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Unraveling the Mysteries of Carbon Nanotubes Using a State-of-the-Art Spectral Imaging NIR Photoluminescence System

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The majority of single-walled carbon nanotubes (SWNTs) are semiconductors with direct band gap energies approximately inversely proportional to the tubes' diameter. The recent discovery of near-infrared (NIR) band gap photoluminescence from isolated semiconducting SWNTs provides researchers with a powerful experimental tool for understanding the fundamental properties of SWNTs and has led to key developments in nanotube applications (1). The successful assignment of SWNT spectral features to specific structural species was one of the main achievements in the field (2).

Experimental Conditions

Prof. R. Bruce Weisman's group from Rice University's Department of Chemistry in Houston, Texas, has adapted a setup for studying the near-IR photoluminescence of individual nanotubes in a variety of media. The setup contains a Nikon TE-2000U inverted microscope coupled via one of its output ports to a 2D-OMA V liquid nitrogen-cooled InGaAs PI/Acton camera. Samples were excited with an external diode laser, the beam of which was focused with an aspheric lens mounted to a three-axis translation stage. The available excitation power at the sample was 30 mW, with the excitation intensity varying between ca. 1 and 50 kW/cm².

The researchers detected nanotube luminescence using a Nikon PlanApo 60x/1.4 oil-immersion, or a 60x/1.0 water-immersion objective. They also used a dichroic beamsplitter in series with a dielectric long-pass filter with a cutoff wavelength of either 946 or 1125 nm in order to selectively transmit the near-IR nanotube emission and block the excitation light. To measure the spatially resolved emission spectra of objects in the microscope's observation field, a second output port of the microscope was coupled to the input slit of a small near-IR spectrograph via an optical fiber. A cryogenically cooled 512-element InGaAs photodiode array (PI/Acton 2D-OMA V) was mounted to the spectrograph's exit port. The spectrum of a single nanotube in the image field was measured by translating it into the standard position and flipping the microscope's mirror from the imaging port to the spectrograph port. Initial studies of individual isolated SWNTs using this apparatus have been described in a recent publication (3).

Results

The Weisman Group's setup allowed for the fluorescence from individual SWNTs to be imaged at frame rates as high as 150 Hz, with emission spectra captured within only a few seconds.

The illustration in Figure 1 shows a sequence of near-IR fluorescence micrographs (color-coded for intensities) of an individual long nanotube in room temperature water suspension. The emission from this SWNT was sufficient to permit a frame exposure time of only 1 ms, revealing valuable information about the tube's bending motions. The nanotube's spectrum, shown in the right frame of Figure 1, was acquired in only 2 s. The peak emission wavelength identifies the nanotube as a (11, 3) structure, which has a diameter of 1.014 nm and a chiral angle of 11.7 degrees.

Conclusion

The researchers determined that NIR photoluminescence is a powerful tool for analyzing SWNT properties. PI/Acton's linear and 2D-OMA V detectors proved valuable tools for making new discoveries in nanotube research.

References

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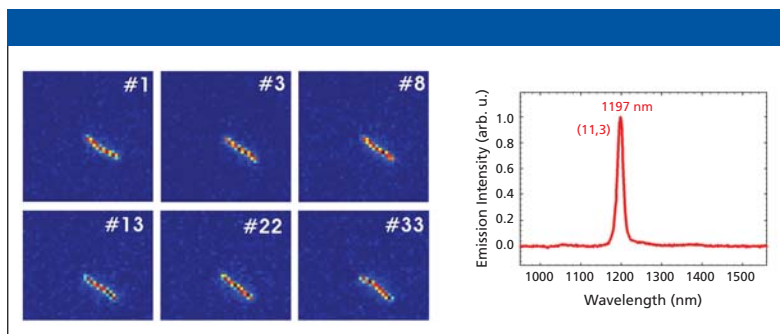


Figure 1: Left panel: near-IR fluorescence images of an individual, 6- μ m-long SWNT in aqueous surfactant suspension. Right panel: emission spectrum of the nanotube, as measured in a 2 s acquisition.

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