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Peltier Properties of n-type and p-type β-$FeSi_2$fabricated through FAPAS Process

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ABSTRACT
Thermoelectric properties ofinexpensive and eco-friendly β-$FeSi_2$ were studied and its ability to pose as a peltier device were investigated for a particular temperature range. The Seebeck coefficient and Peltier coefficient of β-$FeSi_2$ are measured and calculations show how efficient it can prove to be when used in a peltier module. Plots of Peltier coefficient/Temperature verses Temperature shows maximum at 150 K. On the basis of these results an explanation for the maximum temperature gradient and efficiency of β-$FeSi_2$at room temperature is suggested.

Keywords-β-$FeSi_2$, Figure of Merit, Temperature Gradient, Peltier Coefficient, Peltier Cooling Efficiency.

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I. INTRODUCTION

Thermoelectric studies are widely used to determine the efficiency of various semiconductors to contribute to the peltier effect. Research on alternatives to replace the current model are being conducted to pose less harmful to the environment and as economically viable. Because of the advantages of iron disilicide such as low cast, non-toxicity, high Seebeck coefficient, large working temperature range and high resistance to oxidation, it attracts a widespread attention. In high temperature (above 970°C) the $FeSi_2$ will decompose into nonstoichiometric α-Fe_2Si_5 with a tetragonal structure and ε-FeSi with a cubic structure[1,2], which exhibit metallic conduction. After annealing they will transform β-$FeSi_2$, which is kind of semiconducting ceramics with an energy gap of 0.87 eV[3], stable below 970°C.

As per the present authors knowledge no information is available on the peltier cooling efficiency of the peltier module constructed using p and n-type β-$FeSi_2$crystals in the literature. Moreover, there is need of thorough study of whether or not β-$FeSi_2$ can replace Bi_2Te_3 in the current peltier modules. The results of such study are presented in this communication.

II. EXPERIMENTAL

To Crystals of p-type and n-type β-$FeSi_2$were prepared by FAPAS method[4]. The amount of heat is difficult to measure precisely than the temperature difference, so that the Seebeck coefficient is much easier to measure. The Peltier coefficient is related to the Seebeck coefficient.The Peltier coefficients for both p and n-type β-$FeSi_2$ crystals were calculated using the relation $\pi = ST$ where S is the Seebeck coefficient at the absolute temperature T.

For constructing a peltier device, the semiconductor samples were alternately mounted on top of well separated silver strips with silver paste to replicate a peltier module. Peltier coefficient/Temperature verses Temperature graph was plotted. Maximum current of the constructed β-$FeSi_2$ peltier devicewas calculated from equation $I_{max} = A(\pi\sigma)/L$ where A is the cross-sectional area and L is the length of the β-$FeSi_2$semiconductor, π is the peltier coefficient and σis the electrical conductivity of β-$FeSi_2$.

The maximum temperature gradient between the hot and the cold end was measured using two pairs of copper constant thermocouples. Peltier cooling efficiency was calculated from the experimental values obtained.

III. RESULTS AND DISCUSSION

The maximum current through the module was 14 amperes. The values of Peltier coefficient (π) in the range of 300 K to 400 K computed from the measured values of Seebeck coefficient are given in Table 1 along with the thermal conductivity and electrical resistivity of p and n-type β-$FeSi_2$. It can be observed from Fig.1[5]that the Peltier coefficient/Temperature value of n-type β-$FeSi_2$ semiconductor increases with respect to the absolute temperature up to 150 K at which it acquires the highest value. However beyond this temperature the value starts to decrease with increasing temperature. As can be seen in Fig.2 similar trend is observed for the p-type β-$FeSi_2$ semiconductor. At 300 K the maximum temperature gradient was experimentally measured to be 0.82 K and theoretically calculated to be 1.06 K for p-type semiconductor. The maximum temperature gradient for n-type semiconductor was experimentally measured to be 0.44 K and theoretically calculated to be 0.6125 K. The Figure of Merit (or Peltier cooling efficiency) was found to be 2.12 for p-type and 1.225 for n-type semiconductor.

Table 1:- Thermoelectric Properties of β-$FeSi_2$

Material	π(V)	ρ(Ωm)	k($Wm^{-1}K^{-2}$)	Figure of Merit
p-$FeSi_2$	0.21	0.009	4	1.125
n-$FeSi_2$	0.24	0.009	3	2.12

The electrical resistivity of β-$FeSi_2$ is 0.009 Ωm which is far less than 0.00001 Ωm of Bi_2Te_3. Though the peltier coefficient of β-$FeSi_2$ is 4 times that of Bi_2Te_3, the values of thermal conductivity and electrical resistivity bring down the maximum temperature gradient that can be achieved.

IV. CONCLUSION

By comparing the values of temperature gradient of Bi_2Te_3 and β-$FeSi_2$ semiconductors, it is clearly visible that β-$FeSi_2$ cannot pose as a better alternative to Bi_2Te_3 in peltier module. Thus pure β-$FeSi_2$cannot be directly used in the manufacturing of peltier cooling devices as the temperature gradient between the two sides of the module is tending to zero.

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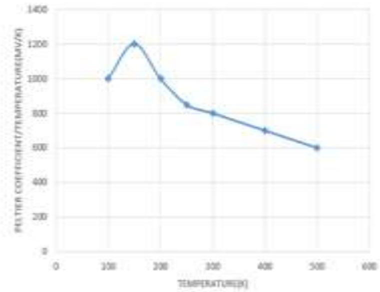

Figure 1 –Peltier Coefficient/Temperature Vs Temperature for p-type β-$FeSi_2$ semiconductor

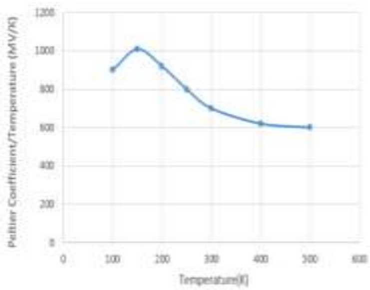

Figure 2 –Peltier Coefficient/Temperature Vs Temperature for n-type β-$FeSi_2$ semiconductor

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