MAR06-2005-007282

Abstract for an Invited Paper
for the MAR06 Meeting of
the American Physical Society

Density gradient ultracentrifugation of single-walled nanotubes

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We demonstrate the bulk separation and enrichment of single-walled carbon nanotubes (SWNTs) by diameter via density gradient ultracentrifugation.(1) Means for sorting SWNTs by their physical and electronic structures are essential for future electronic and optical applications where semiconducting SWNTs mono-disperse in diameter are necessary. The separation is driven by subtle variations in the buoyant density of these nanomaterials with small changes in their physical structure. After centrifugation in a density gradient, focused bands of various colors consisting of isolated SWNTs are clearly visualized by eye. By fractionating the centrifuge tube and characterizing the absorbance and photoluminescence spectra of the sorted SWNTs, it is apparent that SWNTs of decreasing diameter are increasingly more buoyant. This scalable and non-destructive separation strategy uses centrifugation equipment already utilized in the solution-based processing of carbon nanotubes, and simultaneously separates isolated and aggregated SWNTs, which sediment to larger buoyant densities due the reduced solvation and surface-to-volume ratios of these larger structures. Along these lines, the removal of aggregates and spurious materials is evidenced by significantly lower background absorbencies in optical absorbance spectra. For the case of isolated SWNTs, we propose a geometric-based hydration model to describe the unexpected trend of increasing density with increasing diameter. The effectiveness of this technique is best demonstrated for SWNTs that are small in diameter. For example, in the small diameter regime, it is possible to sort the (6,5) and (7,5) tubes, which differ in diameter by only 0.7 Å. (1) M. S. Arnold et al. Nano Lett. 5 (2005) 713-718.