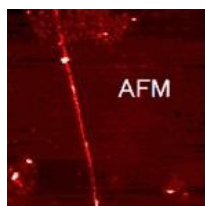


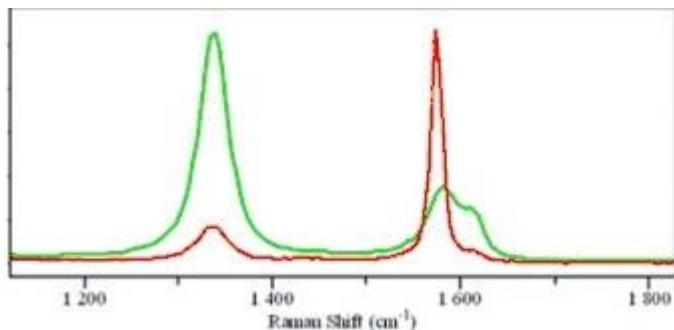
## Carbon Nanotubes: Chemical Mapping Using Raman Microscopy

The Nanonics MultiView series ([MV 1000](#), [MV 2000](#), and [MV 4000](#)) provide complete hardware and software integration for the full suite of AFM and Raman characterization of all your materials including AFM, Raman, TERS, and NSOM characterization. AFM together with Raman based methods have become the method of choice for characterizing carbonaceous materials. For carbon nanotubes, AFM-Raman imaging is especially useful for differentiating the different kinds of nanotubes.

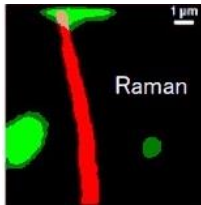
Below is a 10um x 10um AFM topography image of carbonaceous material on silicon clearly showing the presence of a nanotube on the surface in addition to some round carbonaceous domains at the top and bottom two corners.



Raman spectra were collected both on the nanotube and the circular domains. Below the red spectrum corresponds to the Raman spectrum on the nanotube showing a large peak at  $1575\text{cm}^{-1}$  and a smaller peak at about  $1340\text{cm}^{-1}$ . A Raman spectrum from the round domains is shown in green revealing a large peak at  $1340\text{cm}^{-1}$  and a weak, dual peak at about  $1600\text{cm}^{-1}$ . These spectra clearly differentiate the carbon nanotube and the surrounding disordered material. Finally, a Raman intensity map at  $1600\text{cm}^{-1}$  and  $1340\text{cm}^{-1}$  was collected with the



resulting image shown below, clearly mapping the carbon nanotube (red) and the regions of disordered materials (Green)

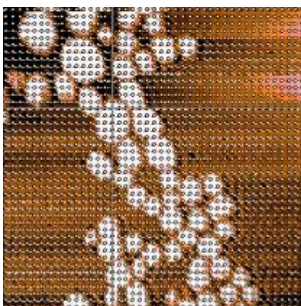


### ***Raman difference spectroscopy***

Nanonics has implemented into the Multiview 2000 and 4000 series a set of specialized AFM scanning protocols of **Raman difference spectroscopy** effectively discriminating between the near-field and far-field contribution of the scattered Raman signals. The upper scanner in the scanning head enables automated vertical tip motion at every pixel during the AFM/Raman mapping. Thus, a Raman map can be collected while the tip is in contact with the sample (near-field signal) and then again when the tip is retracted at a predetermined distance above the sample (far-field signal) and then retraces the substrate. The software then automatically calculates the difference between the intensity of the Raman spectrum when the TERS probe is in contact and when the probe is retracted.

A Multiview 4000 with a TERS probe was used to collect Raman difference spectra of carbon nanotube clusters in the images shown below. A topography map of the clusters is shown in (a) revealing several hundred nanometer round domains of carbon nanotubes.

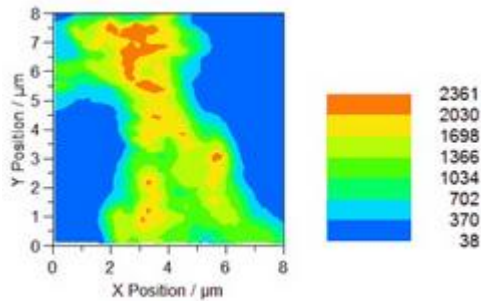
(a)



Next an AFM-Raman map with the probe in contact with the sample was collected in (b) showing the Raman intensity at  $405\text{cm}^{-1}$ . The Raman map was collected at an array of 1850

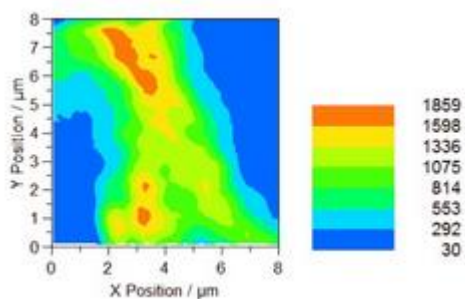
points (pixels shown in the topography image) where measurements were separated by 180nm.

(b)

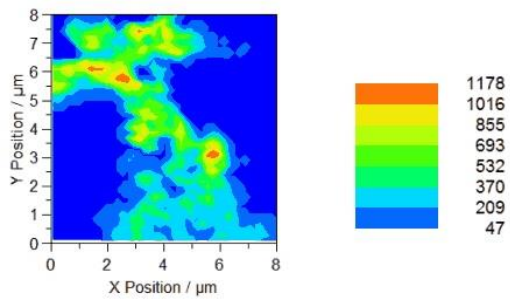


The tip is then retracted, and the Raman intensity map at  $405\text{cm}^{-1}$  is again collected as shown in (c). The difference map between (b) and (c) is shown in (d), clearly providing significantly better resolution in the Raman intensity map that can be accurately correlated with the topographic map in (a), revealing important chemical information about the various CNT clusters.

(c)



(d)



- 1850 Raman points
- 180nm distance between points

Tip IN 405 cm<sup>-1</sup>

Tip OUT 405 cm<sup>-1</sup>

Difference Raman:

**TERS Raman  
Difference At  
One Point**

405 cm<sup>-1</sup> Peak Intensity