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Investigation of Digital Imaging Processing in Determining Nano-Particle Size Distribution Based on Scanning Electron Microscopic Image

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Nanoparticle (NP) size is a critical property that determines the performance of NP-products, and is potentially related to the process yield and safety. Therefore NP measurement is essential, and especially the accurate size and shape distribution is the basic quantities of interest.

Scanning electron microscope (SEM) is popularly used due to both of its unique surface sensitivity and convenience. SEM measurement of NP may be highly dependent on the experimental condition and analysis protocol. Further, since SEM often collects data as many as hundreds to thousands of NPs for the sizing, the measurement is time-consuming.

The measurement procedure consists of the following sequential steps: sample preparation, image acquirement, particle analysis (image processing), and data analysis (See Fig.1). Among them, the determination of particle boundaries in SEM images is the key steps to make the measurement objective, rapid and automatized. Conventionally, it has been performed manually, which is prone to the personal error and significant loss of time as well.

The particle analysis is divided into several sub-steps: de-noising image, image thresholding, hole-filling, discarding unwanted NPs and artifacts, and obtaining sizes for all remained NPs. De-noising is the two-dimensional filtering of the taken image to suppress the image noise. Image thresholding converts the grey-level image to the binary image. It has a significant impact on the analyzing process itself as well as the results. Digital thresholding is used to separate NPs from background. The hollow region within any particle are filled with white against black background. The unwanted objects are discarded type by type based on the suitable criterion. With the finally remained NPs, particle size-related parameters are determined digitally to get the statistical mean and other quantities. We note that the determined NP sizes significantly change depending on the type of threshold, while Otsu threshold was chosen since it is stable in several kinds NPs we have tested (See Fig. 2). Another thing to stress is the exact discarding of unwanted objects in terms of the automation. In addition to previous feature parameter-based judgment, we also applied machine learning technique to see whether we can increase the discarding accuracy, where the former technique is used to the initial setting of the response in the training data. This presentation will cover these two issues on digital image processing [3].

References:

[1] RC Gonzalez, RE Woods and SL Eddiins in "Digital Image Processing Using MATLAB", 2nd ed. (Mc Graw-Hill, India).
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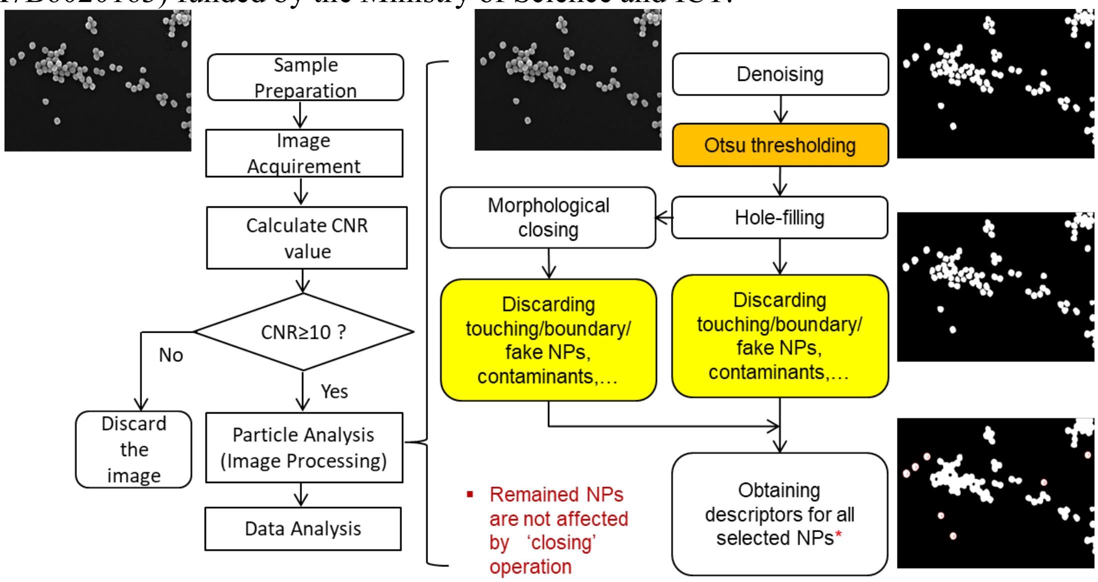

Figure 1. Workflow for determination nanoparticle size distribution from SEM images.

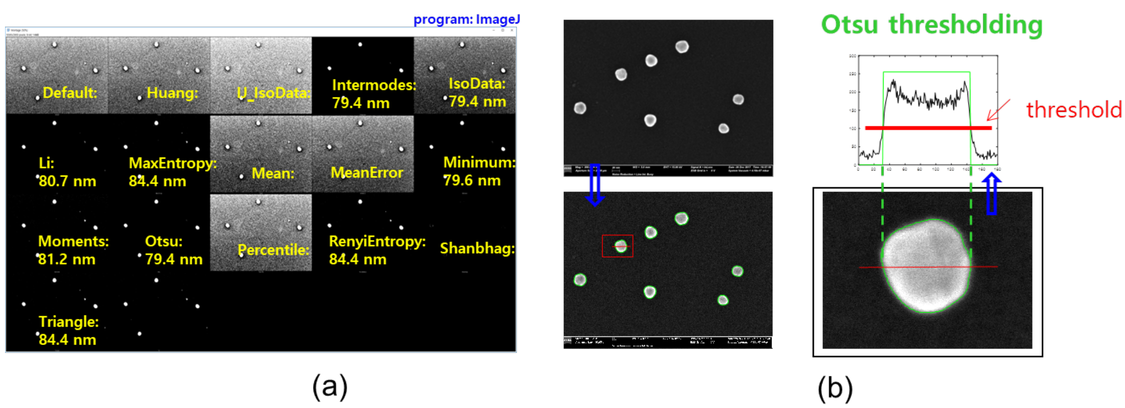

Figure 2. (a) Different threshold-binary images and the determined diameter. (b) Otsu thresholding.

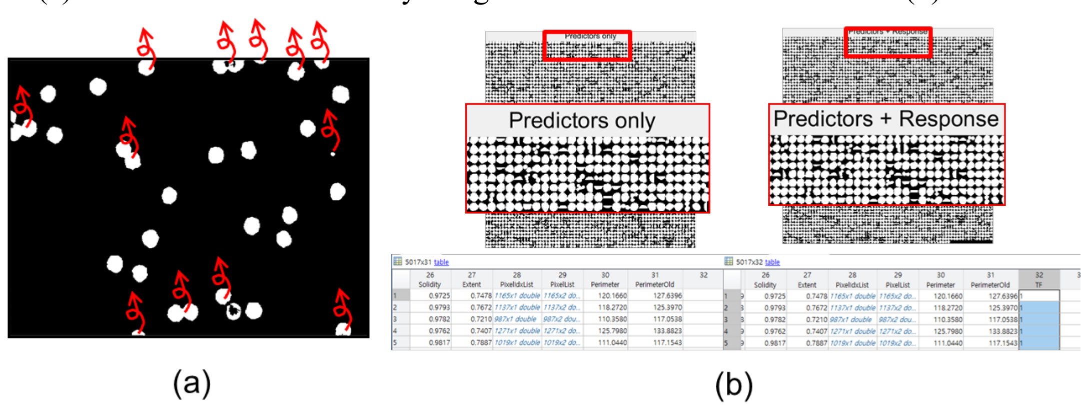

Figure 3. Two approaches to discarding unwanted objects in the binarized SEM image based on either chosen values of some feature parameters (a) and the machine learning (b).

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