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Electrical properties of coal-peats found in Faridpur and Khulna districts of Bangladesh

T. Hossain [a], N. Zaman [a], A.B.M. Shah Jalal [a], A. Hossain [b], Tofazzal Hossain [b] and N.Z. Ara Ahmed [b]

[a] *Bangladesh University of Engineering and Technology, Dhaka-1000 (Bangladesh)*
[b] *Bangladesh Council of Scientific and Industrial Research Laboratory, Dhaka (Bangladesh)*

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Abstract

The electrical resistivity of coal-peats found in the Faridpur and Khulna districts of Bangladesh has been studied. The change in resistivity with temperature indicates that the peats from this region are semi-conducting and also graphitic in nature. The resistivity variation as a function of temperature is found to be rather random in the temperature ranges 240–280 °C, 294–319 °C and 248–316 °C for the peat samples collected from Chanda and Bahia Beels of Faridpur district, and from Kola Mouza of Khulna district, respectively. In the temperature ranges 454–624 °C of Chanda Beel peats, 402–571 °C of Baghia Beel peats, and 366–550 °C of Kola Mouza peats, the hydrocarbons and oxides of different materials are found to decompose, and the molecules of the parent materials become structurally ordered. Here, a liquid-crystal mesophase is thought to form and, hence, a sharp fall in resistivity is observed, indicating the semi-conducting as well as the graphitic nature of the samples. It has also been found that peats of different areas are structurally different as revealed from the curves of resistivity versus inverse of temperature.

INTRODUCTION

There are several million tons of coal-peats in deposits in different regions of Bangladesh. This huge quantity of peat may satisfy fuel requirements to some extent. Moreover, this raw material may be artificially changed into graphitised or non-graphitised carbon, using suitable methods such as mechanical or heat-treatment processes.

Begum and Hossain [1] have studied 84 samples of Bangladeshi coal-peats collected from Chanda and Baghia Beels, Faridpur district and from Kola Mouza, Khulna district. Their study showed that Bangladeshi peats are not suitable raw materials for chemical processing, but that they can be used as fuel because of their high calorific value. Differential thermal analysis (DTA) revealed that peats of the three areas are structurally different.

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Riley [2] determined the electrical conductivity of coke during carbonisation up to 700 °C. The rapid increase in conductivity with temperature in the region of 700 °C indicated the formation of graphite crystallites.

Manchuk et al. [3] studied the electrical conductivity of carbonised peat. The addition of $AlCl_3$ to the peat decreases the electrical conductivity of the composites with silicates. The electrical conductivity increases as the composite volume fraction increases and the percentage of $AlCl_3$ decreases.

Bel'kevich et al. [4] found that the electrical conductivity of peat semi-coke decreased exponentially as the coking temperature increased from 200 to 400 °C.

The main objective of the present investigation was to study the change in the electrical resistivities of Bangladeshi coal-peats in the temperature range 105–700 °C. The effect of heating the samples at different temperatures was to evaporate and release the trapped and absorbed gases in the samples. The state of ordering and purity of the samples were estimated by measuring the resistivity of the samples at different temperatures.

EXPERIMENTAL

The raw coal-peats of higher calorific value from Chanda and Baghia Beels, Faridpur district and from Kola Mouza, Khulna district, were collected and cleaned by the float-and-sink process [5]. The samples were purified further by washing successively with quinolene and distilled water. Cleaned, sun-dried samples of varying thickness were selected for measurement of electrical resistivity. The samples were made into tablets with well-polished surfaces of diameter in the range 4.50–5.25 mm and thickness in the range 2–3 mm. One of the samples thus prepared was then put into a borosilicate glass cylinder, 5.30 mm internal diameter and 7.20 mm external diameter. A nickel-plated iron piston was inverted vertically into the glass cylinder from both ends. In order to achieve good electrical contact, the sample was pressed by applying 250 psi on the piston. The complete assembly was placed inside a tubular furnace. The resistance was then measured by a standard d.c. bridge, reading to the nearest microvolt, at a heating rate of 2–3 °C min^{-1} in the temperature range 105–700 °C. The temperature was measured by a calibrated iron–constantan thermocouple. Two, three or four readings were taken for each temperature; the mean readings were then recorded for analysis. The standard deviation for the readings was $\sigma_T = 0.004$–0.006; and the standard deviation for two successive readings for two sucsessive temperatures was $\sigma_S = 0.005$.

RESULTS, DISCUSSIONS AND CONCLUSIONS

The sample resistances and, hence, the resistivities at different temperatures were determined. The change in resistivity (ρ) with temperature (T) is

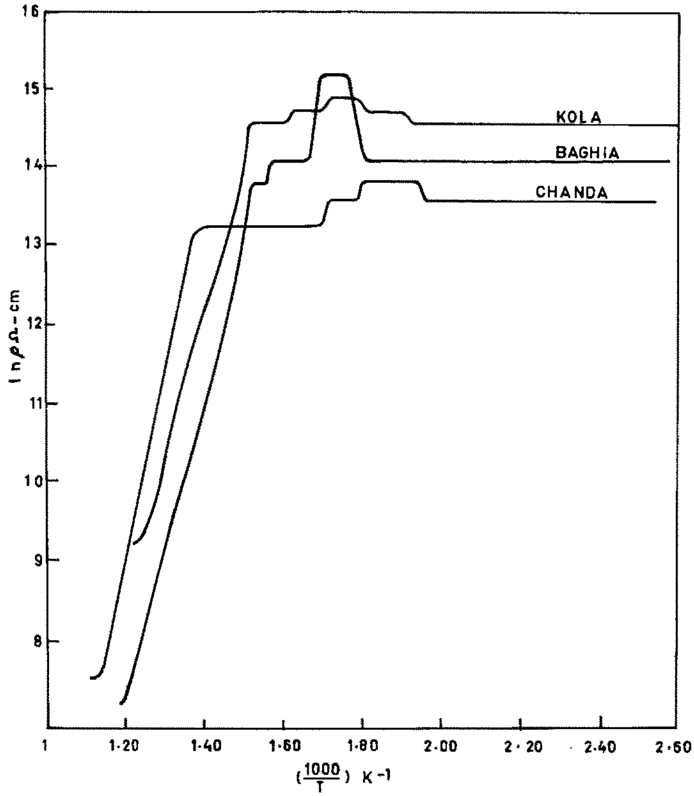

Fig. 1. Resistivity variation with temperature.

shown in the plot of ln ρ against $1000/T$ (K^{-1}) (Fig. 1). It can be seen that for all the samples, the resistivity remains unchanged up to a certain temperature, i.e. 240 °C for Chanda Beel peats, 294 °C for Baghia Beel peats and 248 °C for Kola Mouza peats. The resistivity then increases up to 279 °C for Chanda Beel peats, 319 °C for Baghia Beel peats and 315 °C for Kola Mouza peats. After that the behaviour of all the samples becomes similar to that observed initially.

The temperature ranges over which the resistivity increases refer to the initial stage of carbonisation of the samples. Irregular variations in resistivity occur due to the evolution of various hydrocarbon gases, CO_2, etc., during the heat-treatment, and due to the rearrangement of the atoms in the molecules of the samples. Because of the rearrangement of the atoms, the energy gap increases and the valence electrons need more energy to jump from valence bands to unfilled conduction bands. As a result the resistivity increases with temperature at this stage.

Above this stage, i.e. at 454 °C for Chanda Beel peats, 402 °C for Baghia Beel peats and 366 °C for Kola Mouza peats, the samples start decomposing. These temperatures may be called the transition temperatures of the samples after which a sharp fall in resistivity is observed. Here the ordering of the molecules in the parent materials begins and hence the energy gap decreases gradually so that intrinsic conduction in the samples takes place. The more the molecules are ordered structurally, the more the conduction becomes significant and, hence, the resistivity decreases continuously with increasing temperature. The fall in resistivity continues to 624° C for Chanda Beel peats, 571° C for Baghia Beel peats and 550° C for Kola Mouza peats. Thus the temperature intervals 454–624° C, 402–571° C and 366–550° C may be called the temperature intervals of the transition zones, otherwise called the mesophase intervals [6,7] for the Chanda Beel peats, Baghia Beel peats and Kola Mouza peats, respectively. Although the peats of different areas are structurally different, they have similar semi-conducting properties and the peak samples are assumed to be graphitic in character.

In the present investigation, the sudden change in resistivity with temperature, both in heating and cooling of the samples, indicates that there is a critical temperature at which the samples undergo a transformation with respect to their electronic behaviour. This transition temperature may mark the excitation of the electrons to the conduction band and the overcoming of the band gap in organic semi-conductors. Some aspects of the behaviour of

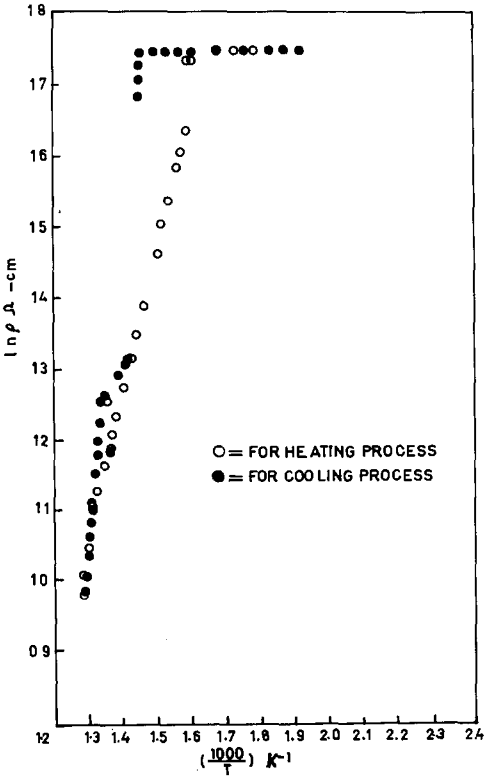

Fig. 2. Resistivity variation with temperature.

the peats in the heating and cooling processes indicate some irreversibility, as shown in the ln ρ versus $1000/T$ curve in Fig. 2. Because the samples could not be purified completely and because some irreversible vaporisation and grain reorientation processes are expected to accompany the heating, the small hystersis observed is not unusual. Moreover, the average excitation energy calculated from the experimentally obtained transition temperatures was 0.06 eV, which is in agreement with the excitation energy of the band gap for semi-conductors.

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