Z02-3720

Electrical Conductivity and Linear Rheology of Multi walled Carbon Nanotube/Acrylonitrile Butadiene Styrene Polymer Nanocomposites Prepared by Melt Mixing and Solution Casting

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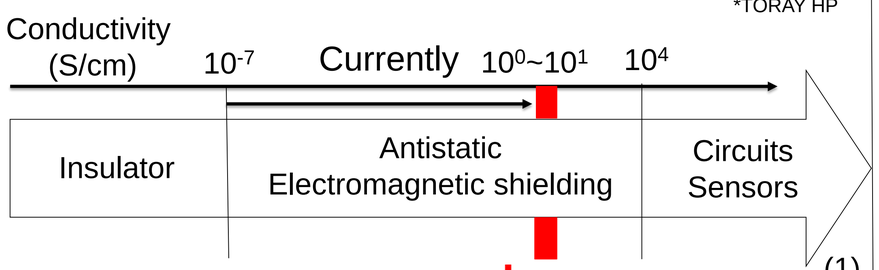
Introduction

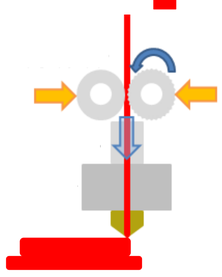
Conductive polymer composite*

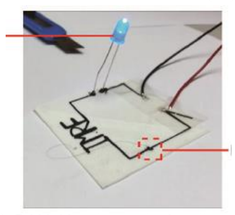
*TORAY HP



(1)

Conductive filler
- Carbon Black (CB)
- Graphene
- Carbon fiber (CF)
- Carbon nanotube



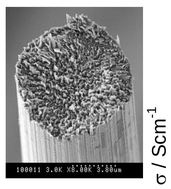


(1) S.W. Kwok *et al*., Applied Materials Today, **9,** 167 (2017)

Ultimate goal: For 3D printing

High conductivity: for printing a wide variety of electrical and functional components, devices etc.
High processability: for printing using commercially available conventional 3D printers.

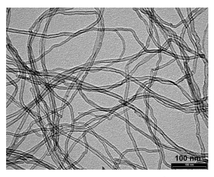
CF



*Japan Chemical Fiber Association HP

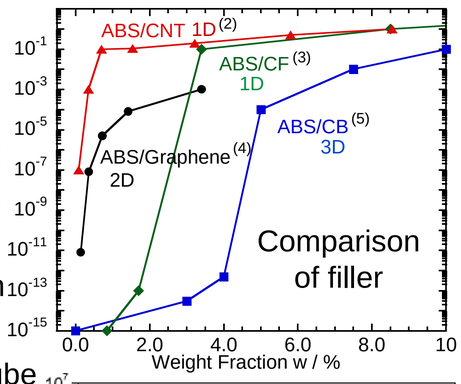
Length 6 mm
Diameter 7 μm

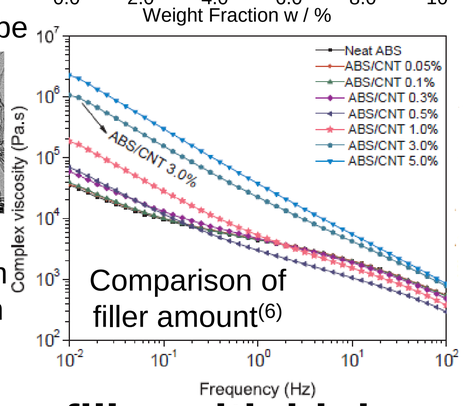
Carbon nanotube



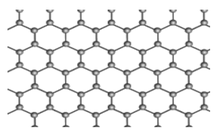
*Nanocyl HP

Length 1.5 μm
Diameter 9.5 nm





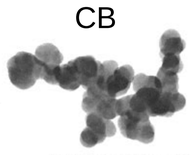
Graphene



*NTT AT HP

Size 180 μm

CB



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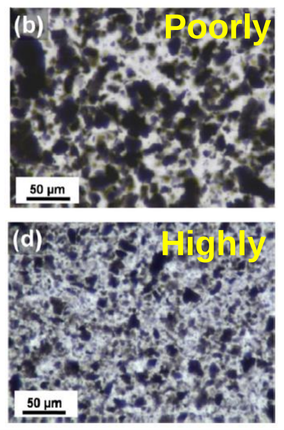
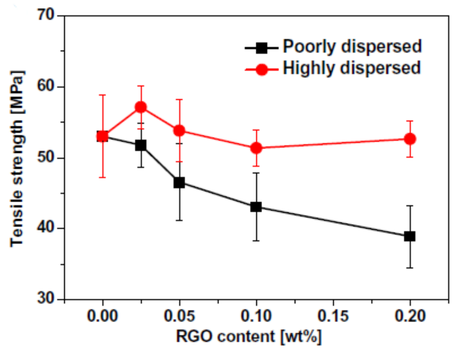
*Mitubishi Chemical HP

Particle size 12 nm

Effect of dispersion on physical properties (7)





	Advantage	Disadvantage
Melt Mixing	Fast, Scalable	Poor dispersion (?)
Solution Casting	Good dispersion	Solvent disposal

Conductive filler with high aspect ratio

Multi-walled carbon nanotubes

(2) Al-Saleh *et al.*Journal of Polymer Science Part B : Polymer Physics, **50**, *1356* (2012). (3) X. Liang *et al.*, Materials Letters, **43**, 144 (2000). (4) Chong *et al*. ACS Applied Materials & Interfaces, **6**, 12252 (2014). (5) Al-saleh *et al*., Carbon, **60**, 146 (2013). (6) D.P. Schmitz et al., *Mater*ials Today Communications **15**, 70 (2018).

Melt mixing vs Solution casting

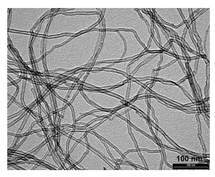
Electrical Conductivity: 4 point probe
Linear Rheology: oscillatory shear

(7) L-C Tang *et al*., CARBON, **60**, 16 (2013)

(1) Sample

ABS (Beijing Tiertime Technology Co., Ltd.)

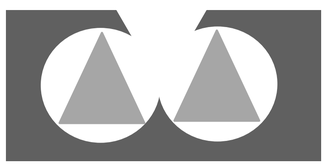
MWCNT (Nanocyl NC7000™)
Average length 1.5 μm
Average diameter 9.5 nm



(2) Sample preparation

Melt mixing

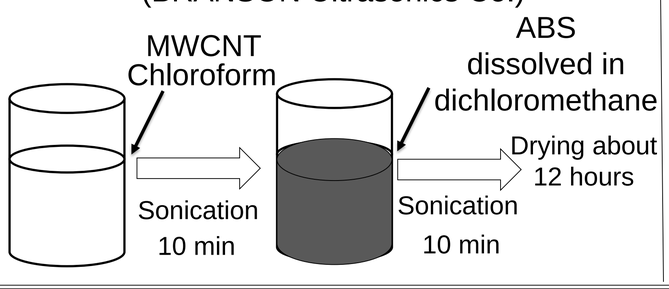
Twin screw melt mixer
(Toyo seiki seisaku-sho Co.)



200 ℃ 50 rpm 10 min

Solution casting

Ultrasonic homogenizer
(BRANSON Ultrasonics Co.)



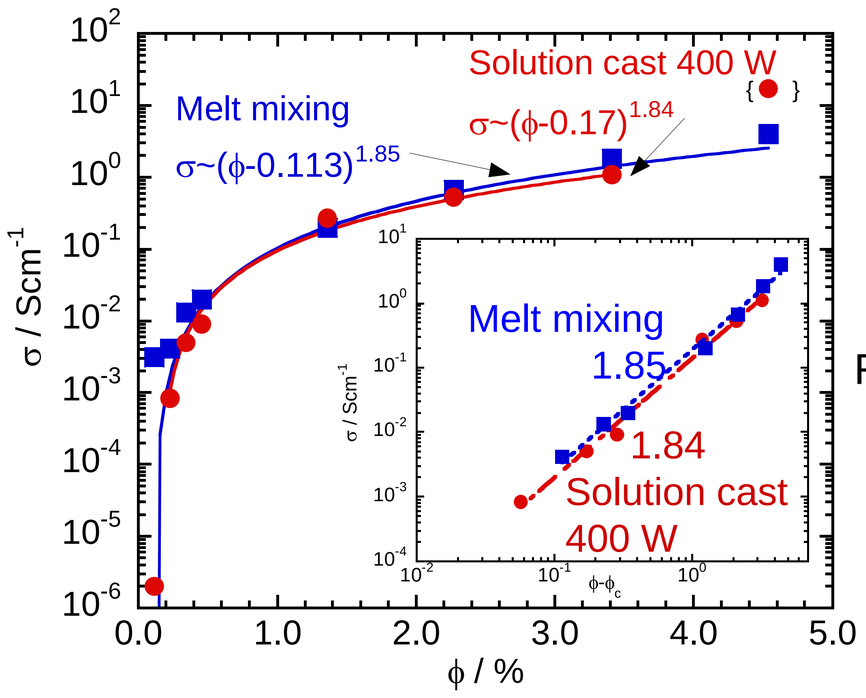
(3) Measurement

1.Conductivity
Digital multimeter 2110
(Keithley)

2.Linear rheology
MCR 301 (Anton Paar)
Frequency sweep
10^{-2} ~ 10^{2} rad*s^{-1}
$\gamma = 1$

Results and Discussion

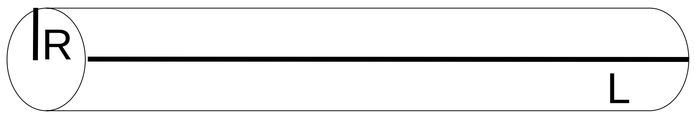
(1) Conductivity(8)



Conductivity percolation

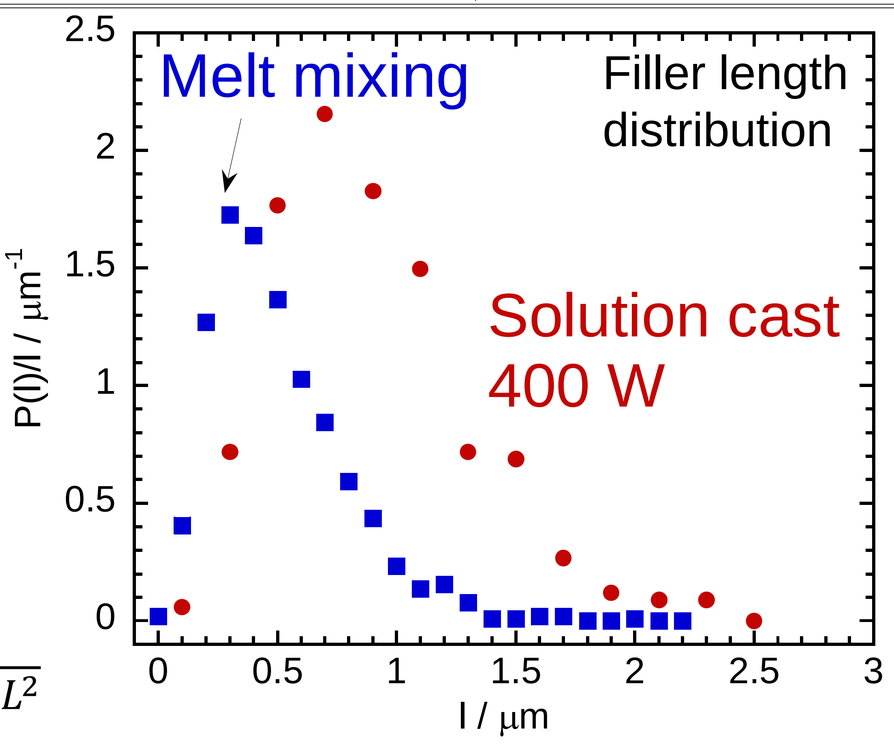
$$\sigma = \sigma_0(\phi - \phi_{c\sigma})^{t_\sigma}$$

σ : Conductivity
ϕ : Filler volume fraction
$\phi_{c\sigma}$: Percolation threshold
t_σ : Critical exponent



R : 4.8 nm

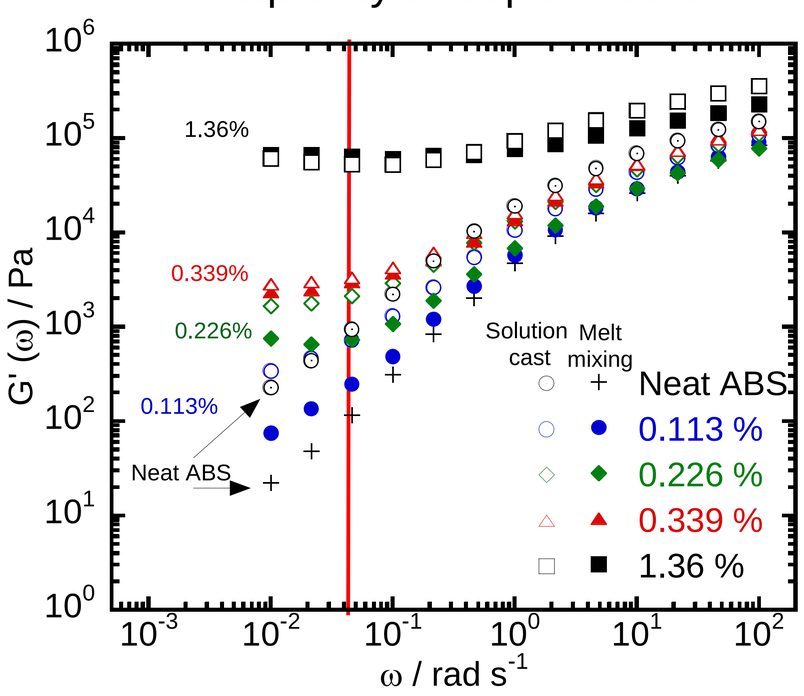
$$\phi_{ct} = \frac{\frac{4}{3}\pi R^3 + \pi R^2 L}{16\pi R^3 + 8\pi R^2 L + \pi R L^2}$$



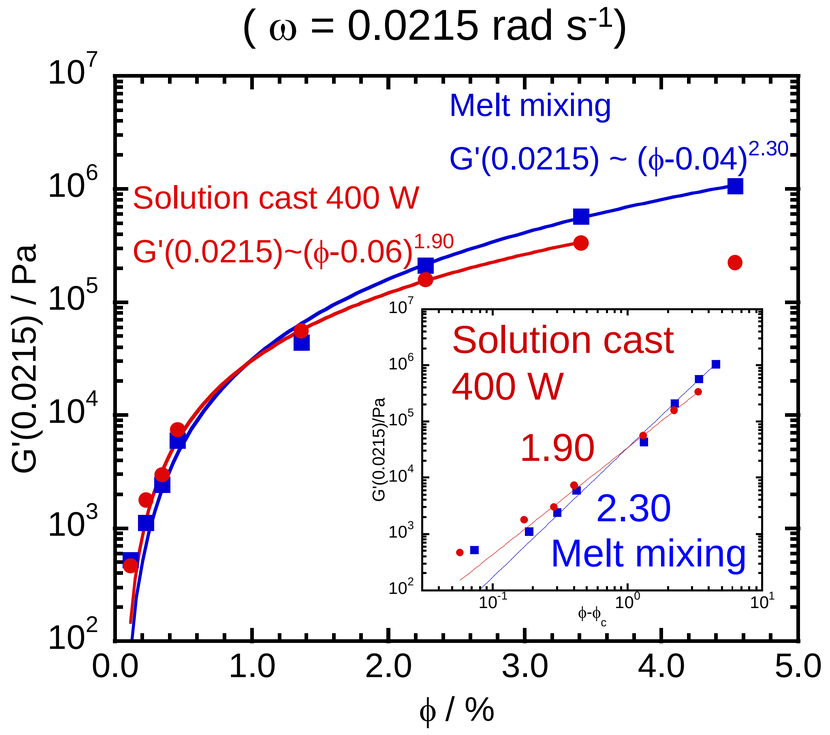
	$\phi_{c\sigma}$ / %	L_{ave} / μm	ϕ_{ct} / %	*s*	CV ≡ *s*/L_{ave}
Melt mixing	0.113	0.4	1.1	0.27	0.50
Solution casting	0.170	0.9	0.60	0.40	0.45

(2) Linear rheology(8)

Frequency sweep at 200℃



Power-law fitting
(ω = 0.0215 rad s^{-1})



(8) S. K. Sukumaran *et al., Journal of The Electrochemical Society*, **166** (9), B3091 (2019).

Electrical Conductivity: Melt mixing using an internal batch mixer is at least as good as solution casting!
→ No special mixing processes or protocols are required.
The obtained conductivity values are close to the highest values reported in the literature.
→ No modification or treatment of the filler surface is required.
Percolation: The dependence of the electrical conductivity and the storage modulus on the filler content can be described by power-laws.
→ The conductivity exponent is close to theory (assuming random filler distribution).