Characterizing SWCNT Dispersion in Polymer Composites

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*The authors acknowledge financial support from the NASA URETI on Bio Inspired Materials (NCC-1-02037). The authors thank Dr. K. E. Wise (NIA) and Dr. E. J. Siochi (NASA LaRC) for helpful discussions on radial power spectrum density and fractal dimensions.

Abstract

The new wave of single wall carbon nanotubes (SWCNT) infused composites will yield structurally sound multifunctional nanomaterials. The SWCNT network requires thorough dispersion within the polymer matrix in order to maximize the benefits of the nanomaterial. However, before any nanomaterials can be used in aerospace applications a means of quality assurance and quality control must be certified. Quality control certification requires a means of quantification, however, the measurement protocol mandates a method of “seeing” the dispersion first. We describe here the new tools that we have developed and implemented to first be able to “see” carbon nanotubes in polymers and second to measure or quantify the dispersion of the nanotubes.

Imaging the True Dispersion

Optical, electron and probe microscopy tools have been utilized in order to establish the effectiveness of visualizing carbon nanotubes in polymer matrices. However, the data extracted from these tools is insufficient to develop a quantitative measure of the dispersion. What was needed was a means of the 3-D distribution of the tubes. The new tools we developed allows for the collection of data from “Poly-Transparent” imaging to begin to refine our models and understanding of the nature of the true dispersion.

Poly-transparent 3-D Images

Poly-transparent imaging causes the non-conducting polymer to become transparent and allows the imaging of the conductive SWCNTs deep within the sample. Imaging the sample in their natural state illustrates the effects that mixing conditions, sonication, polymer chemistry, and SWCNT composition have on the overall dispersion and resulting material properties. Poly-transparent imaging permits three-dimensional imaging of the SWNT network arrangement within the host polymer. The information derived from the three dimensional model provides the information necessary to determine a methodology to quantify the dispersion of the SWCNT network within the host polymer.

Image processing

The dispersion of the nanotubes can be measured directly from the Poly-Transparent images by performing a series of image processing techniques. First we perform a 2-D Fast Fourier Transform (FFT) analysis of the image. This figure shows the progression of some of the dispersion characterization tools and SWCNT dispersion procedures. Notice how the true nature of the SWCNT dispersion becomes apparent under high 3D Poly-Transparent imaging. The tubes here is 20nm diam. and 1000nm for columns 2,3, and 4 respectively.

RSPD plotting

Next we radially integrate over the spatial domain of the 2-D FFT to produce a plot of Radial Power Spectral Density (RSPD). The peaks of this plot correspond to dominant features within the image.

Fractal Dimension

The degree of ordering, or randomness, of the sample must also be determined to effectively measure the dispersion. The degree of randomness can be quantitatively characterized by determining the fractal parameter based upon the partitioning function associated with the Poly-Transparent images.

Minkowski Functions

The Minkowski fractal connectivity is another image analysis tool that can be utilized to verify the local structures characteristics gathered from RSPD plots and fractional dimension analysis.

Dispersion Summary

The dispersion characteristics of the six samples can be compared by observing the RSPD plots and the fractal dimension associated with each Poly-Transparent image.