BOUNDARY EXTRACTION AND ANALYSIS OF PORE STRUCTURE OF ACTIVATED CARBON BY TRANSMISSION ELECTRON MICROSCOPY AND FUZZY TEMPLATE

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INTRODUCTION

Activated carbons are used widely as absorbent materials and expected to be useful as new electrical materials, for their very large specific surface areas (SSA). In order to examine detailed information, such as an adsorption property, the detail configuration of pore based on the image of a transmission electron microscope (TEM) needs to be analyzed.[1,2] However, the quantitative validation of pore boundaries is difficult, since TEM image photographs of the activated carbon has the ambiguous shade gradient in the boundary part of pores. In this report, we will show the application of the idea of fuzzy template to the parsing of TEM images, and the extraction of the boundaries.

BOUNDARY EXTRACTION MODEL

The picture which include ambiguous light and shade image was considered to be a fuzzy set, and the boundary extraction was performed from the idea of the 'interior' and the 'exterior' obtained on the basis of the fuzzy template drawn from the fuzzy theory.

The steps of a boundary extraction for the case of 1-dimensional sample are illustrated in Fig. 1. From the plot (a), which shows the normalized shade value of the picture image, the interior region is obtained as (b) using the 3-pixel fuzzy template. In this example, the grade values of three pixels of the template are set to 0.5. The grade value of the template pixels and the shade values of the picture image correspond to the template pixels are compared each other. If all the grade values of the template pixels are smaller than the shade values, the shade value of the pixel of the picture is employed as the value of that pixel. On the other hand, the grade values of at least 1 pixel of the template is larger than the shade value, the value of that pixel is set to 0. The 'internal area' is judged from the result. Figure 1(c) shows the result of 'external' judgment. The same fuzzy template mentioned above is applied to the reversed original plot of Fig. 1(a), and the result is interpreted as the 'exterior'. The sum-set of the obtained 'interior' and the 'exterior' is shown in Fig. 1(d). From the reversed plot of Fig. 1(d) the boundary region can be obtained as the region which is neither the 'interior' nor the 'exterior' (Fig. 1(e)).

APPLIED THE METHOD TO THE ANALYSIS OF PORE STRUCRE

Figure 2 shows the result of the application of explained method to the TEM images of activated carbon. Since actual TEM image is 2-dimensional photographs, a 3x3-pixel fuzzy template was used to the analysis. The pictures shown here are enlarged images (about 6% of the processed area). The obtained 'interior' and the 'exterior' of the original TEM image (a) are shown in Fig. 2(b) and (c), respectively. Figure 2 (d) shows the extracted boundaries from the evaluated result of (b) and (c). Compared with the results of manual extraction, the similar results are obtained from this method, and the validity of our method is suggested. Figure 3 (a) and (b) show the distribution of pore girth and area, respectively. The peak of the distribution of pore girth of the three samples is near 15 nm. Concerning the pore area, every activated carbon have a smooth distribution with a peak of near 1 nm^2 (see figure 7 (b)). It is thought that this difference depends on the activation process with NaOH.

The activated carbon materials are thought to have the complicated architecture with various sizes of pores, from the analyzed results. Since it should be supposed that it is hard to detect small pores by means of well known gas-adsorption method, the method proposed in this report is thought to be suitable to analyze the pore architecture of the active carbon in detail.

REFERENCES

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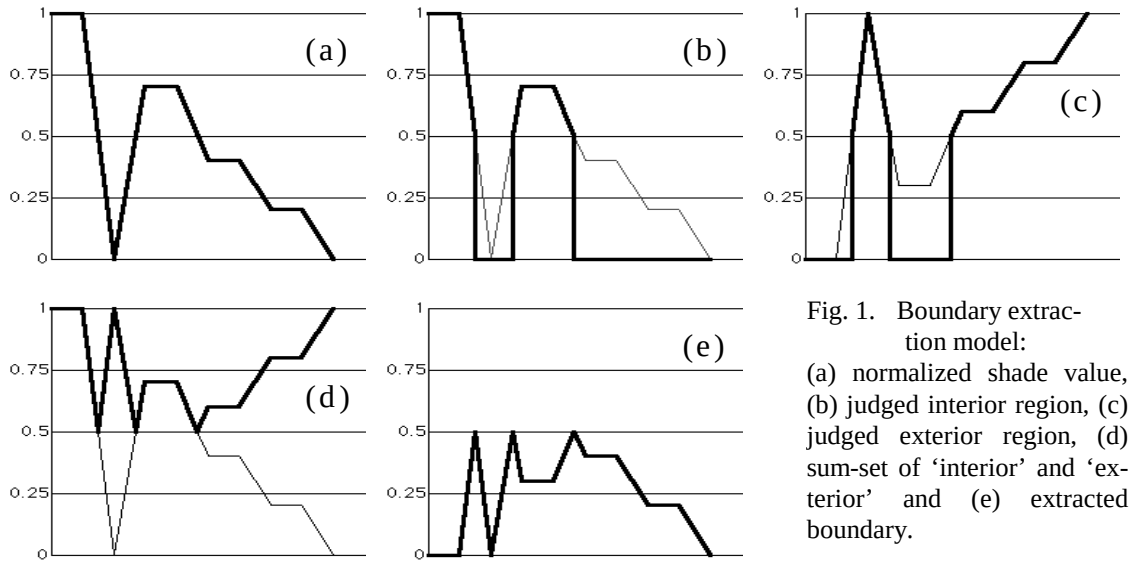


Fig. 1. Boundary extraction model:
(a) normalized shade value, (b) judged interior region, (c) judged exterior region, (d) sum-set of 'interior' and 'exterior' and (e) extracted boundary.

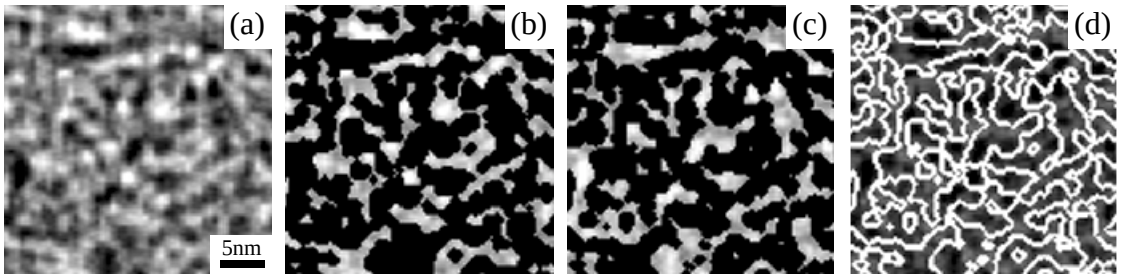
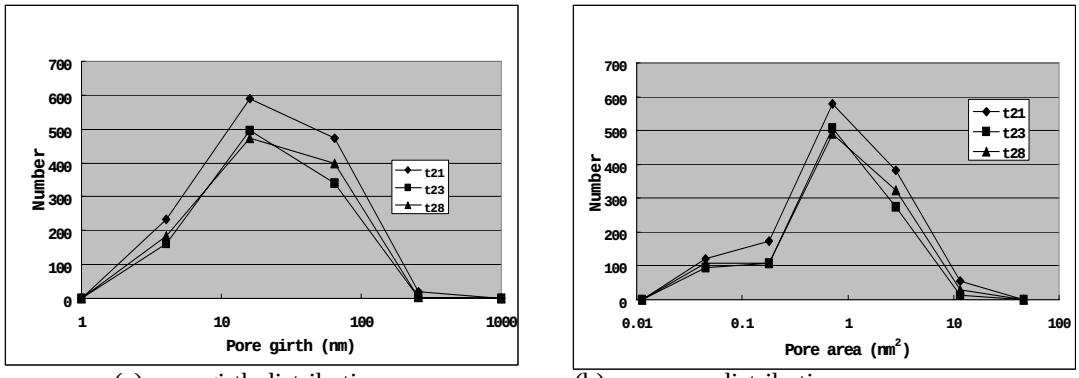


Fig. 2. Extraction the boundaries from the TEM image of activated carbon: (a) enlarged original image, (b) judged interior, (c) judged exterior and (d) extracted boundaries of the pore.



(a) pore girth distribution (b) pore area distribution

Fig.3. Pore size distribution:(a) pore girth, (b) pore area.