STUDY OF TRANSPORT PHENOMENON IN SOME AMORPHOUS MATERIALS

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AIM OF WORK

Rocks are one of the most important constituents of the solid part of our planet. Measurement of the physical properties of rocks, particularly the thermal properties, is becoming an important subject of intensive research in many countries; that is due to many practical purposes.[1]

The complex methods used for the measurement of thermal properties of solids enable us to measure thermal capacity, conductivity and diffusivity coefficients in one experiment. For this reason, they are considered the most productive methods and are developed in many laboratories all over the world.

In this work, the apparatus for the measurement of the mentioned properties, was used for the investigation of the thermal properties of olivine and pyrophillite at high temperature.

The theory of the used method was elaborated, developed, and improved to process the excess information for extra control of the obtained results.

The experimental results were analysed and compared to the published data.

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INTRODUCTION

INTRODUCTION

A need for data and information on thermophysical properties of rocks is becoming apparent in the field of geothermal energy, engineering materials, and geosiences. Problems encountered in geothermal power generation and in the design and site-selection of hardened subsurface defence facilities, under-ground power plants, under-ground storage. reservoirs, underground nuclear waste disposal, underground nuclear tests, buried pipelines for transporting petroleum or water, ... etc. along with continued interest in thermal tunneling techniques, have greatly increased the demand for data on thermophysical properties of rocks in recent years. In geosciences, accurate data on heat flow in the earth's crust are needed to obtain a better under standing of the earth's history and its current make-up. Information is also needed in the evaluation of the newly developed theories on sea floor spreading and platetectonics in addition to supplying details for the substantial deep sea rock boring programe now underway. Earthquake prediction analysis also depends to some degree on thermophysical properties and heat flow in rock measses. In all, these varied research activities have signaled the desire for an organized body of knowledge on the thermophysical properties of rocks.

Besides, measurement of the heat capacity will help the understanding of the structure of these materials. Knowledge of the thermal conductivity and diffusivity coefficients and their dependance upon temperature will undoubted she some light on the heat conduction mechanism in the investigated specimens.

Measurement of the thermal properties is carried out, by using a great variety of steady and non-steady state methods. The best of these methods are the so called periodic temperature methods since they enable us to measure the thermal capacity, conductivity and diffusivity coefficients in one experiment.

An apparatus for measurement of the mentioned properties, was constructed at the Department of Physics, Faculty of Science, Al-Azhar University. This apparatus was calibrated and used for the investigation of the thermal properties of Al_2O_3 and Fused quartz in the temperature range 400 : 1200°K.

The second step was to elaborate develop and improve the theory of the used method to process the excess information obtained from the time and spatial distribution of the phase, as well as the amplitude of temperature oscillations given by two temperature sensors. This enables us to get some extra control of the obtained results.

Moreover, the mentioned apparatus was used for the measurement of thermal capacity, conductivity and diffusivity coefficients of olivine and pyrophillite in the temperature range from 400 - 1200°K.

Accordingly, the obtained information was used to determine each of the mentioned properties by 3 different independent ways. These results were compared with each other, and the accuracy of each way was calculated. As a result it was found that the obtained experimental values confirmed each other. This gives more confidence in the obtained results, and reduces much the random errors of this experiment.

Finally, the obtained experimental results for the mentioned properties were compared with the published data.

A set up for measuring the electrical conductivity of rocks was constructed and accordingly the electrical resistivity of olivine and pyrophillite specimens was measured in the temperature range from 200 to 1200°K.

Heat conduction in both these substances was found to be mainly due to phonons. The radiative part of thermal conductivity was found to be very small. This confirms the results at higher temperatures obtained by El-Sharkawy.[2]

CHAPTER I

CHAPTER I

REVIEW ABOUT THE THERMAL CAPACITY, CONDUCTIVITY, DIFFUSIVITY AND ELECTRICAL CONDUCTIVITY COEFFICIENTS OF DIELECTRIC SOLIDS.

1. The thermal capacity:

The thermal capacity of a medium is defined as the amount of heat absorbed by unit mass of the medium when its temperature is raised by one degree. The thermal capacity at constant volume Cv is defined by:

$$C_v = \left(\frac{\partial \mathcal{E}}{\partial T} \right)_v \qquad (1)$$

where: $\partial \mathcal{E}$ is the amount of heat added and ∂T is the increase in temperature.

The thermal capacity of solids were calculated using the classical theorem of equipartition of energy. It was assumed that each atom or molecule in a solid was able to vibrate about a fixed point and since this vibration can extend in three dimensions. The total energy of atom per free degree of freedom is equal to KT, and for the three dimensions the total energy is equal to 3KT.

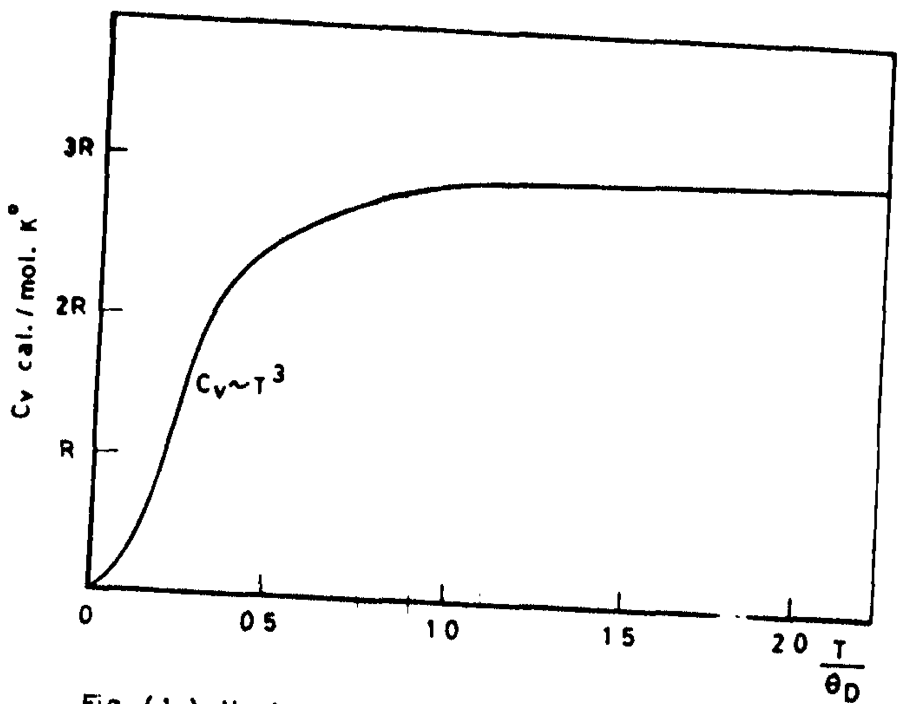

Fig. (1) Heat capacity of a solid according to the Debye approximation.

The energy diffuses through the solid can be represented by elastic waves or lattice vibrations, the unit of these elastic waves is called phonon.

The thermal capacity at very low temperature is given by

$$C_v = \frac{12\pi^4}{5} \cdot R \left(\frac{T}{\theta_D} \right)^3 \qquad (6)$$

where θ_D : Debye temperature .

At high temperature the C_v is equal to 3R, which is good agreement with Einstien and Duleng and Petit.

The thermal capacity of dielectric solids is plotted against temperature in Fig. (1). This curve verifies all the experimental data of C_v of insulators at low and high temperatures.

From the experimental point of view, it is much more convenient to measure the thermal capacity of a solid at constant pressure than at constant volume.

The relation between the two thermal capacities Cp and C_v is given by:

$$C_p - C_v = \alpha_v^2 \; T \, V/K \qquad (7)$$

where K - the compressability

α_v - the thermal expansion coefficient

V - the molar volume.

Thus C_v may be calculated from C_p measurements if at the same time α_v and K are known at the temperature of interest.

The relation between K, α_v and C_v are given by:

$$\gamma = \frac{\alpha_v \cdot V}{K \cdot C_v} \tag{8}$$

The quantity γ is called the Grunadsen constant and its practically independant of temperature thus by calculating γ, one may obtain an approximation for C_v at other temperature from a knowledge of the coefficient of volume expansion.

2. The Thermal Conductivity:

The thermal conductivity λ of a solid can be defined with respect to the steady state flow of heat along a specimen withen which their exists a temperature gradient dT/dX

$$q = - \lambda \, dT/dX \tag{9}$$