NoPo Nanotechnologies India Private Limited

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Bangalore

Comparison Between NoPo HiPCO® Carbon Nanotubes and Tuball Graphene nanotubes

Table 1 Comparison of As-Produced Tuball and NoPo HiPCO®

Specification	Unit of Measure	Tuball (Raw)[1]	Evaluation Method	NoPo (Raw)[2]	Evaluation Method
Appearance	-	Black Powder	Visual inspection	Black fluffy powder	Visual inspection
SWCNT Content	wt.%	>80	OCSiAl internal method: ash residue	>80	TGA: NIST Special Publication 960-19
SWCNT Length	µm	>5	AFM	>1	AFM
Specific Surface area	m^2/g	>300	BET (ISO 9277:2010)	>1300	BET (ISO 9277:2010)
SWCNT Outer Dia	nm	1.6 +/- 0.4	Optical absorption (ISO/TS 10868:2017)*	0.8 +/-0.2	Optical absorption, Raman Spectroscopy, TEM
G/D Ratio	Unit	>40	Raman (532 nm): NIST Special Publication 960-19	>40	Raman (532 nm): NIST Special Publication 960-19
Metal Impurities	wt%	<15	OCSiAl internal method. ICP-AES	<15	TGA: NIST Special Publication 960-19
Moisture	wt.%	< 5	Infrared Thermogravimetry	<2	Thermogravimetric Analysis

Table 2 Properties of Purified Tuball and NoPo HiPCO®

Specification	Unit of Measure	Tuball (Purified)[1]	Evaluation Method	NoPo HiPCO® (Purified)[2]	Evaluation Method
Appearance	-	Black Powder	Visual inspection	Black fluffy powder	Visual inspection
SWCNT Content	wt.%	99.0 +/- 0.5	OCSiAl internal method: ash residue	>99	TGA: NIST Special Publication 960-19
SWCNT Length	µm	>5	AFM	>1	AFM
Specific Surface area	m^2/g	800-1600	BET (ISO 9277:2010)	>1300	BET (ISO 9277:2010)
SWCNT Outer Dia	nm	1.6 +/- 0.4	Optical absorption (ISO/TS 10868:2017)*	0.8 +/-0.2	Optical absorption, Raman Spectroscopy, TEM
G/D Ratio	Unit	>40	Raman (532 nm): NIST Special Publication 960-19	>40	Raman (532 nm): NIST Special Publication 960-19
Metal Impurities	wt%	In ppm Cr < 350 / Fe< 8000 / Cu < 20 / Ni < 350 / Zn < 20	OCSiAl internal method. ICP-AES	<1	TGA: NIST Special Publication 960-19
Moisture	wt.%	< 5	Infrared Thermogravimetry	<2	Thermogravimetric Analysis

*The analysis of the nanotube diameter is applicable for the diameter range from 1 nm to 2 nm.

Reference:

1. https://tuball.com/additives/tuball
2. https://www.mdpi.com/2311-5629/5/4/65
3. https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication960-19.pdf

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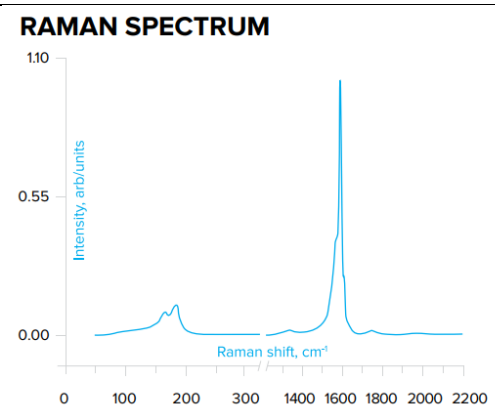
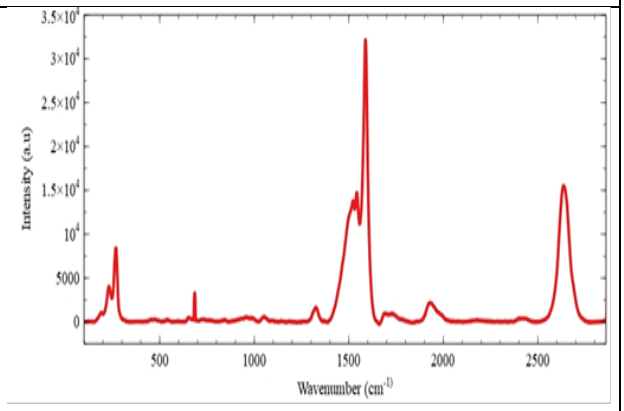
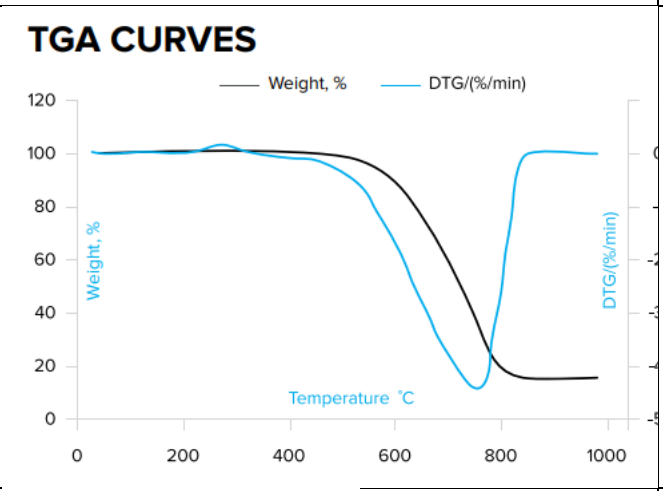
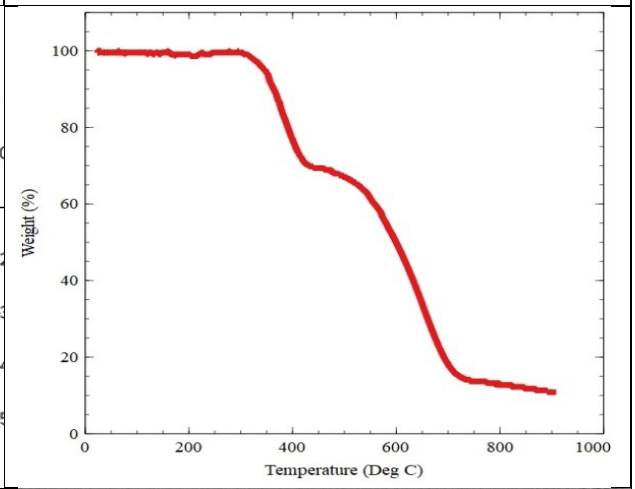
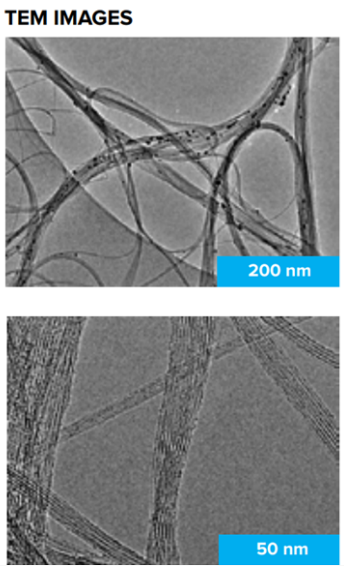
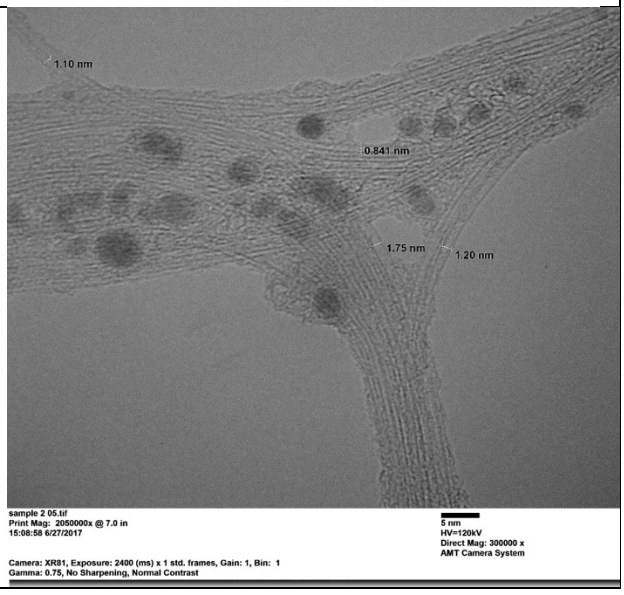
As Produced (Raw)

OCSiAl	NoPo HiPCO®
	
	
	

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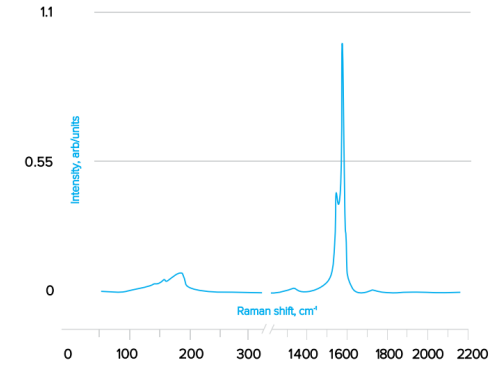
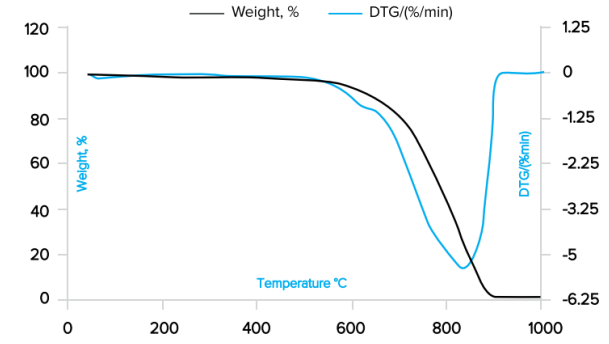
Purified

OCSiAl

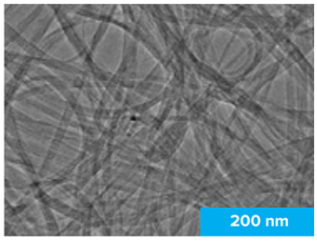
RAMAN SPECTRUM

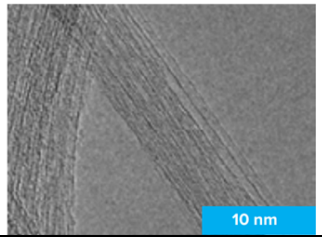


TGA CURVES



TEM IMAGES





NoPo HiPCO®