Raymor Nanotech

NanoIntegris

Technical Data Sheet

RN-020
Raw SWCNTs

RN-120
Pre-purified SWCNTs

RN-220
Purified SWCNTs

''Using plasma, Raymor Nanotech provides high quality and purity SWCNTs on an industrial scale, rendering SWCNT based applications viable commercially.''

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

Summary

Using a patented plasma torch process, Raymor Nanotech produces raw single-wall carbon nanotubes (SWCNTs) at high rates, enabling the lowest prices on the market. As shown by the detailed analysis below, the plasma-grown SWCNTs display a high graphitization level, diameters (0.9-1.9 nm) and lengths (0.5-4 µm) close to those of laser- and arc-grown SWCNTs. The purity of the raw SWCNTs (RN-020) is comparable to the purity of the best arc-discharge producers on the market. The following pages will display the information gathered by thermogravimetric analysis, Raman spectroscopy and optical absorption on the raw (RN-020), pre-purified (RN-120) and purified (RN-220) SWCNTs. A brief summary of the measurement protocols as well as a table showing our typical parameters will complete this technical data sheet. Please visit www.raymor.com for more details on our prices and our technology. For our semiconducting SWCNTs, please visit www.nanointegris.com or contact us directly.

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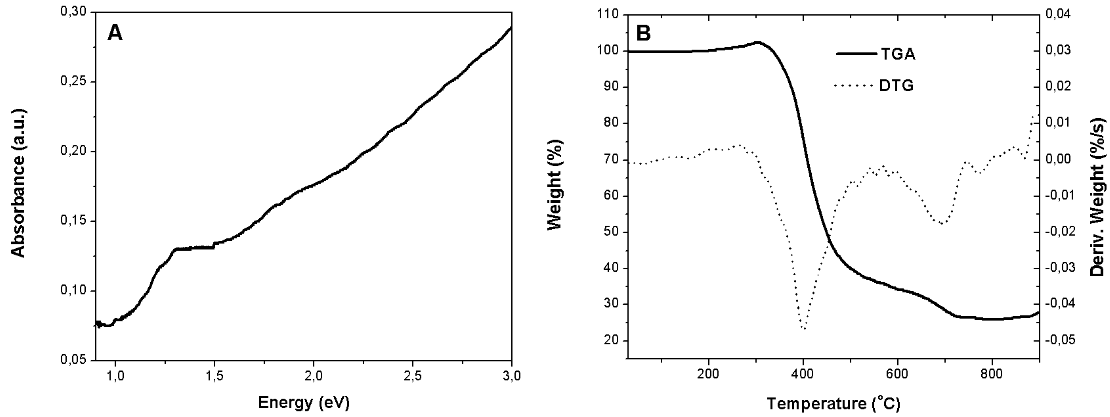
1. RN-020 Raw SWCNTs



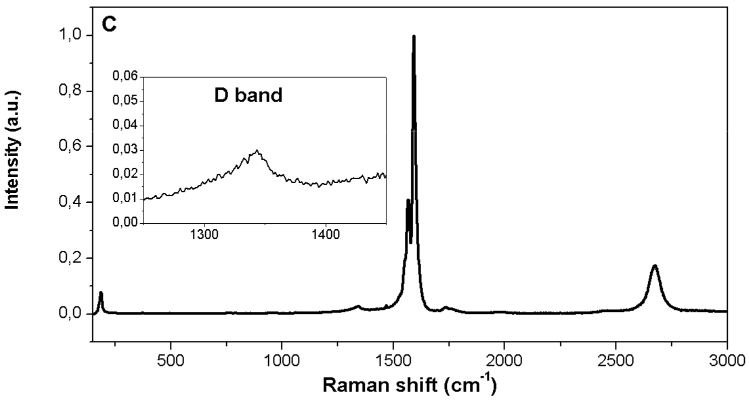


Figure 1. A. Optical absorbance plot for RN-020 raw SWCNTs. **B.** Thermogravimetric analysis of RN-020 raw SWCNTs. **C.** Raman spectra of RN-020 raw SWCNTs.

Typical parameter ranges for RN-020 raw SWCNTs

Parameter	Measurement	Typical range
G/D ratio with BWF subtraction	Raman spectroscopy at 514 nm	57
G/D ratio without BWF subtraction	Raman spectroscopy at 514 nm	50
Ash content	Thermogravimetric analysis	27%
1st oxidation peak	Thermogravimetric analysis	400 ºC
2nd oxidation peak	Thermogravimetric analysis	690 ºC
Itkis index	Optical absorption	0.08

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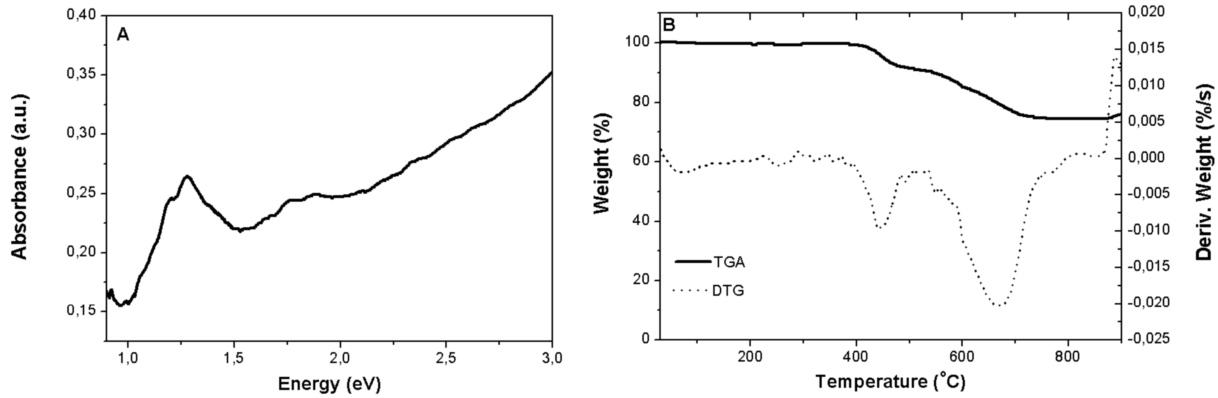
2. RN-120 Pre-purified SWCNTs



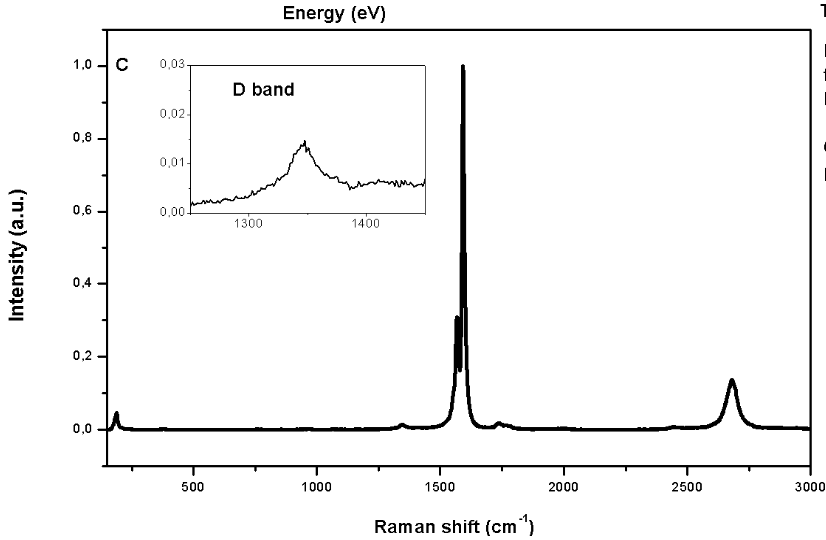


Figure 2. A. Optical absorbance plot for RN-120 pre-purified SWCNTs.
B. Thermogravimetric analysis of RN-120 pre-purified SWCNTs.
C. Raman spectra of RN-120 pre-purified SWCNTs.

Typical parameter ranges for RN-120 pre-purified SWCNTs

Parameter	Measurement	Typical range
G/D ratio with BWF subtraction	Raman spectroscopy at 514 nm	77
G/D ratio without BWF subtraction	Raman spectroscopy at 514 nm	71
Ash content	Thermogravimetric analysis	75%
1st oxidation peak	Thermogravimetric analysis	445 ºC
2nd oxidation peak	Thermogravimetric analysis	670ºC
Itkis index	Optical absorption	0.14

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3. RN-220 Purified SWCNTs

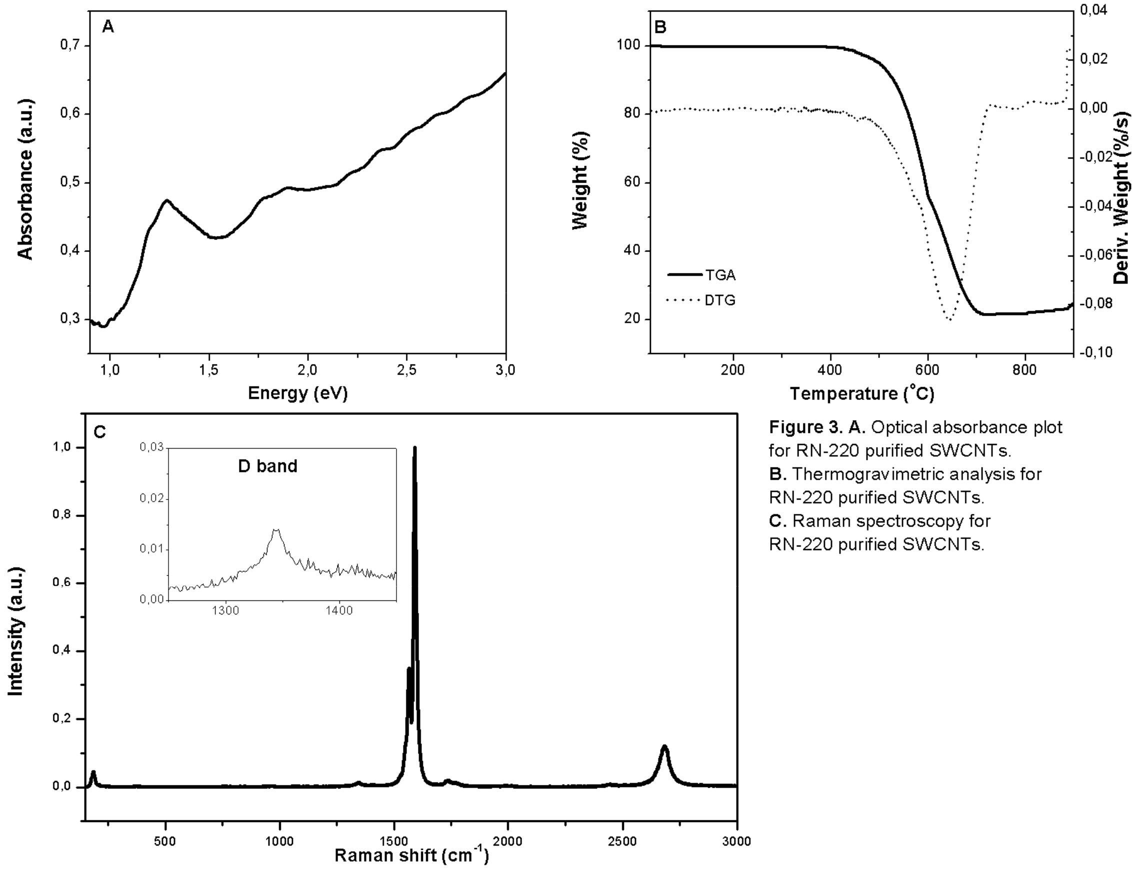

Figure 3. A. Optical absorbance plot for RN-220 purified SWCNTs.
B. Thermogravimetric analysis for RN-220 purified SWCNTs.
C. Raman spectroscopy for RN-220 purified SWCNTs.

Typical parameter ranges for RN-220 purified SWCNTs

Parameter	Measurement	Typical range
G/D ratio with BWF subtraction	Raman spectroscopy at 514 nm	91
G/D ratio without BWF subtraction	Raman spectroscopy at 514 nm	80
Ash content	Thermogravimetric analysis	21%
1st oxidation peak	Thermogravimetric analysis	580 ºC
2nd oxidation peak	Thermogravimetric analysis	650 ºC
Itkis index	Optical absorption	0.14

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4. Methodology for thermogravimetric Analysis (TGA)

For a typical TGA analysis, we place a 3-10 mg SWCNT sample into the properly calibrated TGA apparatus (Shimadzu). Using a slope of 10 ^{o}C/min, the temperature is raised from 0 to 900 ^{o}C in flowing air (18 ccm).

The ash content is the lowest value of the weight curve that we read off where the curve is flat (between 800-900 ^{o}C). In order to determine the oxidation peaks, the TGA curve is smoothed with 150 data points. The derivative of the TGA is calculated with the TGA software and the oxidation peaks are the 2 minima of this derivative curve.

5. Methodology for Raman spectroscopy

For Raman spectroscopy, the samples are prepared as follows: a 2 mg samples is homogenized in 1 ml of acetone using sonication during 1 min. The mixture is deposited onto a glass slide and the acetone dries. The samples are measured using Raman spectroscopy (Renishaw) at λ=514 nm with a calibrated laser power (typically 35 mW). The laser beam diameter at the focal point is 120 µm.

Before we calculate the G/D ratio, the constant baseline is subtracted from the Raman spectra.

To calculate the G/D more accurately, the Breit-Wigner-Fano profile, a contribution from the G band, is subtracted to obtain the height of the D band. This procedure leads to lower D band heights and higher G/D ratios. However, subtracting the Breit-Wigner-Fano (BWF) profile leads to some uncertainty because it is difficult to model this profile accurately.

6. Methodology for Optical Absorption

For optical absorption measurements, <1 mg of SWCNT is dispersed in 20 ml of DMF using sonication (2 minutes of sonication with 600W at 12% with 1/8 inch tip). Using further dilution and sonication cycles, we calibrate the SWCNT concentration in the DMF such that the absorbance at 800 nm is between 0.1 and 0.3. The optical absorbance is then measured in a double beam UV-vis-NIR spectrophotometer (Shimadzu).

To calculate the Itkis index, the π-plasmon and metallic SWCNT contribution to the background (below the S_{22} band) are modeled as a straight line (between 1-3 eV). Once this background is subtracted, we integrate the area of the S_{22} band between 1.1 and 1.55 eV. The band area is divided by the total absorption (including the background) between 1.1 and 1.55 eV to yield the Itkis index.

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