NOW POSSIBLE

NoPo

NANOTECHNOLOGIES

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Using the goodness of **carbon nanotubes** to make the world more efficient

NANOTECHNOLOGIES

NoPo Nanotechnologies

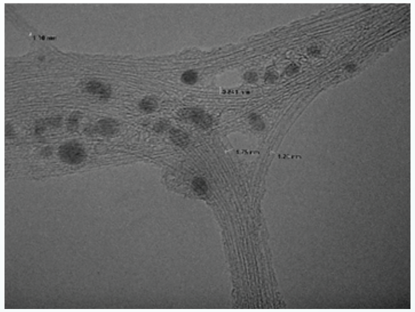
Single-walled Carbon Nanotubes (SWCNTs) are the forefront of nanotechnology, revolutionizing a myriad of sectors with their extraordinary properties. Just a single atom layer thick, these tiny tubes possess an astounding tensile strength of 50-100 gigapascals, up to 100 times stronger than steel, yet only one-sixth the weight. Their exceptional electrical conductivity, up to a 1000X greater than copper, and superior thermal conductivity, exceeding that of diamond, make them ideal for applications in electronics, energy, and medicine.

Technology

NoPo has been focused on building technology that can be scaled up at an industrial level. The gas phase chemical vapor deposition system developed at NoPo operates at high temperatures and high pressures to produce high quality SWCNTs and is highly scalable. Nanotubes that are produced via this process have very low structural defects compared to the other CNTs.

We understand the industry's requirement of high purity SWCNT without any catalyst presence. At NoPo, we have also developed patented technology for purification of Nanotubes to remove 99% of catalyst particles to produce high pure SWCNT suitable for electronics, healthcare and battery operations.

SWCNT HiPCO®



OUTER DIA.
0.6-1.2nm

LENGTH
700-1200nm

WALL THICKNESS
1 atom

SPECIFIC SURFACE AREA (1GM)
>1300 sq.m

G/D RATIO
25-40

At NoPo we have established the continuous process to manufacture single-walled carbon nanotubes of such small diameters in bulk. HiPCO® is considered benchmark Nanotube and is used in applications where specific, repeatable properties are required.

The HiPCO® Advantage

01 Smaller diameters are easier to disperse and stay in a dispersion longer

02 Small diameter nanotubes have higher conductivity and tensile strength

03 Iron is easy to remove compared to all the other catalyst components such as Co, Bimetal, etc. present in other commercially available nanotubes

04 We have developed methods to functionalize and disperse Nanotubes in most common solvents. Due to high consistency of product, the results remain same from batch to batch

HiPCO® in a snapshot

01 NoPo HiPCO® (Raw)

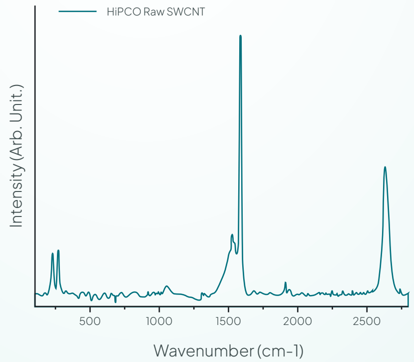
APPEARANCE	SWCNT CONTENT (WT.%)	SWCNT LENGTH (NM)	SPECIFIC SURFACE AREA (M2/G)
Black fluffy powder	**>70**	**700–2000**	**>1300**
SWCNT OUTER DIAMETER (NM)	G/D RATIO (UNIT)	METAL IMPURITIES (WT.%)	MOISTURE (WT.%)
0.8+/-0.2	**25–40**	**<25**	**<2**

02 NoPo HiPCO® (Purified)

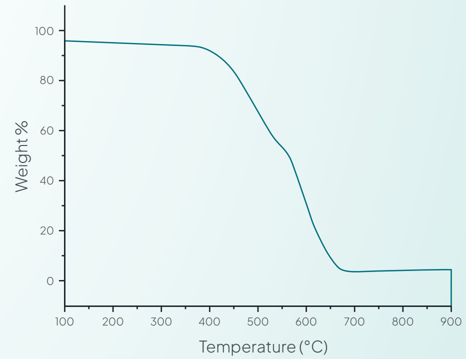
APPEARANCE	SWCNT CONTENT (WT.%)	SWCNT LENGTH (NM)	SPECIFIC SURFACE AREA (M^2/G)
Black fluffy powder	**>90**	**700–1000**	**>1300**
SWCNT OUTER DIAMETER (NM)	G/D RATIO (UNIT)	METAL IMPURITIES (WT.%)	MOISTURE (WT.%)
0.8+/-0.2	**25–40**	**<8**	**<2**

03 NoPo HiPCO® (Super Purified)

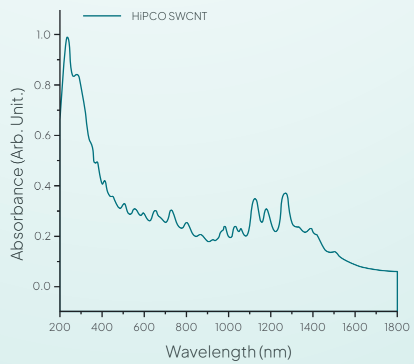
APPEARANCE	SWCNT CONTENT (WT.%)	SWCNT LENGTH (NM)	SPECIFIC SURFACE AREA (M^2/G)
Black fluffy powder	**>99**	**700–1000**	**>1300**
SWCNT OUTER DIAMETER (NM)	G/D RATIO (UNIT)	METAL IMPURITIES (WT.%)	MOISTURE (WT.%)
0.8+/-0.2	**25–40**	**<1**	**<2**



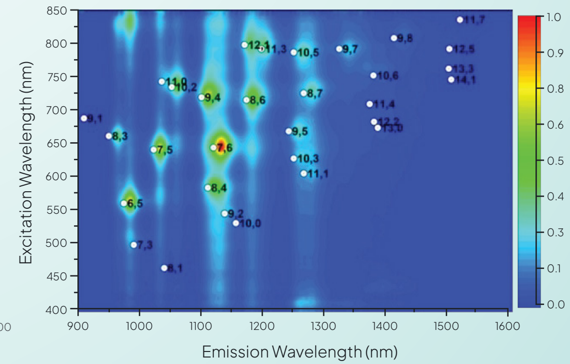
Raman spectrum of as produced NoPo HiPCO® single walled carbon nanotubes



Thermogram of as produced NoPo HiPCO® single walled carbon nanotubes



UV VIS NIR Absorbance data of Raw HiPCO® nanotubes



2D map NoPo HiPCO® raw SWCNTs PL data of HiPCO® nanotubes

HiPCO® Semiconducting SWCNT

Semiconducting SWCNT (Sc-SWCNT) are unique 1D structures with high electronic, mechanical, thermal conductivity, and photophysical properties.

<1.0nm Sc-SWCNT

DIAMETER RANGE
0.75–1.0nm

LENGTH RANGE
100–700nm

SOLUTION COLOUR
Blue

METAL CATALYST IMPURITY
<1%

AMORPHOUS CARBON IMPURITY
1–5%

ELECTRONIC ENRICHMENT
80–99%

>1.0nm Sc-SWCNT

DIAMETER RANGE
>1.0nm

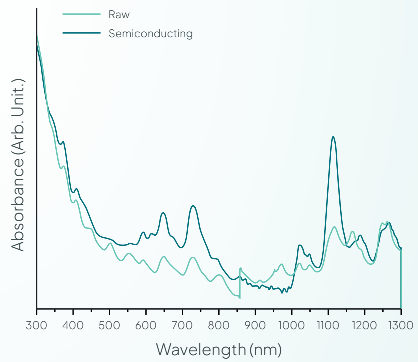
LENGTH RANGE
100–700nm

SOLUTION COLOUR
Forest green

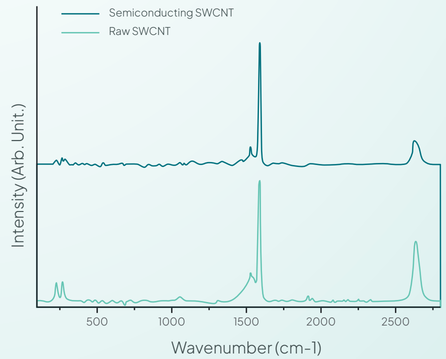
METAL CATALYST IMPURITY
<1%

AMORPHOUS CARBON IMPURITY
1–5%

ELECTRONIC ENRICHMENT
80–99%



UV Vis NIR spectrum of as-produced and semiconducting SWCNT



Raman spectrum of as-produced and semiconducting SWCNT

HiPCO® SWCNTs are purified using Aqueous Two-phase Extraction (ATPE) which separates semiconducting nanotubes from metallic nanotubes. Available in an aqueous solution or powder form.

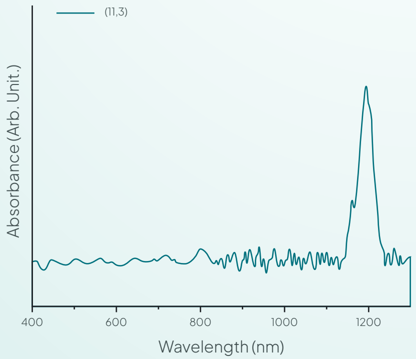
The company offers Sc-SWCNTs with 99% and above semiconducting components, and their electronic type enrichment is characterized by UV-VIS NIR absorbance and photoluminescence spectroscopy.

Single Chiral SWCNT

Single Chiral Carbon Nanotubes are a type of single-walled carbon nanotubes (SWCNTs) that have a specific helical symmetry or chirality, which affects their properties. The chiral angle is the angle between the tube's axis and a line connecting two equivalent points on the tube's perimeter, and it determines the electrical and mechanical properties of the nanotube.

A single chiral SWCNT can have either a right-handed (R) or left-handed (L) twist, depending on the direction of the helicity. This helicity can affect the electronic properties of the nanotube, as R and L nanotubes have different bandgap energies, conductivity, and optical properties.

NoPo HiPCO® single chiral SWCNT solution



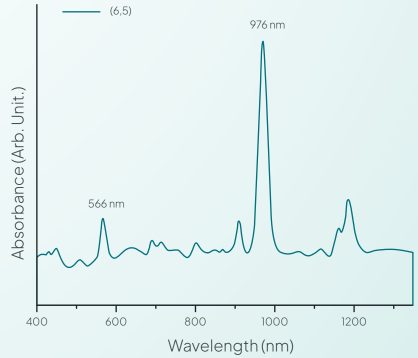
UV Vis NIR spectrum of single chiral (11,3) SWCNT

CHIRALITY	DIAMETER	LENGTH RANGE	SOLUTION COLOUR
(11,3)	**1.014 nm**	**100–700nm**	**Dark Green**

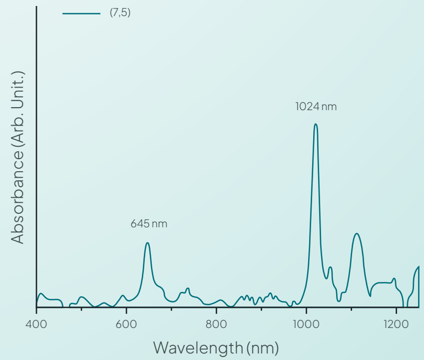
METAL CATALYST IMPURITY	AMORPHOUS CARBON IMPURITY	ELECTRONIC ENRICHMENT
<1%	**1–5%**	**80–99%**

Potential applications include their use as high-performance electronic and optoelectronic integrated circuits (ICs), due to their extremely high carrier mobility and current-carrying capacity. They could also be used in the development of high-performance SWCNT computers and microprocessors, and their structure-tunable optical and electrical properties could be utilized in the design of carbon-based electronic and optoelectronic devices

At NoPo we have developed a scalable process for separating (11,3), (7,5) and (6,5) single chiral single walled carbon nanotubes.



UV Vis NIR spectrum of single chiral (6,5) SWCNT



UV Vis NIR spectrum of single chiral (7,5) SWCNT

Metallic SWCNT

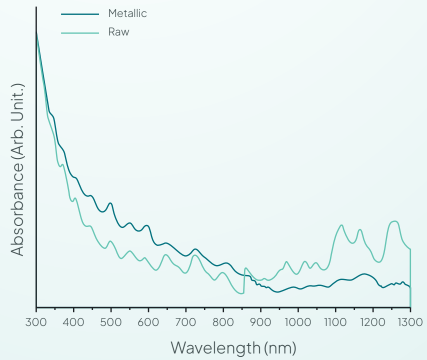
Metallic single-wall carbon nanotubes (m-SWCNT) have metallic conductivity behavior and have a wide range of applications. Metallic SWCNTs are characterized by a band structure that contains partially filled electronic bands near the Fermi level, which allows for the easy flow of electrons through the nanotube. This makes metallic SWCNTs attractive for applications in electronics, such as interconnects and electrodes, where high conductivity is desirable.

s-SWCNTs show a gate-dependent conductance due to their bandgap, while m-SWCNTs show a gate-independent conductance due to their partially filled electronic bands.

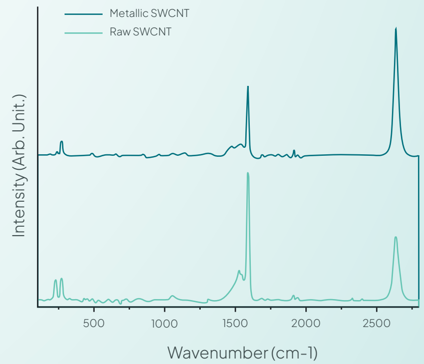
NoPo HiPCO® metallic SWCNT solution

DIAMETER RANGE **<1.0nm**	LENGTH RANGE **100–700nm**
SOLUTION COLOUR **Rust**	METAL CATALYST IMPURITY **<1%**
AMORPHOUS CARBON IMPURITY **1–5%**	ELECTRONIC ENRICHMENT **80–99%**

The presence of m-SWCNTs in a sample can affect its properties and performance in applications. For example, m-SWCNTs can increase the thermal conductivity and electrical conductivity of a composite material. Their high electrical conductivity and high surface area make m-SWCNTs useful for battery applications. They are used in electrodes to enhance charge storage and transfer. Additionally, m-SWCNTs can provide a pathway for fast electron transfer, which can enhance the rate of charge and discharge.



UV Vis NIR spectrum of as-produced and metallic SWCNT



Raman spectrum of as-produced and metallic SWCNT

Researchers have investigated the use of m-SWCNTs as electrode materials for various types of batteries, such as lithium-ion batteries, sodium-ion batteries, and supercapacitors.

At NoPo we have developed the process for sorting m-SWCNTs producing 99% purity m-SWCNTs at scale.

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