Poster Paper: Image Analysis for Automatic Characterization of Nanomaterials

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***Abstract*—Nowadays, the development of new technology depends strongly on nanomaterials study, which is carried out usually by microscopy techniques allowing the images acquisition of materials for their posterior characterization. When this feature extraction is performed through a human observer it can become slow, laborious and subjective, a situation that has generated great interest in image analysis because it has the potential to overcome this problematic. This paper proposes a system based on image analysis for automatic characterization of nanomaterials. The system consists of four stages: preprocessing, segmentation, feature extraction and validation. Results of applying these stages on images acquired with different microscopy techniques are shown. Finally, some challenges and opportunities in this area are discussed.**

Keywords—image analysis; nanomaterials characterization; digital microscopy.

I. Introduction

The selection of suitable material for new technology development is important, examples, steel selection in the first industrial revolution and silicon in communication and information areas. Today's materials are studied, designed and applied based on techniques of optic, electronic and atomic force microscopy. Each microscopy technique allows imaging of materials for characterization (study), which is traditionally done by visual inspection of a person on the computer. This way, to perform characterization tasks as counting and measuring carbon nanotubes in an image (Fig. 1) is laborious and subjective. Moreover, the lack of versatile programs to work with any image makes expensive specialized tools are acquired. These drawbacks can be overcome by creating a system that uses image analysis for automatic characterization of materials images. Next, the main stages of this system are described.

II. Preprocessing stage

At this stage, causes of noise in the image acquisition process that affect the feature extraction of materials are identified and strategies are proposed to reduce it. The main sources of noise in digital microscopy are photon noise, thermal noise and readout noise. The image degradation due to these types of noise can be modeled by Poisson, Gaussian and exponential distributions and removed through methods that

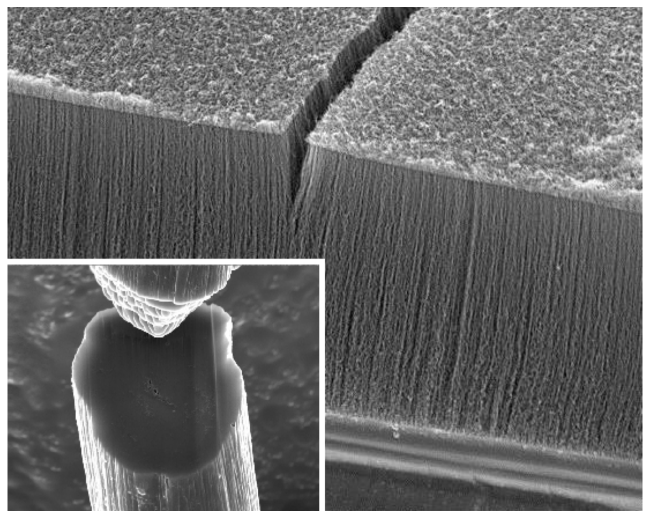

Fig. 1. Scanning electron microscopy images of carbon nanotube (bottom left) and carbon nanotubes forest for characterization (rest of image).

apply the inverse process in order to recover the original image. Some methods widely used in images with low noise are filtering techniques such as Gaussian, mean and median filtering [1].

III. Segmentation stage

This is the most difficult and important stage of the system because a good material characterization depends on it. Once the image has been enhanced, several segmentation methods are applied to separate its constituent materials of the background image and the best result is selected (Fig. 2). Most segmentation methods are based on two basic properties of intensity values: similarity and discontinuity [2]. In the first case, the image is divided into similar regions according to a predefined criterion, examples of these methods are merging, thresholding and region growing. In the second case, the image separation is carried out by abrupt changes in intensity such as the object edges, the most used method in this category is edge detection. One desirable option is that the system can combine methods of different category (merging with edge detection) to improve segmentation results and therefore the material characterization.

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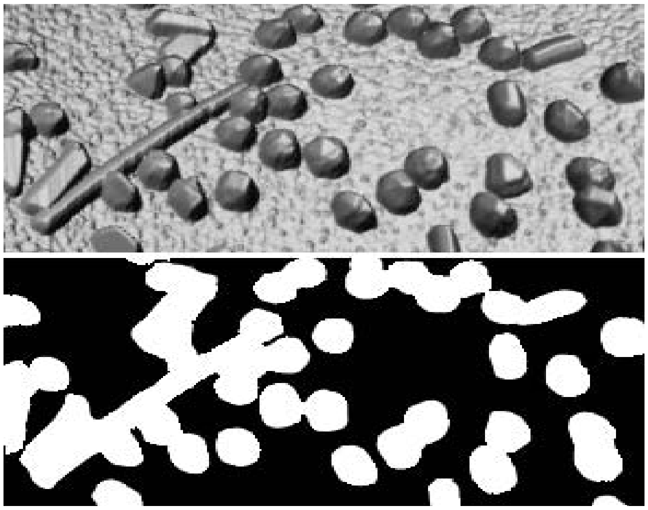

Fig. 2. Atomic force microscopy image of nanoparticles (above) and segmented image by thresholding (below).

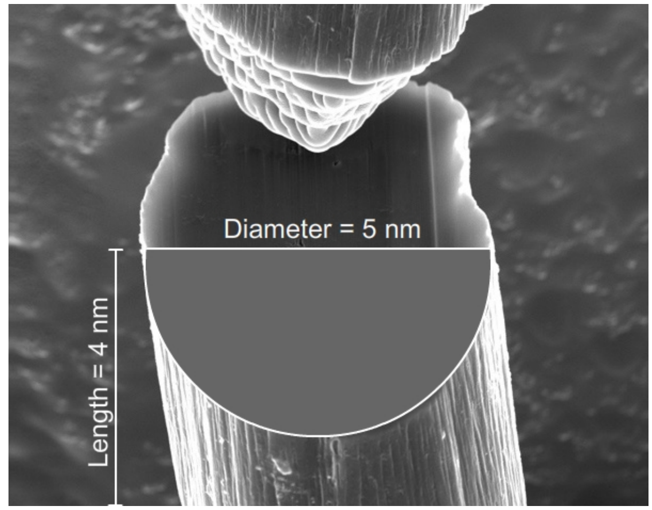

Fig. 3. Features extraction of diameter and length on a carbon nanotube image.

IV. FEATURE EXTRACTION STAGE

Once the image is segmented, a list of different parameters for nanomaterial characterization is extracted. Returning to the nanotubes characterization example, these parameters can include diameter size, length, area, counts and density (Fig. 3). A complete list of features is shown in [3]. Generally, the feature extraction is achieved by applying a connected components algorithm on segmented image to label interest objects, in our case nanomaterials. So, the material area can be calculated counting the pixels number that it occupies in the picture, the material count getting the labels number assigned by the algorithm and its density as a combination of these parameters (count/area). It is important that the system perform a full characterization of materials for their good study.

V. VALIDATION

The validation objective is to confirm that the extracted features in the previous step are correct. To achieve this, reference images whose characterization is well known are introduced to the system. If characterizations match, the system is working properly. The main disadvantage of this validation form is that we need to manually characterize a large number of reference images, which may not be completely accurate [4].

VI. CHALLENGES AND OPPORTUNITIES

Current systems for the nanomaterials study work only one type of image, either scanning electron microscopy image or atomic force microscopy image. Creating a system that works both image types is an opportunity area because the cost of professional programs for nanomaterials images processing is very high. Moreover, if the system is able to correlate both image types of a same material could be made topography, composition and 3D complete studies with a single tool. Another challenge exists in imaging of non-conductive samples with scanning electron microscope. Samples are loaded electrically and their images are saturated in brightness [5]. Here would be good to include intelligent postprocessing methods to detect this problem and correct it.

VII. CONCLUSIONS

A system for automatic characterization of nanomaterials where image analysis is used as the main methodology is a viable option as a support tool to carry out materials studies. Firstly, it would extract features with greater reliability and accuracy compared to the traditional method. Secondly, it would be a cheaper way for studying materials compared to current professional programs. Finally, it would help in the automation of the large volumes analysis of nanomaterials samples reducing time and effort to people who perform this task.

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