

Effects of Sn dopant on power factor of $Tl_{8.67}Sb_{1.33-x}Sn_xTe_6$ nanoparticles

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In this research work the thermoelectric and electrical performance of Sn doped Tellurium Telluride $Tl_{8.67}Sn_xSb_{1.33-x}Te_6$ ($x=0.61, 0.63, 0.65, 0.67, 0.68, 0.70$), was studied. The samples were synthesized by melting method. By XRD and EDX analysis it has been confirmed that single phase tetragonal crystal structure with no any other impurities. The Seebeck co-efficient (thermo power) (S) shows increasing positive trend showing p-type semiconductor characteristics with whole temperature range from 300 to 550 K. At ambient temperature complex behavior of Seebeck coefficient for Sn doped compounds has been observed initially S decreasing with increase in Sn concentration i.e. $x=0.65$, and then S increases with increase in Sn contents up to $x=0.70$. In addition the electrical conductivity (σ) and the power factors have also shows the same complex behavior with the increase of Sn concentrations. Telluride's are narrow band-gap semiconductors, with all elements in common oxidation states, according to $(Tl^+)_9(Sb^{3+})_1(Te^{2-})_6$. It is found that the power factor is increases with Sn concentrations as well as increase in temperature range from 300-500 K.

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1. Introduction

Due to the increasing crises of energy and thermal pollution the researchers start to introduce and discover novel sources of energy. In which thermoelectric materials play the most important rule due to its reliability, easily available and becoming as a green energy source [1]. As these thermoelectric materials needs only temperature difference to produce electrical energy form waste heat energy so becoming the attraction of researchers.

The thermoelectric properties of Lead (Pb) were doped to Thallium telluride (Tl_9Te_{10}) materials by Yu *et al.* [3] to study the thermoelectric properties of the sample. Ball milling and hot pressing techniques were used to synthesize the sample of the Bulk material i.e. $(Tl_{0.02}Pb_{0.98}Te)$ of 3-7 μm of grain size. The electrical conductivity (σ) and seebeck coefficient (S) of the compound were calculated. The Seebeck coefficient at a temperature at a temperature 25 $^{\circ}C$ and 400 $^{\circ}C$ were observed i.e. 150 $\mu V/K$ and 300 $\mu V/K$ simultaneously which was higher than sodium (Na) doped materials. The sample of PbTe shows a very high thermoelectric and high figure of merit ZT at a temperature 550 $^{\circ}C$.

The polycrystalline sample of Thallium antimony telluride ($TlSbTe_2$) was synthesized by K. Kurosaki *et al.*[4] and studied the thermoelectric properties of the compound. The pellets of the compound were closed in a quartz container and heated up to 923K for 05 hours and then the pellets were pressed in the presence of organ gas up to 80 MP at a temperature 637K. The thermal and electrical properties of the pallets were studied in a temperature range from 300 to 800 K. The seebeck co-efficient of the sample at a temperature 666 K was almost equal to 224 $\mu V/K$ which is considerable to the state of art to $TlSbTe_6$ and thermoelectric materials and shows a complete positive value in the whole temperature range. A synthesized nano polycrystalline compound Thallium antimony telluride ($TlSbTe_2$) shows a low thermal conductivity and high figure of merit ZT i.e. reached up to 0.8 at temperature 715 K mostly occur in cluster of thermoelectric materials.

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The thermoelectric properties of a compound like thallium in the various polycrystalline samples of AgTlTe, TlSbTe₂ and Tl₉BiTe₆ were confirmed by K. Kurosaki *et al.* [5] that these were p type semi conducting materials and TlBiTe₂ were n-type semi conducting materials. Such type of materials shows that those materials have low thermal conductivity and also have low seebeck coefficient. at room temperature the thermal conductivity of AgTlTe at room temperature is 0.25 Wm⁻¹ K⁻¹. The thermo electrical nano compound shows comparatively high ZT i.e. for Tl₉BiTe₆ at 590k is 0.86, TlBiTe₂ at 760 K is .015, TlSbTe₂ at 715 K is 0.87 and while for AgTlTe at temperature 580 K is 0.61.

A nano compound (Bi_{0.2}Sb_{0.8-x}Pb_x)₂Te₃, was doped by Pb and synthesized by hot pressing sintering and with quenching technique by C.C. Lin *et al.* [6] and their thermoelectric properties were studied .the doping of Pb and Te create a low effective mass and as a result the metallic properties improved. All the synthesized samples were just like a rhombohedra structure of Sb₂Te₃. For PbTe and Pb composite with x= 0.02, 0.05 the thermal conductivity at temperature 325 K was 0.20 and 0.28 W/mk and also the figure of merit become bitter in the thermo electrical materials group.

Ball milling and spark plasma frottage/sintering techniques were used by X.X. Li *et al.* [7] for synthesizing the sample while keeping in the sealed evacuated quartz tube. In the n type semiconductor (Bi_xPb_{1-x}Te)_{0.88}(PbS)_{0.12} is a compound in which PbTe is a primary state of like (NaCl) sodium chloride type structure, while the behavior of PbS is less as compare. Overall the doping of Pb shows a behavior of lowering the electrical resistivity. The electrons carrier increases from 4.5x10¹⁸ cm⁻³ when x=0 to 2.8x10¹⁹ cm⁻³ for when x=0.003 at a temperature 298K. the doping of Bi also increases the electrical conductivity from 0.65 to 1.63 W/mk. Wich means that the power factor and figure of merit (ZT) also improved of the sample (Bi_{0.001}Pb_{0.999}Te)_{0.88}(PbS)_{0.12} .whose value reached to 1.20 at a temperature 573 K which is better than the (PbTe)_{0.88}(PbS)_{0.12} sample.

The thermo electric properties of the polycrystalline type nano compounds like Tl₄PbTe₃, Tl₄SnTe₃ and Tl₂GeTe₃ were studied by Kosuga, Atsuko, *et al.* [8] at various temperature ranges from 300 to 500K. They synthesized the compounds by using solid state reaction method and showed better results in the seebeck coefficient and figure of merit (ZT). Two of the compounds i.e. Tl₄PbTe₃, Tl₄SnTe₃ shows a tetragonal structure while Tl₂GeTe₃ showed orthorhombic structure. The compounds also showed a metallic nature i.e. in the order of 10⁻⁵ to 10⁻⁴. The figure of merit of the compounds i.e. Tl₄PbTe₃ is 0.71, Tl₄SnTe₃ is 0.74 at a temperature 673 K, respectively and 0.24 for Tl₂GeTe₃ at 473 K.

The samples of the compound PbTe doped by Sb₂Te₃ was synthesized by T. Suet *al.* [9] using high temperature and pressure technique and studied their thermoelectric properties at room temperature. In the XRD pattern it was confirmed that PbTe is a n type semiconductor and all the properties are like sodium chloride (NaCl). With the doping of Sb₂Te₃ the thermal conductivity decreases as long as the doping concentration increased. The value of ZT increases till it attained its highest value at a temperature 670 K, and after that its value decreases with the increasing of dopant.

In the series of quaternary telluride i.e there exist thermoelectric properties which were investigated by H.Kleinke *et.al.* [10]. The compound was added in different ratio in which Tl has special values i.e. 8.33, 8.67, and a value of 9. The ratio of SnBi was adjusted with the ratio of Tl doping, which occur the change in the QTS i.e. in the properties of electrical, Seebeck coefficient and also figure of merit (ZT). A single crystal technique was used for XRD pattern which explain Tl_{8.67}Sn_{0.50}Bi_{0.82}Te₆. The conductivity was low i.e. within the range of 0.2 to 0.6 W/mk at a temperature 370k, which illustrate the maximum value of the power factor and for Tl₂(SnBi)Te₆ i.e. 8.1μWcm⁻¹k⁻² for Tl₉Sn_{0.2}Bi_{0.8}Te₆ at a temperature 587 K and for Tl_{8.67}Sn_{0.50}Bi_{0.83}Te₆ nano compound is 4 μWcm⁻¹k⁻² at the same temperature. The value of ZT for Tl_{8.33}Sn_{1.12}Bi_{0.55}Te₆ at temperature 575k is a reasonable of 0.6 and for Tl_{8.67}Sn_{0.50}Bi_{0.83}Te₆ at a temperature 525 K is also 0.6.

The doped lead telluride (PbTe) added with antimony of bismuth telluride (Bi₂Te₃) was revived by ZHU Pin Wen *et al.* [11], in which compound telluride Sb₂Te₆ showed a by layer nano compound of bismuth antimony with a composite of Te₃. This showed that for each doped of PbTe the value of ZT increases and the thermal conductivity decreases with compound Sb₂Te₆ up to

1.03. Similarly with doped of Bi_2Te_3 up to nearly 7.63. it was also confirmed that when the ratio of PbTe is in lesser amount the more is the value of ZT , so it better for the manufacturing of thermoelectric materials to use lesser ratio.

The thermoelectric properties of isostructure ternary thallium (Tl) chalcogenides nano compounds TlGdQ_2 , here ($Q=\text{Se}, \text{Te}$) and Tl_9GdTe_6 were studied by H.Kleinke *et.al.* [12]. the ternary compound TlGdQ_2 is isothermal to TlSbQ_2 , while Tl_9GdTe_6 has isothermal to Tl_9BiTe_6 of space group 14mcm . A ternary nano compound TlGdSe_2 was a semiconductor of high seebeck coefficient and have low thermal conductivity. The thermal conductivity of the compound TlGdTe_2 was observed that it was premeditated in the order of $0.5 \text{ Wm}^{-1}\text{k}^{-1}$ which is favorable for electrical conductivity of the ternary compound i.e Tl_9GdTe_6 .while in the thermoelectric devices it is comparatively high i.e $850 \Omega^{-1}\text{cm}^{-1}$ at room temperature and also the seebeck co-efficient is high i.e. nearly $27 \mu\text{VK}^{-1}$. The value of ZT at a temperature 550 K almost nearly 0.5.

The thermoelectric stuff was also revived by Z. Renet. *al.* [13] to fuse ternary group like $(\text{Tl}_{0.02}\text{Pb}_{0.98}\text{Te})$ with the absorption of different lead telluride (PbTe). Thallium (Tl) was doped to lead telluride (PbTe) and synthesized by using Ball Milling and Hot pressing techniques to their thermoelectric properties. For removing flaws, to reduce the grain size of the compound and made the ternary compound mechanically strong the nano particles of silicon (Si) be also added i.e. $\text{Tl}_{0.02}\text{Pb}_{0.98}\text{TeSi}_{0.02}$. Due to which the seebeck co-efficient and electrical conductivity becomes high and thermal conductivity attained its lower value and hence as a result the ZT increased. The value of ZT of $(\text{Tl}_{0.02}\text{Pb}_{0.98}\text{TeSi}_{0.02}\text{Na}_{0.02})$ at a temperature 770 K is 1.7.

In the research of H. Kleinke *et. al.* [14] on thallium telluride nano materials like Tl_4PbTe_3 and Tl_4SnTe_3 concluded that these are thermoelectric nano ingredients having figure of merit (ZT) 0.74 and 0.71 respectively at a temperature 673K. In the nano composite i.e. $\text{Tl}_{10-x}\text{Pb}_x\text{Te}_6$ and $\text{Tl}_{10-x}\text{Sn}_x\text{Te}_6$ "X" is the ratio of Sn or Pb which is the function of thermoelectric properties of the compounds. By keeping different ratio of "X" i.e. 1.9 and 2.02 the value of ZT is 1.2 and if the value of two compounds [$(\text{Tl}^+)_8(\text{Pb}^{2+})_2(\text{Te}^{2-})_6$] and [$(\text{Tl}^+)_8(\text{Sn}^{2+})_2(\text{Te}^{2-})_6$] be balanced of large valance number of electrons. For keeping the values of "X" dissimilar then the P type charges be less. The value of ZT for $\text{Tl}_{8.10}\text{Pb}_{1.90}\text{Te}_6$ and $\text{Tl}_{8.05}\text{Sn}_{1.95}\text{Te}_6$ is very up to 1.46 and 1.26 at temperature 685 K respectively.

2. Experimental Procedure

For the synthesis of the samples a solid state reaction technique was used i.e. Sn was doped $\text{Tl}_{8.67}\text{Sn}_x\text{Sb}_{1.33-x}\text{Te}_6$, with different ratio i.e. $x=0.61, 0.63, 0.65, 0.67, 0.68, 0.70$ system. The starting materials of the compound were Tl^{+1} , Sb^{+3} , Sn^{+3} , and Te^{-2} in highly pure form all they were put in the air free silica tube in the presence of argon gas to avoid from all any type contamination i.e. like moisture, oxygen etc. and then were heated for at least 24 hour to a temperature 923K in a constant rate for 1K/minute. After completing the heat treatment the sample was allowed to cool down to a room temperature with a very slow rate to avoid from quenching, disorder of the system and deformation. The nano compound was kept for at least 24 hour at room temperature, for 24 hour at 650 C° , 60 hours for 560 C° and then finally for 70 hour at 400 C° .finally the sample of different ratio of "X" were put in to the pellet forms by pressing and then start the measurement.

3. Results and discussion

3.1. X-Ray diffraction

The crystal structure of the chalcogenide system was studied by XRD. With this technique we find the grain size of the nano system by using sharer formula, miller indices, lattice parameter and inter planner distance [15]. The XRD of $\text{Tl}_{8.67}\text{Sn}_x\text{Sb}_{1.33-x}\text{Te}_6$ was compare with $\text{Tl}_9\text{Sb}_{1-m}\text{Sn}_m\text{Te}_6$ [2] are shown in the figure 1.

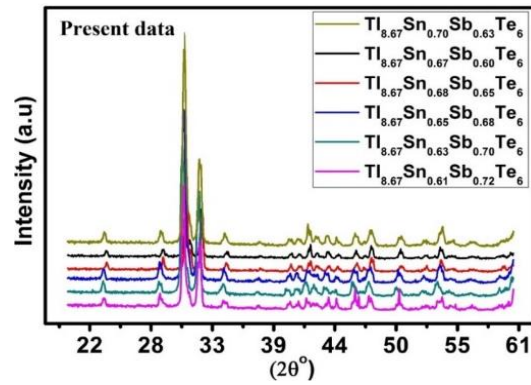


Fig. 1. XRD spectra of $Tl_{8.67}Sn_xSb_{1.33-x}Te_6$ and reference data [2]. (with $x=0.61, 0.63, 0.65, 0.67, 0.68$ and 0.70).

3.2.1. Crystal structure analysis

The XRD of the nano system clarified that the compound was a single phase of no any other impurities. The volume, lattice parameter and the crystalline size of the unite cell are given in the table. With careful study it was confirmed that the crystal structure of the nano compound $Tl_{8.67}Sn_xSb_{1.33-x}Te_6$ has closely similar to $Tl_{10}Te_6$ nano material [16].

Table 1. Volume, Lattice parameters (a & c) and crystalline size of unit cell.

Samples	Crystallize Size (D) nm	D Spacing		Volume (\AA^3)
		a=b	c	
$Tl_{8.67}Sn_{0.61}Sb_{0.72}Te_6$	28.13	8.79	13.005	1005.50
$Tl_{8.67}Sn_{0.63}Sb_{0.70}Te_6$	28.48	8.45	13.075	1022.90
$Tl_{8.67}Sn_{0.65}Sb_{0.68}Te_6$	28.85	8.82	13.00	1012.44
$Tl_{8.67}Sn_{0.67}Sb_{0.66}Te_6$	29.65	8.81	13.001	1009.086
$Tl_{8.67}Sn_{0.68}Sb_{0.65}Te_6$	30.84	8.84	13.062	1022.67
$Tl_{8.67}Sn_{0.70}Sb_{0.63}Te_6$	30.31	8.90	13.096	1039.22

3.2. Scanning Electron Microscopy (SEM)

It is non-destructivity techniques to study the surface of the nano compound and is used to find out the size of the particle distribution, surface morphology, crystalline size and structure of the nano compound. With the increasing of Sn dopants to $Tl_{8.67}Sn_xSb_{1.33-x}Te_6$ nano compounds the scattering rate of also electrons increases. The smaller the grain size hence more the scattering of electrons and hence more the power factor[17].

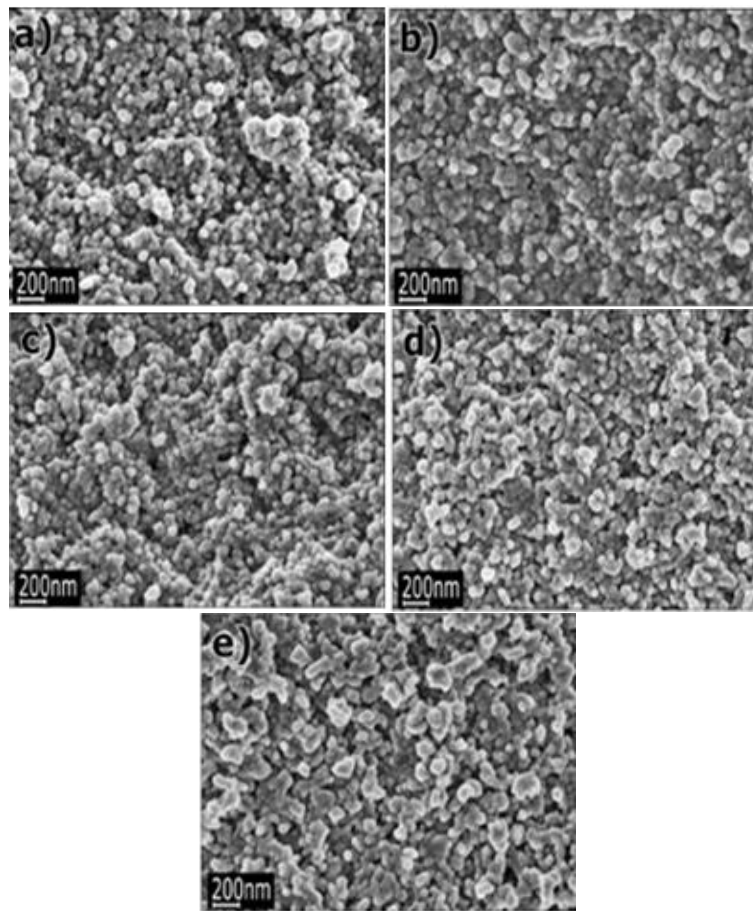


Fig. 3. SEM images are shown for the size of 200nm of all the samples.

3.2.1 Energy Dispersive X-Ray (EDX) Analysis

All the samples were analyzed by EDX analysis to extract the elemental information from the samples. The elemental ratio each element in the samples were extracted which were in the atomic ratio of i.e. Sn=9.91.73), Sb =9.97), Te =34.41), Tl =57.89.

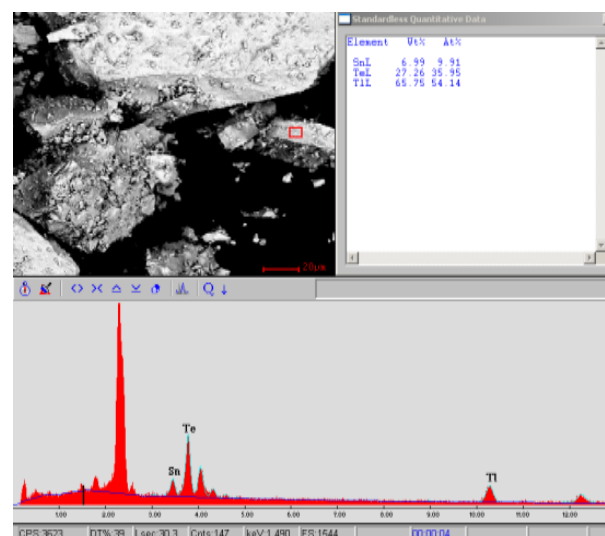


Fig. 4. EDX data for $Tl_{8.67}Sn_{0.63}Sb_{0.70}Te_6$, (room temperature), for the confirmation of elemental analysis in the nano system; all the other nano compounds have the similar stoichiometric ratios as per designed.

3.3. Physical properties

3.3.1. Seebeck Coefficient Measurements

For obtaining better results of ZT one should to optimize the properties like thermal and electrical of the nano compound, in which of the best approach is to slightly change the band gap energy of the semiconductor. Here we have doped Sn in the ratio of i.e. 1-10% which change the Fermi level and the band level to our required level for increasing the power factor. If a specified dopant is doped to the intrinsic semiconductor an extra energy band level is formed i.e. a specified type of energy level, which is called acceptor levels are up the valance band and those down are called donor band[18]. Now if the dopant elements have less numbers of electrons then the semiconductor is in the acceptor level make the compound p-type, while if the dopant have more electrons then the original one then it make the compound n-type and it is the best possible way to clarify the Fermi level of the band diagram. From the it is clear that $Tl_8Sn_2Te_6$ is p-type compound and was also reported by [19] that the Fermi level of the same compound occur in the band gap energy level.

The see beck .coefficient of the compound can be calculated by using formula [20] given below.

$$S = \frac{8\pi^2 k_B^2}{3eh^2} m^* \cdot T \left(\frac{\pi}{3n}\right)^{2/3}$$

From above relation it is clear that see beck co efficient mostly depends upon the charge carrier ‘e’ and effective mass , ‘ m^* ’. Our results showed that a band gape of 0.23ev was for $Tl_{8.67}Sn_{0.70}Sb_{0.63}Te_6$ nano compound. [21]. It was also observed that in a cooled pellets pressed in the rectangular shape (5x1x1 mm) as a function of temperature. No specific change occur in the see beck coefficient of the samples by keeping the samples in the open air for more than one week, so for any change in the see beck coefficient the samples were annealed for at least 6 hour to a temperature 400°C .

The graph b/w temperature ranges (300K to 550K) and see-back coefficient of the nano compound $Tl_{8.67}Sn_xSb_{1.33-x}Te_6$, with different concentration of Sn =0.61, 0.63, 0.65, 0.67, 0.68, 0.70 wt. % are given below. From the graph it is clear that the see beck coefficient of compound increases with the increase in temperature. The maximum value of see beck co efficient is for concentration of 0.63.

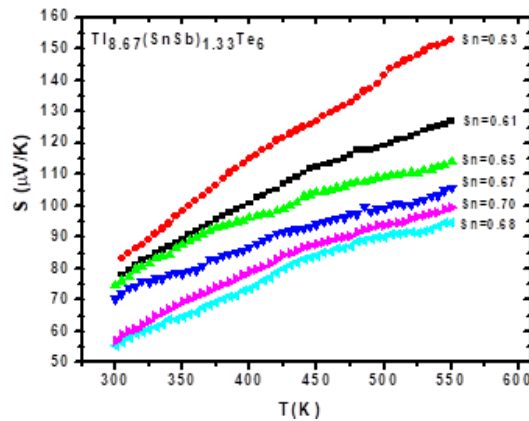


Fig. 6. Seebeck Co-efficient S with various temperatures of $Tl_{8.67}Sn_xSb_{1.33-x}Te_6(x=0.61 \text{ to } 0.70)$.

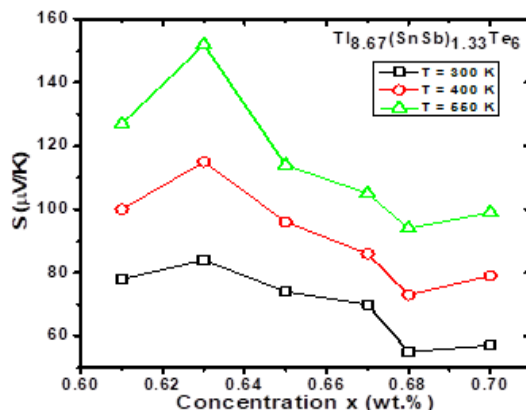


Fig. 7. Variation in trends of S at room temperature 300, 400 and 550 K.

Table 2. The observed values from graph of Seebeck coefficient for $Tl_{8.67}Sn_xSb_{1.33-x}Te_6$ of thermoelectric properties at 300 K, 400 & 550 K for all concentrations.

Samples	Seebeck Coefficient $\mu\text{V/K}$ at 300	Seebeck Coefficient $\mu\text{V/K}$ at 400	Seebeck Coefficient $\mu\text{V/K}$ at 550
$Tl_{8.67}Sn_{0.61}Sb_{0.72}Tl_6$	78	100	127
$Tl_{8.67}Sn_{0.63}Sb_{0.70}Tl_6$	84	115	152
$Tl_{8.67}Sn_{0.65}Sb_{0.68}Tl_6$	74	96	114
$Tl_{8.67}Sn_{0.67}Sb_{0.66}Tl_6$	70	86	105
$Tl_{8.67}Sn_{0.68}Sb_{0.65}Tl_6$	55	73	94
$Tl_{8.67}Sn_{0.70}Sb_{0.63}Tl_6$	57	79	99

3.3.2. Electrical Conductivity Measurement

The graphical representation of electrical conductivity and temperature are shown. From the graph it is clear that with the increase in temperature conductivity of the nano compounds decreases. This may probably be due to scattering of charge carriers with the phonons of the grain boundaries of the nano materials [22]. There also appear some non-monotonic changes b/w the concentration of Sn_x with electrical properties for the nano compound. It is also possible and debatable that some impurities of chemical compound innovate the grain boundaries and possibly cause to lower the electrical phenomenon of the chalcogenides nano system [23]. From this it is clear that two main factors which occur changes in the electrical properties are grain boundaries and grains.

From above and over all study we observed that electrical conductivity decreased with the increase in temperature which is probably due to the degenerate semiconducting behavior of the compound, the conducting grains, grain boundaries of the poor conducting nature and scattering of charge carriers with the phonons.

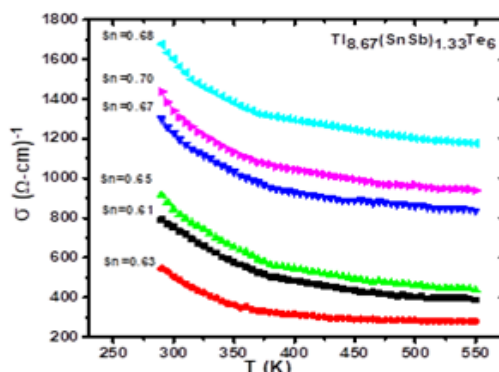


Fig. 8. The electrical conductivity of $Tl_{8.67}Sn_xSb_{1.33-x}Te_6$ versus temperatures are shown.

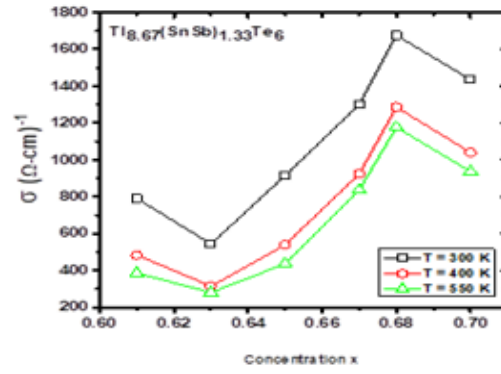


Fig. 9. Variation in trends of σ at 300,400 and 550 K.

Table 3. Electrical conductivity σ (Ω - cm^{-1}) of $\text{Tl}_{8.67}\text{Sn}_x\text{Sb}_{1.33-x}\text{Te}_6$ ($0.61 \leq x \leq 0.70$) of thermoelectric properties at 300,400 & 550 K.

Samples	Electrical Conductivity (Ω cm) $^{-1}$ at 300 K	Electrical Conductivity (Ω cm) $^{-1}$ at 400 K	Electrical Conductivity (Ω cm) $^{-1}$ at 550 K
$\text{Tl}_{8.67}\text{Sn}_{0.61}\text{Sb}_{0.72}\text{Te}_6$	792	484	387
$\text{Tl}_{8.67}\text{Sn}_{0.63}\text{Sb}_{0.70}\text{Te}_6$	544	315	280
$\text{Tl}_{8.67}\text{Sn}_{0.65}\text{Sb}_{0.68}\text{Te}_6$	915	540	437
$\text{Tl}_{8.67}\text{Sn}_{0.67}\text{Sb}_{0.66}\text{Te}_6$	1300	924	837
$\text{Tl}_{8.67}\text{Sn}_{0.68}\text{Sb}_{0.65}\text{Te}_6$	1676	1286	1176
$\text{Tl}_{8.67}\text{Sn}_{0.70}\text{Sb}_{0.63}\text{Te}_6$	1436	1040	937

3.4. Power Factor

A Seebeck coefficient has a acute effect on the power factor (PF). So to change the power factor we have to increase the seebeck coefficient. A complicated behavior was noted in the power factor on doping of Sn. Among the entire nano compound the P.F. of $\text{Tl}_{8.67}\text{Sn}_{0.68}\text{Sb}_{0.70}\text{Te}_6$ showed maximum value i.e. 9.61×10^6 and 5.53×10^6 ($\text{Wtt-cm}^{-1}\text{-K}^{-2}$) at 550K and 300 K simultaneously. While the lowest was for a compound $\text{Tl}_{8.67}\text{Sn}_{0.63}\text{Sb}_{0.60}\text{Te}_6$ i.e. 0.573×10^7 and 0.378×10^7 ($\text{Wtt-cm}^{-1}\text{-K}^{-2}$) at 550K and 300K respectively. With doping of Sn seebeck coefficient increases hence power factor also increased.

Form the table it is clear that at concentration 0.68 the power factor 9.61×10^6 $\text{Wcm}^{-1}\text{K}^{-1}$ was increased and at concentration 0.63 is 4.67×10^6 $\text{Wcm}^{-1}\text{K}^{-1}$ the P.F. was decreased, which was due to the increase in hole and grains boundaries scattering.

The temperature and power factor shows a complex behavior so it cannot clarify the dependency on temperature.

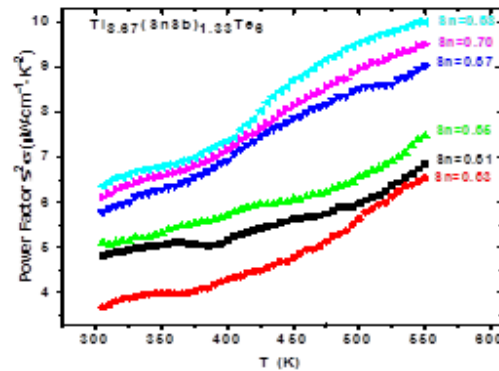


Fig. 10. Variation of Power factor with temperature for $\text{Tl}_{8.67}\text{Sn}_x\text{Sb}_{1.33-x}\text{Te}_6$ ($0.61 \leq x \leq 0.70$).

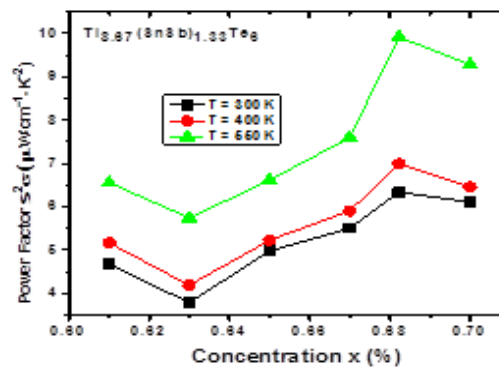


Fig. 11. Variation in trends of power factor at 300,400 and 550 K.

Table 4. The increment of the power factor Power Factor $s^2\sigma$ ($\mu W \cdot cm^{-1} \cdot K^{-2}$) by various dopant Agents.

Sample	Power Factor $s^2\sigma Wcm^{-1}K^{-1}$ at 300K	Power Factor $s^2\sigma Wcm^{-1}K^{-1}$ at 400 K	Power Factor $s^2\sigma Wcm^{-1}K^{-1}$ at 550 K
$Tl_{8.67}Sn_{0.61}Sb_{1.33-0.61}Te_6$	4.67×10^6	5.16×10^6	6.85×10^6
$Tl_{8.67}Sn_{0.63}Sb_{1.33-0.63}Te_6$	3.78×10^6	4.18×10^6	5.73×10^6
$Tl_{8.67}Sn_{0.65}Sb_{1.33-0.65}Te_6$	4.98×10^6	5.22×10^6	6.41×10^6
$Tl_{8.67}Sn_{0.67}Sb_{1.33-0.67}Te_6$	6.43×10^6	7.00×10^6	9.59×10^6
$Tl_{8.67}Sn_{0.68}Sb_{1.33-0.68}Te_6$	5.53×10^6	6.99×10^6	9.61×10^6
$Tl_{8.67}Sn_{0.70}Sb_{1.33-0.70}Te_6$	5.10×10^6	6.46×10^6	9.27×10^6

4. Conclusions

In this paper we studied the effect on physical properties of Sn doped $Tl_{8.67}Sn_xSb_{1.33-x}Te_6$ nano compound of various concentration i.e. ($x = 0.61, 0.63, 0.65, 0.67, 0.68$ and 0.70). The XRD study showed that the nano compound is single phase of tetragonal structure with no impurities and have equal space group $14/m\bar{c}m$ with that of Tl_5Te_3 . The electrical and thermo electrical properties of the nano compounds were gently observed and noticed a lot of changes with the concentration of Sn. It was also noticed that the see beck co efficient decreased with thwe high concentration of Sn= 0.65 which was probably due to higher scattering of electrons in the nano system, while the electrical conductivity of the compound increased with the concentration of Sn. When the concentration of Sn=0.65 is increased beyond this value there occur a tremendous change in the power factor of the nano system. We have made an investigation to study the optimization of Sn dopant concentration to along with desired thermoelectric characteristics of $Tl_{8.67}Sn_xSb_{1.33-x}Te_6$ chalcogenides nano compounds. It was concluded by doping of Sn with various ratio a tremendous changes occur in the power factor (PF) of the thermo electric nano materials.

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