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Scanning Electron Microscope Micromorphology Characterization of Coal Samples from No.3 Coal Seam in Chengzhuang Mine Area

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ABSTRACT

Matrix pores in coal reservoirs are important storage sites for adsorbed and free state CBM, and their adsorption amount is closely related to the development of pores and pore structure characteristics in coal. In this paper, coal samples from No. 3 coal seam of Chengzhuang coal mine were taken as the research object, and the microscopic morphology of coal matrix pore fissures was studied by scanning electron microscope. The results found that: in the coal samples of the study area, the pneumatic pores and dissolution pores are especially developed, and more fissures are developed at the same time due to the influence of tectonic action on the coal seam. The coal samples of Chengzhuang No.3 coal seam have many kinds of pore morphologies, mainly including round, wedge-shaped, triangular, slit-shaped and some irregular pores. The morphology, size and distribution of these pores have an important influence on the physical and chemical properties of the coal seam, which provides an important experimental basis for further research on the physical and chemical properties of coal seams and their roles in CBM adsorption, transportation and mining processes.

KEYWORDS

Anthracite; Scanning Electron Microscopy; Microscopic Morphology; Pore Morphology.

1. INTRODUCTION

Coal is a porous medium with a double structure of pore-fracture development[1,2], and its internal structure is complex and diverse, which plays a crucial role in the adsorption, diffusion and transportation of CBM to a large extent[3,4]. The study of the structural characteristics of the pore-crack structure of the coal body is the basis for revealing the mechanism of CBM storage. At present, scanning electron microscopy (SEM) analysis is one of the main means of studying the structure of porous media, which can visually observe the structural particles on the surface of the coal body, the size of the pore-cracks and the fracture characteristics, the microstructure of the pore-cracks, as well as the pore morphology. SEM has high magnification, resolution, clarity and strong stereoscopic sense of image, which can easily realize the observation of pores of different levels and genesis types, and the directional description and characterization of coal pores[5]. In view of the obvious effects and advantages of SEM in coal porosity observation, the author used SEM to observe the microporosity of No. 3 coal seam in Chengzhuang Mine, and the research results are intended to provide reliable and useful technical parameters for the development of coalbed methane in the study area.

2. SCANNING ELECTRON MICROSCOPE IMAGE OBSERVATION AND ANALYSIS

2.1. Experimental Instrument and Sample Preparation Process

The experimental instrument used in this experiment is the ZEISS SIGMA 300 field emission scanning electron microscope (SEM), which consists of five parts: the electron gun and focusing system, the focusing and stage shifting components, the detection system, the display and recording system, and the control system, as shown in Figure 1.

Figure 1. ZEISS SIGMA 300 field emission scanning electron microscope

Sample preparation is a critical step in obtaining high quality images and performing accurate analysis. In order to ensure that the samples can be stabilized under high vacuum and present clear surface morphology and microstructure, the preparation process needs to follow strict standard operation procedures. Firstly, anthracite samples from the study area were taken and made into 1 cm3-sized sample blocks, and the sample surface was swept to keep it clean. Then, in order to improve the electrical conductivity of the samples, it is usually necessary to spray gold on them, which is fixed on the sample stage with conductive adhesive and sprayed with gold, to increase the electrical conductivity of the surface, and finally, the processed samples were glued to the SEM sample stage, and the stage was loaded into the SEM sample Finally, the treated sample is glued onto the SEM sample stage, and the sample stage is loaded into the sample chamber of the SEM and vacuumed to the required working pressure to start the observation of the sample microscopic morphology.

2.2. Imaging Principle

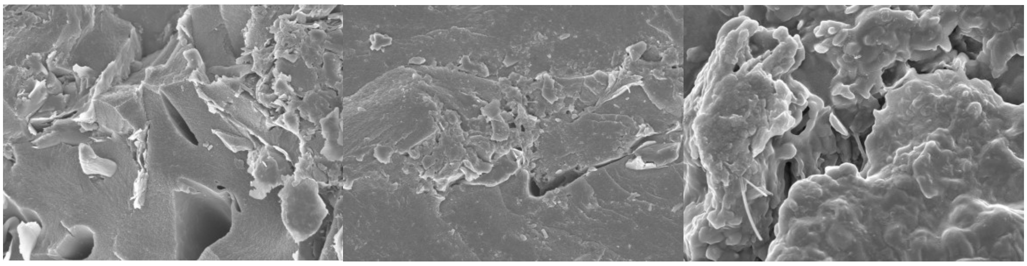
The principle of SEM test is that by scanning a focused electron beam over the surface of a sample, due to the interaction between the focused electron beam and the sample, a variety of physical signals such as secondary electrons, back-scattered electrons and characteristic X-rays will be generated[6]. The detector then collects these physical signals and converts them into electrical signals, which are then amplified and processed to form a final image of the sample's surface topography. Due to the uneven surface structure of the coal body and the existence of cracks-pores of different shapes and sizes, the scanned image shows differences in light and darkness, i.e., the gray scale values of each pixel point in the image are different. Therefore, the surface structural characteristics of the coal samples in the study area can be analyzed by the difference in gray value.

2.3. Results and Analysis

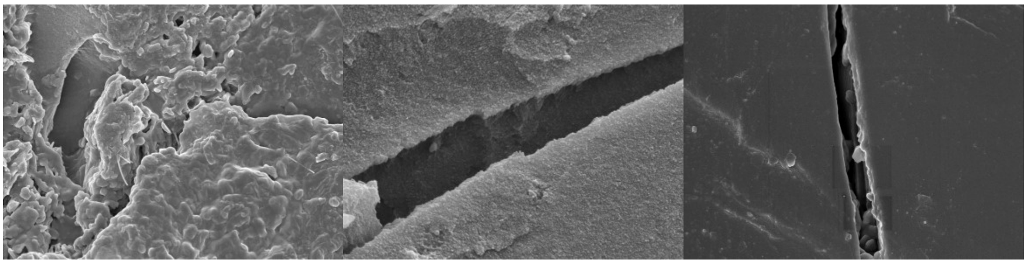
Figure 2 shows the SEM results of the pore and fissure structure of the coal samples in this paper, and the analysis shows that in the anthracite coal samples of the No. 3 coal seam in the study area, the pneumatic and metamorphic pores are relatively developed, and a small number of fissures are developed at the same time. Among them, the metamorphic pores mainly include air holes with different morphologies. Air holes are mainly formed in the stage of coal metamorphism, which belongs to the type of pores of coal metamorphism genesis. They are formed by the “anger” and “gas gathering” in the process of coal formation[7,8], as shown in Figure 2(a) and Figure 2(b): the pores in the coal samples in the study area show different morphologies, mainly round, oval, oblate, and a small number of irregularly shaped pores, with smooth edges; the size of pores varies, and most of the pores have different diameters, and most of the pores have different sizes. The pore size varies, and most of the pores are below 5 μm in diameter;

Dissolution holes are the holes formed by the dissolution of some soluble and unstable components of coal, such as carbonate collodion, feldspar minerals, and some rock fragments, under long-term water, gas, and their coupling in the process of coal-forming action[9], such as Figure 2(c) and Figure 2(d). These pores usually occupy a certain proportion in the microstructure of coal and have an important influence on the physical and chemical properties of coal. Dissolution holes can increase the porosity of coal and improve the adsorption capacity and permeability of coal, thus affecting the gas content and emission characteristics of coal seams.

Fissures in coal refer to various cracks and crevices formed within the coal body due to crustal movement, magma intrusion, hydraulic action and other factors in the process of coal formation and evolution of geological history[10]. As shown in Figure 2(e) and Figure 2(f), the degree of development of fissures in coal directly affects the physical and chemical properties of coal, such as the strength, hardness, brittleness, abrasiveness, adsorption and so on. In the process of coal mining, the degree of fissure development also affects the stability of the coal seam and the support of the coal wall. The higher the development degree of fissures in coal, the greater the degree of fragmentation of the coal body, the worse the stability of the coal seam, and the greater the difficulty of supporting the coal wall. Through the study of the distribution characteristics, development law and formation mechanism of the fissures in coal, it can provide a scientific basis for coal mining, optimize the mining plan of the coal seam, and improve the utilization efficiency of coal resources. At the same time, it can also provide technical support for the reinforcement and support of the coal body to ensure the safe production of coal mines.



(a) air-bubble (b) air-bubble (c) Dissolution holes



(d) Dissolution holes (e) fracture (f) fracture

Figure 2. Different pore fracture morphologies under SEM

3. COAL SURFACE PORE STRUCTURE FEATURE EXTRACTION

In order to more intuitively see the pore morphology in the coal, Image J was used to binarize the images, and the electron microscope images were imported into the image processing software, and by constantly debugging the threshold value to get the binarized images presenting only the black and white colors, in which the white area is the minerals, and the black area is the pores, and the binarized images of the coal samples are shown in Figure 3.

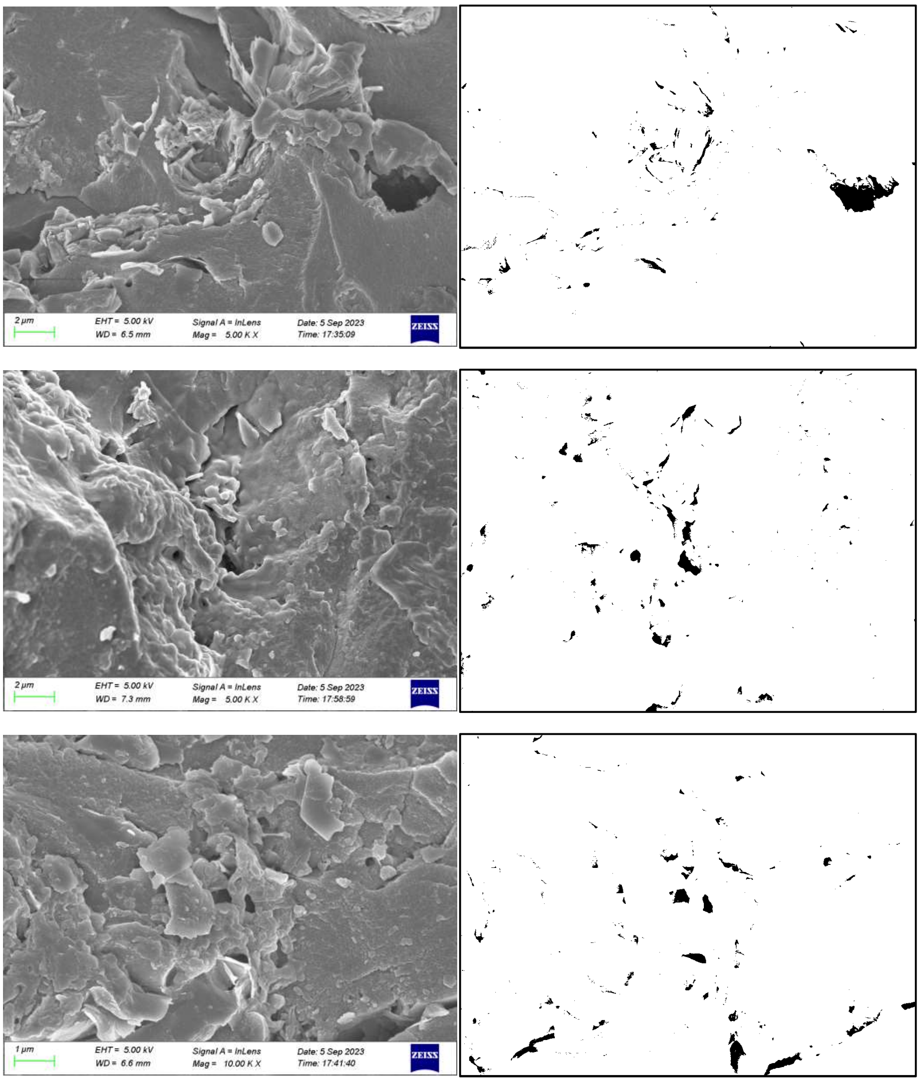


Figure 3. binarized scanning electron microscope image

In the binarized image of Figure 3, we can clearly observe the existence of multiple pore morphologies in the coal samples of No. 3 coal seam. These pores mainly include circular, wedge-shaped and triangular pores, slit-shaped pores and some irregular pores. The existence of these pores has an important effect on the physical and chemical properties of the coal seam, such as the permeability, porosity, and adsorption capacity of the coal seam. Therefore, the study of the morphology, size, distribution and connectivity of these pores is of great significance for understanding the reservoir properties of coal seams.

4. CONCLUSION

In this paper, the pore and fissure morphology characteristics of coal samples from No.3 coal seam of Chengzhuang coal mine were tested by scanning electron microscope for detailed observation and analysis, and the following important conclusions were drawn from the observation of the surface morphology of the coal samples:

(1) Under the scanning electron microscope, mainly pneumatic and dissolution pores are developed in Chengzhuang anthracite, and more fissures can be developed at the same time due to the influence of tectonic action on the coal seam.

(2) A variety of pore patterns exist in the coal samples of Chengzhuang No. 3 coal seam, mainly including round, wedge-shaped, triangular, slit-shaped and some irregular pores. The morphology, size and distribution of these pores have an important influence on the physical and chemical properties of the coal seam, which provides an important experimental basis for the further study of the physical and chemical properties of the coal seam and its role in the adsorption, transportation and mining of CBM.

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