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THERMAL CONDUCTIVITY OF GEL GROWN STRONTIUM OXALATE

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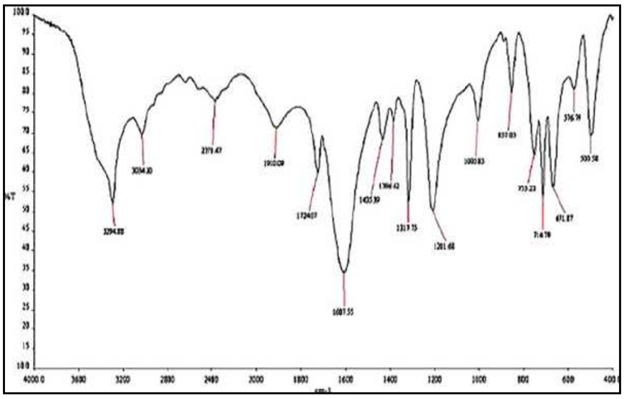
ABSTRACT:

Thermal conductivity of gel grown strontium oxalate crystals as a function of temperature has been studied at 335 and 349K by using divided bar method. The thermal conductivity of strontium oxalate crystal at 335K was found 2.3 $Wm^{-1}K^{-1}$ and 1.59 $Wm^{-1}K^{-1}$ at 349K. The reduction of thermal conductivity with rise in temperature may be due to reduction in mean free path of phonons in the solid.

KEYWORDS : *strontium oxalate, gel method, thermal conductivity, thermoelectric material.*

1. INTRODUCTION

Thermal conductivity play vital role for the developers engaged in the field of highly insulating materials. Many researchers have addressed the need and emphasizing materials used for building insulation [1,2]. Many projects of NASA has



been focusing on the development of materials, such as those based on aerogels [3].A material possessing both very high and very low thermal conductivity has wide applications. Solid materials like diamond and silicon have high thermal conductivity and therefore they are used in thermal electronic devices [4-11]. Low thermal conductivity materials like skutterudites [12-13], clathrates [14-15], and Zintl phases [16] have found high thermoelectric efficiency [17]. The thermal conduction in solid is directly correlated with the harmonicity and anharmonicity of thermal vibrations. Thus, materials possessing harmonic thermal vibrations are responsible for very high thermal conductivity, whereas anharmonic vibrations are attributed for low thermal conductivity. A number of factors like impurities, dislocations and crystal boundaries contribute to thermal conduction in solids.

The quantity of heat that passes through a substance in unit time of unit area and unit thickness, when its opposite faces are differ in temperature by one degree is known as thermal conductivity. The S.I. unit of thermal conductivity κ is Watt per meter Kelvin ($Wm^{-1}K^{-1}$). Measurements of thermal conductivity is an important property for investigating lattice defects or imperfection in solid. This property also provides an opportunity for investigating existing intriguing physical phenomenon and therefore to study thermal conductivity of solid material is of great technological interest.

Prismatic, transparent and well facet crystals grown by gel method [18] were used in the present work for the measurement of thermal conductivity of crystals as a function of temperature has been studied at 335 and 349 K. Strontium oxalate is also a pyro nature material, which shows great promise as barium oxalate [19, 20], in pyrotechnic and high temperature electronic applications [21, 22], it is therefore interesting to investigate the thermal properties such as thermal conductivity of this material.

2. EXPERIMENTAL PROCEDURE

Thermal conductivity of strontium oxalate crystal was measured at 335 K and 349 K by adopting the similar process as used in barium oxalate crystals [23]. The position of thermocouple junctions A, B, C, and D as well as position of strontium oxalate crystals, 'X' fixed in the stainless steel bar are shown in **Figure 1**

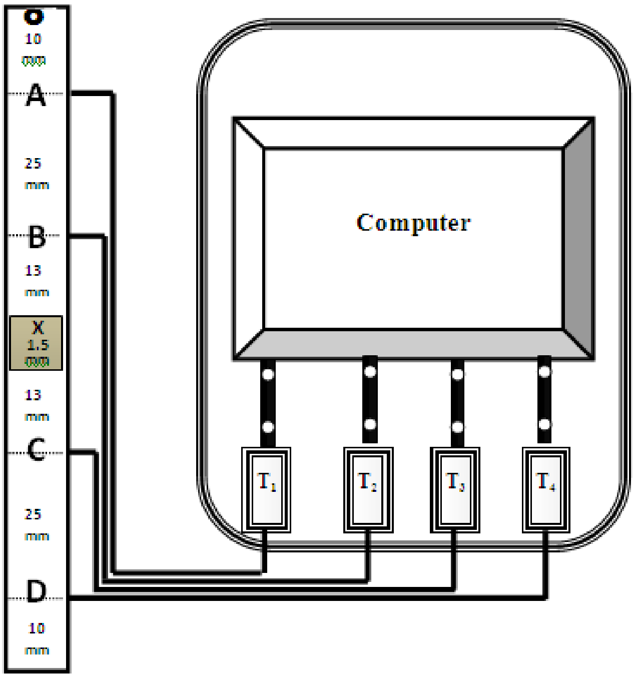
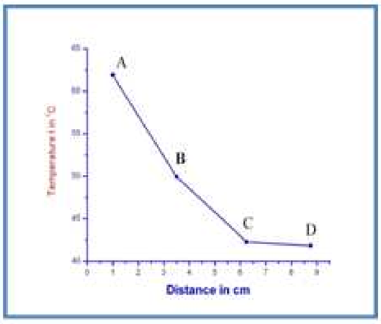


Figure 1: A schematic presentation of equipment for measurement of thermal conductivity:

This experiment is interfaced with computer to record directly the temperature of thermocouple junctions. Two crystals of same thickness 1.5mm were used to determine thermal conductivity at 335 K and 349 K. Crystals kept at the position X in the metal bar are shown in **Figure 1.** The equipment was properly setup for working and then thermal conductivity was measured adopting the similar procedure used in case of barium oxalate crystals [23].

Temperatures at thermocouple positions A, B, C and D were measured after every minute. Successive lowering of temperatures with increasing distances from heating end 'O' of metal rod at A, B, C and D were observed and then average temperature at each of these positions were simply determined. A plot of temperature at 335 K and 349 K versus distance on a rod at positions A, B, C and D are shown in **Figure 2** and **Figure 3** respectively.



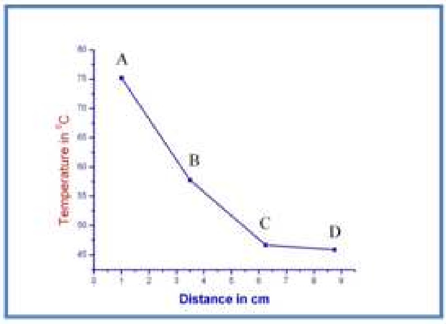


Figure 2: Plot of Temperature versus distance on a a rod rod at different positions

Figure 3: Plot of Temperature versus distance on at different positions

From these plots the temperature gradients and thereby coefficient of thermal conductivity, κ_c of the crystal were calculated. using the equation

$$\kappa_c = \kappa_m \left[\frac{(\frac{dT}{dx})_m}{(\frac{dT}{dx})_c} \right]$$

3. OBSERVATIONS AND RESULTS

Graphs plotted between Temperatures versus distance on a rod at different positions as shown in **Figure 2** and **Figure 3** were used to calculate temperature gradient and then thermal conductivity, κ_c of the crystal.

Determination of thermal conductivity(κ_c) of strontium oxalate

Thermal conductivity is determined by using the equation-

$$\kappa_c = \kappa_m \frac{(\frac{dT}{dx})_m}{(\frac{dT}{dx})_c}$$

Where κ_m is the coefficient of thermal conductivity of the metal. $(\frac{dT}{dx})_m$ is the temperature gradient of metal and $(\frac{dT}{dx})_c$ is the temperature gradient of the crystal

[A] At 335K

From **Figure 2,**

$(\frac{dT}{dx})_m = 0.32$ and $(\frac{dT}{dx})_c = 2.21$

κ_m = 3.8 x 10^{-3} cal sec^{-1} cm^{-1} deg^{-1}

∴ κ_c = 5.5 x 10^{-3} cal sec^{-1} cm^{-1} deg^{-1}

= 0.0055 cal sec^{-1} cm^{-1} deg^{-1}

(κ_c) At $_{335K}$ = **2.3 W $m^{-1}K^{-1}$**

[B] At349K.

From **Figure 3,**

$(\frac{dT}{dx})_m = 0.22$ and $(\frac{dT}{dx})_c = 2.21$

κ_m = 3.8 x 10^{-3} cal sec^{-1} cm^{-1} deg^{-1}

∴ κ_c = 3.8x 10^{-3} cal sec^{-1} cm^{-1} deg^{-1}

= 0.0038 cal sec^{-1} cm^{-1} deg^{-1}

(κ_c) At $_{349K}$ = **1.59 W $m^{-1}K^{-1}$**

4. Discussion

The thermal conductivity equation implies that the process of thermal energy transfer is a random process. The energy does not simply enter one end of the specimen and proceed directly in a straight path to the other end, but rather the energy diffuses through the specimen, suffering frequent collisions, such conductivity process brings the temperature gradient.

Resistance to heat flow in dielectric solids arises from scattering of phonons by defects in the crystal structure such as lattice defects, grain boundaries, presence of isotopes and impurities etc. The thermal conductivity of nonmetallic crystal solid is due to phonon interaction. The collisions of phonons with each other result in an alteration of phonon frequencies and their moments. In the harmonic solid such phonon–phonon interactions are not possible; thereby such solid possesses high thermal conductivity. In solids with an-harmonic lattice interactions, there is a coupling between different phonons, which limits the value of the mean free path and hence lowers the thermal conductivity [24, 25].

As mentioned a perfect harmonic crystal has no thermal resistance mechanism; hence it has infinite thermal conductivity. This point was addressed by Slack [24] from the perspective of insulators in which the phonons are maximally coupled and as a function of the number of atoms in the unit cell. The thermal conductivity of some crystalline solid approaches to minimum as the temperature reaches to melting point [24].

The thermal conductivity of strontium oxalate crystal at 335K and 349K were found 2.3 and 1.59 $Wm^{-1}K^{-1}$ respectively. The results are showing decrease in the thermal conductivity with the increase in the temperature as observed in barium oxalate[23]. This decrease in thermal conductivity may be due to reduction of mean free path of phonons in solid

These experimental results in the present work are well in agreement with the G. A. Slack findings [24]. The concept of minimal thermal conductivity can be a useful guide and attempt to develop material with exceptionally low thermal conductivities e.g. thermo electrics. The thermal conductivity of an insulator can be reduced either by increasing the size of the unit cell, the pressure of heavy atoms, random atomic substitution, increasing optic acoustic couplings and increasing lattice symmetry [24].

5.CONCLUSION

Thermal conductivity of strontium oxalate crystals at 335 and 349K were studied by divided bar method.

Following are the point wise conclusions.

a. The thermal conductivity of strontium oxalate crystal at 335K was found 2.3 $Wm^{-1}K^{-1}$ and1.59 $Wm^{-1}K^{-1}$ at 349K.

b. The thermal conductivity is reducing with rise in temperature.

c. This reduction in the thermal conductivity may be due to reduction in mean free path of phonons.

Low thermal conductivity of this material can lead to develop it as a thermo electric material.

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