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Quantification of Microstructural Features in Carbon Nanotube /Nanodiamond hybrids

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The properties of nanostructured advanced materials such as carbon nanotubes and nanocrystalline diamond (CNT/NCD) hybrids are known to be closely linked to their morphology, therefore requiring reliable measuring techniques based on quantitative microscopy supported by digital image processing. The development of such techniques is strongly related to hardware evolution and software availability for digital image processing and analysis.

This work aims at establishing an image processing method to estimate two microstructural features: the diameter distribution of carbon nanotubes within CNT/NCD hybrids obtained by microwave plasma chemical vapour deposition [1] and CNTs number radiation per NCD cluster area. These features strongly influence the electrical, thermal and mechanical macroscopic properties. In this new material, CNTs develop on top of a NCD layer, originating a composite structure formed by nanodiamond conglomerates, or clusters, well interconnected by multiwall carbon nanotubes, resembling a neuronal network.

The method is based on the routines of a public domain digital image processing software: the NIH Image J. The here presented approach consists on the following steps: In the original image (Figure 1a), a Sobel edge detector is applied to highlight sharp changes in intensity in the image followed by gray-level threshold before the final conversion to binary scale (Figure 1b). After that, a Fill Holes filter is applied followed by watershed segmentation (Figure1c). The main problem is that false objects are still present and could distort the results for analysis. Therefore, a double shape parameter filter was applied to circumvent this difficulty: aspect ratio and perimeter ratio [2]. A previous definition of range limits for such shape factors was needed, requiring a preliminar sampling from a representative subset of digital images to test the influence of artifacts introduced by image processing (Figure1d). A comparison with the original image along with a polygonal representation of NCD clusters and the table with the morphological parameters values are presented in Figure 2.

References

1. Fernandes *et al.*, Diamond and Related Materials, 18 (2-3): 160-163, 2009
2. Horovistiz *et al.*, Journal of the European Ceramic Society, 24 (4): 619-626, 2004

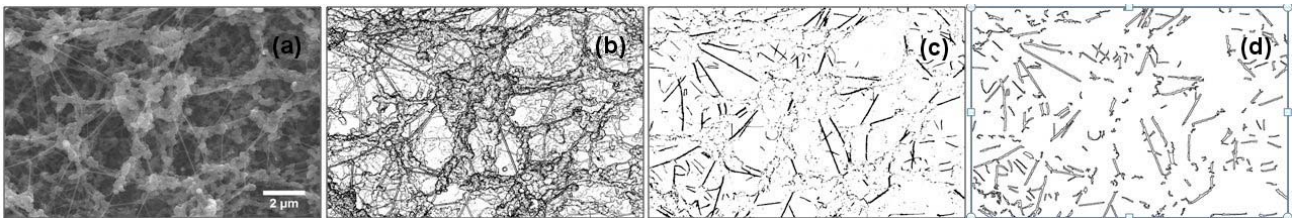
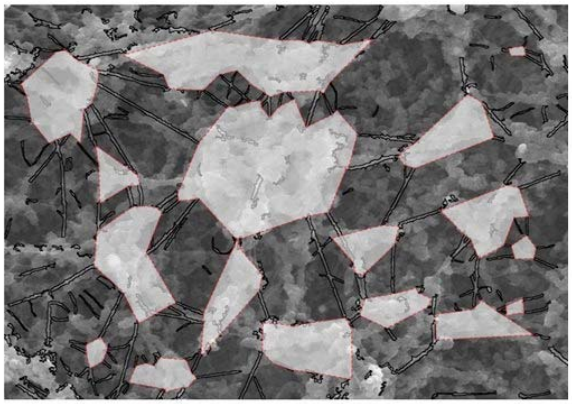


Figure 1. Sequence of digital image processing: (a) original image; (b) Sobel filter + threshold; (c) Fill holles filtering + watershed segmentation; (d) shape parameter segmentation.



Morphological parameter		
CNts diameter	Mean (nm)	59
	Standard deviation (nm)	14
	Coefficient of variation	0.2
CNTs number radiation/NCD cluster area	Mean (μm^{-2})	9
	Standard deviation (μm^{-2})	10.3
	Coefficient of variation	1.1

Figure 2. Polygonal representation of NCD clusters with the CNTs radiations (left) and data to morphology from descriptive statistics of distributions.

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