Thermoelectric Properties of Semiconducting materials

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Abstract: *Thermoelectric is a science and technology associated with electric converters, that is the generation of electrical power using the Seeback effect and refrigeration using the Peltier effect.Thermoelectric generators are being used to provide electrical power in medical, military, deep space applications, automobiles and industry applications. Now a days there is an increase in the requirement for thermoelectric cooler in the use of infrared detectors and in optical communication system.*

I. Introduction

Early 19th century scientist in 1950's Thomas Seeback discovered the thermoelectric Phenomena, if a temperature gradient is applied across the junctions of two dissimilar conductors, electrical current would flow.

Later in 1960's Jean peltier, on the other hand, found that the current passing through two dissimilar electrical conductors caused heat to be either emitted or abserved at the junction of the materials.These thermoelectric phenomena found in 1950's and 1960's are the basis for today's thermoelectric Industries. All practical applications in thermo electric devices come into existence after developing the semiconductor technology from mid 20th century.Now one can produce thermoelectric "module '' with high efficiency solid state heat- pumping for both cooling and heating with modern techniques and units can also be used to generate DC power in special circumstances (e.g., conversation of waste heat).

Seebeck coefficients increased to the order of 100 µV by the development of synthetic semiconductors in 1920's. Further, it has enhanced the interest in thermoelectric. With that realization, reasonable efficiencies were made possible with several semiconductors thermo elements. Efficiency of solid state energy conversion was based on the Seebeck effect for power generation and Peltier effect for cooling the materials should possess High electrical conductivity, high Seebeck Coefficient and low thermal conductivity.

The materials with high figure of merit proved to be High challenging task. This interest brought good development of thermoelectric materials.The flow of electrons and phonons is associated with the thermoelectric effect.This flows and their associated potentials contribute to the Irreversible process .In contrast the thermoelectric effect are found to be thermodynamically reversible.This phenomenological theory was described by the Thermodynamics irreversible theory, which enables the entropy changes due to reversible and Irreversible flow of energy to be considered simultaneously.The problem of adequate thermodynamic derivation of thermo electric has occupied the attention of successful.

Identification of problems
**Problems and Definitions**

Generalization of thermoelectric phenomena in case of non isothermal conducting media have been considered. Such a physical approach enables description of thermoelectric energy conversion in a new general context. Generality of current excitation physical phenomena of a thermoelectric nature and thermo electric current has been shown.A generalized model of thermoelectric energy conversion has been studied . On its basis technique of new type of thermo elements have been developed .Variants of new type of thermo elements with unique properties formed against such procedure have been demonstrated. It was shown that existing thermo elements have limitations in thermoelectric energy conversion .Possibilities to improve the thermo electric conversion efficiency by involving new physical factor in the process of thermoelectric energy conversion have been analysed. All versions of thermoelectric energy conversion have been clarified.New approaches of thermoelectricity development resulting from them have been analysed. Thermoelectric material's figure of merit value have been reported about ZT=1 so far. further it has been has to be increased more than that report value of 1.

To study the thermoelectric properties of semiconductor materials for the cooling Applications by Peltier effect. Thermoelectric properties include thermal conductivity, electrical resistivity thermoelectric power and figure of merit.These properties are measured for semiconductors compounds $(BiSb)_2Te_3$ and $Bi_2(Se,Te)_3$

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and it is shown as the most promising material for thermoelectric applications to refrigeration. The superior thermoelectric properties of this semiconductor materials are attributed to reduction in the lattice thermal conductivity and increasing the electrical conductivity by allowing without affecting thermoelectric power.It has an electrical conductivity σ of about 10^3 ohm $^{-1}$cm^{-1}, and carrier concentration exceeding 10^{18}/cc. At this level it remains extrinsic up to about 200^0C.The thermal conductivity k for a solid is the sum of lattice vibration component k_1 and electric component k_e as mentioned earlier which is proportional to σ .

II. Methodology

The Gradient Freeze method and mechanical alloying are used for preparation of thermoelectric materials .

Figure:13. Schematic Diagram

(Gradient Freeze Method):
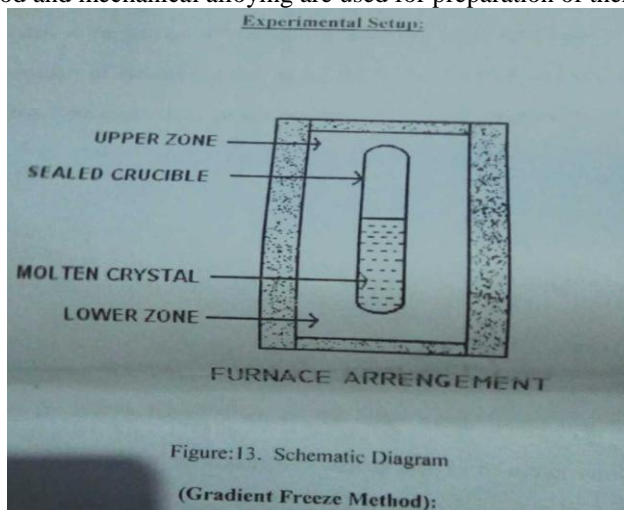
In this method the molten material is subjected to gradient cooling by moving the ampoule gradually out of the hot zone.

1. The elements of high purity Bi, Sb and weighed according to Stoichiometric ratio and powdered in a pestle and mortar.
2.   kept into the 10 mm quartz tube sealed after a evacuationto about 10^{-5} by using diffusion pump
3. Ssealed Quartz tube hanged by wire into middle of the hot zone of the Furnace.
4. The other end of wire is wound on a Pulley, which is in turn is fixed , to aclock motor.
5. The diameter of the pulley should be chosen to get the optimum.
6. The rate of movement of the growth ampoule about 10 mm / hr.
7. The temperature of the Furnace should be 100^oC above the melting.

This point have been carefully taken for designing crystal growth experiment setup as shown in figure . The Furnace used was made of kanthal wire (heating coil) externally wound on a alumina tube of 1.5 inches. The length of the Furnace is considerably long to have long uniform hot Zone.This was designed and fabricated in the laboratory.

Synthesis of material p-type (BiSb)$_2$Te$_3$
Gradient Freeze Method
        The Ternary compound was prepared by weighing is Ultra high purity element of Bi, Te and Sb in the stochiometric ratio by this Formula (Bi$_{1-x}$Sb$_x$)2Te3where x=0.75; moreover 2,4,6,8 weight percentage of excess Te was added to compensate the defects. They were powdered and mixed thoroughly in an agate mortar.The quartz tubes used for melting this material was precoated internally with pyrolytic graphite. The pyrolytic graphite coating is made by cracking under high vacuum high purity organic vapours (toluene or benzene) inside the tube at the temperature of 1100° C to avoid any reaction between tellurium and quartz. The material was put into the quartz tube and it was sealed under high vacuum of 10^{-5} torr using a diffusion pump. One end of the quartz tube was Sharply tapered to facilitate single crystal growth.

Thermoelectric device applications:
1. military ,Aerospace electronic.
2. Portable refrigerators
3. Water coolers
4. Car air conditioners
5. Power generators

6.   thermal energy sensors
7.   Stabilizing Ink temperature in printer and copier.

References

[1].   As the "figure of merit" approaches infinity, the Peltier–Seebeck effect can drive a heat engine or refrigerator at closer and closer to the Carnot efficiency. Disalvo, F. J. (1999). "Thermoelectric Cooling and Power Generation". Science. 285 (5428): 703–6. doi:10.1126/science.285.5428.703. PMID 10426986. Any device that works at the Carnot efficiency is thermodynamically reversible, a consequence of classical thermodynamics.

[2].   The voltage in this case does not refer to electric potential but rather the "voltmeter" voltage , where is the Fermi level.

[3].   "A.11 Thermoelectric effects". Eng.fsu.edu. 2002-02-01. Retrieved 2013-04-22.

[4].   There is a generalized second Thomson relation relating anisotropic Peltier and Seebeck coefficients with reversed magnetic field and magnetic order. See, for example, Rowe, D. M., ed. (2010). Thermoelectrics Handbook: Macro to Nano. CRC Press. ISBN 9781420038903.

[5].   "https://stovefanreviews.com/teg-module-and-seebeck-effect/"

[6].   "http://www.gizmag.com/lumen-flashlight/39893/

[7].   "https://www.technologyreview.com/s/602874/body-heat-powers-this-smart-watch"