Boron Nitride Nanotubes

BNNT, LLC

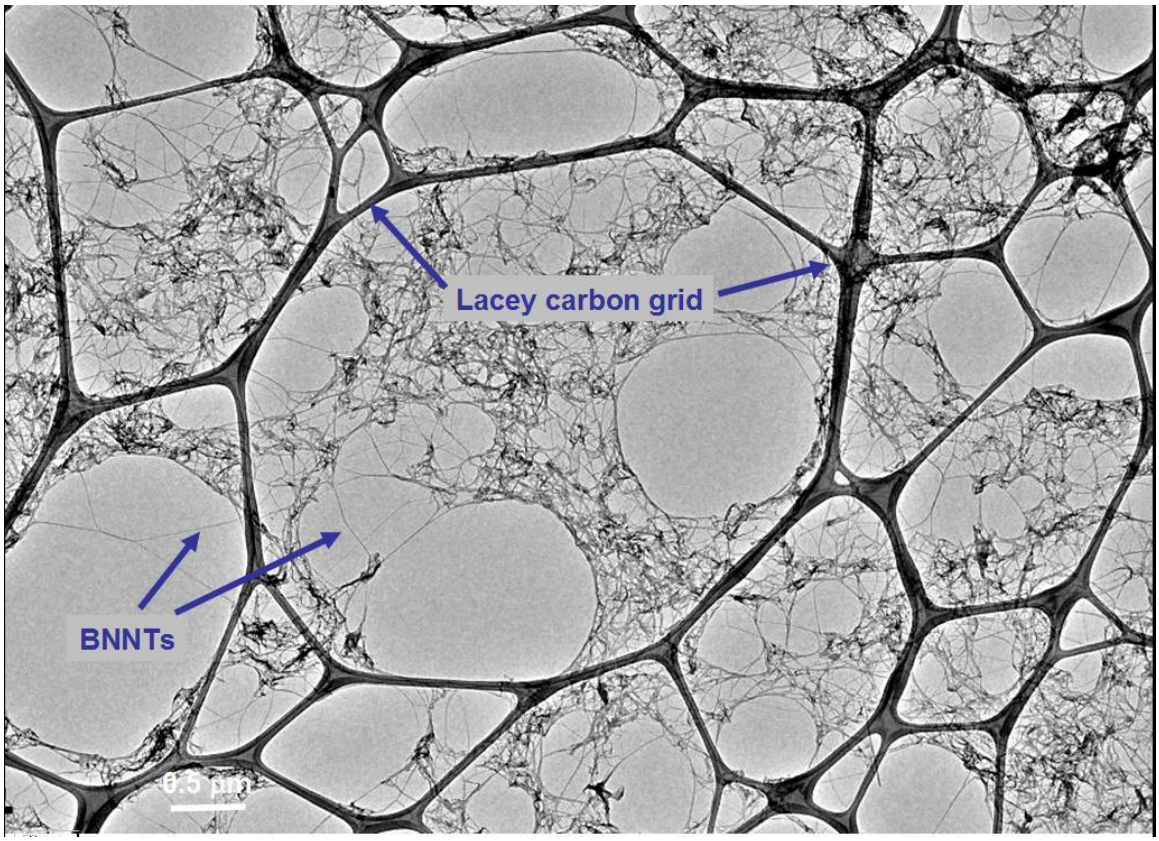
BNNT P1 Beta, Technical data/specifications:

BNNT, LLC tubes are synthesized using the high temperature/high pressure (HTP) method, also called the pressurized vapor/condenser (PVC) method. This method produces highly flexible, high aspect ratio BNNTs with high crystallinity. They are few to single walled tubes with 2 and 3 walls being the most common morphology. The as-grown material has a cotton-like appearance with an unusually low tap density.

The basic specifications of our as-grown material are summarized in the following table:

Purity	40 to 50% by mass
Number of walls	1 to 5 walls typical, 2 or 3 walls most common
Tube length	up to 200 microns by SEM measurement
Surface area	up to 200 m^2/g by BET
Bundles	many isolated tubes, bundles up to 5 tubes across, by TEM
Band gap	5.7 eV direct measurement by low energy EELS spectroscopy
Residual Impurities	hBN flakes and micro-droplets of elemental boron, by TEM
Tap density	Low, about 0.5 mg/cm^3

Below is a TEM of HTP-grown BNNTs on a lacey carbon grid:



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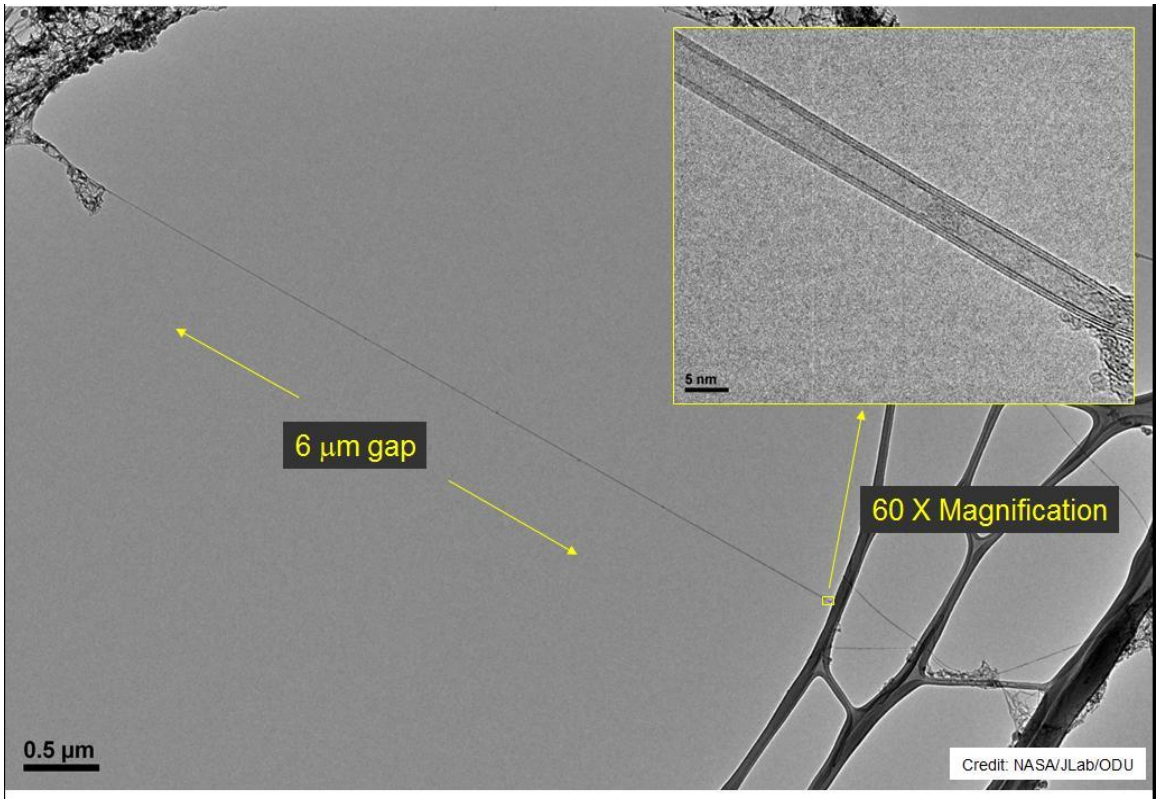
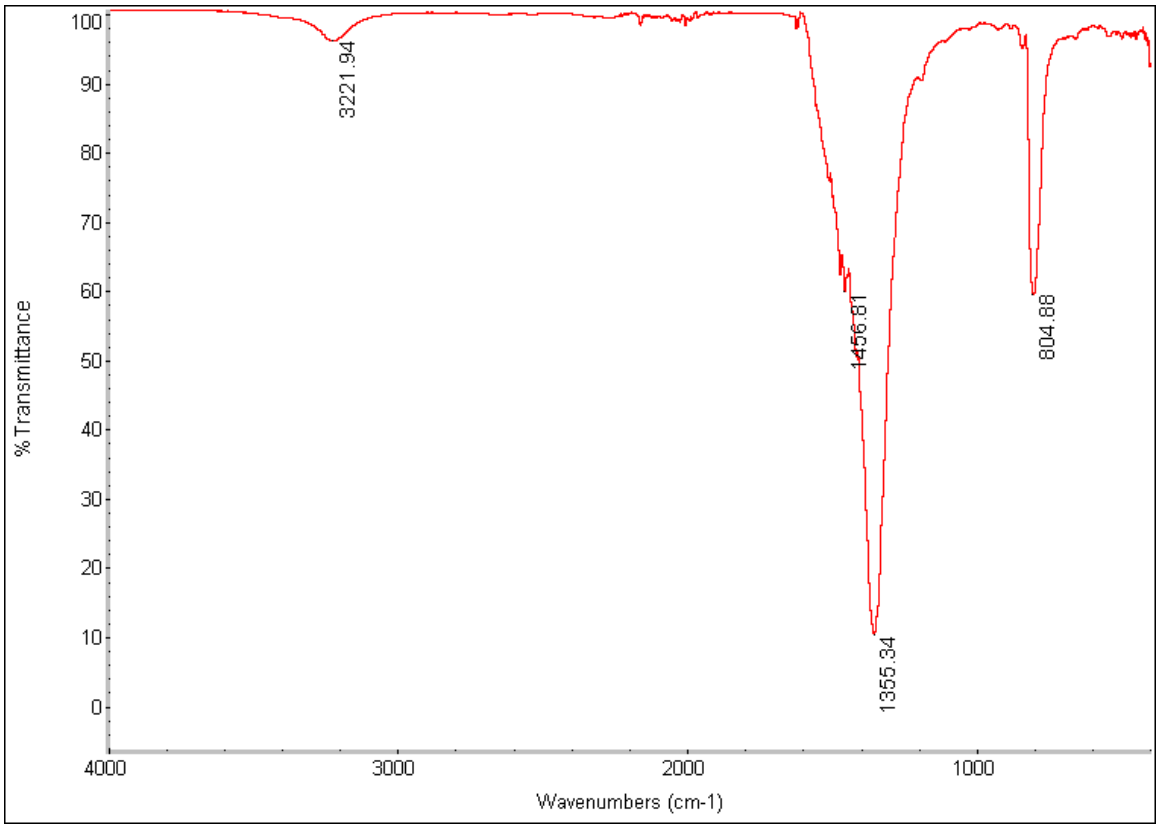
Below is a high resolution TEM of an isolated 3- wall HTP-grown BNNT self-tensioned by electrostatic forces across the gap of a lacey carbon grid:



Isolated, highly crystalline, 10 μm x 4 nm, 3-wall BNNT, strung across air gap (aspect ratio > 2500).

Unlike carbon nanotubes, BNNTs have polar bonds and so can be analyzed with FTIR. Below is an ATR FTIR of our as-grown nanotubes, showing the dominant BN peak around 1360 cm-1



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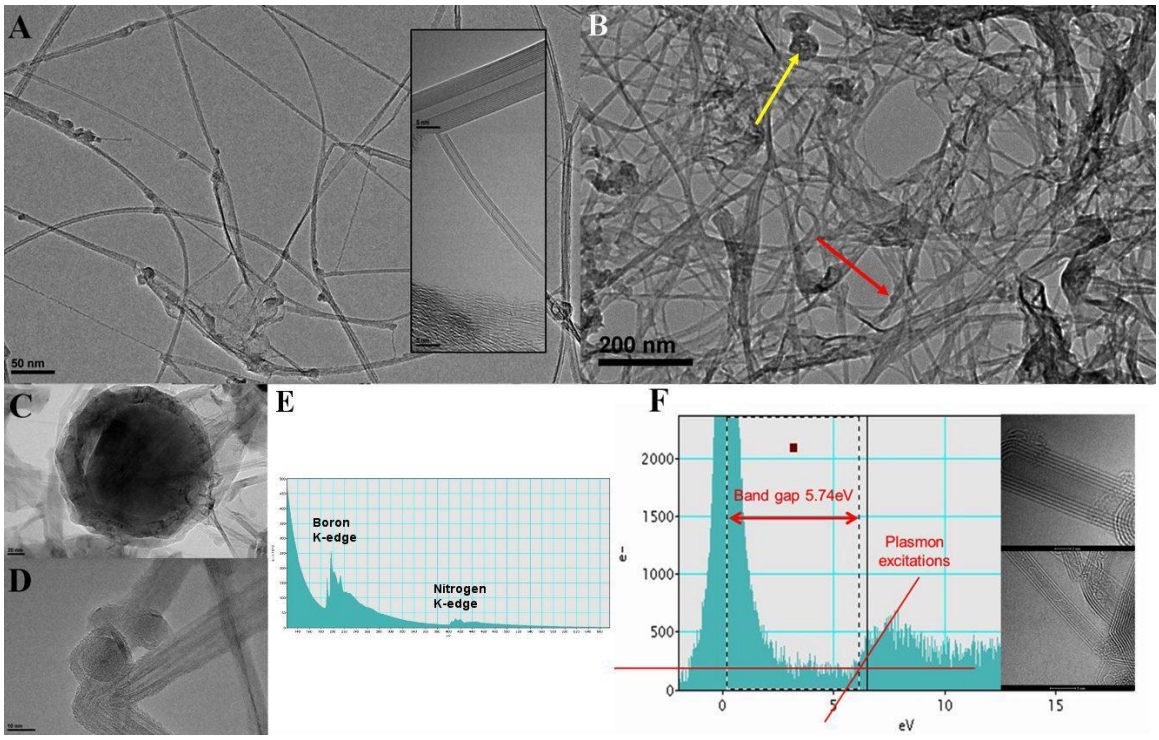
The following figure, excerpted in whole from '**Boron Nitride Nanotube: Synthesis and Applications,'** Amanda L. Tiano et al. (Proc. of SPIE Vol. 9060, 2014), contains additional TEMs of BNNTs grown by the HTP method. EELs spectra show the elemental composition, and low energy EELS spectra show a direct measurement of the band gap.



Representative TEM images of (A) BNNTs with HRTEM inset of a double-walled and 10-walled BNNT, (B) BNNTs and impurity nanoparticle species, (C) > 200 nm h-BN encapsulated B particle, and (D) a < 10 nm h-BN encapsulated B nanoparticle. (E) EELS spectrum line across a BNNT. The K-edges of boron (~ 189eV) and nitrogen (~400eV) can be seen in these spectra showing they form the BN frame of the nanotube and are uniformly distributed. (F) Band gap measurement for a 3-wall BNNT and 6-wall BNNT from low energy EELS spectra.

The full paper is available at:

http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140004051.pdf