Morphological Operations and Histogram Analysis of SEM Images using Python

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Characterization of any Material / Element requires SEM (Scanning Electron Microscopy) analysis. Images captured from SEM are further considered for analysing the Morphology, structure of the material. Due to non-conduction or any technical issues, the image captured may not be accurate for analysis. If the image is accurate also morphological operations can't be performed. In this paper, SEM images are processed to study the histogram analysis for equalizing the image, morphological operations via. Erosion, Dilation etc using Python programming.

Keyword: Morphology, SEM, Gradient, Dilation, Erosion

1 Introduction

Histograms are mainly used to see the image brightness and also checks the need for contrasting the image. A histogram is a graphical portrayal of a gathered recurrence dissemination with consistent classes[1]. It is a region chart and can be characterized as a bunch of square shapes with bases alongside the spans between class limits and with regions relative to frequencies in the comparing classes[2,3]. In such portrayals, every one of the square shapes are contiguous since the base covers the spans between class limits. The statures of square shapes are relative to comparing frequencies of comparative classes and for various classes, the statures will be relative to relating recurrence densities. Images taken from the SEM or EDAX has to be judged whether the image is perfect for further analysis[4]. Before proceeding to the mechanical or electrical characterization of any sample, the image captured from the SEM has to be processed using any of the software's to plot the histogram. Once the histogram is plotted, we can identify the area of the image to be modified (or requires improvement) will be displayed clearly[5]. Accordingly, the contrast, magnification, brightness can be adjusted and finally the required image with better contrast, brightness and magnification can be taken from SEM for further investigation. This equalizes the entire image and also thresholds the image[6].

Histogram equalization is good when histogram of the image is confined to a particular region. It won't work good in places where there are large intensity variations where histogram covers a large region, i.e. both bright and dark pixels are present[7]. Generally, the histogram reflects the intensity distribution of an image. It varies in a pixel range of 0 to 255. We need to read the image from pixel 0 to pixel 255 and plot a histogram table for each intensity[8]. Once the histogram table is developed CDF (cumulative distribution function) needs to be developed in order to equalize the image. CDF calculates the cumulative number of pixels that are existing in an image so that equalized histogram can be generated[9, 10].

From the beginning, histograms might show up straightforward, however research demonstrates in any case. Indeed, numerous blunders, confusions and mix-ups in deciphering histograms have been recorded in the writing. In any case, a deliberate outline of these misinterpretations-a term we use as an umbrella for the manners by which individuals decipher histograms mistakenly has not yet been incorporated[11,12,13]. Research more than once showed the industriousness of the misinterpretations, regardless of different endeavours to further develop insights instruction. Henceforth there is a need to ponder what reasonable hardships might lie at the premise of these steady misinterpretations[14,15]. The point of this audit is consequently to cause a stock of the misinterpretations that to happen when individuals use histograms, just as to classes these misinterpretations along the applied troubles that become manifest in these misinterpretations. In this audit, the word individuals allude to understudies,

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everything being equal, just as to instructors, scientists, instructor teachers and others[16,17].

2 Materials and Methods

Two sample SEM images of previous experimentation on super capacitor are considered for the analysis. Sample 1 is the vertical cut section view of super capacitor, and sample 2 is the horizontal circular section view. Authors have found that the images collected from SEM can be further refined for better visibility and clarity. Code has been developed in python for plotting the histogram and to analyze the morphological operations. Once the histogram of the image is generated, equalization has been implemented on the image, so that the histogram is uniformly distributed throughout the image. Similarly, in morphological operations creating structuring element, dilation of image, erosion and morphological gradient are performed to understand the behaviour of the image captured from the SEM. In analysis the images the following procedure is adopted and the same is presented as flowchart in Fig. 1.

Step 1: Receive the original image from SEM

Step 2: Analyze the histogram of the original image and check whether uniform distribution is available. If uniform distribution is not visible go to Step 3.

Step 3: Apply equalization on the original image

Step 4: Analyze the histogram of the equalized image and check for uniform distribution. If uniform distribution is visible go to step 5 or repeat step 3.
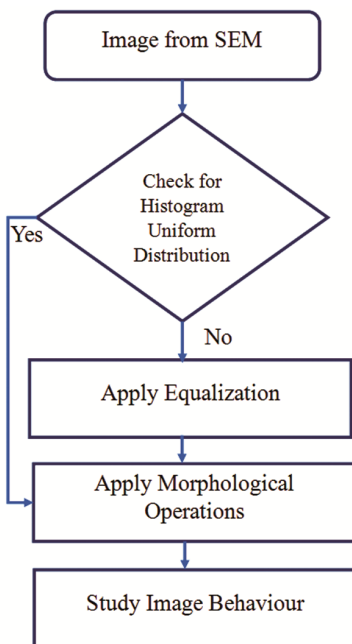
Step 5: Apply morphological operations on original image via. Creating structure element, dilation, erosion and gradient.

Step 6: Study the behaviour of the images which are performed in step 5.

Step 7: Conclude the findings.

3 Results and Discussions

3.1 Sample Analysis

Figure 2 shows the original image of SEM of super capacitor consider for analysis and noted as Sample 1. The general histogram of sample 1 is analysed and the frequency distribution over 255 pixels are plotted and represented in Fig. 3. The same sample 1 is applied with equalizing component and histogram is plotted and can see it is uniformly distributed and also the contrast and intensity of the sample 1 is also changed. Both the image & histogram are presented in Fig. 4.

Figure 5 shows the original image of SEM of horizontal section of super capacitor consider for analysis and noted as Sample 2. The general histogram of sample 2 is analysed and the frequency distribution over 255 pixels are plotted and represented in Fig. 6. The same sample 2 is applied with equalizing component and histogram is plotted and can see it is uniformly distributed and also the contrast and intensity of the sample 2 is also changed. Both the image of sample 2 & its equalized histogram are presented in Fig. 7.

3.1 Morphological Operations

Four basic morphological operations via. Creating structure element, dilation, erosion and gradient are performed to the original image to understand the

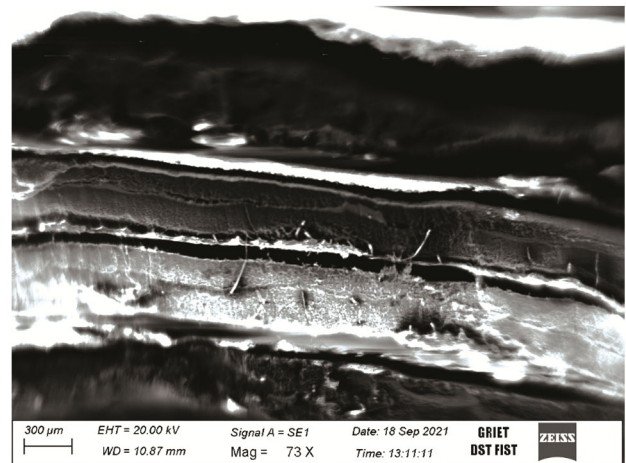Fig.1 — Flowchart of the proposed algorithm.

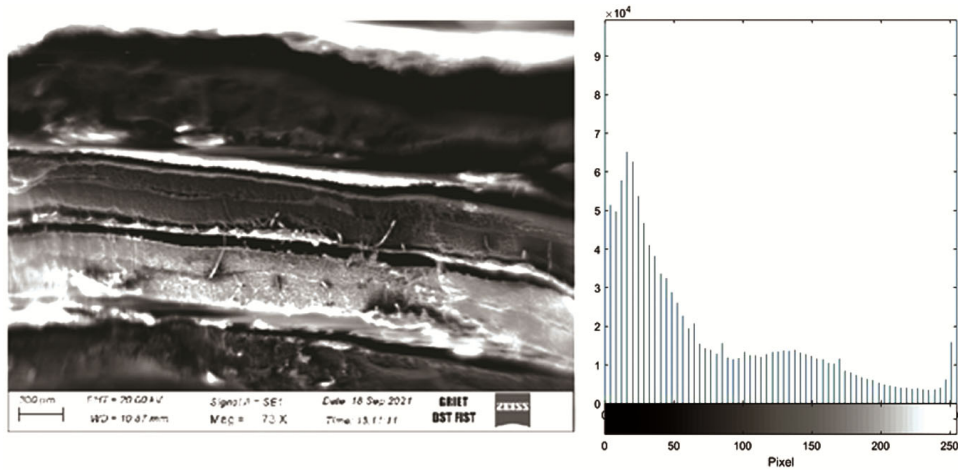Fig. 2 — Original Sample 1 SEM image of Super Capacitor considered for analysis.

Fig. 3 — Original Sample 1 SEM image and its histogram before equalizing.
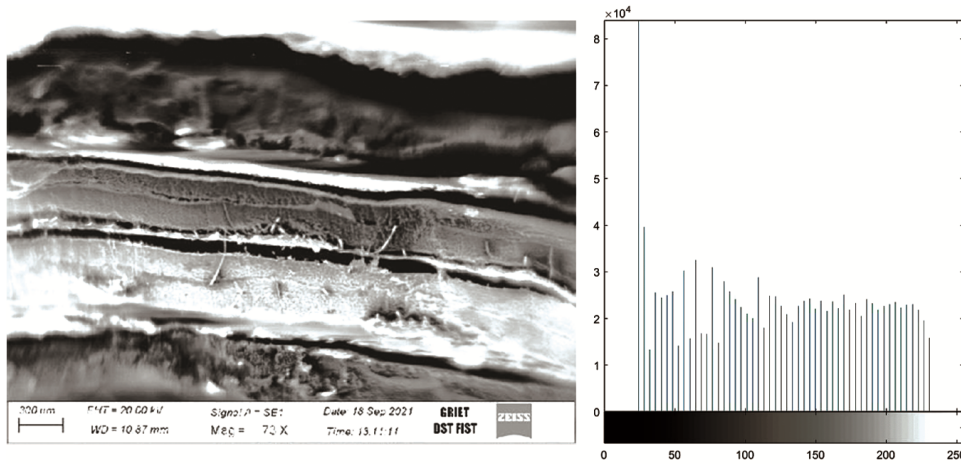

Fig. 4 — Equalized analysis of Original Sample 1 SEM image and its histogram.
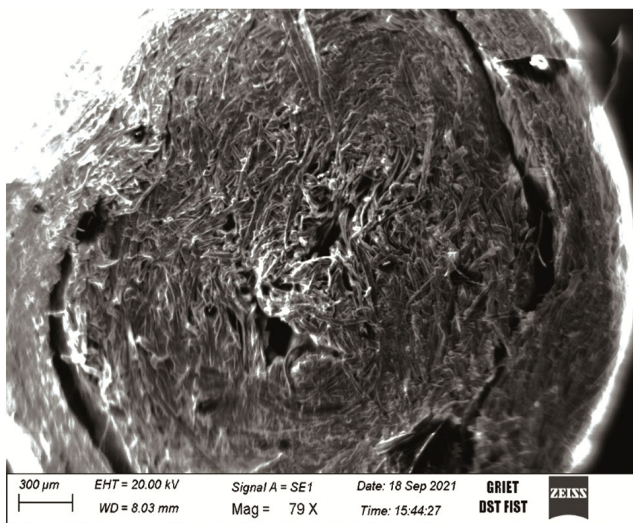

Fig. 5 — Original Sample 2 SEM image of Super Capacitor considered for analysis.

pixel configuration in the image. In dilation the white pixels are increased and subsequently black pixels are reduced, this is mainly done to reduce the holes in the image. Erosion is quiet opposite to dilation; here white pixels are reduced and black pixels are increases. Erosion and dilation are the basic operations of morphology and are referred to mathematical analysis of the image. By performing dilation and erosion we will have structural element of the image. Gradient refers to the difference of the both dilation and erosion of and given image. The difference in the pixel value in gradient denotes contrast intensity of the image which are used for edge detection and segmentation of the image.

Further to the histogram analysis, morphological operations of sample 1 are carried out and the same are presented in Fig. 8 (a) to (d). Fig. 8(a) represents the original SEM image of Sample 1, Fig. 8(b) represents dilated image of Fig. 8(a), Fig. 8(c)
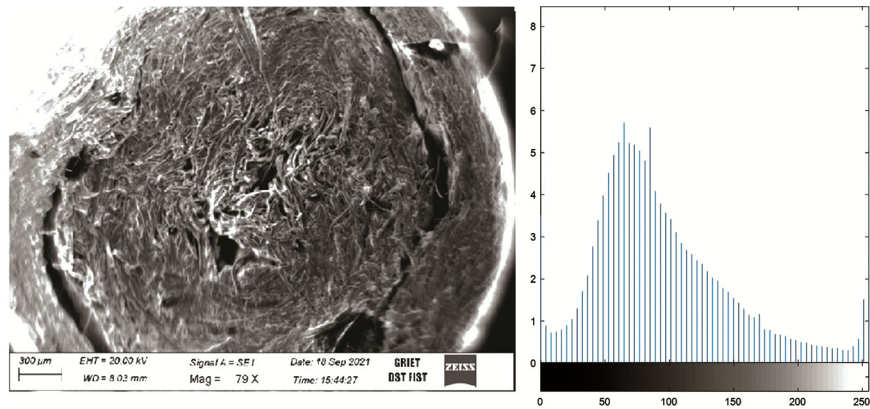
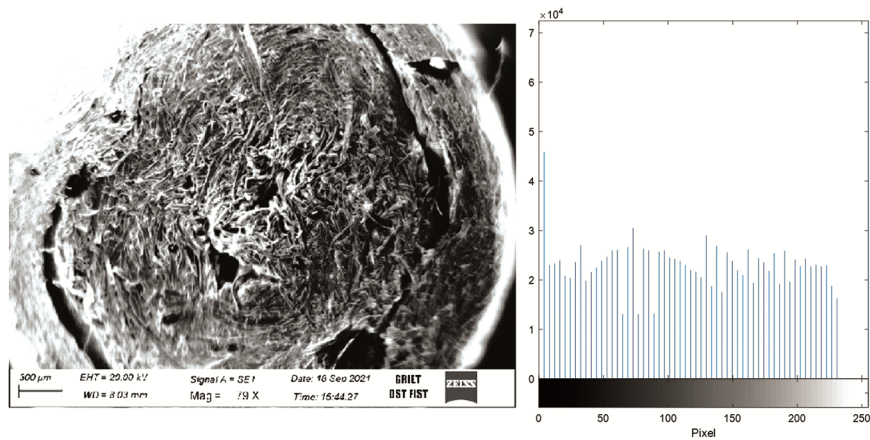Fig. 6 — Original Sample 2 SEM image and its histogram before equalizing.

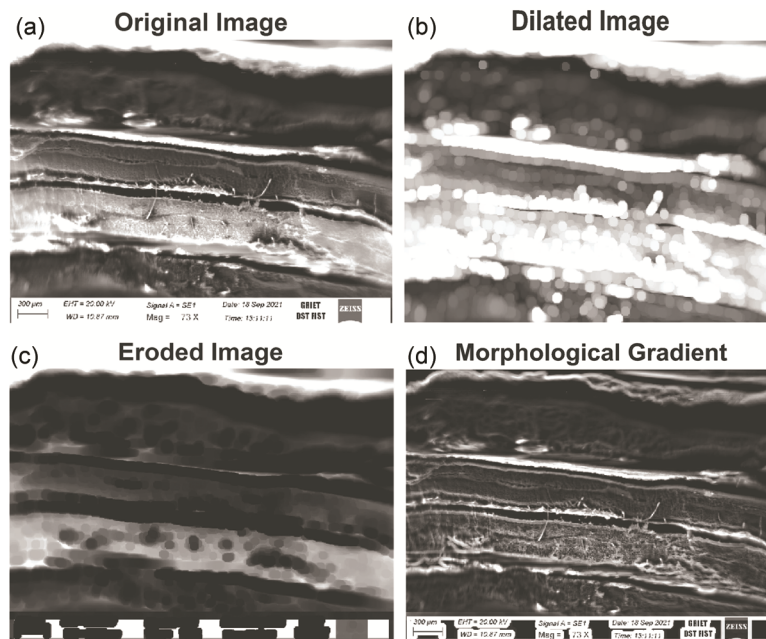Fig. 7 — Equalized analysis of Original Sample 2 SEM image and its histogram.

Fig. 8 — Morphological Operation of Sample 1 (a) Original Image, (b) Dilation Image, (c) Erosion Image, and (d) Gradient Image.
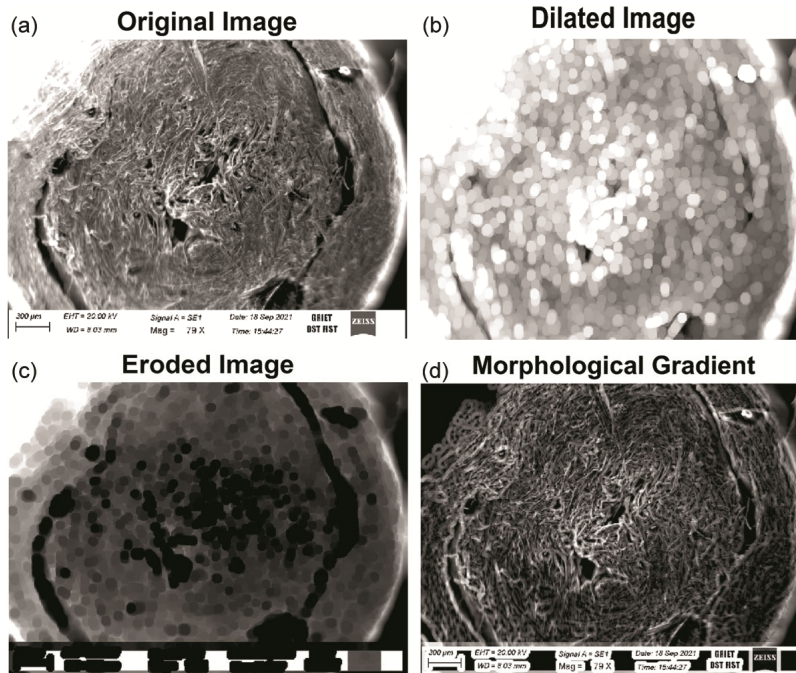
Fig. 9 — Morphological Operation of Sample 2: (a) Original Image, (b) Dilation Image, (c) Erosion Image, and (d) Gradient Image.

represents the eroded image of Fig. 8(a) and Fig. 8(d) represents the morphological gradient of Fig. 8(a).

Similarly, morphological operations of sample 2 is also carried out and the same are presented in Fig. 9 (a) to (d). Figure 9(a) represents the original SEM image of Sample 2, Fig. 9(b) represents dilated image of Fig. 9(a), Fig. 9(c) represents the eroded image of Fig. 9(a) and Fig. 9(d) represents the morphological gradient of Fig. 9(a)

4 Conclusion

Equalization of original SEM images are performed by using uniform distribution by verify the histograms. Corrected and equalized images are considered for further mechanical & electrical characterization. Similarly, Morphological operation such as dilation, erosion and gradient are performed on the original SEM images and found out the error in the images by detecting white and black pixels are corrected the images using morphological gradient method. Histograms and morphological analysis have proved that the captured original SEM images can be further refined for better visibility and contrast by removing unwanted holes in the image. Entire analysis is performed using python programming which is fast and more reliable. Validation of analysed images are verified through MATLAB programming and proved to be accurate.

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