RELATIVE CHIRAL ABUNDANCES OF CARBON NANOTUBES DETERMINED BY RESONANT RAMAN SPECTROSCOPY USING A TUNABLE DYE LASER

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Current single-walled carbon nanotube (SWNT) synthesis methods can produce only a mixture of both metallic and semiconducting chiralities. One common method for measuring the relative abundance of each chirality is through the use of optical absorption spectroscopy. However, since the optical transition energies of SWNTs are highly dependent on diameter, chiral angle, and electronic type; and as-produced samples typically contain many different (*n,m*) species, absorption spectra appear highly congested due to overlap in between multiple optical features. As a result, relative abundance is difficult to extract from such measurements. The use of resonant Raman spectroscopy, however, over a wide excitation wavelength range can avoid such difficulties and is one of the most effective methods to clearly identify chirality. We have set up a high resolution, CW resonant Raman scattering spectroscopy system with a tunable dye laser excitation to quantitatively determine the relative population of different (*n,m*) species in SWNT samples. Using a Rhodamine 6G dye laser pumped with a Nd:YAG laser, we have clearly identified members of the (8,8) and (9,9) metallic families as well as various small-diameter semiconductor chiralities. By combining the diameter-dependent radial breathing mode (RBM) frequency with the at-resonance Raman intensity and electronic linewidth as measured from the excitation profile for said RBM, clear identification of not only chirality but also relative abundance was performed.

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Single-walled carbon nanotube

Single-walled carbon nanotubes (SWNTs) can be metallic or semiconducting according to their chiralities or (*n,m*) species.

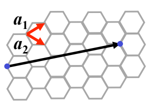
Chiral vector: $C_h = na_1 + ma_2$

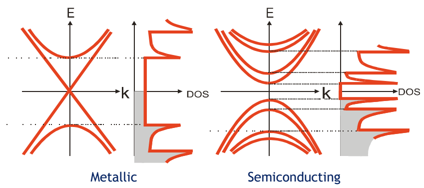
$n - m = 3M + \theta$

1) $M = \theta = 0$
Metal (Armchair)

2) $M \neq 0$, $\theta = 0$
Narrow Gap Semiconductor

3) $M \neq 0$, $\theta = \pm 1$
Wide Gap Semiconductor





Current SWNT synthesis methods can produce only a mixture of both metallic and semiconducting chiralities.

Purpose

Our aim is to quantitatively determine the relative population of different (*n,m*) species in SWNT samples.

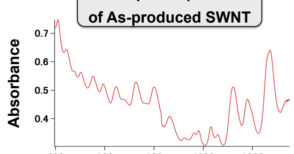
Raman Spectroscopy system

We have set up a high resolution, continuous wave(CW) resonant Raman scattering spectroscopy system with a tunable dye laser excitation.

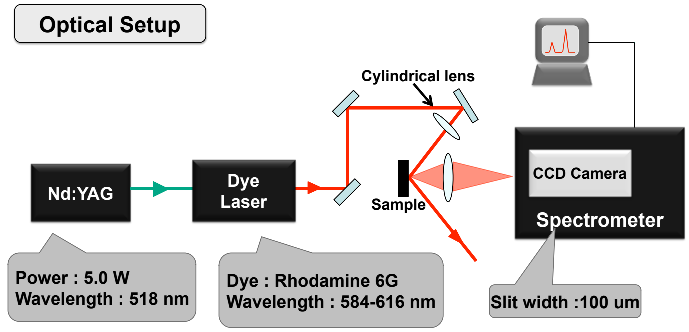
Sample

As-produced SWNT

Absorption spectrum of As-produced SWNT



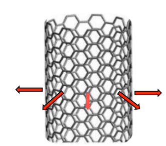
Optical Setup



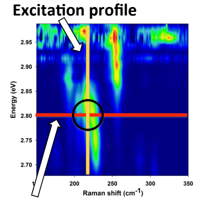
Raman experiments were performed on HiPco-produced SWNTs. The samples were excited by tunable dye laser with powers of 100mW focused in to the nanotube solution.

Radial Breathing Mode (RBM)

- RBM was used to determine the tube diameter of a specific (*n,m*) species and the diameter distribution of a nanotube sample.
- When combined with excitation energy information, RBM can give (*n,m*) species identification



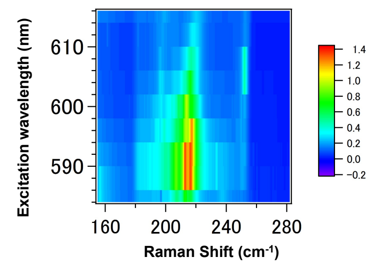
Raman Excitation Profile (REP)



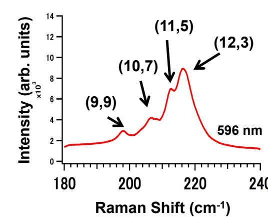
- Vertical slice Raman map.
- When combined with RBM frequency (i.e. diameter) we can uniquely identify (*n,m*)

Results

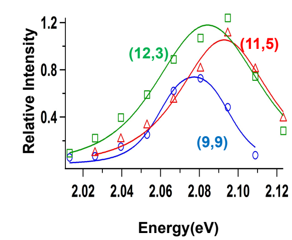
Resonant Raman scattering map



Raman spectrum



REP



Conclusion

- Identification of different chiralities in As-produced SWNT with a tunable dye laser
- Making a dark field spectroscopy system

Acknowledgements

I would like to thank Prof. Kono who provided feedback and valuable comments. I also want to thank Carter and Dr. Erik whose opinions and information have helped me very much throughout the production of this study.