Bangladesh J. Sci. Ind. Res. **41**(1-2), 55-62, 2006

Study of Thermal Conductivity of Hexamethylene Tetramine and Nitrobenzene along with NaOH Doped Paperboards and their use in Electronic and Electrical Devices as Insulator

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Abstract

Thermal conductivity of hexamethyelne tetramine and nitrobenzene along with NaOH doped papers were prepared from Bangladesh jute and their thermal properties were studied by Lee's disc method. The thermal conductivity (K) of paper boards containing HMTA along with 16 % NaOH decrease with the concentration of HMTA up to 0.3 % and then increase with the concentration of the compounds. The highest value of K=3.028x10^{-4}cal.$cm^{-1}$$sec^{-1}$ $degree^{-1}$C concentration for 0.5 % HMTA and the lowest value of K=2.5x10^{-4}cal.cm^{-1} sec^{-1} $degree^{-1}$C concentration for 0.3 % HMTA but the addition of NB contents show the reverse phenomenon.

Introduction

Paper and paperboards prepared from various raw materials such as cotton, wood, cane, bamboo and jute are widely used in almost every sphere of society. It is well known that the fibre is the main constituent of paper and paperboards. Fibre is known as cellulose and the aggregate of the constituent gives rise to paper. As a high thermal resistivity is essential for materials used as thermal insulators so the paper and paperboards are expected to be used as good thermal insulators. But due to the presence of some chemicals and water in paper and paperboards they may exhibit relatively low resistivity. So the study of various physical, chemical, structural, thermal, dielectric and electrical properties of paperboards are very important The enormous application of paper and paperboards in electronic and electrical industries attracts researchers to investigate the thermal properties at various conditions. Terasaki *et al.*[1] reported the thermal conductivity of Japanese papers within temperature range 30^{O} C to 60^{O} C and humidity range from 40 % to 60 %. The conductivity of kraft paper at constant humidity increased from 0.05 to 0.15 kcal/m-hr-C. They also observed that the conductivity of the Japanese papers was increased with the temperature. The conductivity of kraft papers and Japanese papers at constant temperature was found to increase with increasing with humidity. The effect of temperature and conductivity was found greater than that of humidity. Nederveen *et al.*[2] measured the effective thermal conductivity of a number of paper sheets which was measured at high temperature and various water contents by enclosing of pile of sheets between brass plates which were subjected to a sinusoidal varying temperature. The temperature variations at positions in the pile were measured using thermocouple. From the amplitude ratio and phase shift, the conductivity was calculated at low water contents and it is shown that conductivity was proportional to the dielectric loss (D) of the paper. Cowling *et al.*[3] reported the thermal conductivity of paper. They used aqua solution of polymers or copolymers for impregnations. A series of papers published in 1947 and 1948 by O'Sullivan[4,5,6] considered the conduction in the cellulose materials from a fundamental viewpoint. He demonstrated that the conduction in cotton or regenerated cellulose was dependant on association of moisture and naturally occurring electrolytes in the material. If the electrolytes were removed, the conductivity at a given relative humidity is decreased for a fixed salt content. The conductivity was an exponential function of the conditioning relative humidity. In addition, at salt contents greater than about 1 %, the conductivity was largely governed by the moisture content, being insensitive to the amount of type of salts present. O'Sullivan[7,8] showed that ions could migrate between electrodes and conclude that the conduction process in cellulose in ionic, rather than that of electronic. He strengthened that argument by further demonstrating that the moisture dependence observed for conduction of ions as a function of moisture contents.

In the present investigation thermal properties of eight samples of paperboards were studied. Paper and paperboards are produced from jute doped with 16 % NaOH and various concentrations of hexamethylene and nitrobenzene

Materials and Methods

In this experiment the samples of the papers were collected from the Pulp and Paper Division of BCSIR Laboratorise, Dhaka. The papers and paperboards were prepared from jute pulp and other chemicals mixed in several percentage. The diameter of the supplied sheet was 20 cm. The thickness of the samples were different for different samples. For thermal measurement, the samples were cut in circular size of 10 cm in diameter according to the diameter of the slab B as shown in Fig. 1. In this way the following 8 (eight) samples were prepared from the eight supplied samples for the thermal conductivity measurement.

The sample is in the form of disc of area ‘a’ and thickness ‘d’ is placed in between a cylindrical steam chest A and a metal disc B freely suspended in the atmosphere. On passing steam through the cylinder A, a

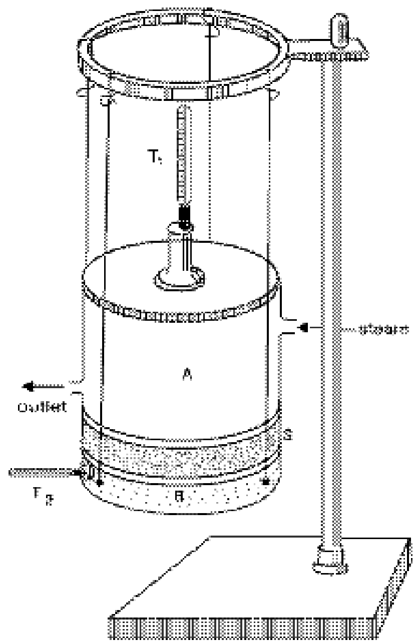

Fig. 1 Lee's Apparatus

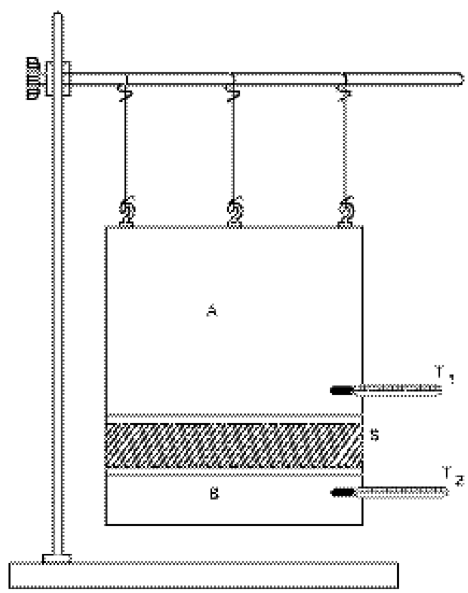

Fig. 2 Lee's disc method

steady state of temperature in attained, so that the rate at which heat conducted across the specimen disc is equal to the rate at which it is emitted from the exposed surface of the metal slab B. If K is the thermal conductivity of the sample disc, d is the thickness and D its diameter, θ_1 and θ_2 are the steady temperature readings indicated by thermometers T_1 and T_2 for A and B then the quantity of heat conducted across the disc is given by

$$Q = K\pi D^2 (\theta_1-\theta_2)/4d\text{------------}(1)$$

If the mass of the metal disc B is M, specific heat S, then the rate of cooling at its temperature θ_2

$$Q = MS \times d\theta/dt\text{------------------}(2)$$

Where, $d\theta/dt$ is the rate fall of temerature at θ_2. Equating equation (1) and (2) We get,

$$K\pi D^2 (\theta_1-\theta_2)/4d = MS \times d\theta/dt$$

$$\text{or, } K=[4\ MSd/\pi D^2 (\theta_1-\theta_2)]\ d\theta/dt\text{----------}(3)$$

To obtain $d\theta/dt$, the metal slab B was heated at a temperature 10^{O} C Above the steady temperature θ_2 and was then allowed to cool. The temperature was recorded at every sixty seconds. A cooling curve of time versus temperature was shown in Fig. 3(a), 3(b), 3(c) and 3(d). The rate of cooling $d\theta/dt$ was obtained from equation (2). When the steady state of temperature, θ_1 and θ_2, at B and A (as in fig.) is attained and remain constant for 5 minutes, the supply of steam was stopped. A tangent was drawn to this curve at temperature θ_2 and rate of fall of temperature was recorded.

For the measurement of thermal conductivity the sample paper and paperboards were placed between the two nickel plated discs of Lee's apparatus. By measuring the heat transmitted through the slab per second and heat lost per second from the lower disc the conductivity was found out from the above equation (3).

Results and Discussion

The thermal conductivity of paperboard produced from jute which contain various types of organic and inorganic compounds were determined in our present experiment. The values of the thermal conductivity were calculated using equation (3) from the cooling curves presented in Fig. 3 (a), 3(b), 3(c), 3(d) and Fig. 4 (a), 4(b), 4(c), 4(d). The values of the thermal conductivity along with different concentration of chemicals were recorded in Table III. From the table it was seen that the steady state temperature and conductivity of the samples containing HMTA decreases with the increase in the percentage of the HMTA up to 0.3 %. then increase further. This occurs because material becomes more thermally insulated with the increase of HMTA. Further increase of the percentage of HMTA, the thermal conductivity was improved as the molecular motion became much larger. In the case of the sample containing NB along with 16 %

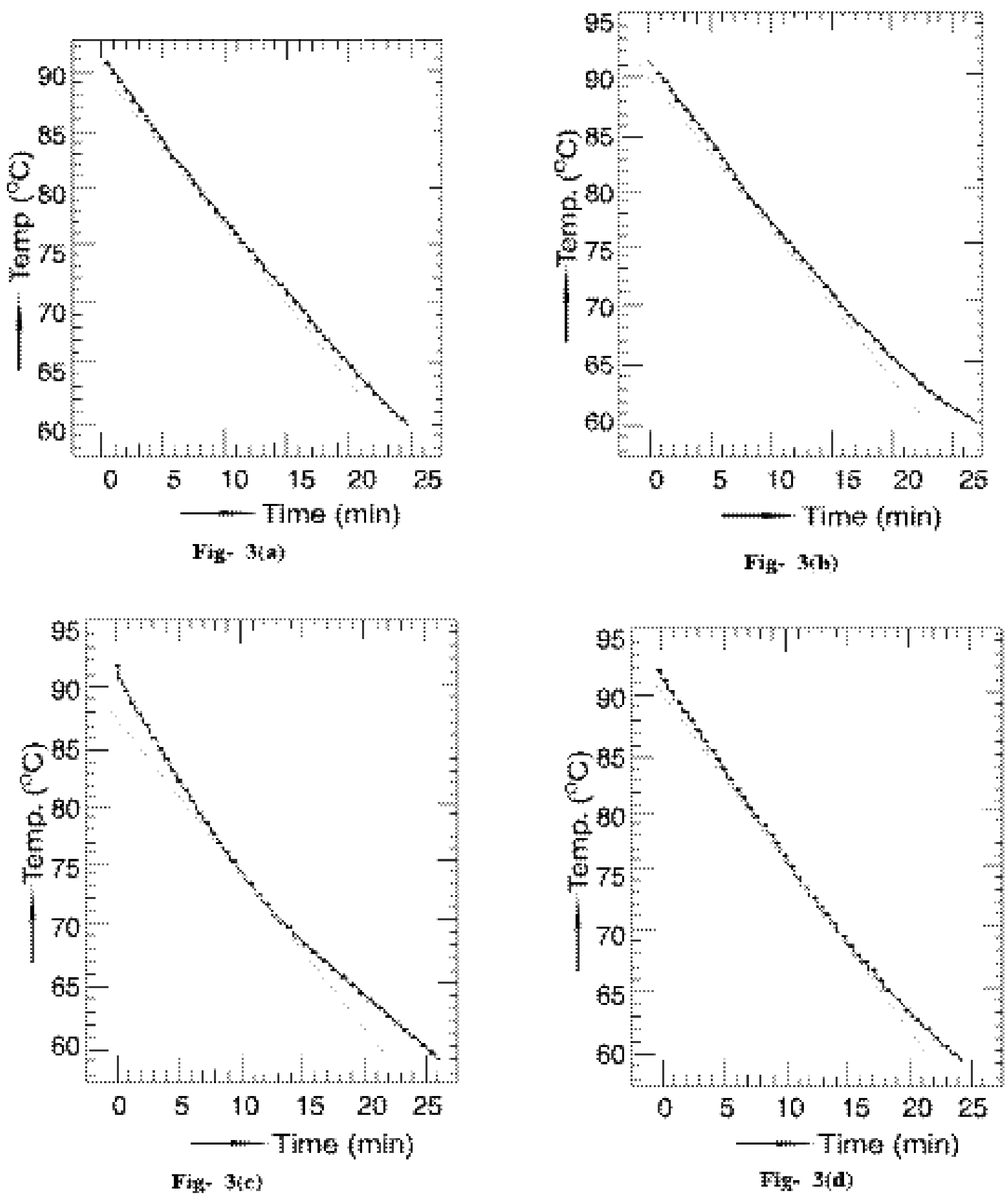

Fig. 3. Plots of temperature against time (cooling curve) for various concentrations of HMTA mixed jute paperboard. (a) 0. 1,(b) 0.2,(c)0.3 and (d) 0.5% HMTA

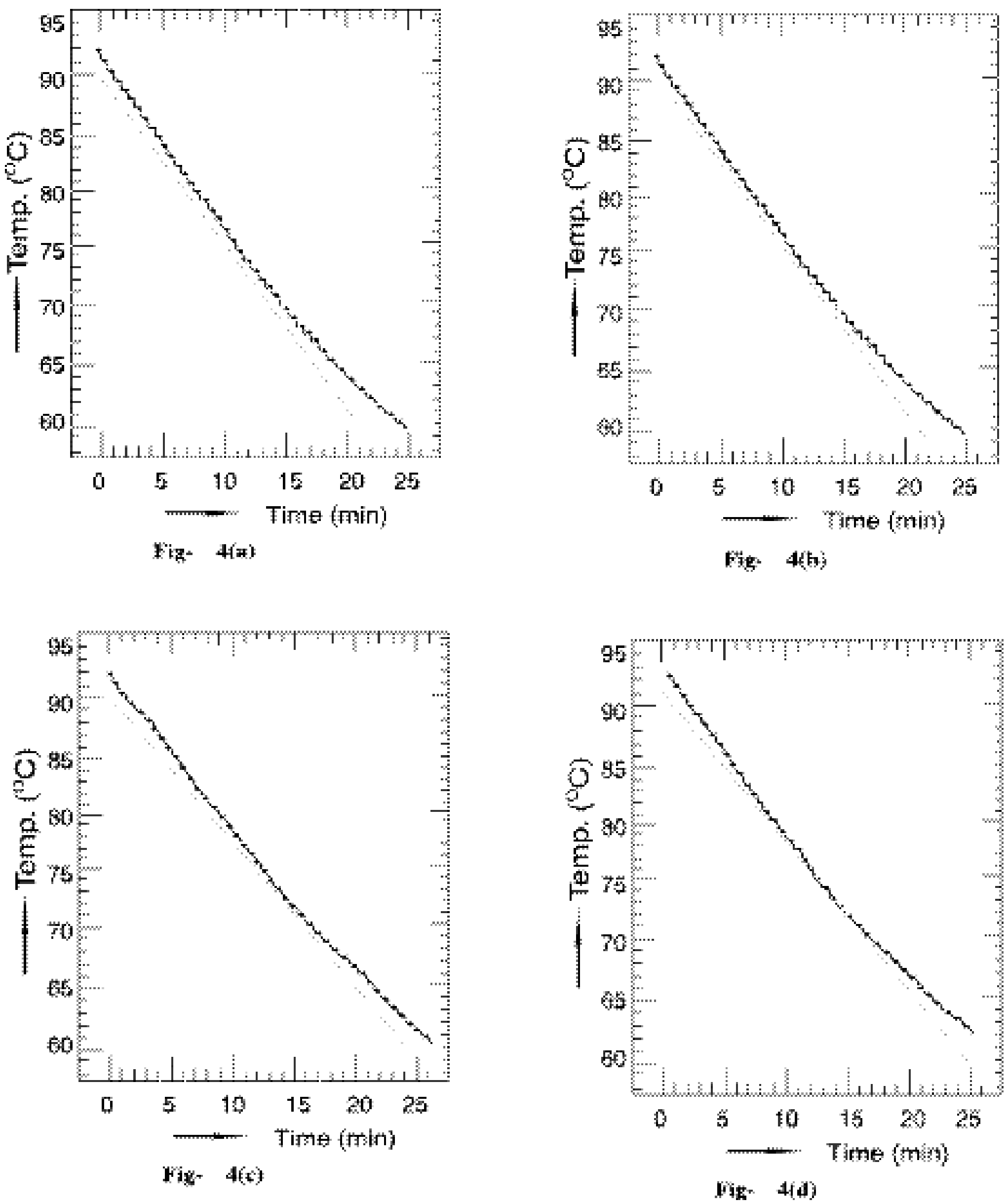

Fig. 4. Plots of temperature against time (cooling curve) for various concentrations of NB-mixed jute paperboard. (a) 1,(b) 2,(c) 3 and (d) 4% NB

Table 1. Comparative statement of thermal conductivity of paper boards.

Sample No.	Steady Temperature ^{O} C		Chemicals and its percentage	$d\theta/dt$	Thermal conductivity Kcal. cm^{-1} sec^{-1} $deg^{-1}C$
	θ_1	θ_2			
1	95.5	86.75	NaOH 16 % HMTA 0.1 %	1.375	2.948×10^{-4}
2	95.5	85.50	NaOH 16 % HMTA 0.2 %	1.456	2.80×10^{-4}
3	95.5	82.50	NaOH 16 % HMTA 0.3 %	1.294	2.506×10^{-4}
4	94.5	85.00	NaOH 16 % HMTA 0.5 %	1.389	3.028×10^{-4}
5	94.5	83.75	NaOH 16 % NB 0.1 %	1.416	2.624×10^{-4}
6	94.5	84.50	NaOH 16 % NB 0.2 %	1.359	2.481×10^{-4}
7	93.5	85.00	NaOH 16 % NB 0.3 %	1.155	2.740×10^{-4}
8	93.5	85.75	NaOH 16 % NB 0.4 %	1.137	2.480×10^{-4}

HMTA = Hexamethylene tetramine
NB = Nitro benzene

NaOH in the paperboards show that the steady state temperature increase with the increasing concentration of NB. It was also noticed that the conductivity constantly increases and decreases with the concentration of NB. This may be due to the fact that the molecular size of paperboard may be expanded first with increasing NB and then reduce due to clustering of the molecules thereby further reducing the thermal conductivity.

Conclusion

The experimental results of different proportion of HMTA and NB doped paperboards produced from Bangladeshi jute lead to the following conclusions :

1. The thermal conductivity (K) paperboards containing HMTA along with 16 % NaOH decrease with the containing of HMTA up to 0.3 % and then increase with the concentration of the compound. This may be attributed by reduction of molecular atomic motions of samples first and increasing the concentration, the carrier motion increases on heating.

2. The highest value of K = 3.028×10^{-4}cal. cm^{-1} sec^{-1} $degree^{-1}$ C for 0.3 % concentration HMTA, but the addition of NB contents shows the reverse phenomenon.

3. On the basis of results it may be concluded that the paperboards produced from jute may be used as insulators in electrical and electronic devices. It is also used in factories as packaging material.

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