Two major types of BNNTs:

1. > 3000 C, HTP BNNTs

"High Temperature and Pressure" BNNTs

- typically 2 to 3 walls
- low defect rate in crystalline structure
- small diameter (~5 nm)
- high aspect ratio, (up to 50,000 observed)

2. < 1200 C, "CVD" BNNTs

"Chemical Vapor Deposition" methods using metallic and oxide catalysts at tube furnace temperatures

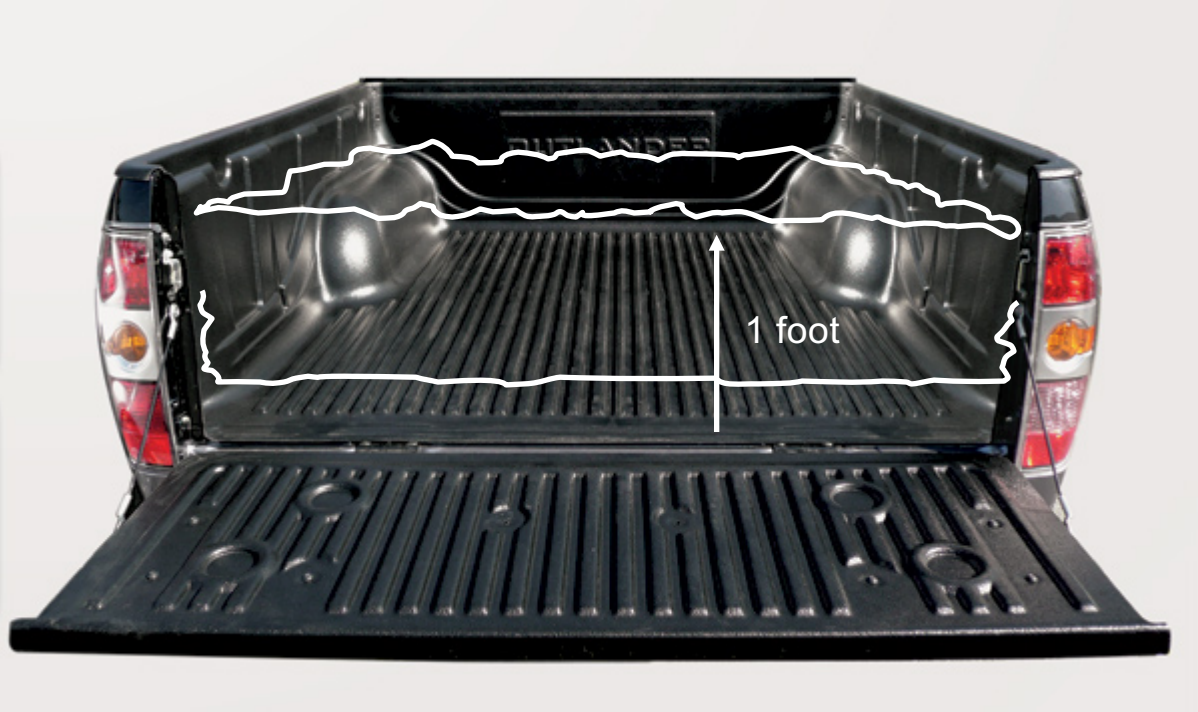
- usually many walls (20 to 100)
- usually stiff
- usually many wall defects, or bamboo, or barb-like structure
- typically ~80 nm diameter

Images that illustrate the properties of HTP BNNTs…

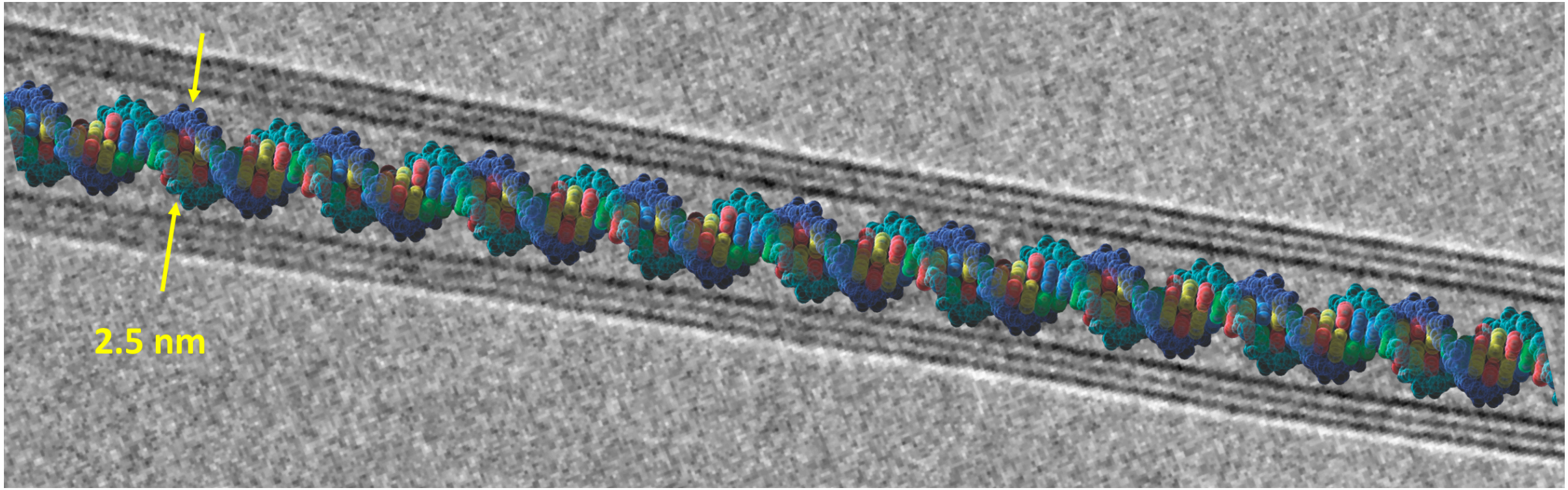
HTP BNNT puff ball (~ 2009)

(From: M. W. Smith et al, Nanotechnology, 20, 505604 (2009))

As-grown HTP-BNNTs have a very low density and high surface area.
One pound (.45 kg) would occupy about 30 cubic feet…



HTP BNNTs are molecular in size. Here is a TEM of a three-walled HTP BNNT with a model of a DNA molecule for comparison. It would fit neatly inside!



TEM of two-walled HTP BNNT

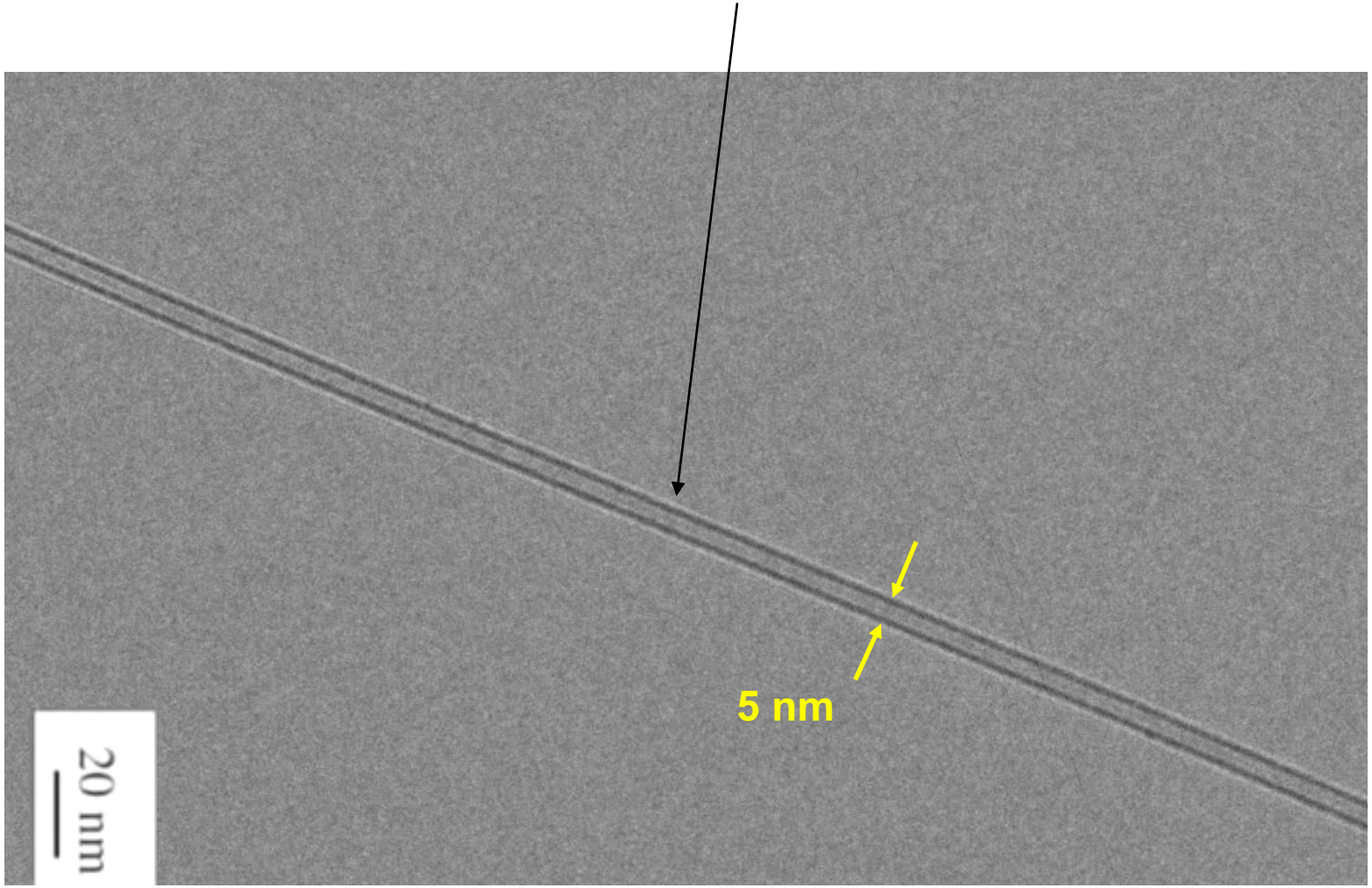


Image: Wei Cao, ODU/ARC

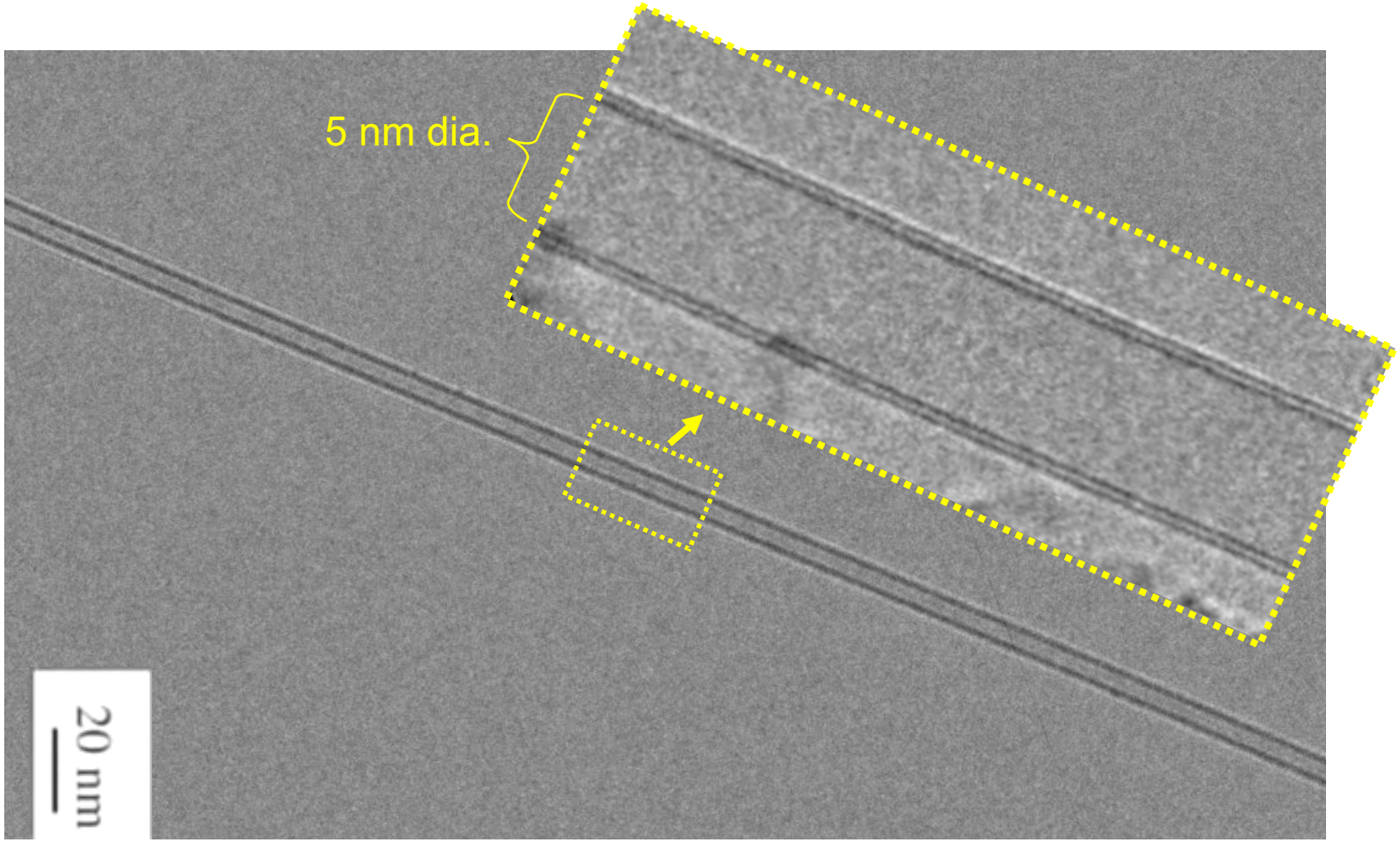
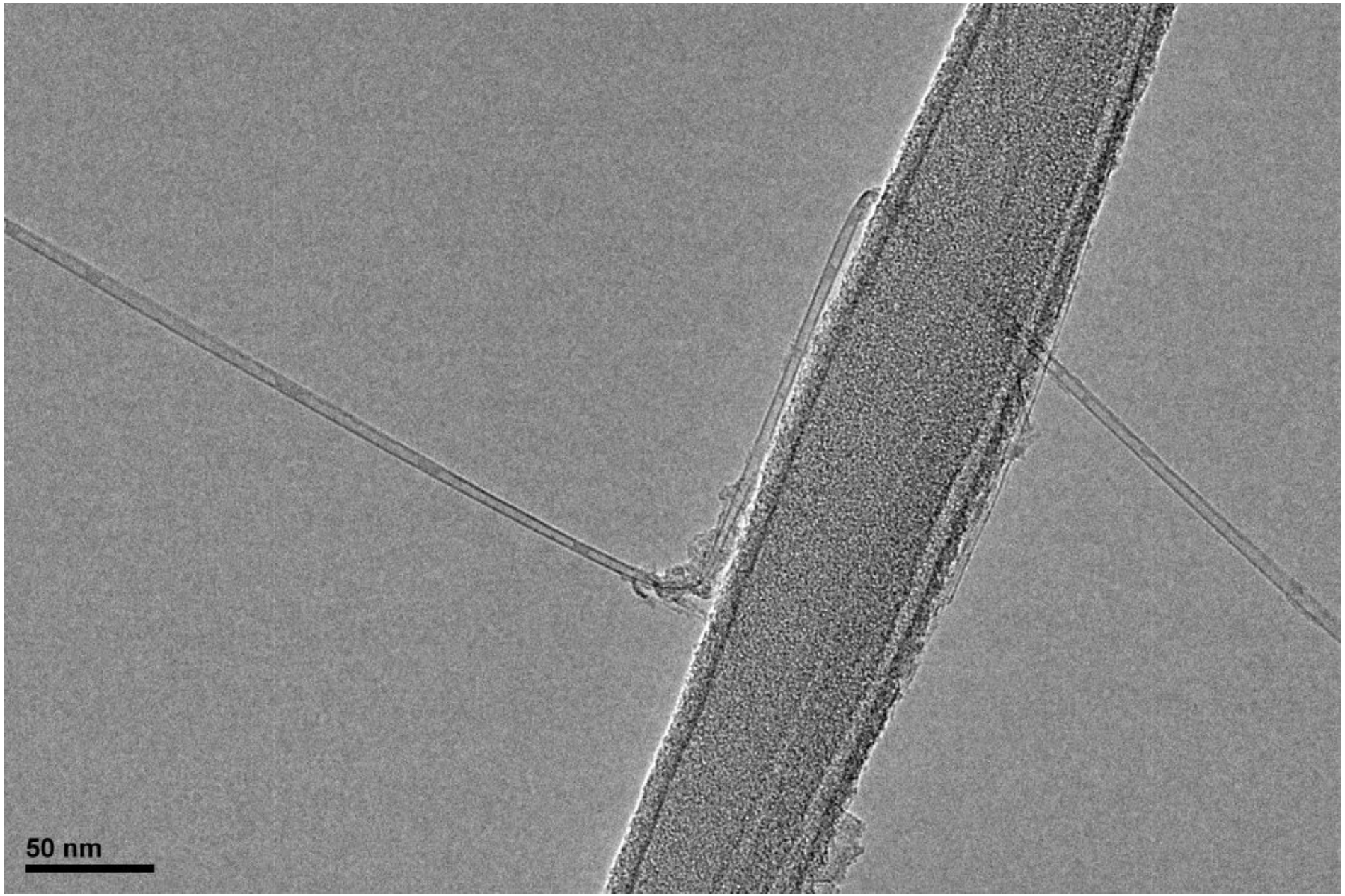
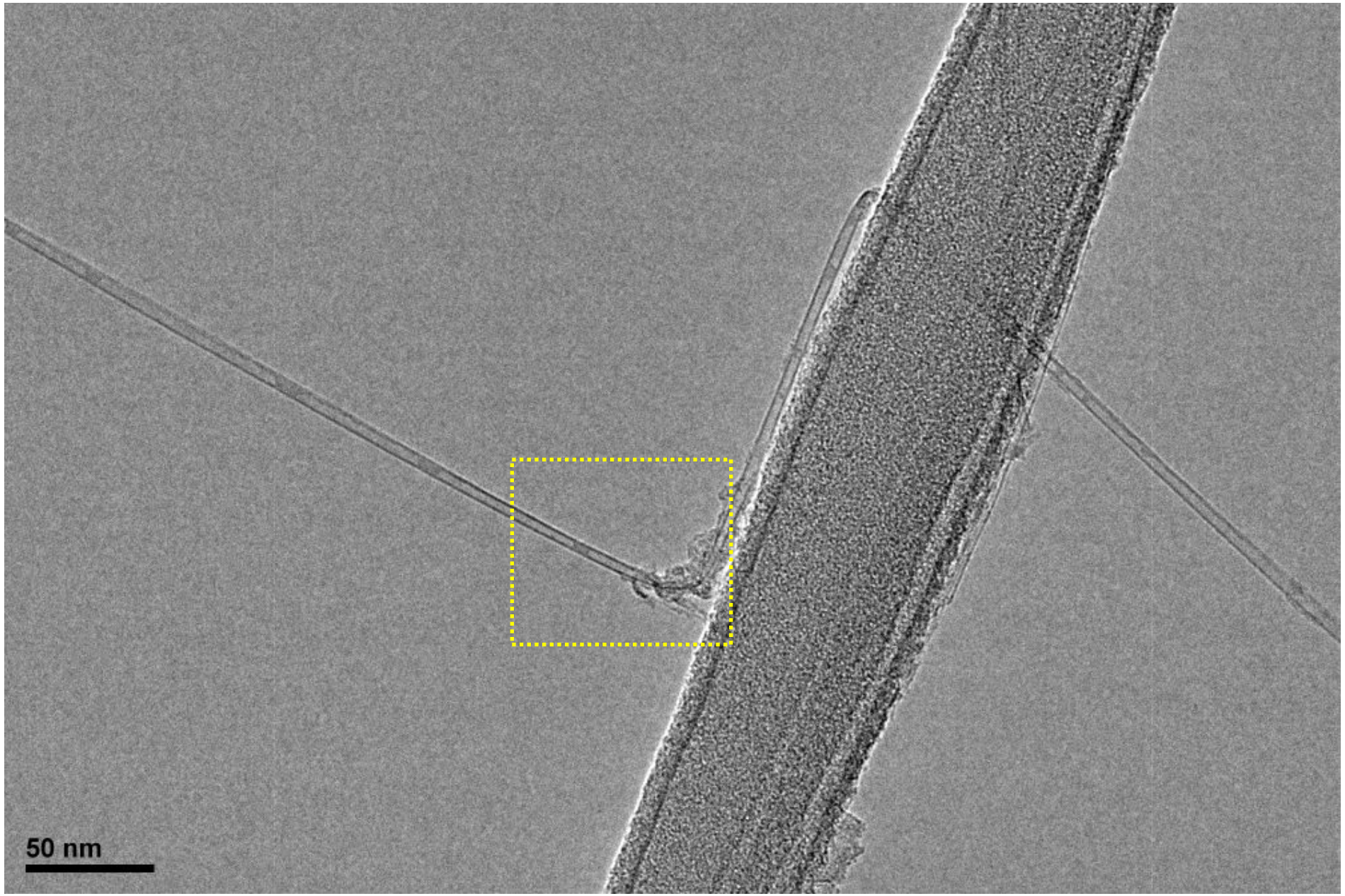
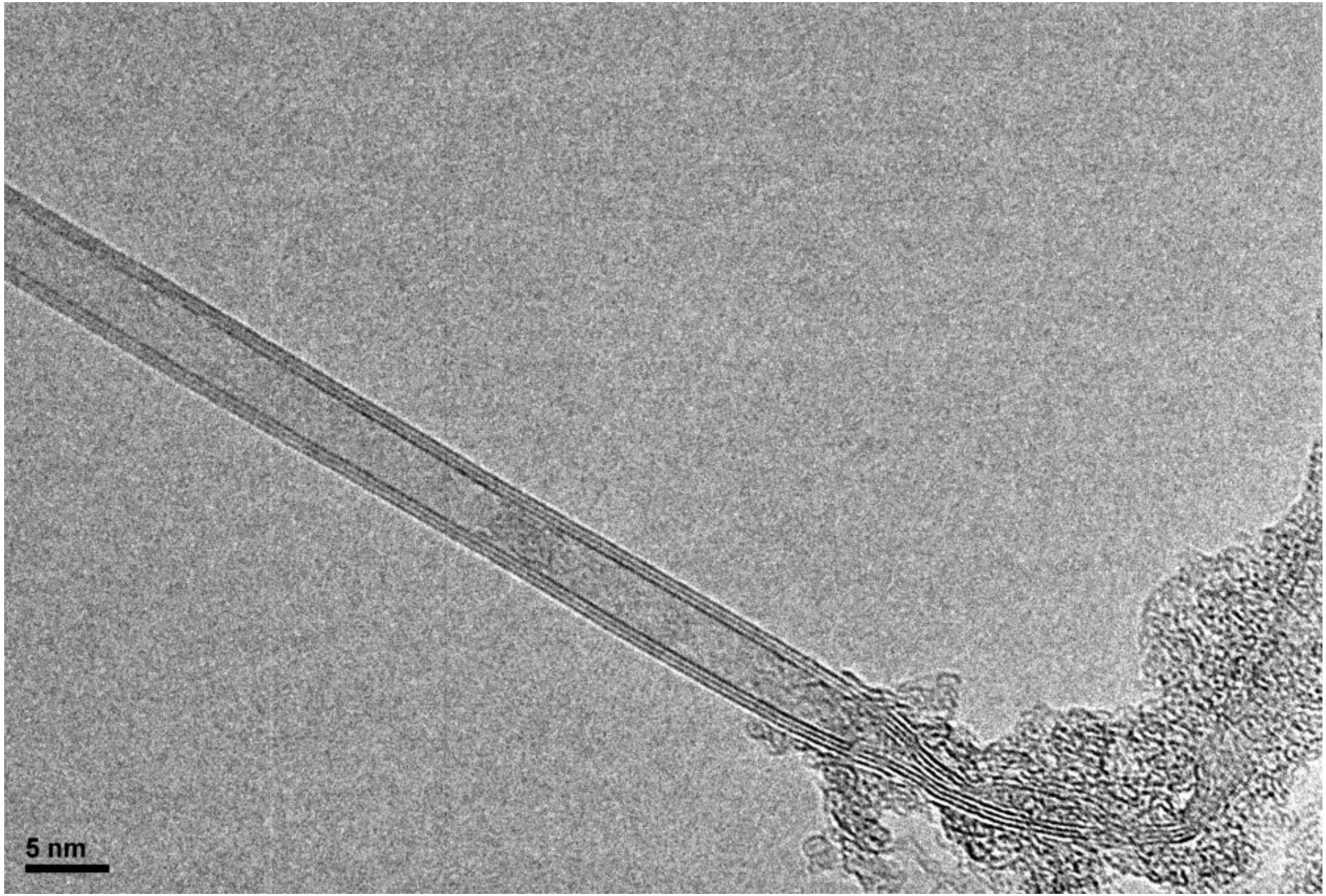


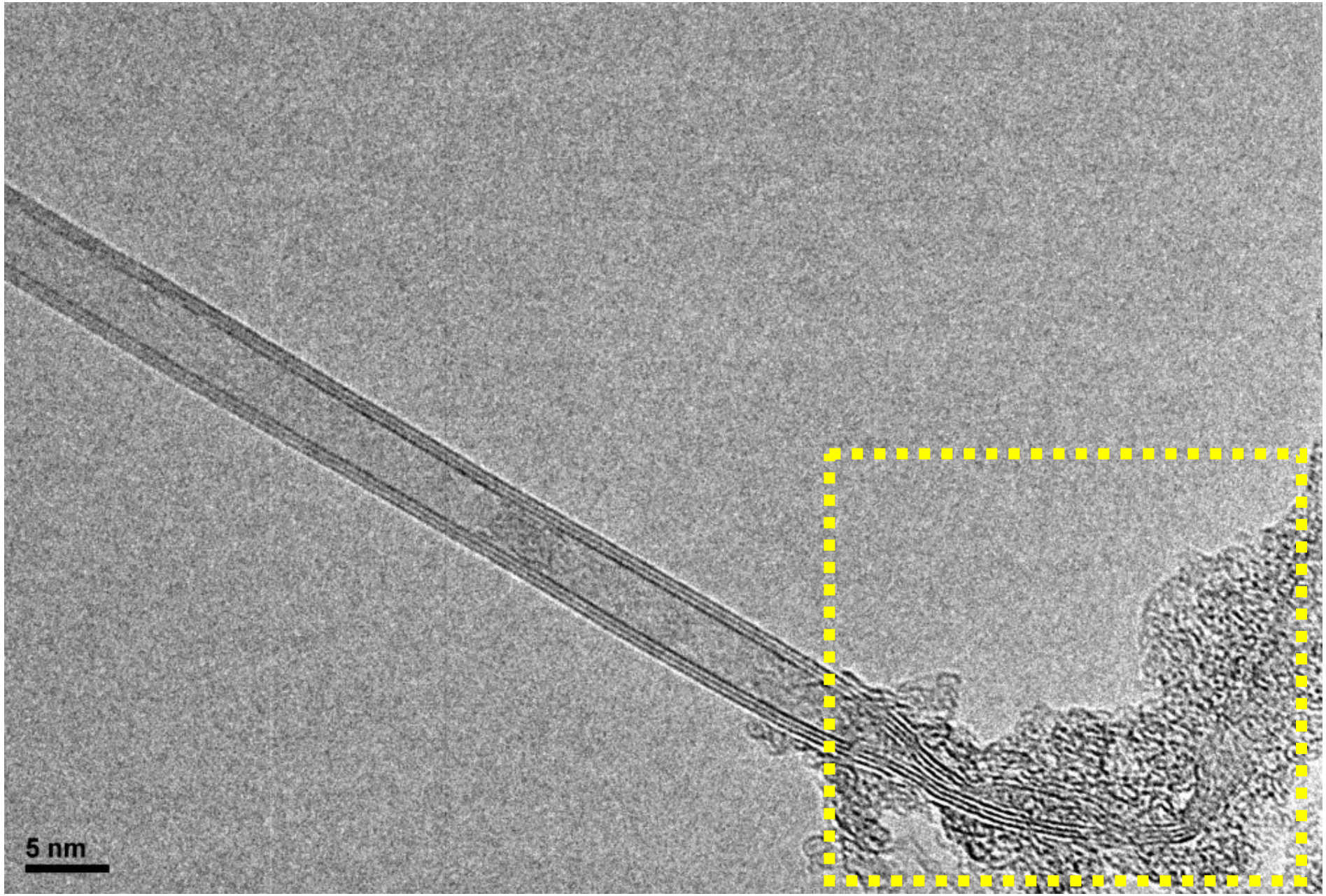
Image: Wei Cao, ODU/ARC

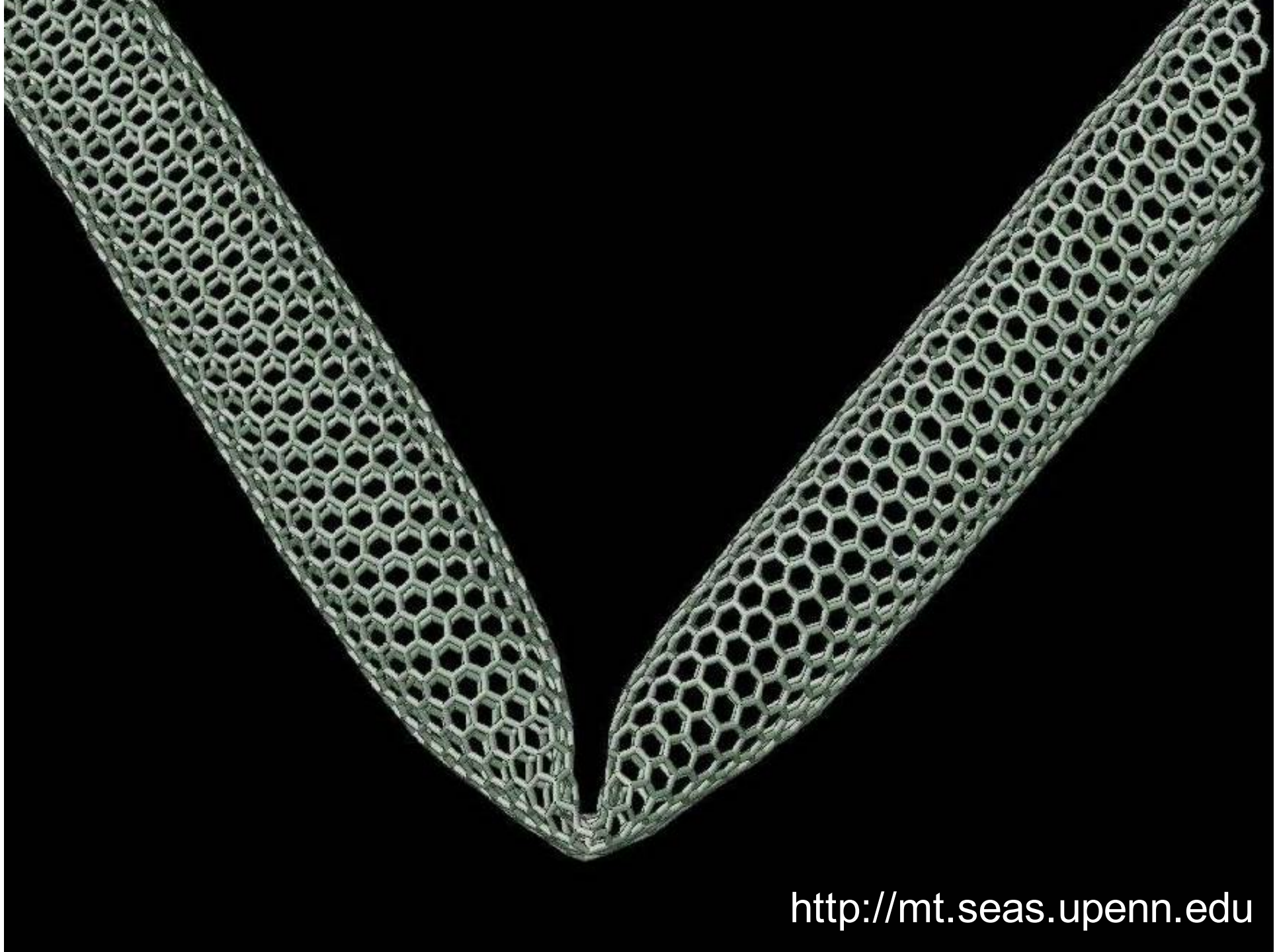
HTP BNNTs are long and flexible. This one is attracted to a lacey carbon grid by electostatic and/or Van er Wals forces…


50 nm

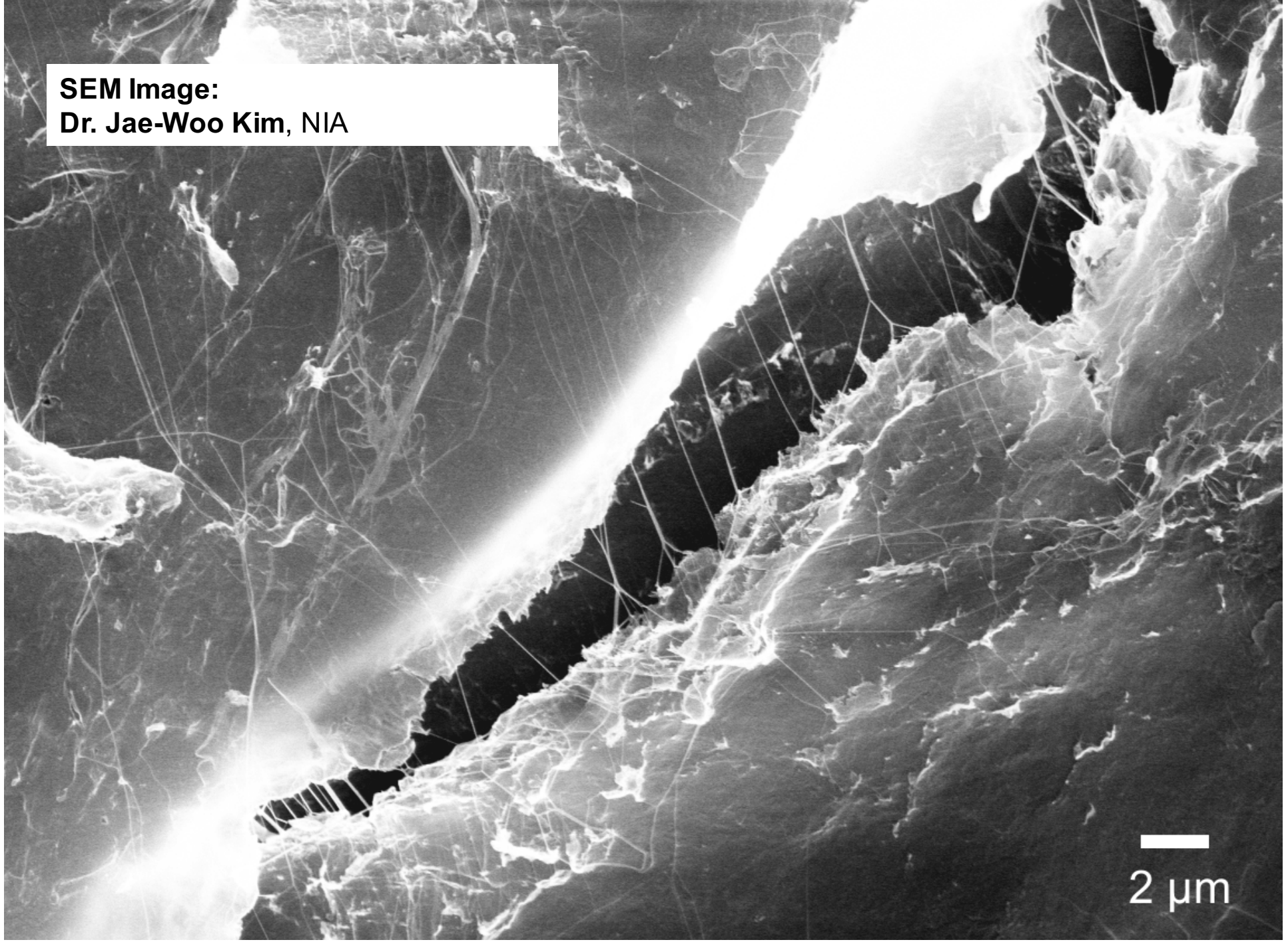

50 nm

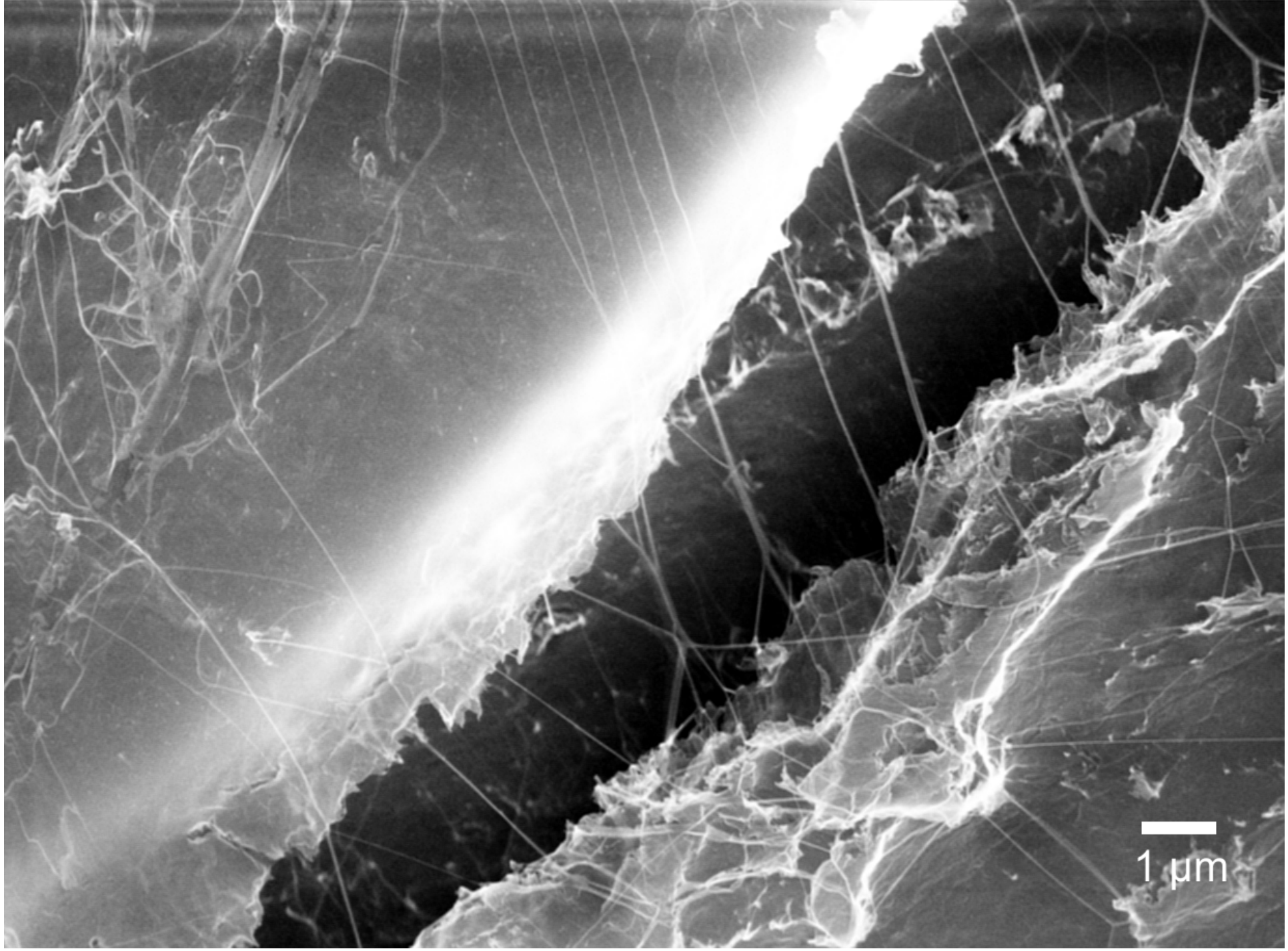

5 nm

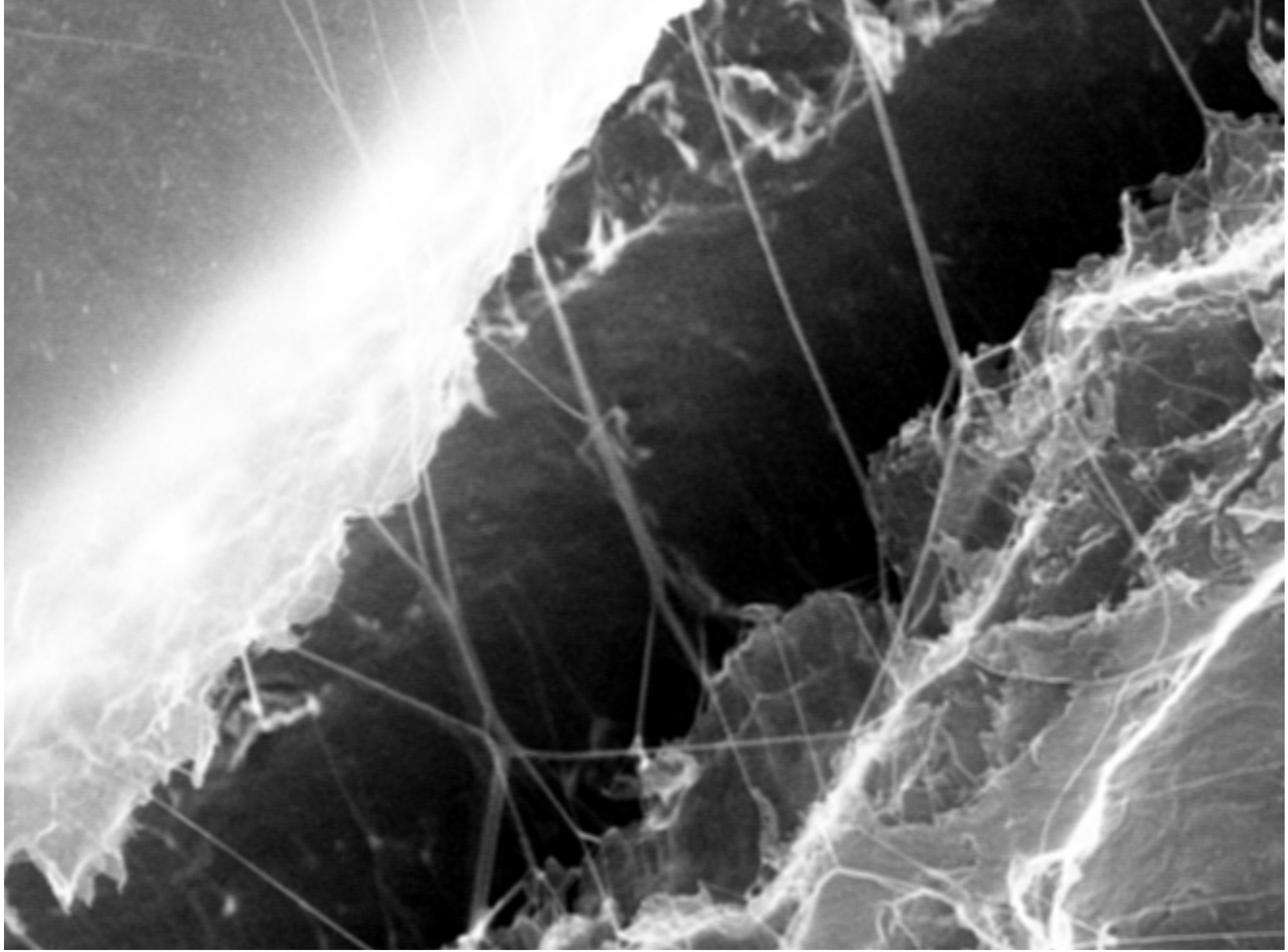

5 nm


http://mt.seas.upenn.edu

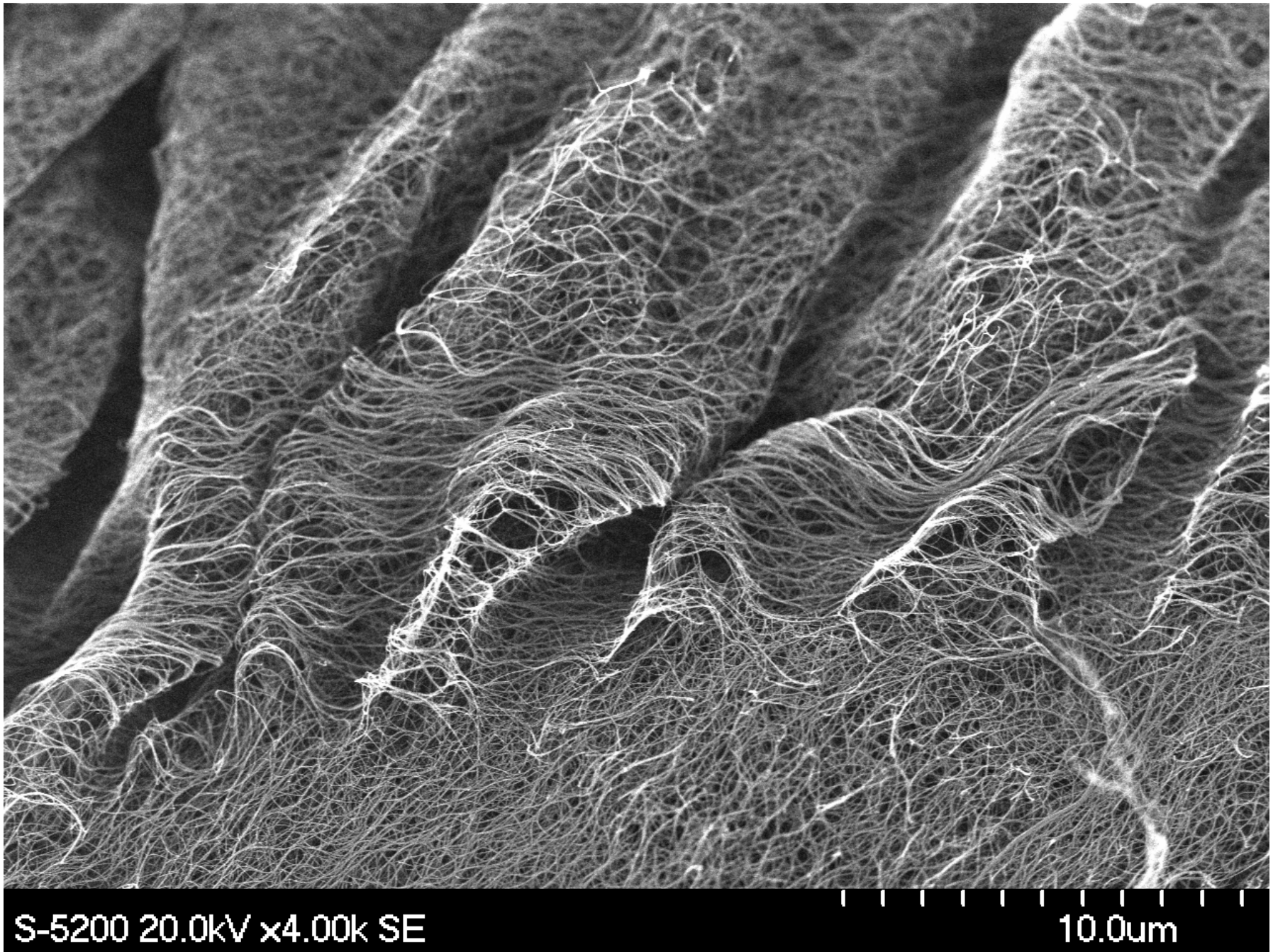
Bridging across a crack in a polymer film by HTP BNNTs…


SEM Image:
Dr. Jae-Woo Kim, NIA
2 μm

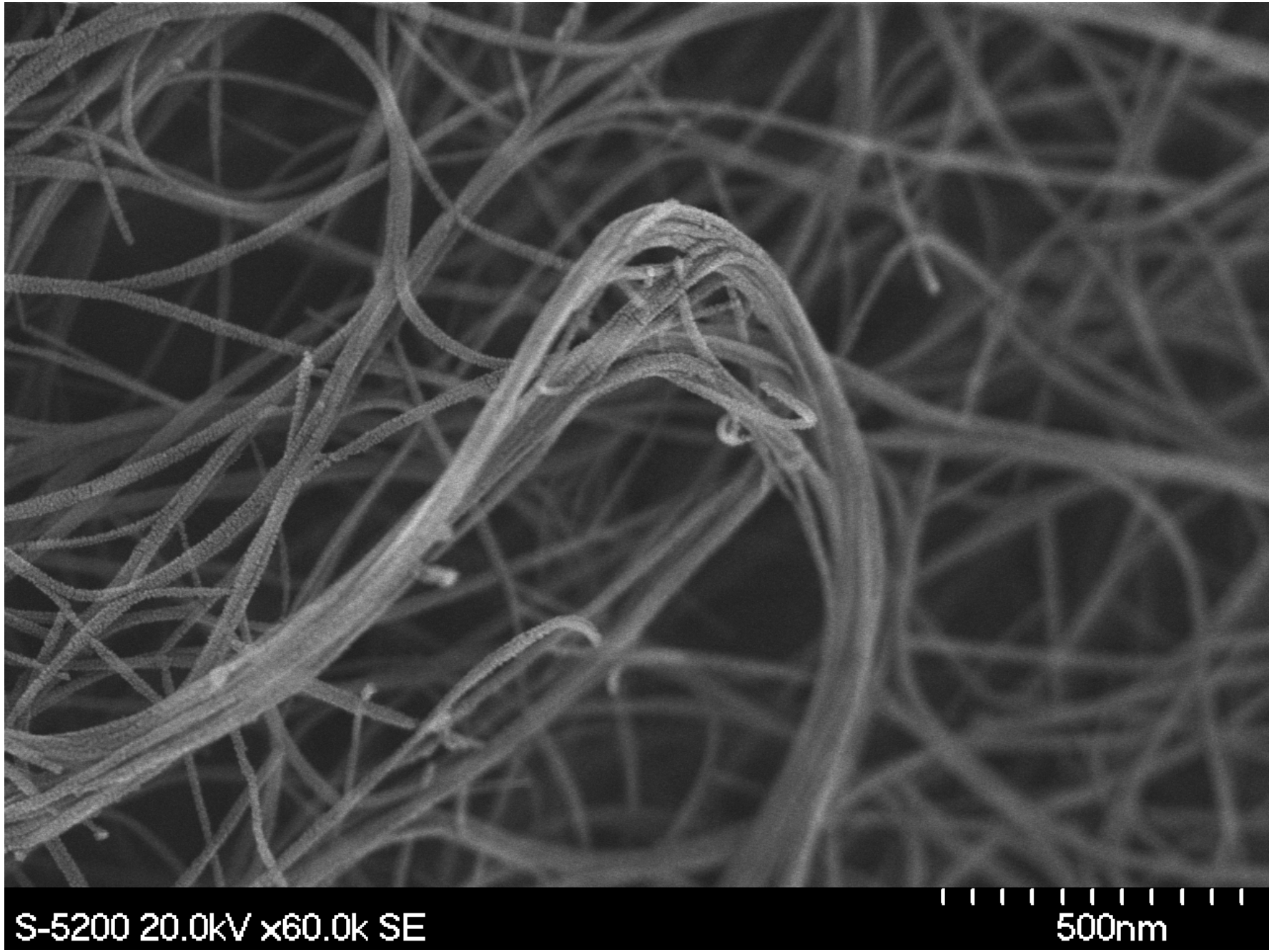

1 µm



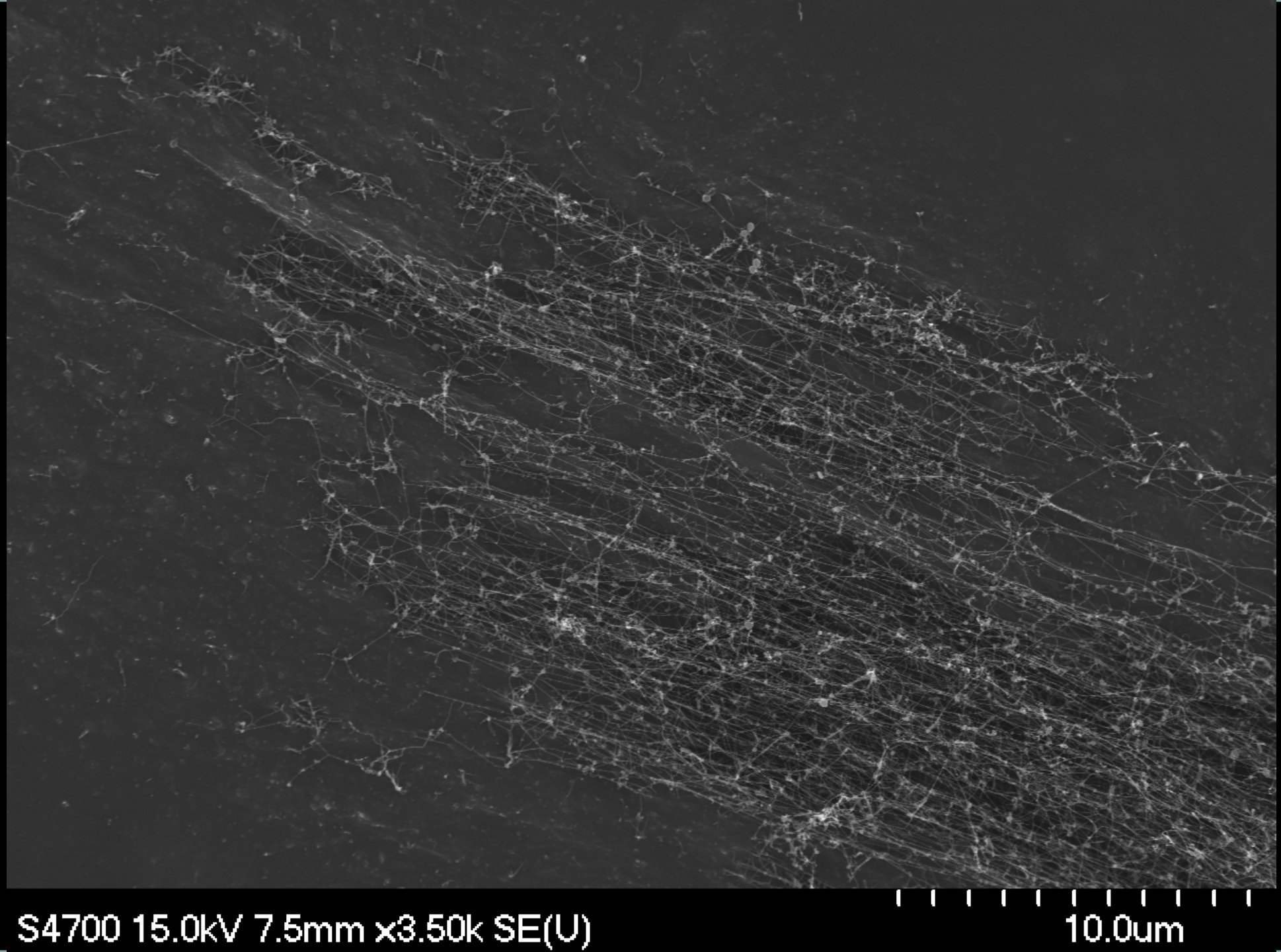
Highy purified HTP BNNTs (gold-sputtered HRSEM)

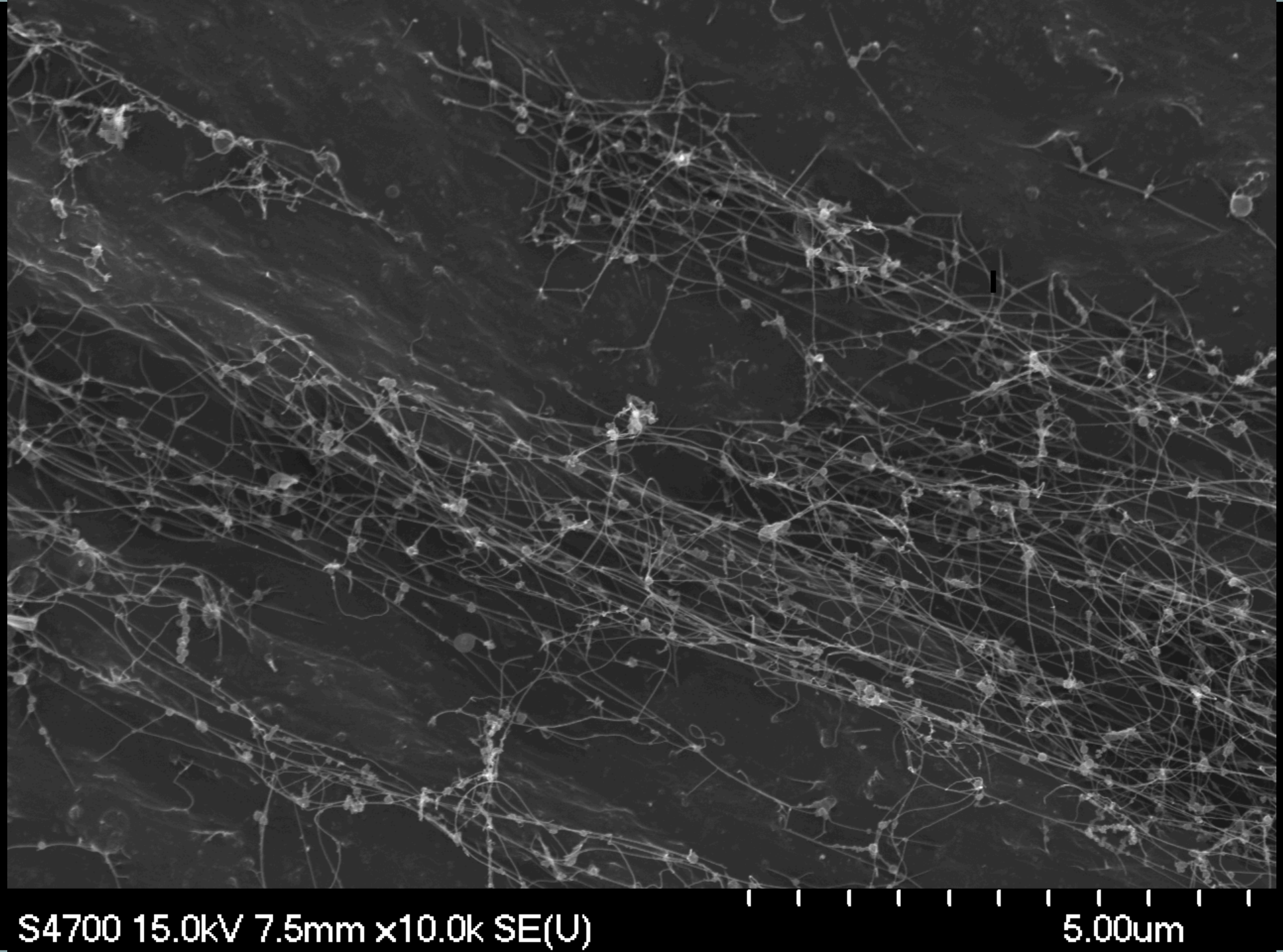


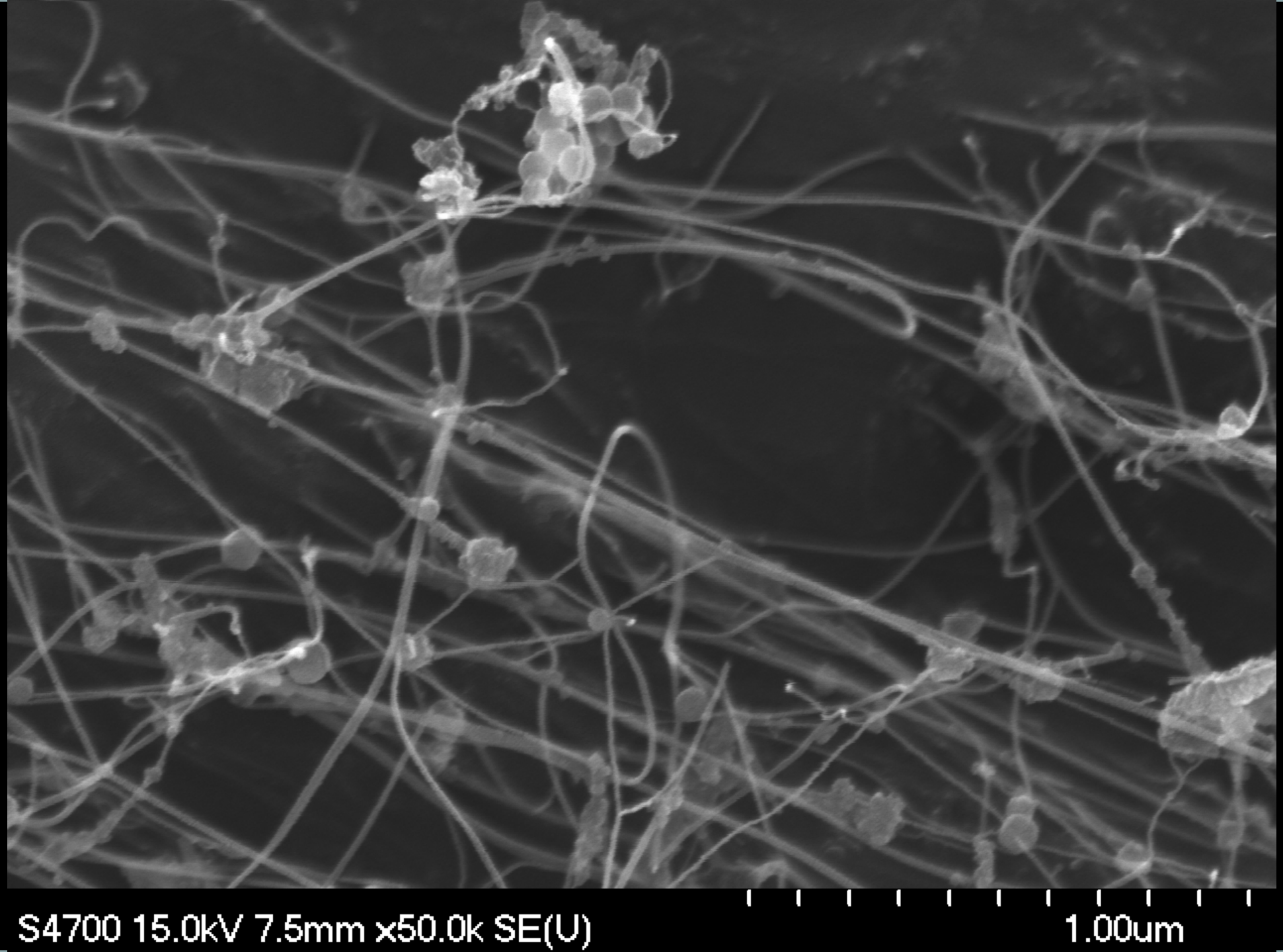
Highly purified HTP BNNTs (gold-sputtered HRSEM)



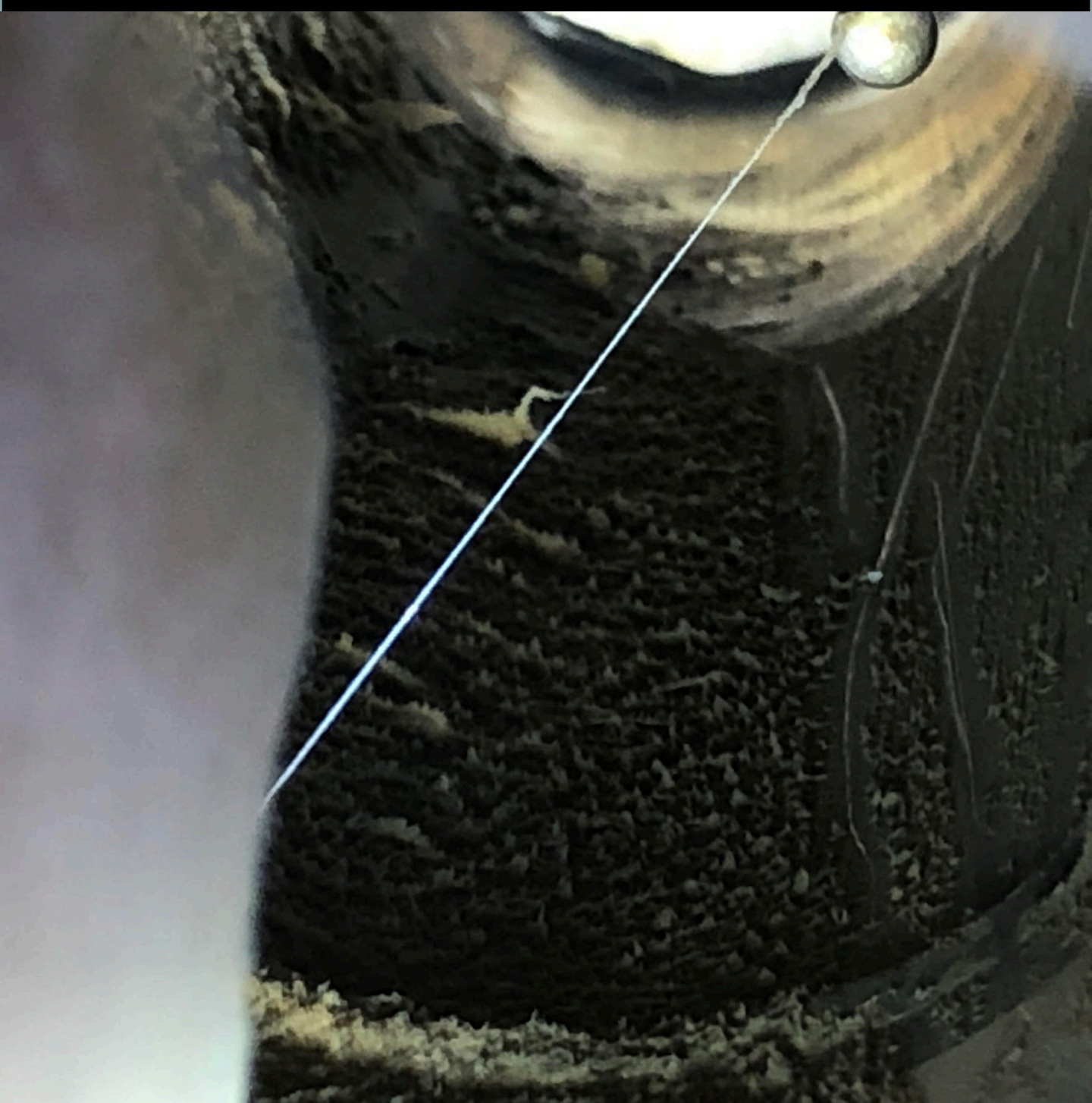
Unpurified HTP BNNT product, SP10 (Hi-res SEM)…


S4700 15.0kV 7.5mm x3.50k SE(U)
10.0um


S4700 15.0kV 7.5mm x10.0k SE(U)
5.00um

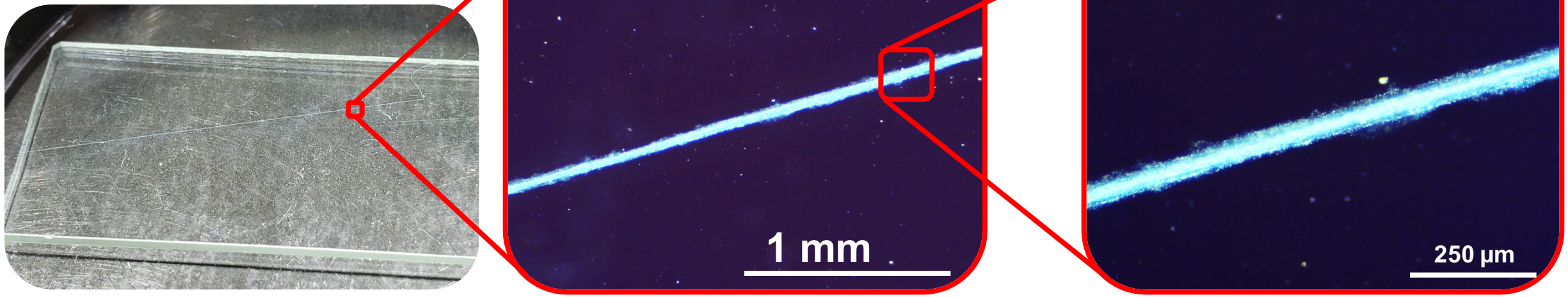

S4700 15.0kV 7.5mm x50.0k SE(U)
1.00um

Dry-spun HTP BNNT yarn…

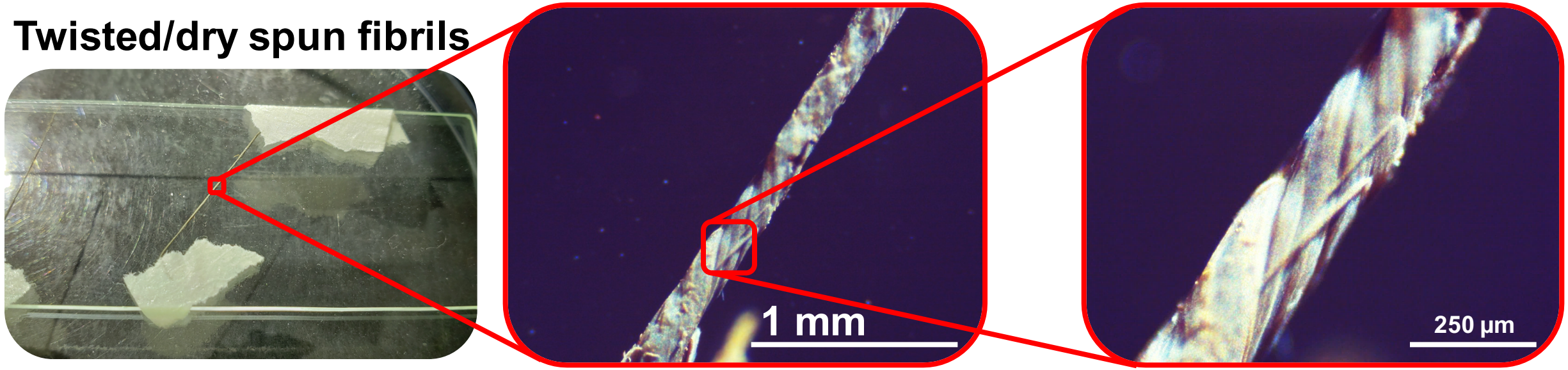


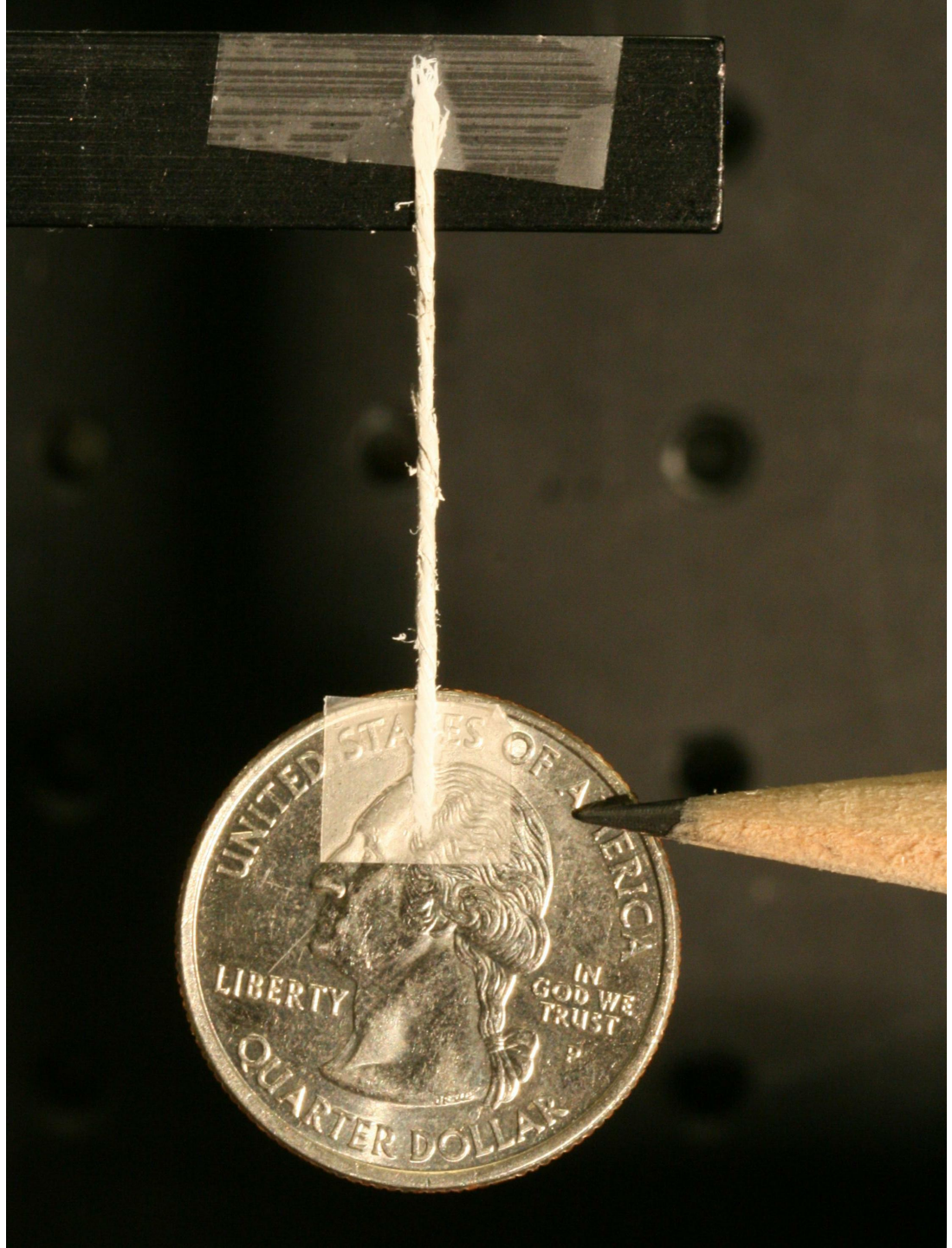
Dry spun BNNT fibers

- Raw BNNT fibril



- Twisted/dry spun fibrils

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