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Automated thermal conductivity measurement of gel grown strontium oxalate crystal

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Abstract

An attempt is made to propose thermal sensing equipment based on the principle of divided bar method for automated thermal conductivity measurement of gel grown strontium oxalate crystal. This system is based on data logger system, contains microcontroller and ADC(PIC16F882) peripheral devices, which are associated with RS-232 serial communication port and interfaced with the computer program to communicate as well as to generates Microsoft Excel CSV file, which hold all necessary data for the measurement of thermal conductivity. Automated measured thermal conductivity of these samples is found to be in good agreement with the manually measured thermal conductivity reported ones...

Keywords: Data Logging, PIC16F882, RS232, Thermal Conductivity, Thermal Sensing equipment

INTRODUCTION

In recent years, analysis of thermal sensing has been adopted by various sophisticated equipments in place of traditional equipments, because of more accuracy, reproducible results and less time consuming [1-4]. One more advantages of modern equipments over traditional equipments is to simultaneous sensing of multiple parameters, which leads them towards medical [5] and industrial applications [6]. It is necessary to have good understanding of equipments for characterization of a sample. Although, many new research works on various thermal sensing equipments have been reported, however in particular, thermal sensing equipments associated with computer program for measurement of thermal conductivity of strontium oxalate is not so far reported. Therefore, an attempt is made to measure thermal conductivity of strontium oxalate using divided bar method [7-8]. Such thermal sensing equipments with data logger system can directly be measured thermal conductivity using computer software. The block diagram of proposed system provides information, how the data can be recorded automatically using computer software and is shown in Figure 1.

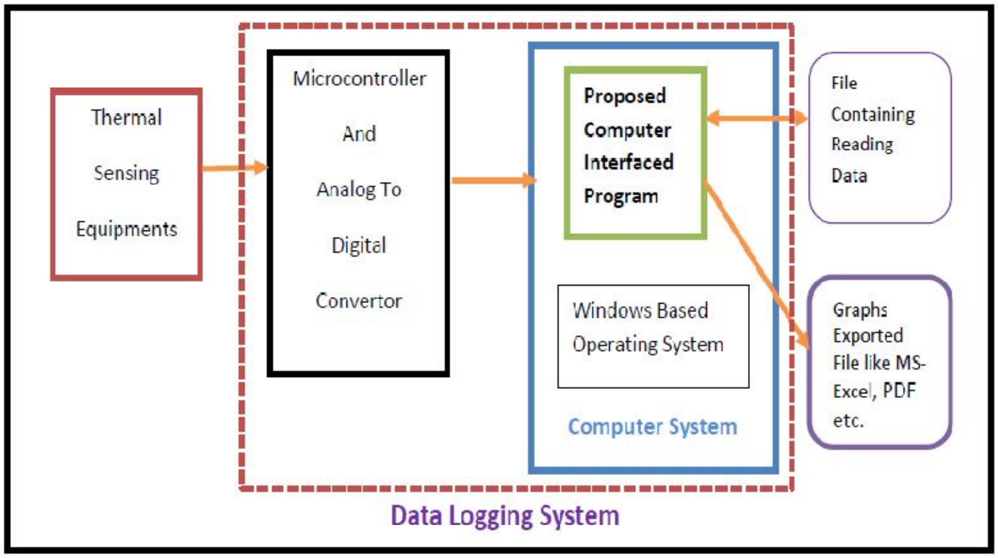

Fig. 1: Schematic block diagram of automated thermal measurement setup

EXPERIMENTAL

Philosophy of thermal Conductivity

Thermal contact conductance [9] phenomenon is based on the study of heat conduction between solid bodies during thermal contact, which is represented by the thermal contact conductance coefficient, h_c. The inverse of this property is termed as thermal contact resistance. When two solid bodies come in contact, say A and B, heat flows from the hotter body to the colder body that temperature gradients maybe represented diagrammatically as shown in Figure 2.

A temperature drop is observed at the interface between the two surfaces in contact. This phenomenon is said to be a result of a thermal contact resistance existing between the contacting surfaces. Thermal contact resistance is defined as the ratio between this temperature drop and the average heat flow across the interface.

According to Fourier's law, the heat flow [10] between the bodies is found by the relation:

$$q = -kA\frac{dT}{dx} \quad \ldots\ldots \quad (1)$$

Where q is the heat flow, k is the thermal conductivity, A is the cross sectional area and dT/dx is the temperature gradient in the direction of flow.

From considerations of energy conservation, the heat flow between the two bodies in contact, bodies A and B, is found as:

$$q = \frac{T_1 - T_3}{\Delta x_A/(k_A A) + 1/(h_c A) + \Delta x_B/(k_B A)} \quad \ldots\ldots\ldots \quad (2)$$

One may observe that the heat flow is directly related to the thermal conductivities of the bodies in contact, k_A and k_B, the contact area A, and the thermal contact resistance, $1/h_c$,

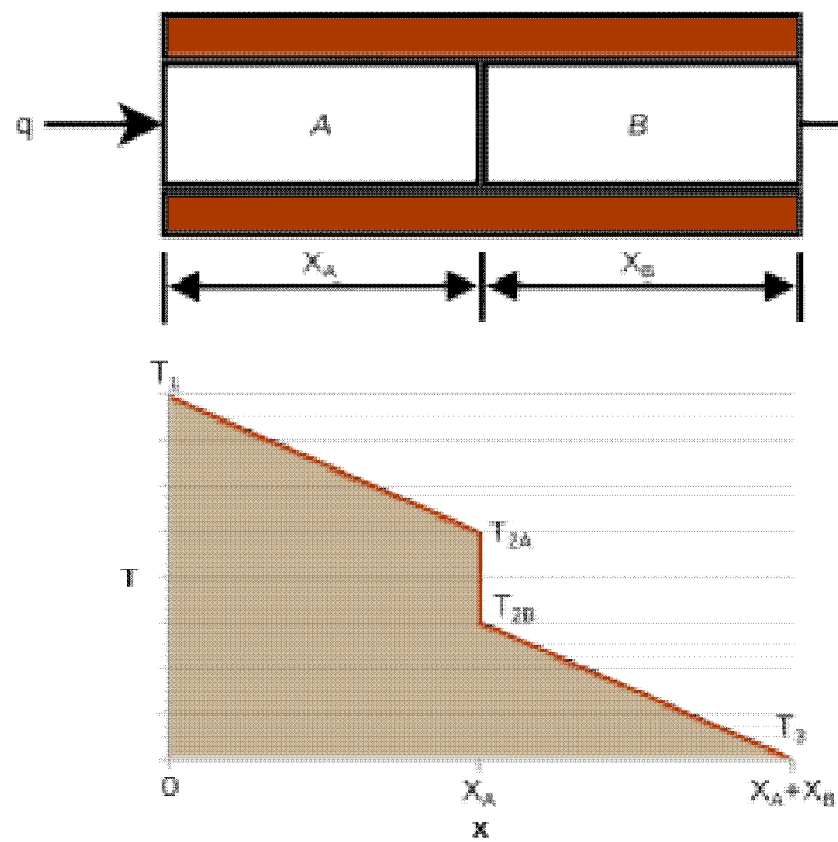

Fig. 2: Heat flow between two solids in contact and the temperature distribution.

There are several methods for the determination of thermal conductivity of insulators, however, one of the more simple methods is known as divided bar method [11-12]. In this method a thin crystal plate is sandwiched between two metal rods. The cross section of the crystal is of the same shape and area as the metal rods. Heat is provided from one end of one block. It passes through the first metal block, then through the crystal and finally passes out from the second block. Conditions are controlled so that a steady state is reached. Temperatures are measured at points denoted as A, B, C and D on metal rod as shown in Figure 3, which helps to determine the thermal gradients $(\frac{dT}{dx})_m$ in the two metal blocks. Extrapolation of the plotted graphs at the crystal-metal interfaces allows determining the thermal gradient in the crystal$(\frac{dT}{dx})_c$. Assuming that the loss of heat by radiation from the surfaces is negligible compared to the heat transferred and equating the heat flowing through the metal block and the crystal. The thermal conductivity of a crystal, κ_c is calculated by the equation

$$\kappa_c = \kappa_m \frac{(\frac{dT}{dx})_m}{(\frac{dT}{dx})_c} \quad \text{..................(3)}$$

Where, κ_m is the coefficient of thermal conductivity of the metal.

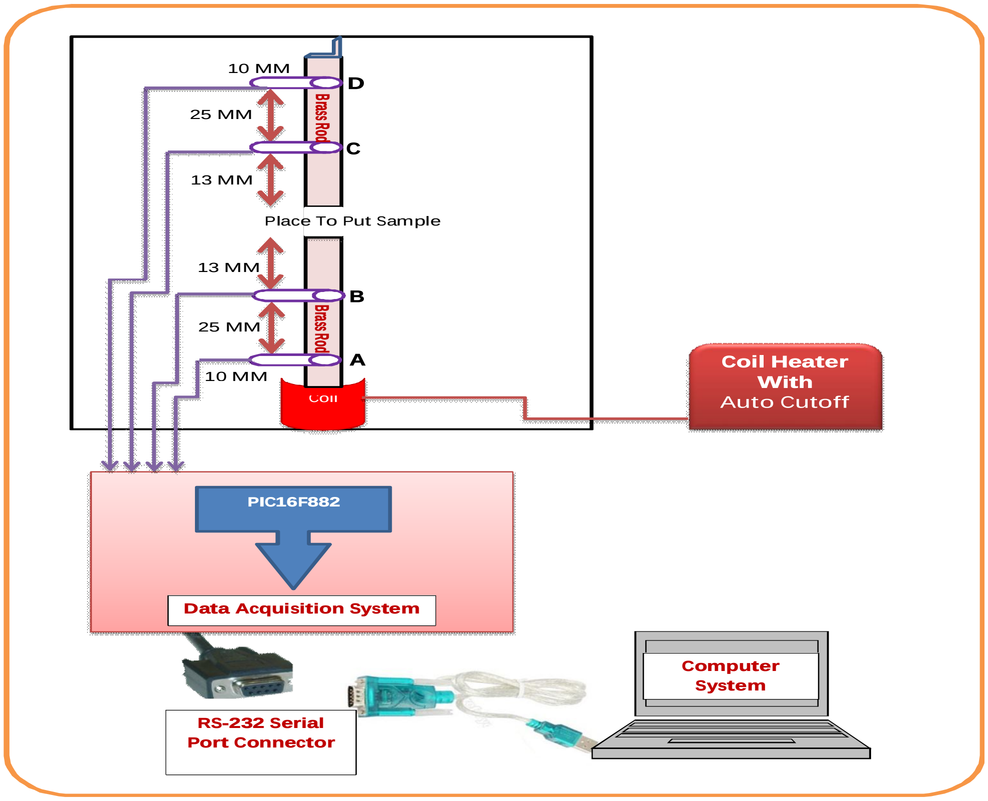

Fig. 3: Block diagram of automated thermal conductivity measurement

Components of proposed automated thermal conductivity measurement instrument

A typical computer system, which is used for data logging consist -

a) A computer
b) Some sensors to measure the physical quantities (e.g. temperature) of interest.
c) An interface used to connect the sensors to the computer.
d) Some software to store and display the information on the computer.

The sensors will measure the physical quantities of interest and pass this data on to the computer via the interface. At regular intervals the computer software will record this data automatically. The software can then be used to display the data as a graph or a table. The type and specification of component with their working are represented in Table 1.

Table 1: Types and specification of components Vs Working

Working	Type	Component
Sensor to sense Temperature	Analog Sensor	PT100
Capturing Sensors Data and Converting to Digital form	Microcontroller with ADC	PIC16F882[13-14]
Communicating with computer	Serial port Communication	RS232
Computer Software to store and display information	Designed Using Visual Studio 2008 [15]	-

In the present work, computer software was used to record and display readings collected from thermal sensing equipment for thermal conductivity measurement of strontium oxalate.

The snapshot of the designed software is as shown in Figure 4. This software is directly connected to the thermal sensing equipment to record readings without any setting, however, at the beginning of the programme, user needs to select the available COM port and feed the value of the thickness of sample, whose thermal conductivity is to be measured. After recording of reading, software program plots graph of temperature against distance to calculate thermal gradient.

This software also creates Microsoft Excel CSV file containing collected readings.

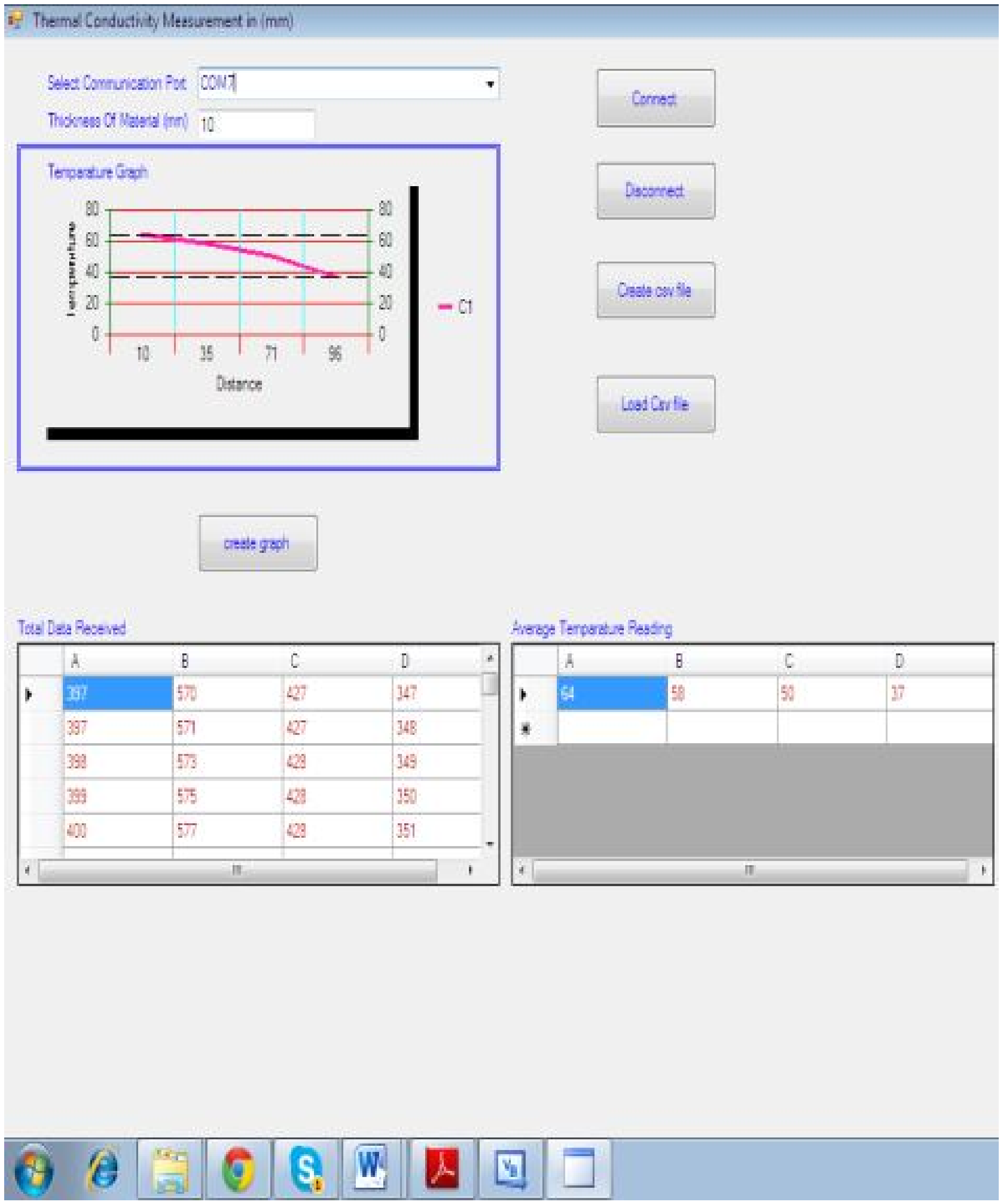

Fig. 4: Snapshot of Computer Software

Steps for using designed computer interfaced program (software)

Step 1. Do all arrangement as Shown in fig.
Step 2. Start Computer Interfaced Program.
Step 3. Select COM Port.
Step 4. Enter Thickness Of Sample In Millimetre.
Step 5. Click On Connect.
Step 6. Wait Till Coil Is heated up to desired temperature.
Step 7. Click On Disconnect.
Step 8. Click On Create CSV file to Create Excel File.
Step 9. Click on Load CSV files to load Excel file into data grid.
Step 10. Click On creates Graph to plot graph.
Step 11. Calculate Slope for finding thermal Gradient.
Step 12. Finally find thermal conductivity using thermal gradient.

Experimental working

To determine thermal conductivity of strontium oxalate crystal, divided bar method was used. In this method, thermal sensing equipment contains stainless steel rod with PT100 sensors installed at different distances as shown in Figure 3. Strontium oxalate crystals of 2.5mm and 1.5mm thickness were used at 53^0C and 62^0C respectively to determine thermal conductivity.

Using electrical heating coil one end of metal bar was heated and kept at constant temperature at 53^0C throughout the experiment. Temperatures of a metal bar at thermocouple position A, B, C and D were measured after every minute and recorded on a computerized system. Successive lowering of temperature with increasing distance from heating end of metal rod at A, B, C and D were observed and the average temperature at each positions were simply determined. A plot of temperature versus distance on a rod at positions A, B, C and D is shown in Figure 5.

Similar experiment was also carried out using another strontium oxalate crystal of 1.5 mm thickness and measured the temperature at the same positions by keeping one end of a metal rod at 62^0 C. A plot of temperature versus distance at positions A, B, C and D is shown in Figure 6. From these graphs the temperature gradients and thereby coefficient of thermal conductivity, κ_c of the crystal were calculated using the equation (3)

OBSERVATIONS AND RESULTS

The measurement of thermal conductivity of gel grown strontium oxalate involves obtaining different values of temperature at different positions with the help of sensors, which are directly stored into Microsoft excel CSV file. Stored data is used to plot graphs and then performing computation subsequently. The graphs directly plotted by the computer shown in Figure 5 and 6 are used to find the values of temperature gradients and further thermal conductivity.

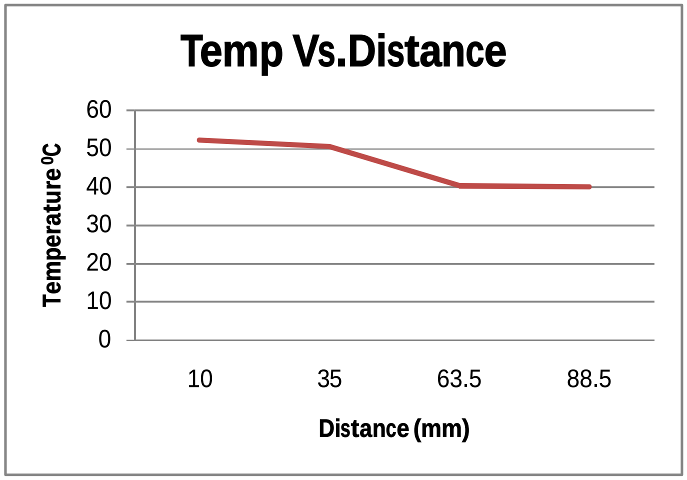

Fig. 5: Plot of Temperature versus distance on a rod at different positions for a sample at 53 ^{0}C

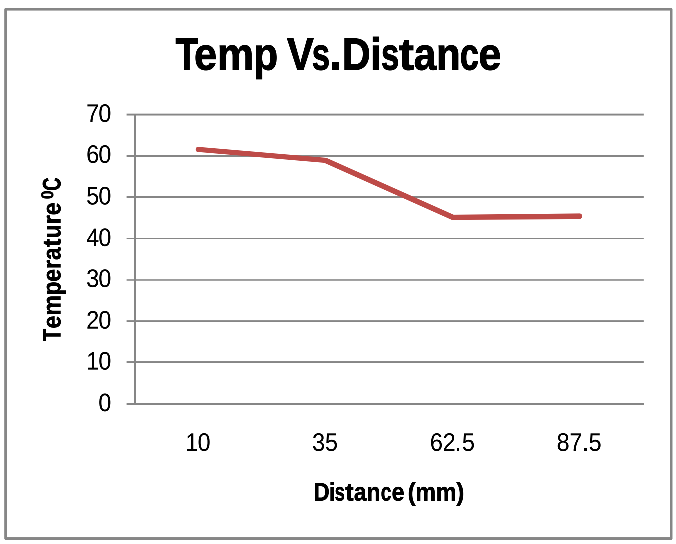

Fig. 6: Plot of Temperature versus distance on a rod at different positions for a sample at 62 ^{0}C

Determination of thermal conductivity of crystals (κ_c):
Thermal conductivity of Strontium oxalate crystal at 53^{0}C

Thermal conductivity of Stainless Steel metal bar (Std. value) is-
κ_m = 3.8X10-2 cal sec^{-1} cm^{-1} degree^{-1}
Temperature gradient from **Figure 1.5**,

$$(\frac{dT}{dx})_m = 0.6728 \quad \text{and} \quad (\frac{dT}{dx})_c = 2.905$$

on substituting these values in the equation (3)

$\therefore (\kappa_c)53^0C = 0.008801$ cal sec^{-1} cm^{-1} deg^{-1}

i.e. $(\kappa_c)53^0C = 3.685$ Wm^{-1}k^{-1}

Similarly, thermal conductivity of Strontium oxalate crystal at 62^0C

$\therefore (\kappa_C)\ 62\ ^0C = 0.007483$ cal sec^{-1} cm^{-1} deg^{-1}

i.e. $(\kappa_c)\ 62\ ^0C = 3.133$ Wm^{-1}k^{-1}

CONCLUSION

Using the designed computer interfaced program (software) and thermal conductivity measurement instrument it is quite easy to record all temperature reading data and storing it into file for further calculations. Also it is very useful for plotting the graphs. This automated thermal conductivity measurement equipment creates faithful and correct data reading for the purpose of thermal conductivity measurement. The automated measured thermal conductivity of Strontium oxalate crystal at 53^0C and 62^0C was found 3.685 and 3.133Wm^{-1}k^{-1} respectively.

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