An Approach for Quantifying Dispersion of Carbon Nanotubes in Ceramic Composites Using TEM Images

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Dispersion of carbon nanotubes (CNTs) in composite materials prepared by sol-gel method is a challenging task. The dispersion of CNTs has a great impact in the properties of composite materials[1]. Actually, no single standard quantitative dispersion method has been adopted in materials science community and generally the dispersion analysis is subjective. In this context, the analysis of TEM images has been an important method for dispersion characterization. We propose a new approach based on graphical model to characterize the dispersion of CNTs identified in the TEM images of alumina samples alumina with CNTs obtained by sol-gel method. The CNTs are identified using a segmentation method based in Otsu threshold and morphological operations[2]. After that, the localization of the CNTs are calculated (Fig. 1) and a full connected graph is created. In order to analyze the spatial distribution of the CNTs, i.e. their dispersion, we calculate the mean connectivity of the nodes in function of its distance. To illustrate this process, Fig. 2 shows all vertexes located in a normalized distance less than 0.2. In Fig. 3 we have a signature of the dispersion of CNTs in a test sample, where in the x-axis are the normalized distances and in the y-axis the mean connectivity of the nodes. In order to quantify the CNTs dispersion, we used two models to simulate different levels of dispersion. Model A contains CNTs randomly distributed (well disperse), and the model B contains agglomerated CNTs. We quantified the dispersion calculating the Hellinger distance among the dispersion signature of our test sample and the simulated models. The results showed the normalized distance between model A and our test sample as 0.0153 and between model B and our sample as 0.0279. The result shows that our test sample has a dispersion signature more similar with model A, indicating a good dispersion of CNTs. These method will be applied, in a next step, to analyze the dispersion of CNTs in sol gel samples.

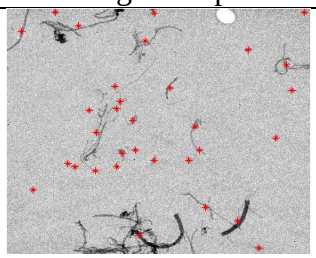

Fig.1 TEM image overlapped with carbon nanotube position (marked with a red asterix).

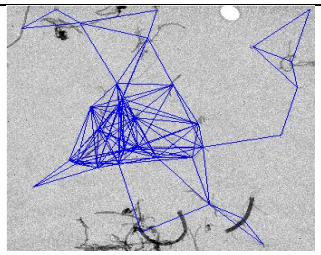

Fig. 2 Graph with all vertex less than a normalized distance of 0.2.

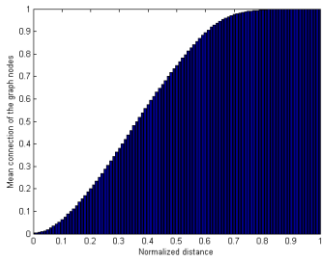

Fig. 3 Histogram of the nanotubes dispersion signature.

Keywords: carbon nanotubes dispersion measurement, image processing, graphical methods, composite material, TEM image.
Work supported by CAPES, CME-UFRGS (Brazil) and AFOSR (grant# FA9550-08-1-0426) (USA).

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