

Unidym™ Carbon Nanotubes

Product Description: HiPco® Single-Wall Carbon Nanotubes

Single-wall carbon nanotubes (SWNT) are polymers of carbon in which the carbon atoms are bonded together in cylindrical form. These unique polymers are part of the fullerene family of carbon discovered by Dr. Richard E. Smalley and colleagues in 1985.

Representative Properties

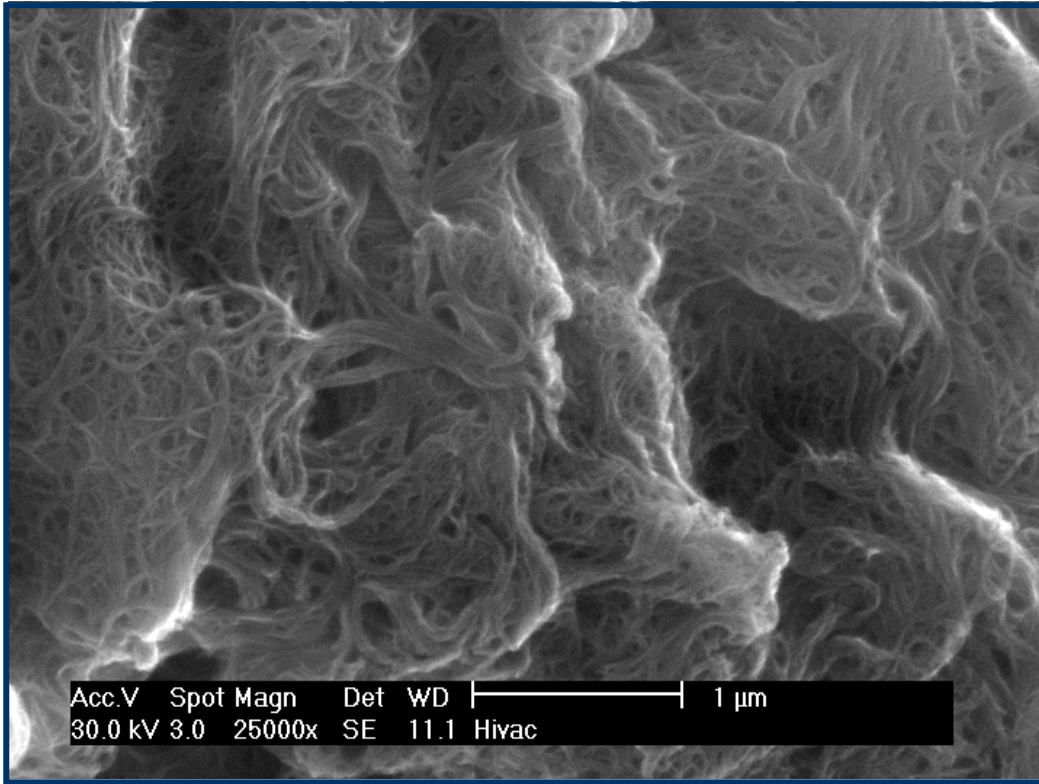
Individual SWNT Diameter ⁱ	~0.8 – 1.2 nm
Individual SWNT Length ⁱⁱ	~100 – 1000 nm
Calculated Molecular Weight ⁱⁱⁱ	~3.4x10 ⁵ – 5.2x10 ⁶ Amu
Color	Black
Morphology	Dry powder of nanotubes bundled in ropes
Maximum Density ^{iv}	1.6 g/cm ³
Bulk Density ^v	~0.1 g/cm ³
TGA Residue as Fe ^{vi}	
- Raw	<35 wt%
- Pure	<15 wt%
- Super Pure	<5 wt%
TGA 1 st Derivative Peak Temperature	Raw ~350 – 410°C Pure ~470 – 490°C Super Pure ~510 – 540°C
TGA Onset Temperature	Raw ~350°C Pure ~440°C Super Pure ~450°C
Maximum Surface Area ^{vii}	1315 m ² /g
BET Surface Area	~400 – 1000 m ² /g
Buckypaper Resistance ^{viii}	~0.2 – 2Ω
Moisture Content	<5 wt%

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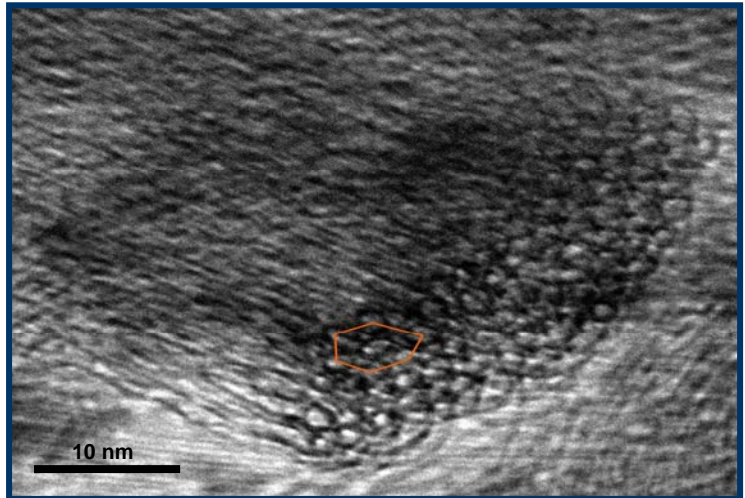
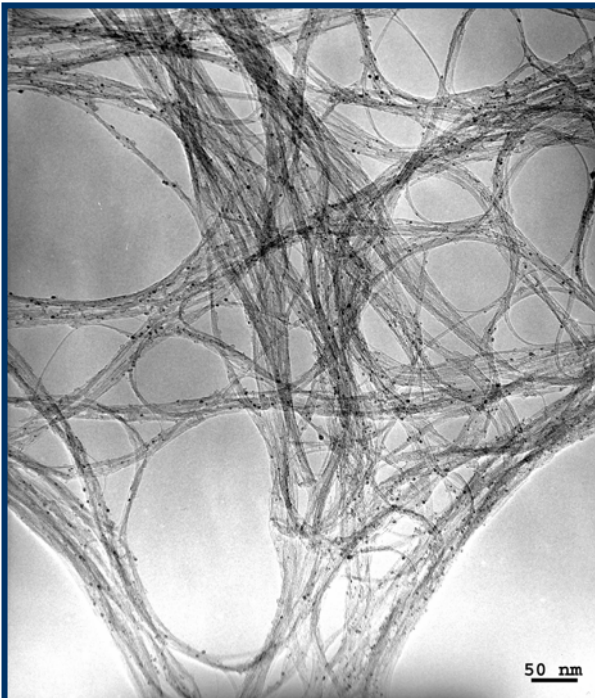
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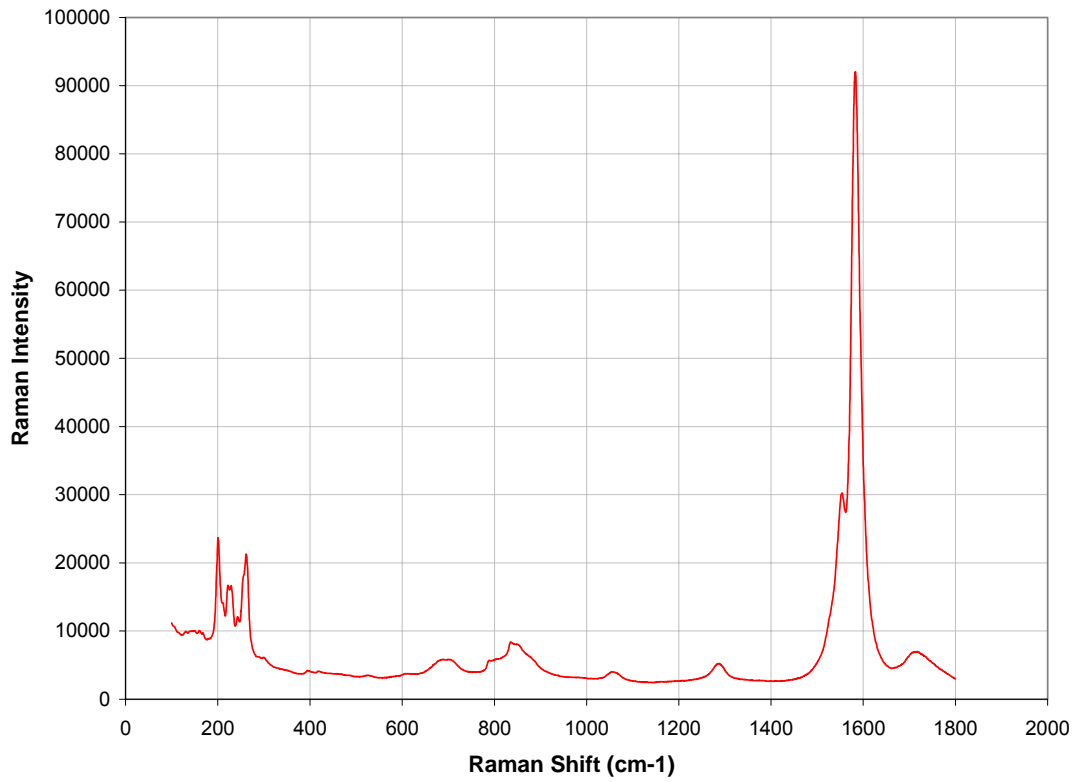
SEM



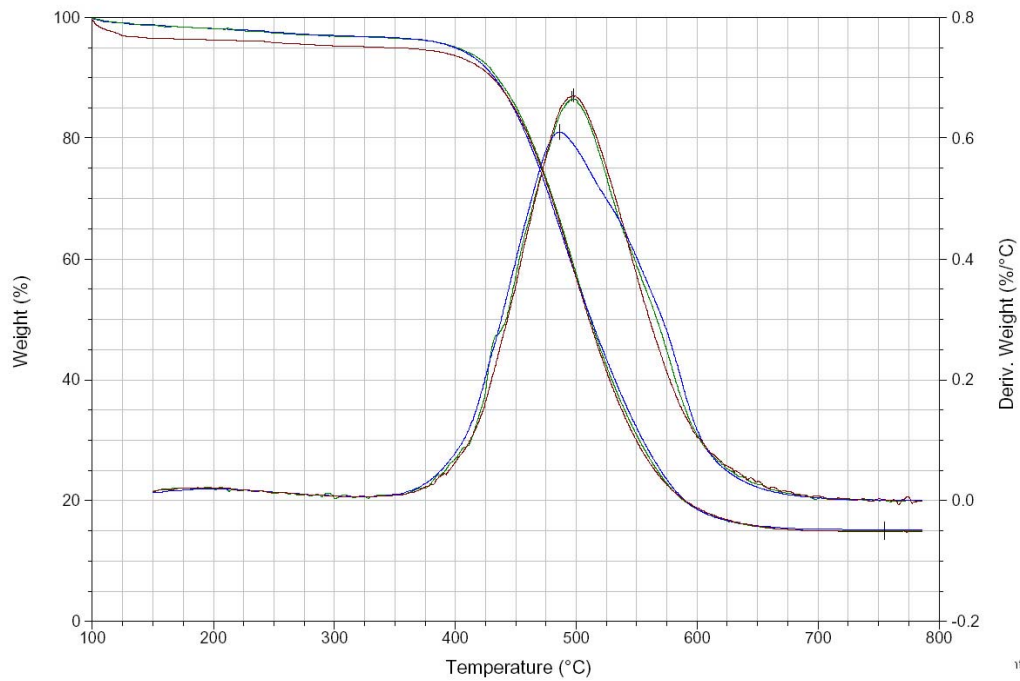
TEM



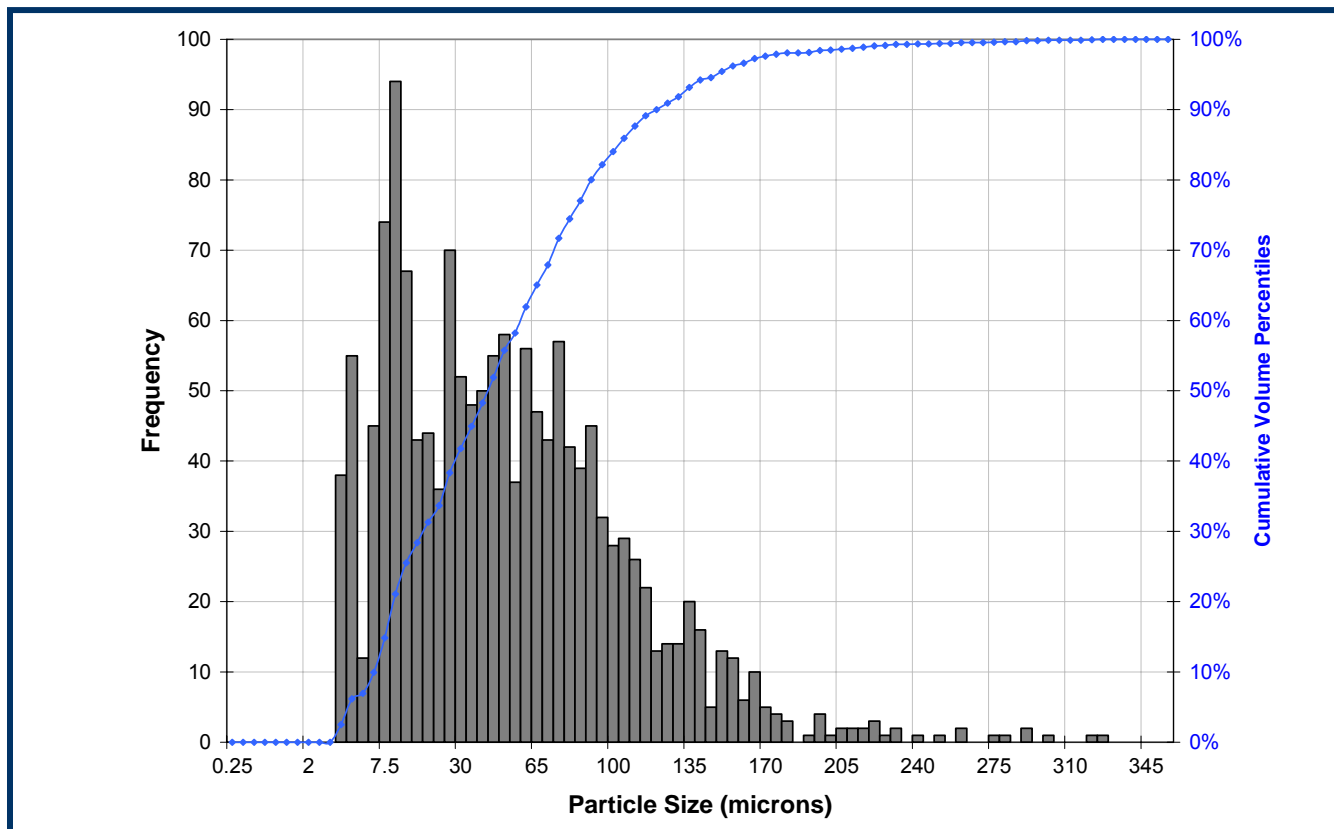
Raman



TGA Profile



Particle Size Analysis^{ix}



- i Diameter distribution measured by Unidym from TEM micrographs. Mean diameter ~1.0 nm.
- ii Measured by Unidym using AFM.
- iii Calculated. Lower limit assumes a SWNT with a diameter of 0.8nm and a length of 100nm. $(0.8\text{nm}/0.245\text{nm})(3.1414)(2 \text{ carbon atoms}) = 20$ carbons around the circumference. For every 0.283nm length there are $4 \times 20 = 80$ carbon atoms. $(100\text{nm}/0.283\text{nm})(80)(12.01) = 339,505$ Amu. Assuming 2 significant digits = 3.4×10^5 . Upper limit assumes a SWNT with a diameter of 1.2nm and a length of 1,000nm. $(1.2\text{nm}/0.245\text{nm})(3.1414)(2 \text{ carbon atoms}) = 31$ carbons around the circumference. For every 0.283nm length there are $4 \times 31 = 124$ carbon atoms. $(1000\text{nm}/0.283\text{nm})(124)(12.01) = 5,262,332$ Amu. Assuming 2 significant digits = 5.2×10^6 .



- iv Calculated assuming single-wall nanotubes of diameter 1.0 nm arranged in crystalline “ropes” or “bundles” (inter-wall spacing 0.3 nm).
- v Value provided is for standard purified SWNTs. Raw and some super pure grades lots will have lower bulk densities. Other product forms may have higher bulk densities.
- vi 800°C in air. The reported figures assume that the residue is present in the product as elemental Fe, and that it is fully converted to Fe₂O₃ during the TGA analysis. Hence, the TGA residual as measured is multiplied by MW Fe₂/MW Fe₂O₃ (1/1.43) to express the result as Fe.
- vii Calculated using geometric arguments assuming an isolated tube. SSA for tubes in “ropes” will be less than the stated value. A. Peigney et al., Carbon 39 (2001), 507-514.
- viii In-house, Unidym buckypaper conductivity test (4 point probe).
- ix The following particle size histogram is indicative of the typical tertiary particle size distribution found in bulk powder. It does not represent secondary particles (aggregates of individual tubes also known as ropes or bundles) nor does it represent primary particle sizes (individual carbon nanotubes).