NanoIntegris

Technical Data Sheet

IsoNanotubes-M
Metallic SWNTs

IsoNanotubes-S
Semiconducting SWNTs

PureTubes
Ultra High Purity SWNTs

8025 Lamon Avenue, Suite 43, Skokie, IL 60077

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NanoIntegris

Better Data

Better Results

> NanoIntegris supplies premium nanomaterials to companies and academic institutions developing next-generation electronics, energy, and biomedical technologies.

We pride ourselves on our **thorough, accurate, and honest material characterization**. Our nanotube powders and dispersions are among the purest in the industry.

What is more, our strict quality control standards and procedures ensure that our products exhibit **exceptionally high batch-to-batch consistency**. We hope the following data provides you with confidence in the quality of our materials.

If you have further questions, **please don't hesitate to contact us.**

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Product Delivery Forms

We currently offer our IsoNanotubes and PureTubes in two delivery forms:

Aqueous surfactant solution and **surfactant-eliminated powder**. Our IsoNanotube and PureTube solutions contain dionized water, nanotubes, and a proprietary combination of ionic surfactants. Our IsoNanotube solutions also contain some iodixanol, a non-ionic, water-soluble iodine derivative which we use as a density gradient medium. Our powders are comprised of nearly 100% nanotubes *(we do not use any binders or fillers)*, and have been formulated so that they are easy to use, break apart, and re-suspend.

IsoNanotubes-M

A

IsoNanotubes-S

B

PureTubes

C

Figure 1. A. 1 mg of metallic IsoNanotubes in solution and 10 mg of metallic IsoNanotubes powder. **B.** 1 mg of semiconducting IsoNanotubes in solution and 10 mg of semiconducting IsoNanotubes powder. **C.** 25 mg of PureTubes in solution and 25 mg of PureTubes powder.

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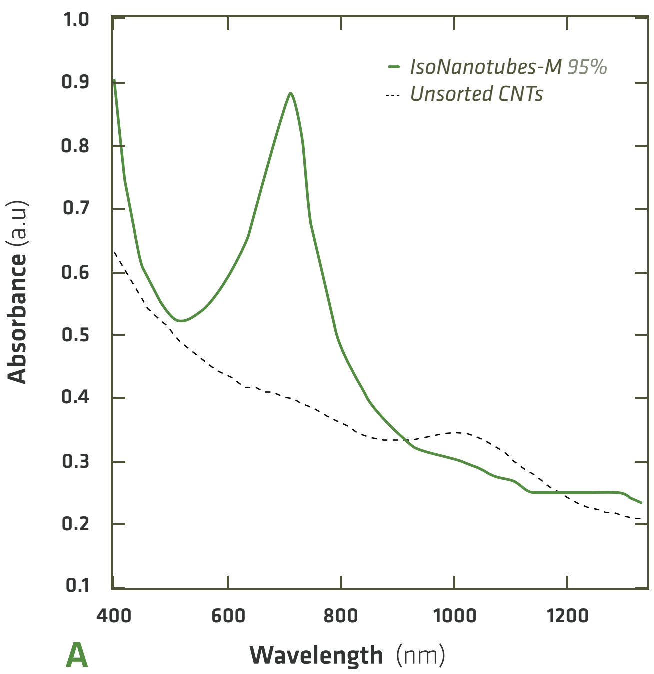
Electronic Type Enrichment

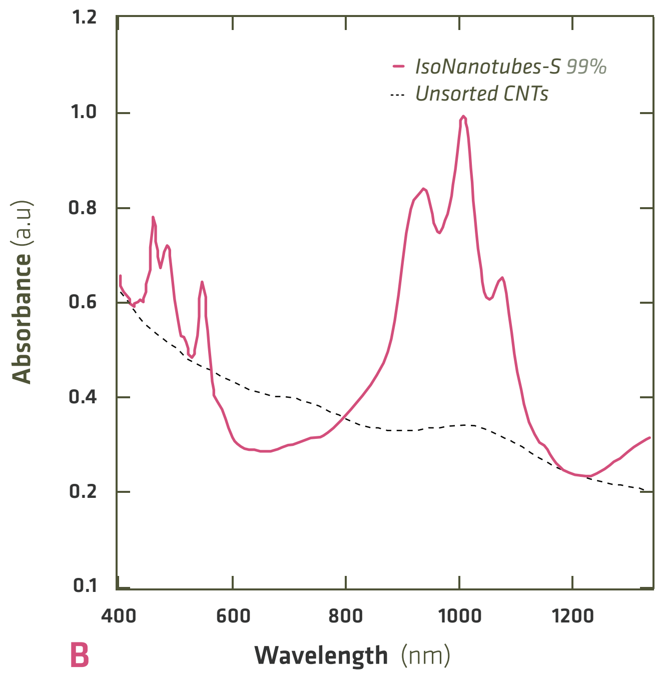
Optical Absorbance

IsoNanotubes-M



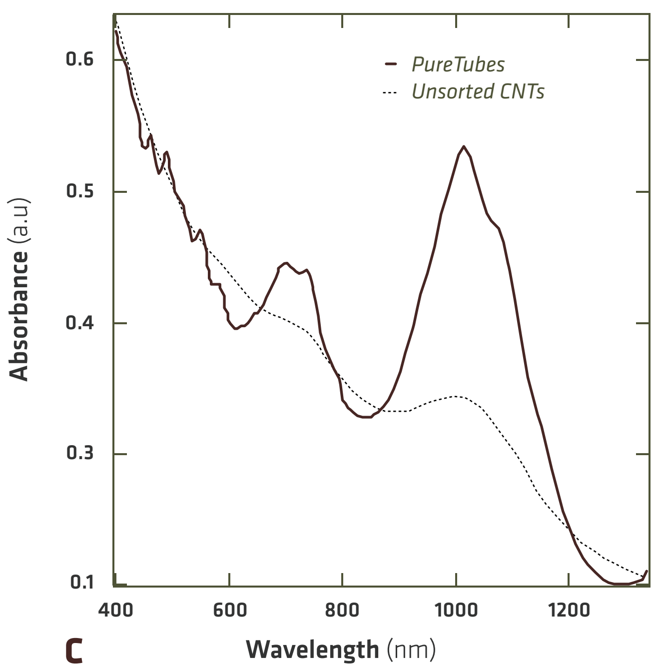
A

IsoNanotubes-S



B

PureTubes



C

Figure 2. A. B. C. Optical absorbance plots for our IsoNanotubes-M (98%). IsoNanotubes-S (99%), and PureTubes, respectively. Following the method of Ouyang et al. (Acc. Chem. Res. 35, 1018 (2002)), we can calculate the transition energies for nanotubes in our diameter range (1.2 - 1.7 nm). We see peaks where we would expect them: S33 transitions should lie between ~450-630 nm, M11 transitions between ~600-850 nm, and S22 transitions between ~ 900-1,270 nm. We estimate our metallic and semiconducting enrichment levels based on ratios of the M11 and S22 peak areas after linear background subtraction. Before comparison, the individual peak areas are scaled by empirically determined values for the M11 and S22 extinction coefficients.

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Metal Catalyst

Neutron Activation Analysis

	Unprocessed SWNTs	IsoNanotubes-M + S	PureTubes
Nickel (wt %)	3.59	0.07	0.23
Yttrium (wt %)	0.70	0.38	0.05
Iron (wt %)	0.70	0.72	0.06
Total (wt %)	**4.99**	**1.17**	**0.34**
Iodine (wt %)	0.00	5.29	0.00

Full elemental profiles of our products are available upon request.

Figure 3. Neutron activation analysis (NAA) data taken from our IsoNanotube and PureTube powders. NAA reveals that our IsoNanotubes and PureTubes contain significantly lower levels of metallic/catalyst impurities than the raw arc discharge SWNTs from which they are produced. Our IsoNanotube samples, however, contain approximately 5% iodine by mass, resulting from residual iodixanol on the surface of the nanotubes that is not eliminated by our surfactant removal procedures.

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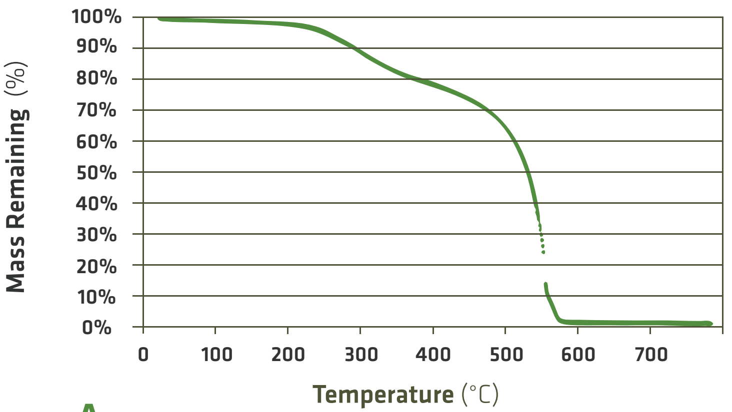
Metal Catalyst

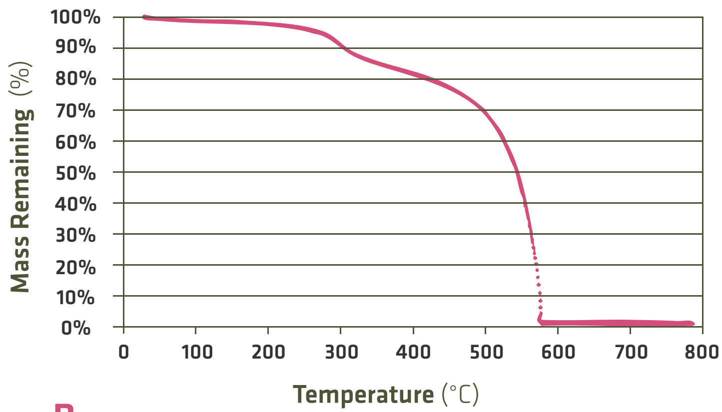
Thermogravimetric Analysis

IsoNanotubes-M



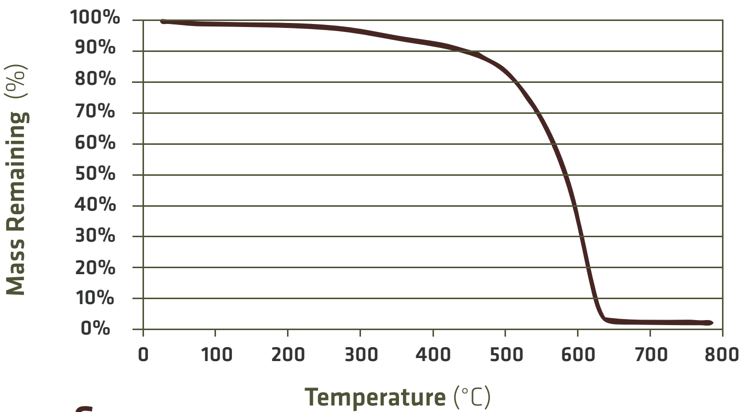
A

IsoNanotubes-S



B

PureTubes



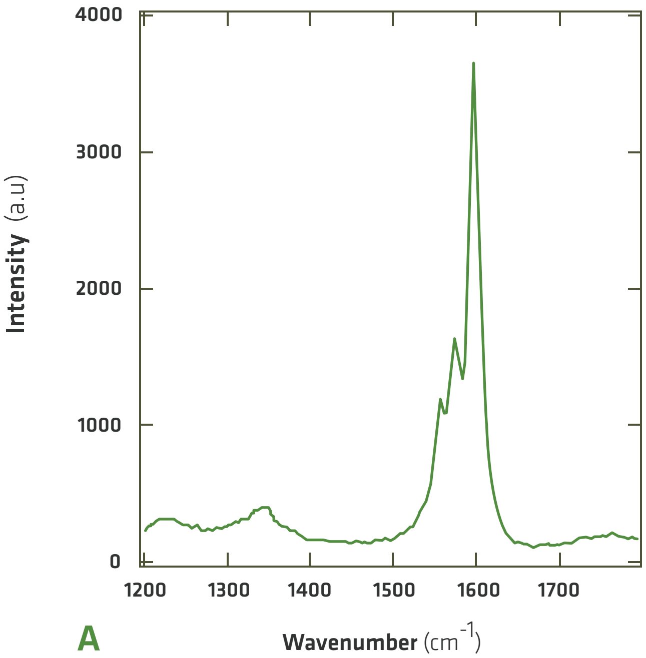
C

Figure 4. Thermogravimetric (TGA) plots of our nanotube products. A, B. Approximately 2/3 of the ~15% mass decrease which occurs between ~200 and ~400°C is attributable to the burnoff of residual iodixanol adsorbed to the surface of the nanotubes. NAA data indicates that our IsoNanotubes contain roughly 5% iodine by mass **(see Figure 3)**; iodine comprises roughly half the mass of an iodixanol molecule. The remaining 5% mass decrease is attributable to the burnoff of residual surfactant and carbonaceous impurities. C. Because our PureTubes do not contain iodixanol, the burnoff of residual surfactant and amorphous carbon is solely accountable for the ~5% mass decrease which occurs between approximately 200 and 400°C.

Amorphous Carbon

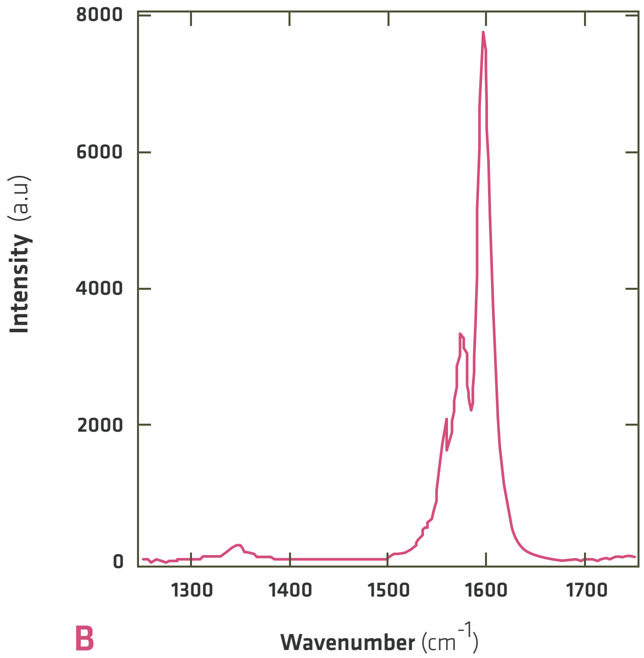
Raman

IsoNanotubes-M (95%)



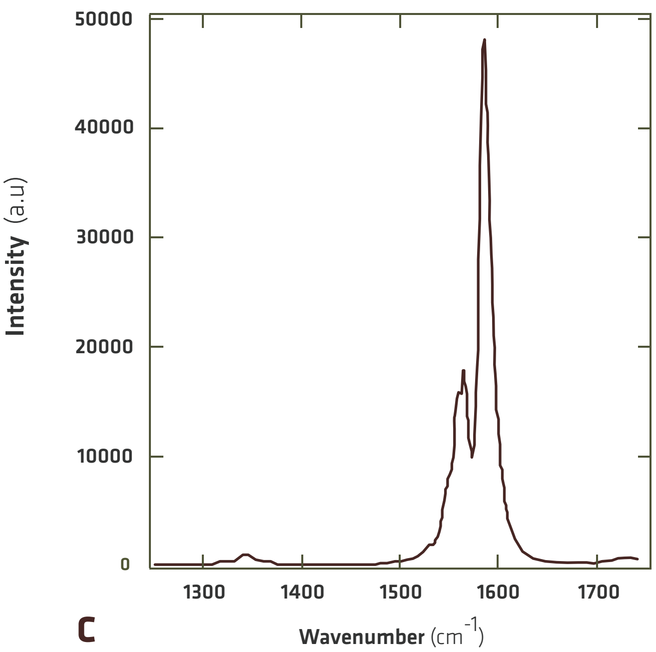
A

IsoNanotubes-S (99%)



B

PureTubes



C

Figure 5. A. B. C. Resonance Raman plots for our **IsoNanotubes-M** (95%). **IsoNanotubes-S** (99%), and **PureTubes**, respectively. All Raman measurements were taken using a 514 nm laser. The G/D ratios of our products range from approximately 12 to 41, indicating extremely low levels of amorphous carbon and/or damaged nanotubes.

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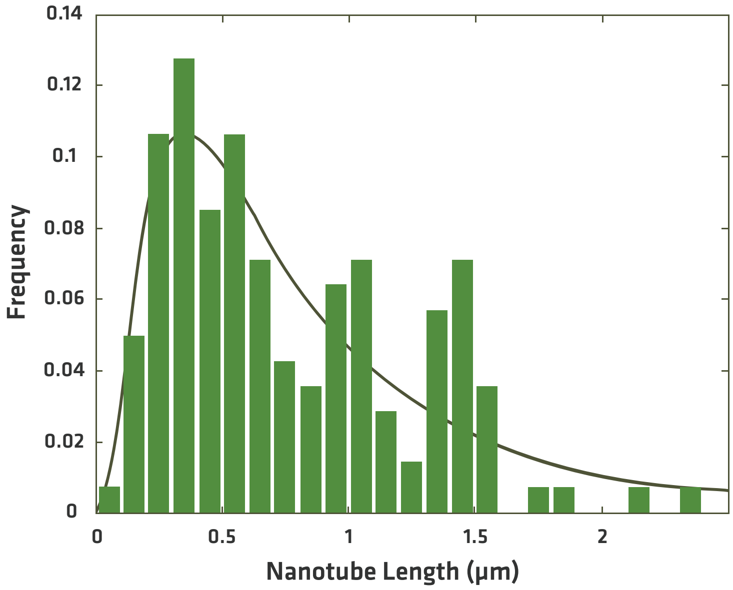
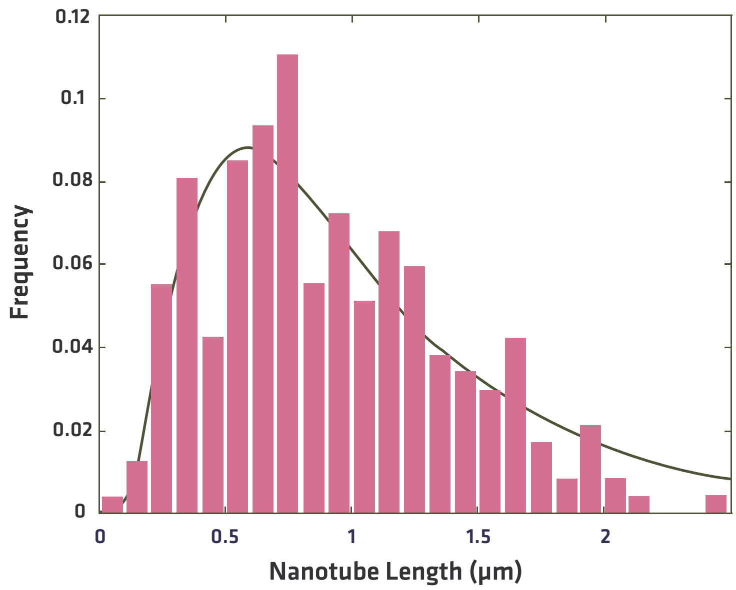
Length

Atomic Force Microscopy

IsoNanotubes-M



IsoNanotubes-S



PureTubes

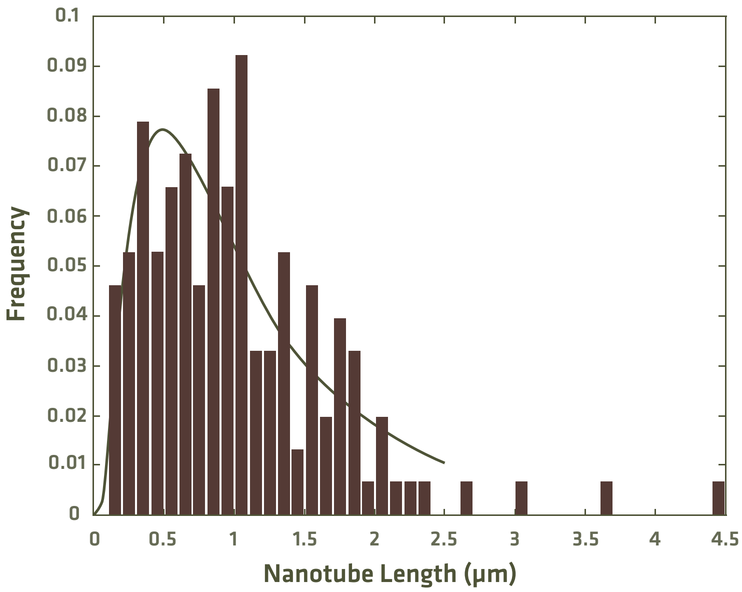


Figure 6. Atomic-force microscopy (AFM) data indicates that our SWNTs range in length from approximately 100 nm to 4 microns. **A. B. C.** Length histograms of our IsoNanotubes-M, IsoNanotubes-S, and PureTubes, respectively.

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Properties at a Glance

Property	IsoNanotubes-M	IsoNanotubes-S	PureTubes	Measurement	Set Figure	Solution	Powder
Nanotube Type	Arc discharge	Arc discharge	Arc discharge	Manufacturer data	n/a	✓	✓
Diameter Range	1.2 - 1.7 nm	1.2 - 1.7 nm	1.2 - 1.7 nm	Manufacturer data	n/a	✓	✓
Mean Diameter	1.4 nm	1.4 nm	1.4 nm	Manufacturer data	n/a	✓	✓
Length Range	100 nm – 4 µm	100 nm – 4 µm	100 nm – 4 µm	AFM	6	✓	✓
Mean Length	~0.5 micron	~1 micron	~1 micron	AFM	6	✓	✓
Catalyst Impurity	~1% by mass	~1% by mass	~0.5% by mass	NAA, TGA	3, 4	✓	✓
Carbonaceous Impurity	< 5% by mass	< 5% by mass	< 5% by mass	TGA, Raman	4, 5	✓	✓
Semiconducting CNT Content	n/a	90%, 95%, 98%, or 99+%	n/a	Optical absorbance	2	✓	✓
Metallic CNT Content	70%, 95%, 98% or 99%	n/a	n/a	Optical absorbance	2	✓	✓
Shelf Life	6 months	6 months	6 months	n/a	n/a	✓	n/a
Nanotube Concentration	0.01 mg/mL	0.01 mg/mL	0.25 mg/mL	n/a	n/a	✓	n/a
Surfactant Concentration	1% w/v	1% w/v	1% w/v	n/a	n/a	✓	n/a
Surfactant Type	Ionic (proprietary mixture)	Ionic (proprietary mixture)	Ionic (proprietary mixture)	n/a	n/a	✓	n/a

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