ABC triblock

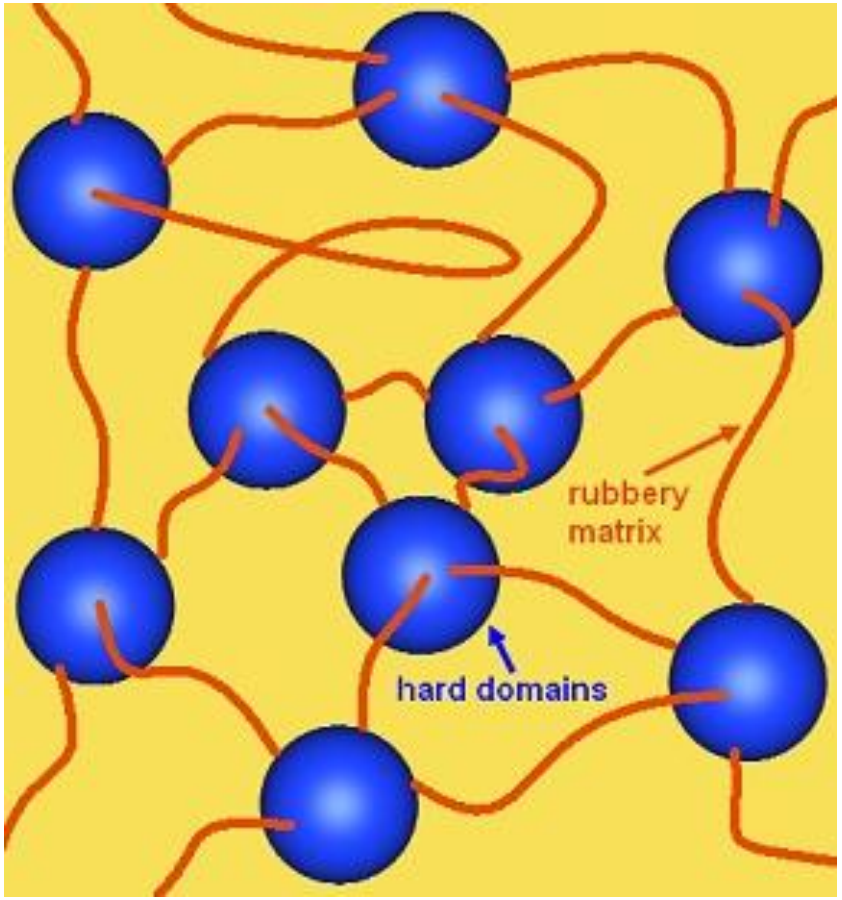


random multiblock



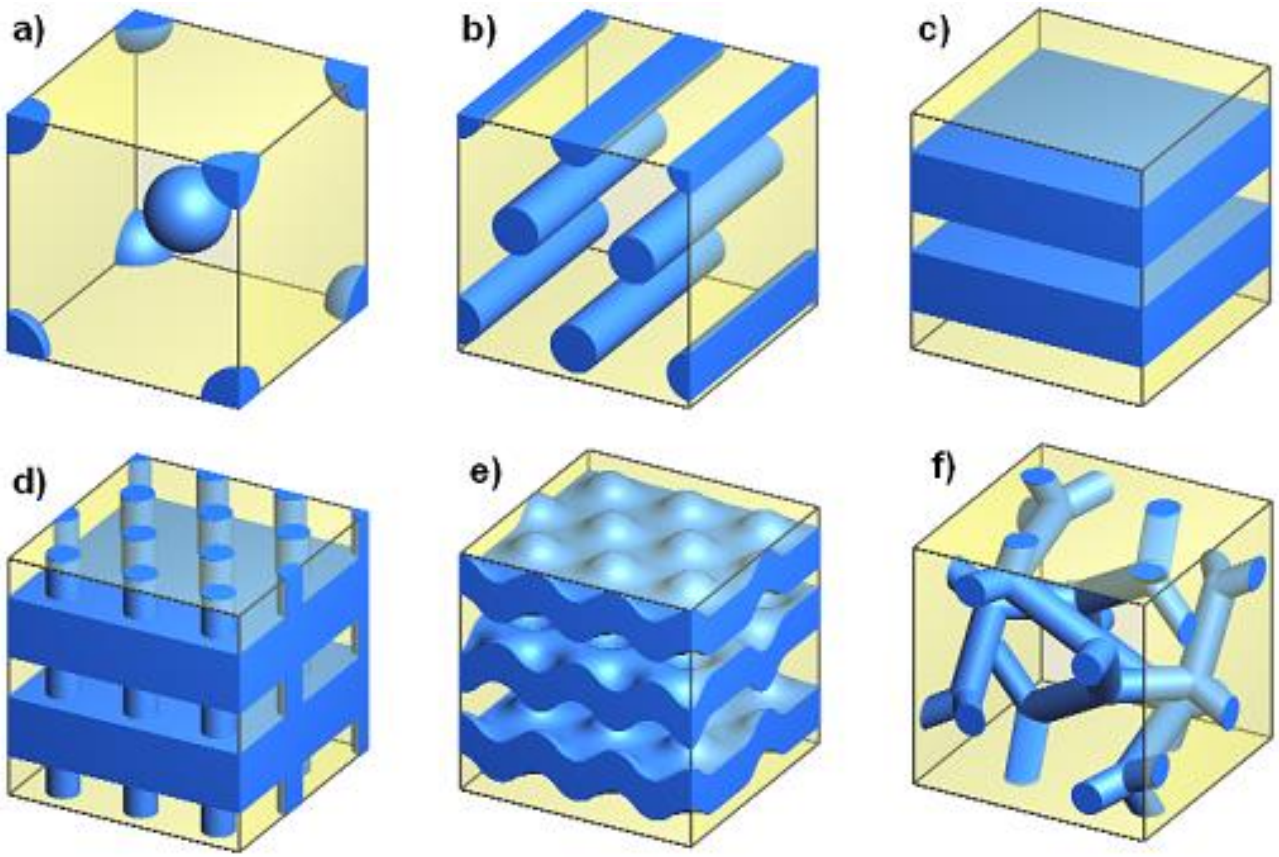
starblock

Morphology – Thermoplastic Elastomers

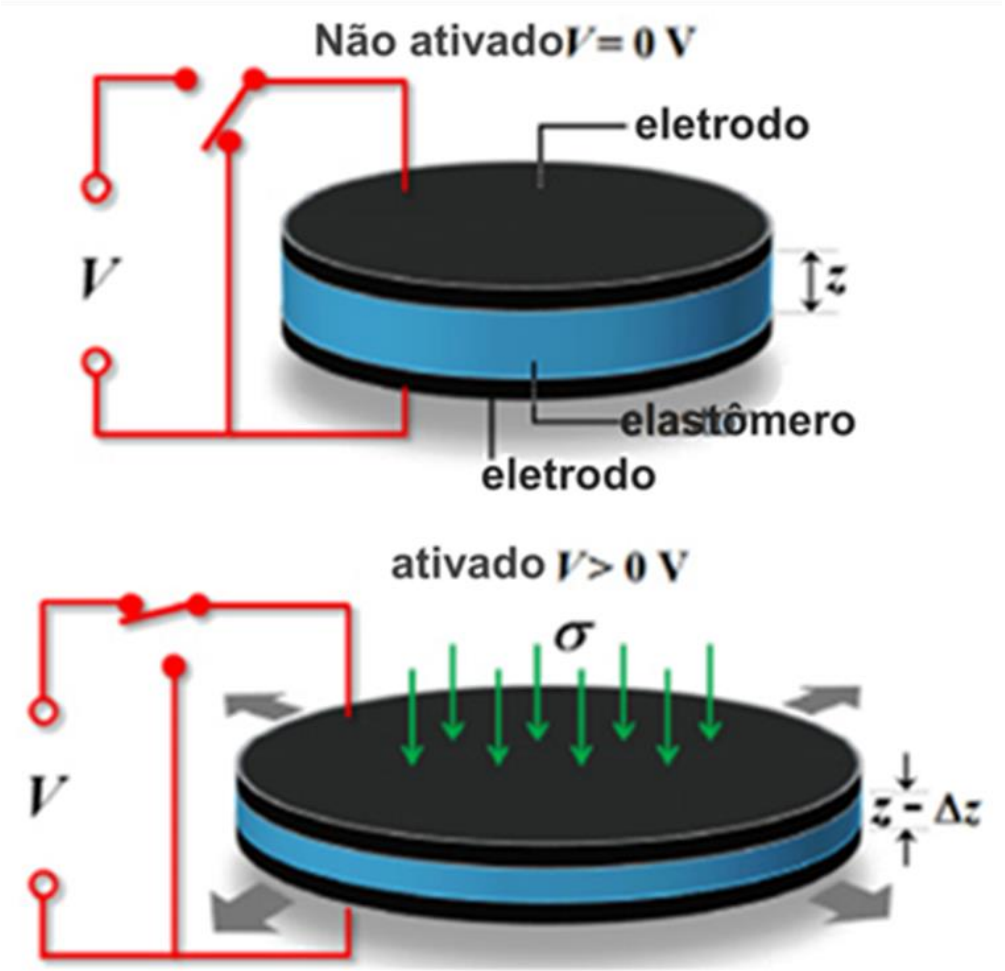


Block Copolymers

Morphology



Dielectric Elastomer Actuators



Block Copolymers

Dielectric Elastomer Actuators

Dielectric Elastomer Actuators

Requirements for a good actuation:

- Low elastic modulus → Block copolymer gels
- High relative permittivity
- High dielectric strength

  } → Nanoparticles
- Flexible electrodes → Conductive nanoparticles

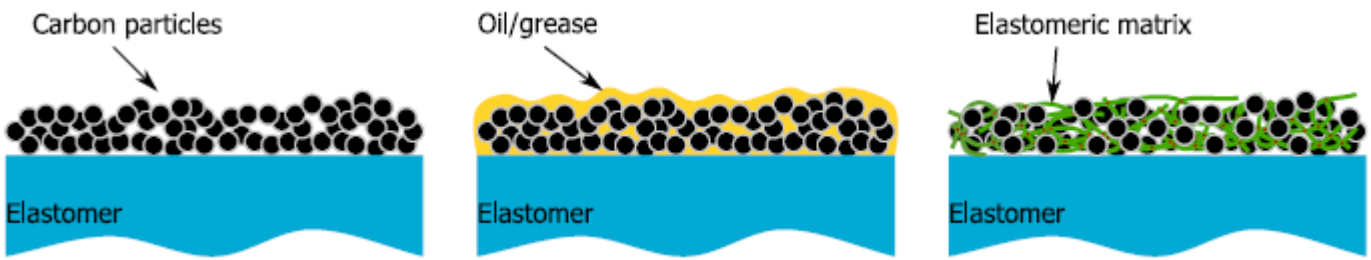
Flexible Electrodes

- The perfect FLEXIBLE ELECTRODE must be
  - Electrically conductive;
  - Able to support high mechanical strain without losing conductivity;
  - Thin and compatible with the dielectric polymer film;
  - Undergo similar amounts of deformation as the polymer film.

Block Copolymers

Carbon-based Flexible Electrodes

- Conductive carbon grease
- Conductive elastomers (block copolymer gels)
- Corrugated graphene membranes

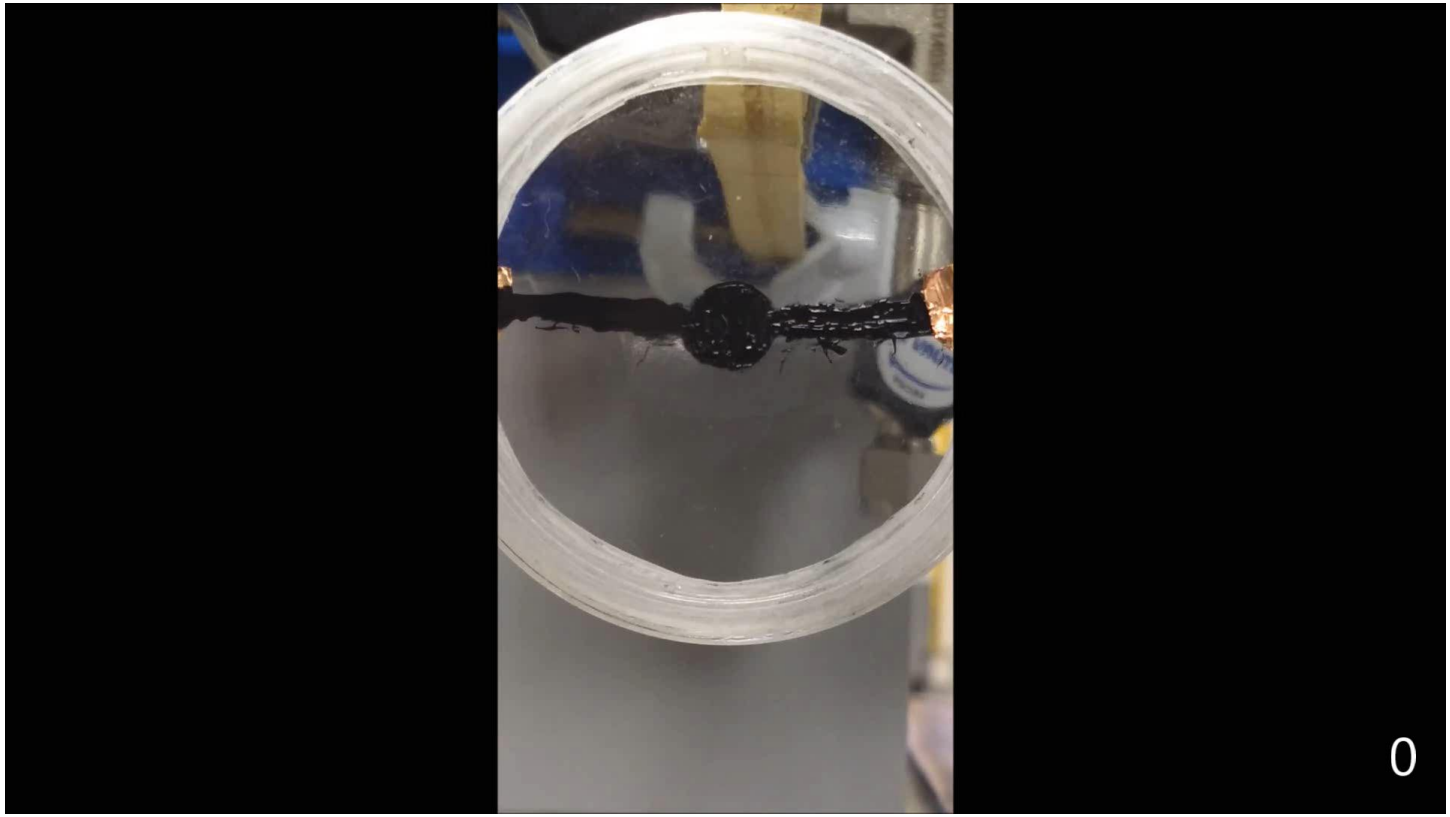


Rosset, Shea, Appl. Phys. A, 110:281, 2013.

Block Copolymers

Carbon-based Flexible Electrodes

- Conductive carbon grease – Carbon Nanotubes



Sousa Jr. R. R.; Carastan, D. J. - 2018.

Block Copolymer Nanocomposites

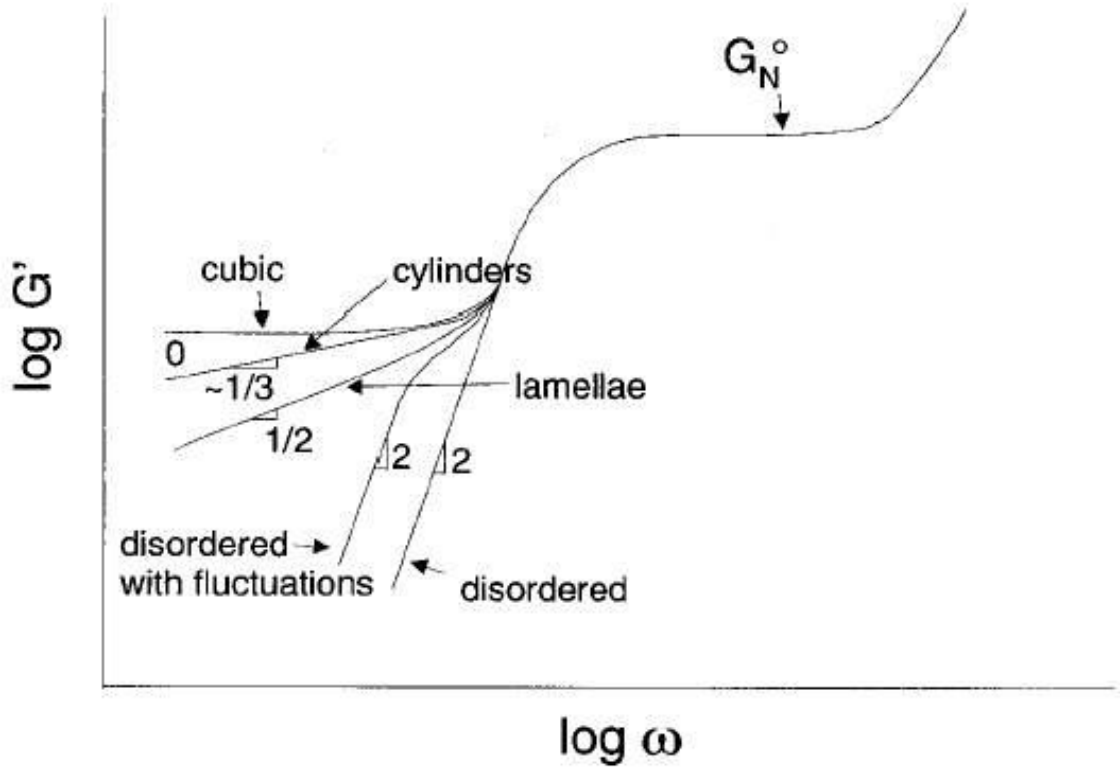
SEBS – Styrene-ethylene/butylene-styrene

- SWCNT
- MWCNT
- 1 and 5 wt%
- Ultrasonic bath and probe

Heinze, D. A., Carastan, D. J.; SBPMat - 2018.

Rheological Properties

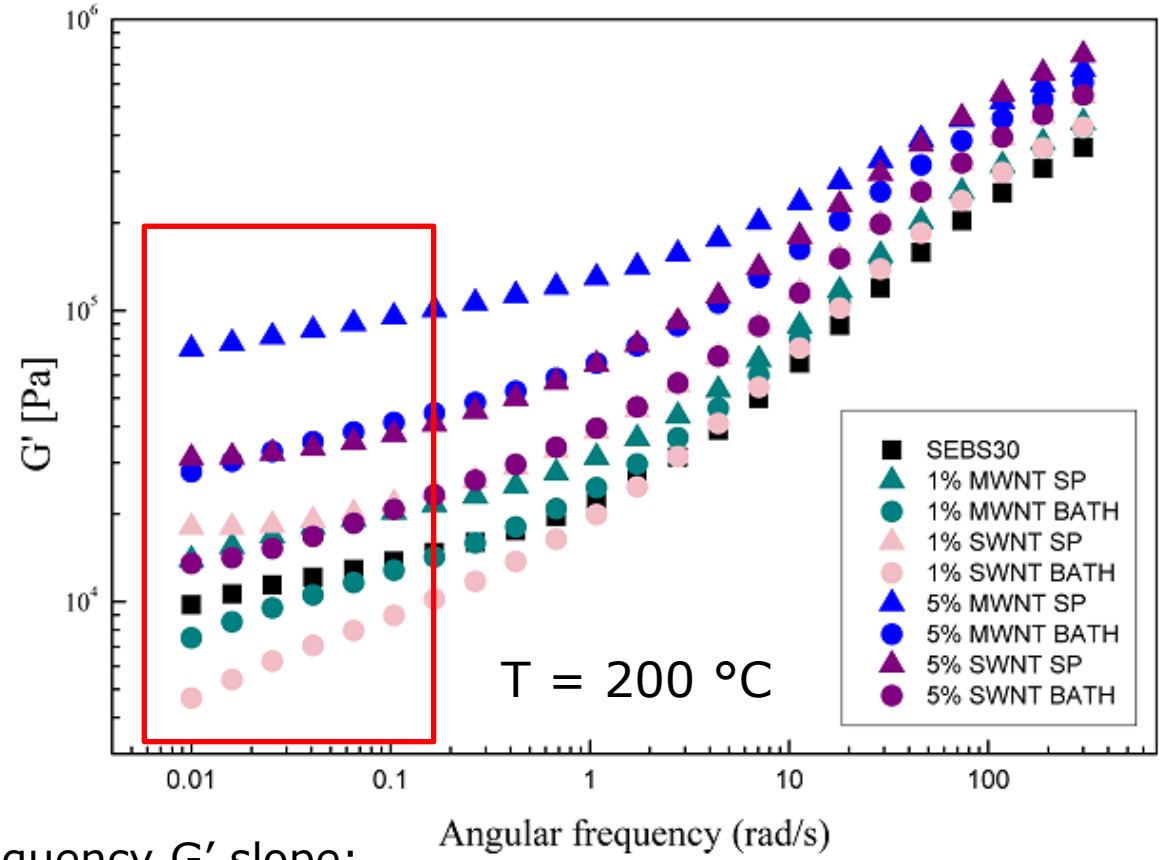
Small Amplitude Oscillatory Shear (SAOS) – Frequency Sweep
Block copolymers:



Kossuth, M. B.; Morse, D. C.; Bates, F. S.; *Journal of Rheology*, 43:167-196, 1999

Block Copolymers

Rheological Properties



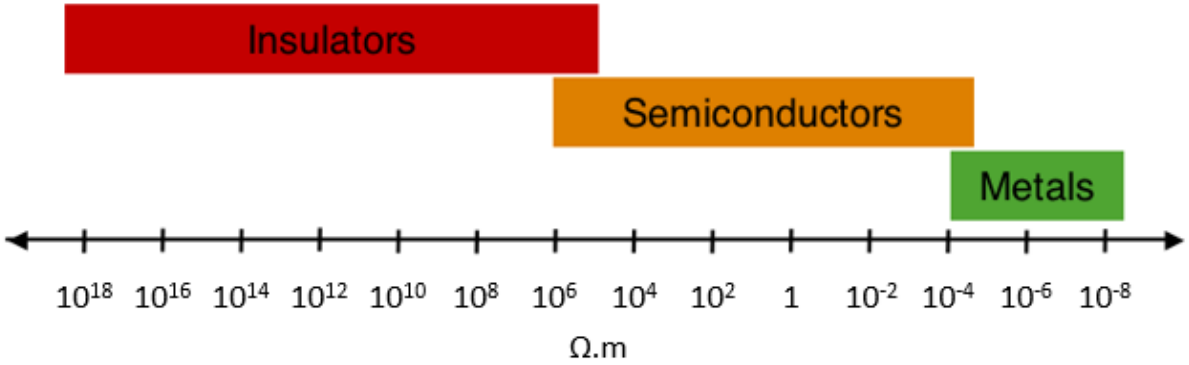
Low frequency G' slope:

Slope	*1% MWNT*	*5% MWNT*	*1% SWNT*	*5% SWNT*
Ultrasonic bath	0.253	0.172	0.296	0.127
Sonicator	0.200	0.106	0.017	0.007

Heinze, D. A., Carastan, D. J.; SBPMat - 2018.

Electrical Properties

Resistivity (Ω.m)	*SEBS30*	*1% MWNT*	*5% MWNT*	*1% SWNT*	*5% SWNT*
Ultrasonic bath	1,05E+08	6,92E+07	5,24E+03	9,07E+07	2,88E+06
Sonicator		2,48E+06	3,54E+03	1,00E+05	6,23E+03



General resistivity values (Ω.m)

Heinze, D. A., Carastan, D. J.; SBPMat - 2018.

Nanocomposites of Block Copolymer Gels

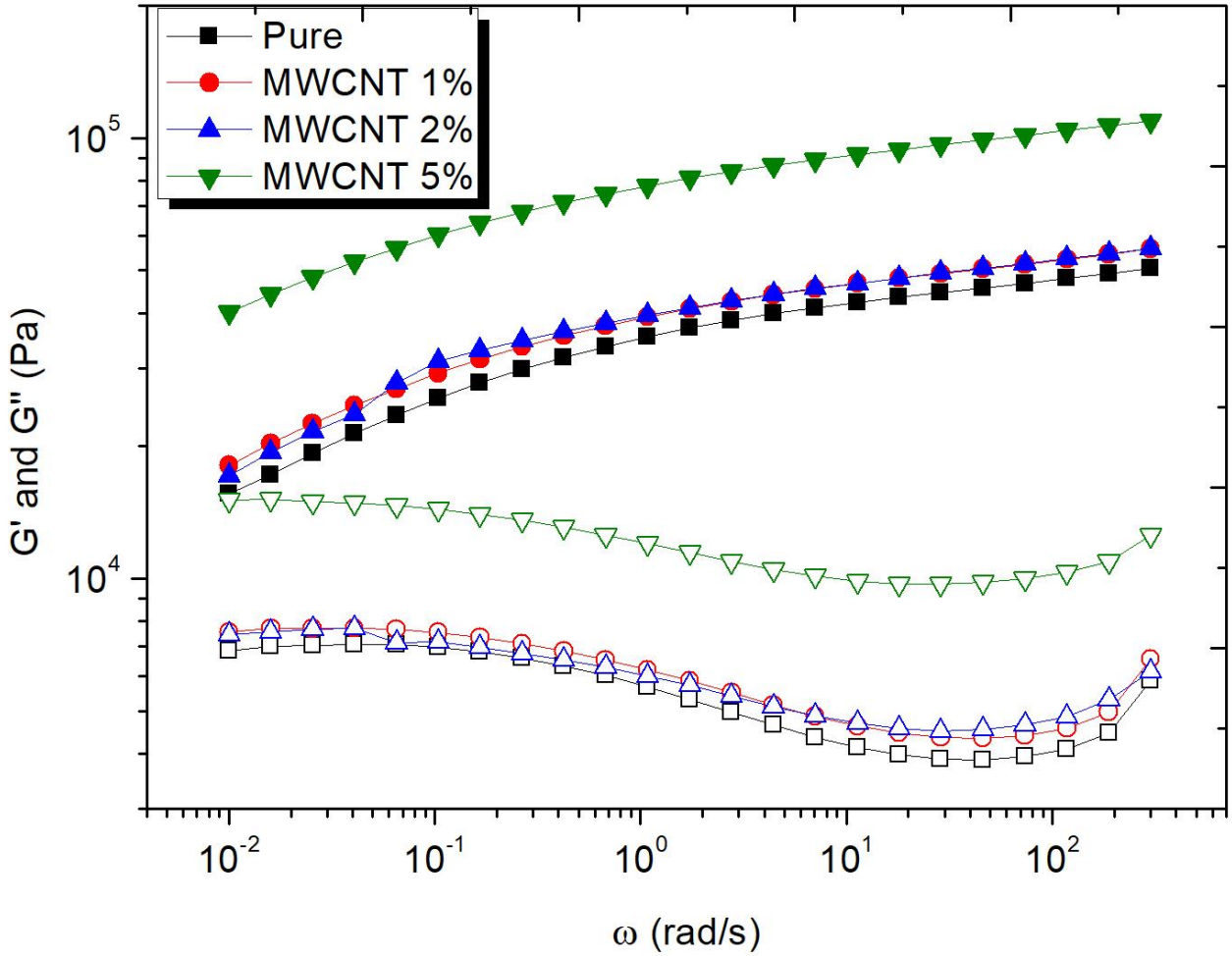
SEBS + Mineral Oil + Nanoparticles

- SWCNT
- MWCNT
- GNP
- 1, 2 and 5 wt%
- Ultrasonic probe

Sacramento, Sousa Jr., Carastan - 2018.

Nanocomposites of Block Copolymer Gels

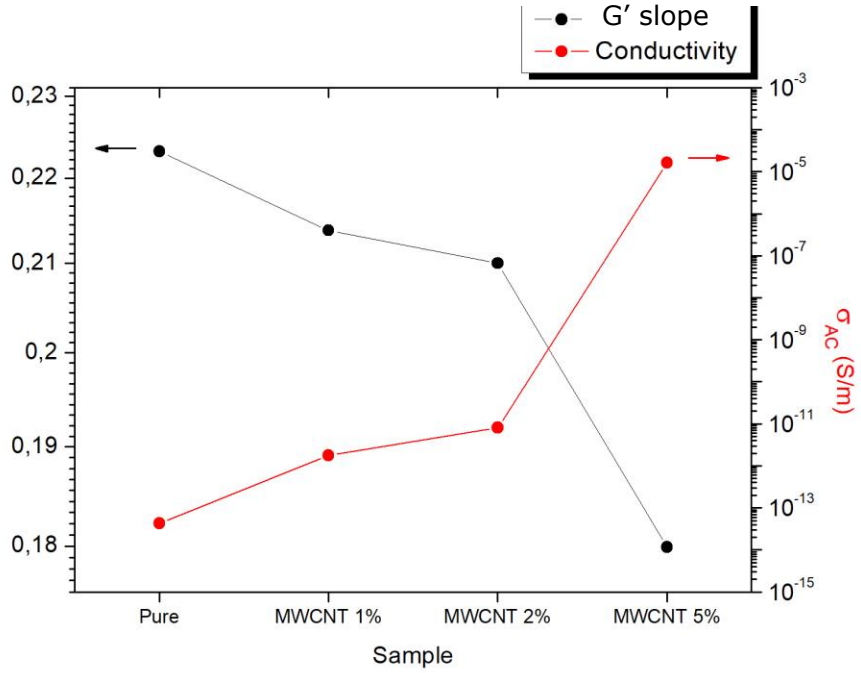
Rheological tests – SAOS – 25 °C

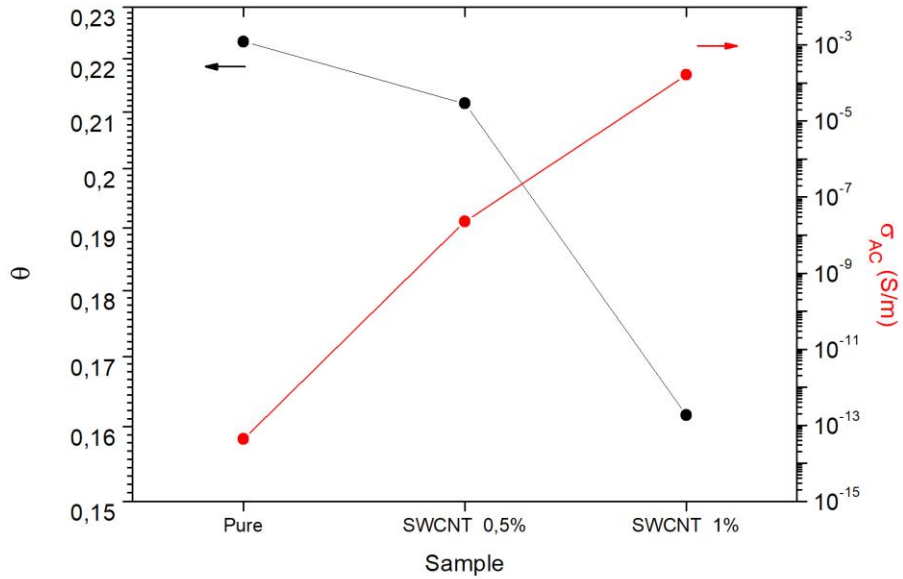


Sacramento, Sousa Jr., Carastan - 2018.

Nanocomposites of Block Copolymer Gels

Electrical / Rheological Percolation



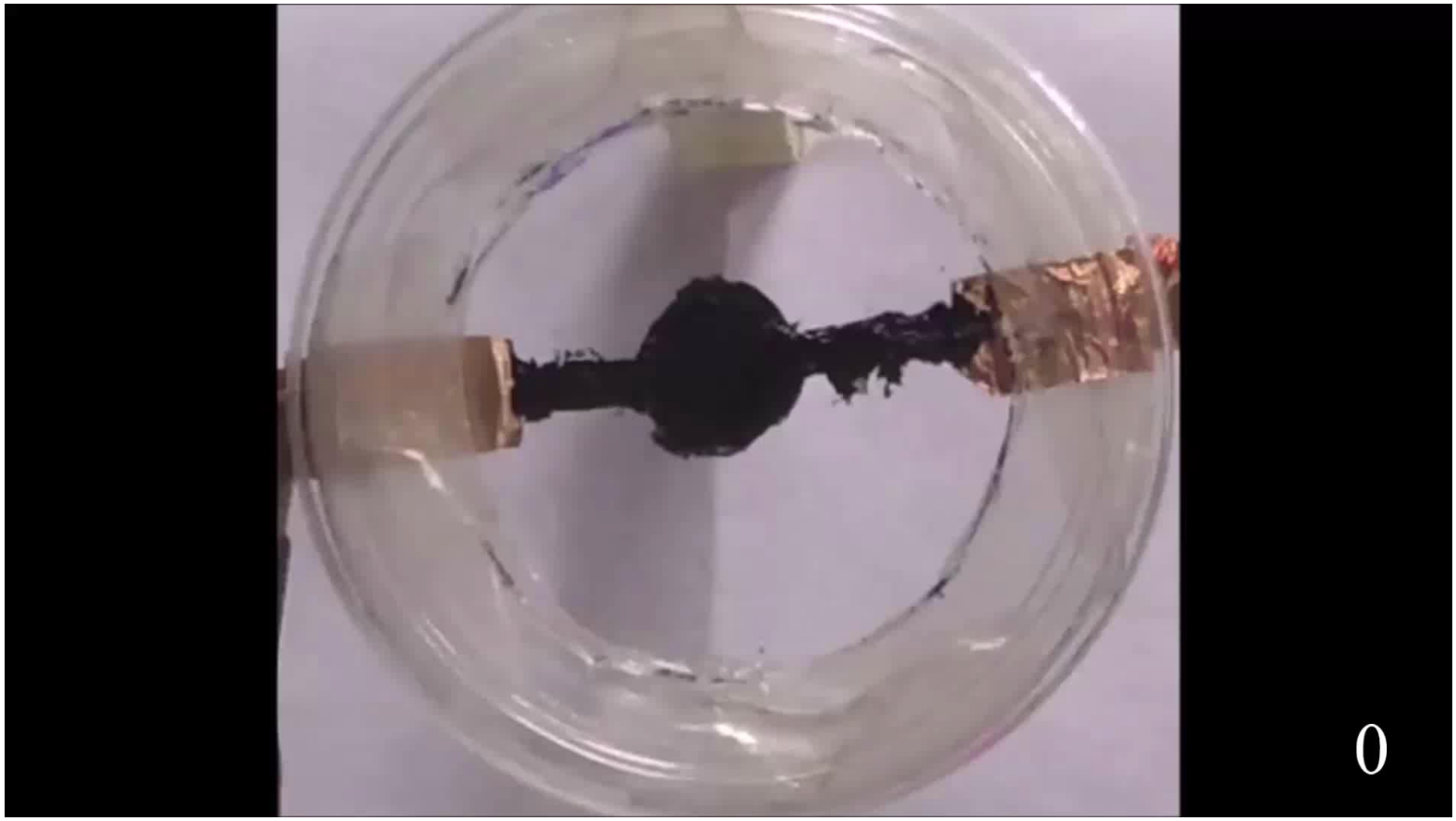


Sacramento, Sousa Jr., Carastan - 2018.

Block Copolymers

Nanocomposites of Block Copolymer Gels

Block copolymer gel + CNT electrode



Sacramento, Sousa Jr., Carastan - 2018.

CONCLUSIONS

- Rheology is a great tool for the morphological characterization of polymer nanocomposites
- Achieving good GNP / CNT dispersion in polymers is still a challenge
- It may not be necessary to achieve full nanoparticle exfoliation / dispersion to reach the desired properties
- Block copolymer gels with carbon nanoparticles are good candidates for flexible electrodes