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STUDY OF THE EFFECT OF TEMPERATURE ON THE ELECTRONIC CONDUCTIVITY OF SILICON AND GALLIUM ARSENIDE: COMPUTATIONAL APPROACH

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Abstract

This work explains the effect of temperature on the electronic conductivity of silicon and gallium arsenide. The equation from where the graphs were simulated was derived based on simple principle of Ohm's law and from where the graphs of variation of conductivity with temperatures were computed and analyzed. Also comparative analysis of the variation of electronic conductivity in both silicon with narrow band gap and that of gallium arsenide with wide band gap is carried out in order to examine the effect of this on the two materials.

Keywords; Computation, Conductivity, Temperature, Silicon, Gallium Arsenide, Ohm's law, variation,

1. Introduction

The study of temperature effect on material has revealed that temperature has effect on the conductivity of virtually all materials in all their states because it moderates the electronic motion and lattice vibration of crystal structure that play dominant rule in electrical conduction in any material. However, the real picture of conduction mechanism some of the material especially metals, semiconductor material, is different from the picture as presented in the classical concept [1]. In a semiconductor both mobility and carrier concentration are temperature dependent.[2]This is the reason why it is a common norm that temperature alters the Fermi level of both n-type and p-type of pure and novel semiconductor material [3] and thereby influencing the overall functionality of the materials[4,1] coupled with the fact that semiconductor is characterized by the activation current carriers either intrinsically or from impurity or both which is an exponential function of temperature. As a result of this, lattice scattering becomes prominent which reduces the mobility of the charge carriers in semiconductor as the temperature increases thereby having explicitly overall effect on the functionality of semiconductor material in all forms [5]. The wide application of Gallium Arsenide and Silicon semiconducting materials in the numerous technological applications such as in the development of nanoparticles [6, 7] and micromaterial had led to veracious study of the various properties of these materials. And again based on the fact that the materials could also be manipulated to suit so many applications some researchers are now engaged in such manipulation [8]. For instance such modification of the surface of semiconductors by laser pulses which has aroused special interest in bio -information technologies [9] that has led invariably for the special interest in the study of the properties of these semiconductor materials in order ascertain which one withstands higher temperature with less effect on the conductivity because some of the equipment made from these materials are operated at different temperature in different places around the Globe and there led us to carry out theoretical examination on the influence of temperature on electrical conductivity of these materials in question.[10,11].

2. Theoretical Derivation

Current flow in semiconductor is by means of electron current I_n and hole current I_p and this means that the net current flowing in the system is given as;

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$$I = I_n + I_p \tag{1}$$

Recall that current $I = neVA$

This implies that $I_n = neV_nA$ and $I_p = peV_pA$, the total current according to equation (1) becomes

$$I = neV_nA + peV_pA \tag{2}$$

Considering the a relationship existing between drift velocity V and electric field E where we have that $V \alpha E$

$\Rightarrow V = \mu E$ where μ is the charge carrier mobility

$\therefore V_n = \mu_n E$ and $V_p = \mu_p E$. Substituting the last terms in Equation (2), we obtain

$I = ne\mu_n EA + pe\mu_p EA$, that can be factorize to be

$$I = eA(n\mu_n + p\mu_p)E \tag{3}$$

Recalling that an applied electric field E is defined as the applied voltage per unit length i.e. $E = \frac{V}{l}$, we have

$$I = eA(n\mu_n + p\mu_p)\frac{V}{l} \tag{4}$$

From Ohm's law,

$$R = \frac{V}{I} \tag{5}$$

Substituting I into Equation (5), we have;

$$R = \frac{V}{eA(n\mu_n + p\mu_p)\frac{V}{l}}$$

$$\therefore R = \frac{l}{eA(n\mu_n + p\mu_p)} = \frac{l}{A} \bullet \frac{1}{(n\mu_n + p\mu_p)e} \tag{6}$$

Following the relationship between resistance and conductivity

$$R = \frac{l}{A} \bullet \rho \tag{7}$$

Comparing Equations (6) and (7), we have: $\rho = \frac{1}{(n\mu_n + p\mu_p)e}$ where ρ is resistivity of the material.

$\rho = \frac{1}{\sigma}$. This implies that $\sigma = (n\mu_n + p\mu_p)e$ (8)

Equation (8) represents the conductivity of a semiconductor. But the electron concentration, n is given as;

$$n = N_c \exp - \left[\frac{E_c - E_f}{KT}\right] \tag{9}$$

The electron conductivity in a semiconductor is given as;

$$\sigma_n = q\mu_n n$$

Substituting the relation in Equation (9), we have;

$$\sigma_n = q\mu_n N_c \exp - \frac{(E_c - E_f)}{KT} \tag{10}$$

Taking the log of both sides of the last equation, we obtain;

$$\ln \sigma_n - \ln q + \ln \mu_n + \ln N_c - \left[(E_c - E_f)/kT\right] \tag{11}$$

For hole conductivity we have;

$$\sigma_n = q\mu_p p \tag{12}$$

But the hole concentration P is given as:

$$P = N_v exp - \frac{(E_f - E_v)}{KT} \qquad (13)$$

Using the last equation in (12) we obtain

$$\sigma_n = q\mu_p N_v exp - \frac{(E_f - E_v)}{KT} \qquad (14)$$

$$\ln \sigma_p = inq + \ln \mu_p + \ln N_v - \frac{(E_f - E_v)}{kT} \qquad (15)$$

By definition the total conductivity is given by

$$\sigma = \sigma_n + \sigma_p$$

$$\alpha = \left[\ln q + \ln \mu_n + \ln N_c - \frac{E_c - E_f}{kT} \right] + \left[\ln q + \ln \mu_p \ln N_v - \frac{E_f - E_v}{kT} \right] \qquad (16)$$

Equation (16) depicts the total conductivity of a semiconductor.

3. Result/Discussion

The mathematical expression explaining the total conductivity of a semiconductor is given in equation (16). From this equation, conductivity was plotted against temperature for both silicon and gallium arsenide. From the graphs and the computed values, it is observed that the conductivity of silicon is maximum at the temperature, 30 K and minimum at 50K from where it increased again gradually reaching 500K. On the other hands, the computed values of the conductivity of the gallium Arsenide is negative, its own increment appears asymptotic with temperature. These results indicate that the temperature of these material has no pattern at which it varies with conductivity in accordance with [1,4] From the study as in [3,8], what has a prominent relation with temperature in the operation of these materials is their impurity levels which affects the electrons/the hole that are the charger carriers.

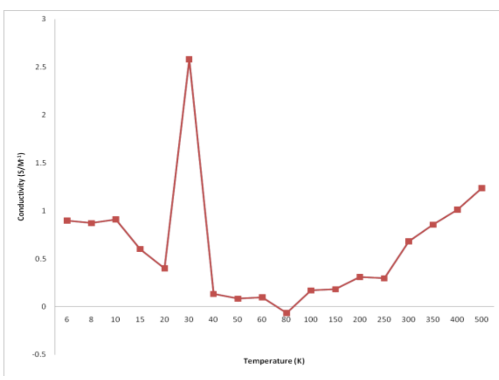

Fig. 1 Graph of conductivity against temperature for silicon for N_d = 4 x 10^{13}

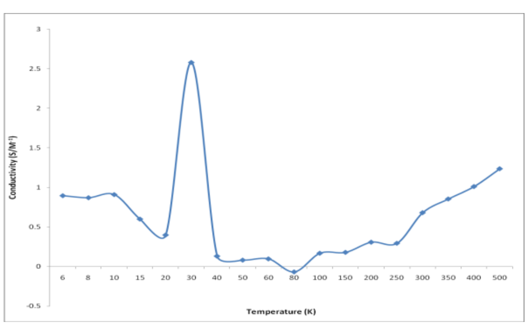

Fig. 2Graph of conductivity against temperature for silicon for N_d =4 x 10^{14}

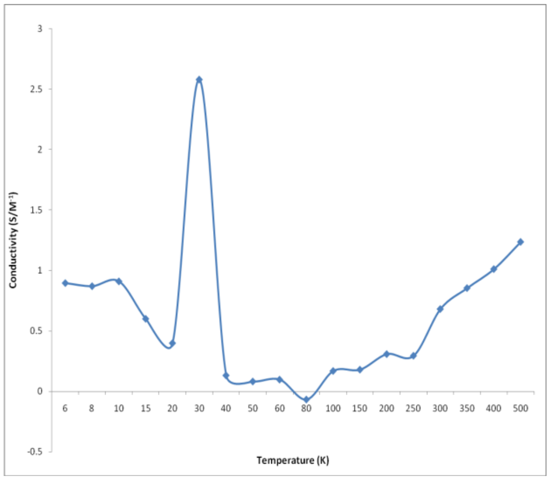

Fig. 3 Graph of conductivity against temperature for silicon for N_d =4 x 10^{15}

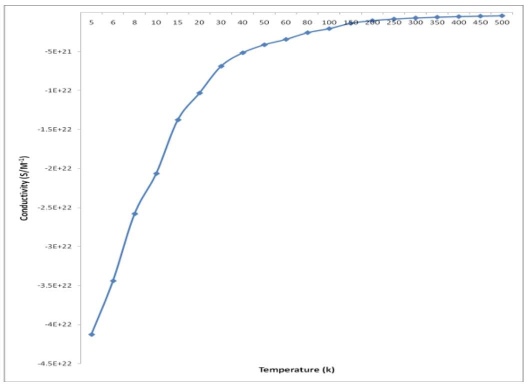

Fig. 4 graph of conductivity against temperature for gallium arsenide for $N_{d\,=}$ 10^{17}

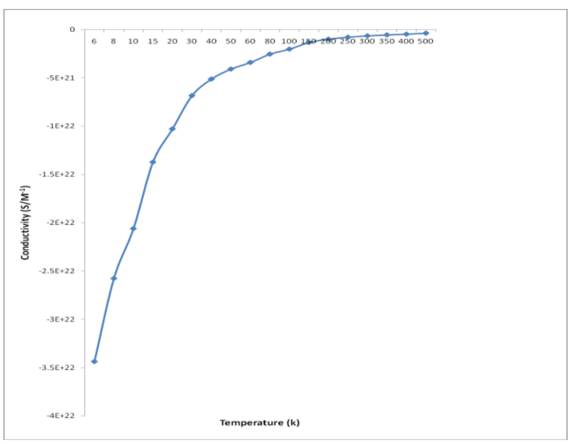

Fig. 5 graph of conductivity against temperature for gallium arsenide for N_d = 10^{15}

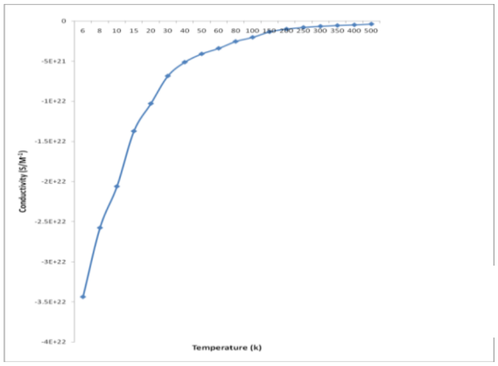

Fig. 6 graph of variation of conductivity with temperature for gallium arsenide for $N_d = 10^{15}$

Table 1; Computed values of conductivity of Silicon from equation (16) when $N_d = 10^{13}$

T(K)	Inq	lnµm	lnNc	lnNv	k	$\frac{E_c - E_f}{KT}$	(A)Dimension parameter of Garliun Arsenide	(B)Dimensional parameter of Silicon	σ
5	10.40789	10.95151	5.44E+01	5.51E+01	1.38E-23	6.90E-23	-3.28E+03	-3.27E+03	3.27E+03
6	10.67367	11.21721	5.44E+01	5.51E+01	.38E-23	8.28E-23	-2.73E+03	-2.72E+03	2.72E+03
8	10.89674	11.44035	5.44E+01	5.51E+01	1.38E-23	1.10E-22	-2.04E+03	-2.04E+03	2.04E+03
10	11.0219	11.56552	5.44E+01	5.51E+01	1.38E-23	1.38E-22	-1.63E+03	-1.63E+03	1.63E+03
15	11.1591	11.70272	5.44E+01	5.51E+01	1.38E-23	2.07E-22	-1.08E+03	-1.08E+03	1.08E+03
20	11.27973	11.82335	5.44E+01	5.51E+01	1.38E-23	2.76E-22	-8.02E+02	-8.01E+02	8.01E+02
30	11.36674	11.91036	5.44E+01	5.51E+01	1.38E-23	4.14E-22	-5.27E+02	-5.26E+02	5.26E+02
40	11.31252	11.93098	5.44E+01	5.51E+01	1.38E-23	5.52E-22	-3.90E+02	-3.89E+02	3.89E+02
50	11.34569	11.92689	5.44E+01	5.51E+01	1.38E-23	6.90E-22	-3.07E+02	-3.07E+02	3.07E+02
60	11.34805	11.8893	5.44E+01	5.51E+01	1.38E-23	8.28E-22	-2.52E+02	-2.52E+02	2.52E+02
80	10.47107	11.62268	5.44E+01	5.51E+01	1.38E-23	1.10E-21	-1.84E+02	-1.83E+02	1.83E+02
100	9.441452	11.01469	5.44E+01	5.51E+01	1.38E-23	1.38E-21	-1.43E+02	-1.43E+02	1.43E+02
150	8.594154	9.985068	5.44E+01	5.51E+01	1.38E-23	2.07E-21	-8.93E+01	-8.86E+01	8.86E+01
200	8.188689	9.13777	5.44E+01	5.51E+01	1.38E-23	2.76E-21	-6.27E+01	-6.20E+01	6.20E+01
250	7.927324	8.732305	5.44E+01	5.51E+01	1.38E-23	3.45E-21	-4.66E+01	-4.59E+01	4.59E+01
300	7.608871	8.47094	5.44E+01	5.51E+01	1.38E-23	4.14E-21	-3.59E+01	-3.52E+01	3.52E+01
350	7.367709	8.152486	5.44E+01	5.51E+01	1.38E-23	4.83E-21	-2.84E+01	-2.76E+01	2.76E+01
400	7.138867	7.977282	5.44E+01	5.51E+01	1.38E-23	5.52E-21	-2.26E+01	-2.19E+01	2.19E+01

Table 2;Computed values of conductivity of Silicon when $N_d = 10^{13}$

T(K)	Inq	lnµn	lnNc	lnNv	K	E_c-E_f KT	A	B	Σ
5	10.40789	10.95151	5.44E+01	5.51E+01	1.38E-23	6.90E-23	-3460.91	-6921.82	3460.91
6	10.67367	11.21721	5.44E+01	5.51E+01	1.38E-23	8.28E-23	-2880.14	-5760.29	2880.144
8	10.89674	11.44035	5.44E+01	5.51E+01	1.38E-23	1.10E-22	-2154.3	-4308.59	2154.296
10	11.0219	11.56552	5.44E+01	5.51E+01	1.38E-23	1.38E-22	-1718.8	-3437.59	1718.796
15	11.1591	11.70272	5.44E+01	5.51E+01	1.38E-23	2.07E-22	-1138.16	-2276.32	1138.158
20	11.27973	11.82335	5.44E+01	5.51E+01	1.38E-23	2.76E-22	-847.788	-1695.58	847.7877
30	11.36674	11.91036	5.44E+01	5.51E+01	1.38E-23	4.14E-22	-557.451	-1114.9	557.4507
40	11.31252	11.93098	5.44E+01	5.51E+01	1.38E-23	5.52E-22	-412.305	-824.61	412.3051
50	11.34569	11.92689	5.44E+01	5.51E+01	1.38E-23	6.90E-22	-325.234	-650.468	325.2342
60	11.34805	11.8893	5.44E+01	5.51E+01	1.38E-23	8.28E-22	-267.222	-534.443	267.2217
80	10.47107	11.62268	5.44E+01	5.51E+01	1.38E-23	1.10E-21	-194.926	-389.852	194.9259
100	9.441452	11.01469	5.44E+01	5.51E+01	1.38E-23	1.38E-21	-151.996	-303.993	151.9964
150	8.594154	9.985068	5.44E+01	5.51E+01	1.38E-23	2.07E-21	-94.976	-189.952	94.97597
200	8.188689	9.13777	5.44E+01	5.51E+01	1.38E-23	2.76E-21	-66.7983	-133.597	66.79827
250	7.927324	8.732305	5.44E+01	5.51E+01	1.38E-23	3.45E-21	-49.7887	-99.5775	49.78874
300	7.608871	8.47094	5.44E+01	5.51E+01	1.38E-23	4.14E-21	-38.4401	-76.8802	38.4401
350	7.367709	8.152486	5.44E+01	5.51E+01	1.38E-23	4.83E-21	-30.4657	-60.9314	30.4657
400	7.138867	7.977282	5.44E+01	5.51E+01	1.38E-23	5.52E-21	-24.4213	-48.8425	24.42126

Table 3; Computed values of conductivity of Silicon from equation (16) when $N_d = 10^{14}$

T(K)	Inq	lnμn	lnNc	lnNv	k	$\frac{E_c-E_f}{KT}$	A	B	
5	10.40789	10.95151	5.44E+01	5.51E+01	1.38E-23	6.90E-23	-3.93E+03	-7.85E+03	7.85E+03
6	10.67367	11.21721	5.44E+01	5.51E+01	1.38E-23	8.28E-23	-3.27E+03	-6.53E+03	6.53E+03
8	10.89674	11.44035	5.44E+01	5.51E+01	1.38E-23	1.10E-22	-2.44E+03	-4.89E+03	4.89E+03
10	11.0219	11.56552	5.44E+01	5.51E+01	1.38E-23	1.38E-22	-1.95E+03	-3.90E+03	3.90E+03
15	11.1591	11.70272	5.44E+01	5.51E+01	1.38E-23	2.07E-22	-1.29E+03	-2.59E+03	2.59E+03
20	11.27973	11.82335	5.44E+01	5.51E+01	1.38E-23	2.76E-22	-9.64E+02	-1.93E+03	1.93E+03
30	11.36674	11.91036	5.44E+01	5.51E+01	1.38E-23	4.14E-22	-6.35E+02	-1.27E+03	1.27E+03
40	11.31252	11.93098	5.44E+01	5.51E+01	1.38E-23	5.52E-22	-4.70E+02	-9.41E+02	9.41E+02
50	11.34569	11.92689	5.44E+01	5.51E+01	1.38E-23	6.90E-22	-3.72E+02	-7.43E+02	7.43E+02
60	11.34805	11.8893	5.44E+01	5.51E+01	1.38E-23	8.28E-22	-3.06E+02	-6.12E+02	6.12E+02
80	10.47107	11.62268	5.44E+01	5.51E+01	1.38E-23	1.10E-21	-2.24E+02	-4.47E+02	4.47E+02
100	9.441452	11.01469	5.44E+01	5.51E+01	1.38E-23	1.38E-21	-1.75E+02	-3.50E+02	3.50E+02
150	8.594154	9.985068	5.44E+01	5.51E+01	1.38E-23	2.07E-21	-1.10E+02	-2.21E+02	2.21E+02
200	8.188689	9.13777	5.44E+01	5.51E+01	1.38E-23	2.76E-21	-7.84E+01	-1.57E+02	1.57E+02
250	7.927324	8.732305	5.44E+01	5.51E+01	1.38E-23	3.45E-21	-5.91E+01	-1.18E+02	1.18E+02
300	7.608871	8.47094	5.44E+01	5.51E+01	1.38E-23	4.14E-21	-4.62E+01	-9.22E+01	9.22E+01
350	7.367709	8.152486	5.44E+01	5.51E+01	1.38E-23	4.83E-21	-3.71E+01	-7.40E+01	7.40E+01
400	7.138867	7.977282	5.44E+01	5.51E+01	1.38E-23	5.52E-21	-3.02E+01	-6.03E+01	6.03E+01

Table4 ;Computed values of conductivity of Silicon when $N_d = 10^{13}$

T(K)	Inq	lnμn	lnNc	lnNv	k	$\frac{E_c-E_f}{KT}$	A	B	σ
5	10.40789	10.95151	5.44E+01	5.51E+01	1.38E-23	2.13E+03	-2.10E+03	-4.20E+03	8.96E-01
6	10.67367	11.21721	5.44E+01	5.51E+01	1.38E-23	1.60E+03	-1.57E+03	-3.14E+03	8.71E-01
8	10.89674	11.44035	5.44E+01	5.51E+01	1.38E-23	1.28E+03	-1.25E+03	-2.50E+03	9.10E-01
10	11.0219	11.56552	5.44E+01	5.51E+01	1.38E-23	8.51E+02	-8.24E+02	-1.65E+03	6.01E-01
15	11.1591	11.70272	5.44E+01	5.51E+01	1.38E-23	6.38E+02	-6.12E+02	-1.22E+03	3.99E-01
20	11.27973	11.82335	5.44E+01	5.51E+01	1.38E-23	4.26E+02	-4.00E+02	-8.02E+02	2.58E+00
30	11.36674	11.91036	5.44E+01	5.51E+01	1.38E-23	3.19E+02	-2.94E+02	-5.88E+02	1.33E-01
40	11.31252	11.93098	5.44E+01	5.51E+01	1.38E-23	2.55E+02	-2.30E+02	-4.61E+02	8.23E-02
50	11.34569	11.92689	5.44E+01	5.51E+01	1.38E-23	2.13E+02	-1.88E+02	-3.76E+02	9.78E-02
60	11.34805	11.8893	5.44E+01	5.51E+01	1.38E-23	1.60E+02	-1.35E+02	-2.70E+02	-6.70E-02
80	10.47107	11.62268	5.44E+01	5.51E+01	1.38E-23	1.28E+02	-1.04E+02	-2.07E+02	1.69E-01
100	9.441452	11.01469	5.44E+01	5.51E+01	1.38E-23	8.51E+01	-6.17E+01	-1.24E+02	1.80E-01
150	8.594154	9.985068	5.44E+01	5.51E+01	1.38E-23	6.38E+01	-4.08E+01	-8.19E+01	3.09E-01
200	8.188689	9.13777	5.44E+01	5.51E+01	1.38E-23	5.11E+01	-2.84E+01	-5.70E+01	2.95E-01
250	7.927324	8.732305	5.44E+01	5.51E+01	1.38E-23	4.26E+01	-2.01E+01	-4.10E+01	6.82E-01
300	7.608871	8.47094	5.44E+01	5.51E+01	1.38E-23	3.65E+01	-1.43E+01	-2.94E+01	8.55E-01
350	7.367709	8.152486	5.44E+01	5.51E+01	1.38E-23	3.19E+01	-9.93E+00	-2.09E+01	1.01E+00
400	7.138867	7.977282	5.44E+01	5.51E+01	1.38E-23	2.55E+01	-3.88E+00	-8.99E+00	1.24E+00

Table5;Computed values of conductivity of Silicon when $N_d = 10^{14}$

T(K)	Inq	lnμn	lnNc	lnNv	k	E_c-E_f KT	A	B	σ
5	10.40789	10.95151	5.44E+01	5.51E+01	1.38E-23	6.90E-23	-3.28E+03	2.90E+03	-2.88E+03
6	10.67367	11.21721	5.44E+01	5.51E+01	1.38E-23	8.28E-23	-2.73E+03	2.18E+03	-2.15E+03
8	10.89674	11.44035	5.44E+01	5.51E+01	1.38E-23	1.10E-22	-2.04E+03	1.74E+03	-1.72E+03
10	11.0219	11.56552	5.44E+01	5.51E+01	1.38E-23	1.38E-22	-1.63E+03	1.16E+03	-1.13E+03
15	11.1591	11.70272	5.44E+01	5.51E+01	1.38E-23	2.07E-22	-1.08E+03	8.71E+02	-8.45E+02
20	11.27973	11.82335	5.44E+01	5.51E+01	1.38E-23	2.76E-22	-8.02E+02	5.80E+02	-5.57E+02
30	11.36674	11.91036	5.44E+01	5.51E+01	1.38E-23	4.14E-22	-5.27E+02	4.35E+02	-4.10E+02
40	11.31252	11.93098	5.44E+01	5.51E+01	1.38E-23	5.52E-22	-3.90E+02	3.48E+02	-3.23E+02
50	11.34569	11.92689	5.44E+01	5.51E+01	1.38E-23	6.90E-22	-3.07E+02	2.90E+02	-2.65E+02
60	11.34805	11.8893	5.44E+01	5.51E+01	1.38E-23	8.28E-22	-2.52E+02	2.18E+02	-1.93E+02
80	10.47107	11.62268	5.44E+01	5.51E+01	1.38E-23	1.10E-21	-1.84E+02	1.74E+02	-1.50E+02
100	9.441452	11.01469	5.44E+01	5.51E+01	1.38E-23	1.38E-21	-1.43E+02	1.16E+02	-9.28E+01
150	8.594154	9.985068	5.44E+01	5.51E+01	1.38E-23	2.07E-21	-8.93E+01	8.71E+01	-6.43E+01
200	8.188689	9.13777	5.44E+01	5.51E+01	1.38E-23	2.76E-21	-6.27E+01	6.97E+01	-4.72E+01
250	7.927324	8.732305	5.44E+01	5.51E+01	1.38E-23	3.45E-21	-4.66E+01	5.80E+01	-3.63E+01
300	7.608871	8.47094	5.44E+01	5.51E+01	1.38E-23	4.14E-21	-3.59E+01	4.98E+01	-2.84E+01
350	7.367709	8.152486	5.44E+01	5.51E+01	1.38E-23	4.83E-21	-2.84E+01	4.35E+01	-2.25E+01
400	7.138867	7.977282	5.44E+01	5.51E+01	1.38E-23	5.52E-21	-2.26E+01	3.48E+01	-1.44E+01

Table6;Computed values of conductivity of Silicon when $N_d = 10^{15}$

T(K)	Inq	lnμn	lnNc	lnNv	K	E_c-E_f KT	A	B	σ
5	10.40789	10.95151	5.44E+01	5.51E+01	2.27E-19	6.90E-23	-3.28E+03	-3.27E+03	3.27E+03
6	10.67367	11.21721	5.44E+01	5.51E+01	2.27E-19	8.28E-23	-2.73E+03	-2.72E+03	2.72E+03
8	10.89674	11.44035	5.44E+01	5.51E+01	2.27E-19	1.10E-22	-2.04E+03	-2.04E+03	2.04E+03
10	11.0219	11.56552	5.44E+01	5.51E+01	2.27E-19	1.38E-22	-1.63E+03	-1.63E+03	1.63E+03
15	11.1591	11.70272	5.44E+01	5.51E+01	2.27E-19	2.07E-22	-1.08E+03	-1.08E+03	1.08E+03
20	11.27973	11.82335	5.44E+01	5.51E+01	2.27E-19	2.76E-22	-8.02E+02	-8.01E+02	8.01E+02
30	11.36674	11.91036	5.44E+01	5.51E+01	2.27E-19	4.14E-22	-5.27E+02	-5.26E+02	5.26E+02
40	11.31252	11.93098	5.44E+01	5.51E+01	2.27E-19	5.52E-22	-3.90E+02	-3.89E+02	3.89E+02
50	11.34569	11.92689	5.44E+01	5.51E+01	2.27E-19	6.90E-22	-3.07E+02	-3.07E+02	3.07E+02
60	11.34805	11.8893	5.44E+01	5.51E+01	2.27E-19	8.28E-22	-2.52E+02	-2.52E+02	2.52E+02
80	10.47107	11.62268	5.44E+01	5.51E+01	2.27E-19	1.10E-21	-1.84E+02	-1.83E+02	1.83E+02
100	9.441452	11.01469	5.44E+01	5.51E+01	2.27E-19	1.38E-21	-1.43E+02	-1.43E+02	1.43E+02
150	8.594154	9.985068	5.44E+01	5.51E+01	2.27E-19	2.07E-21	-8.93E+01	-8.86E+01	8.86E+01
200	8.188689	9.13777	5.44E+01	5.51E+01	2.27E-19	2.76E-21	-6.27E+01	-6.20E+01	6.20E+01
250	7.927324	8.732305	5.44E+01	5.51E+01	2.27E-19	3.45E-21	-4.66E+01	-4.59E+01	4.59E+01
300	7.608871	8.47094	5.44E+01	5.51E+01	2.27E-19	4.14E-21	-3.59E+01	-3.52E+01	3.52E+01
350	7.367709	8.152486	5.44E+01	5.51E+01	2.27E-19	4.83E-21	-2.84E+01	-2.76E+01	2.76E+01
400	7.138867	7.977282	5.44E+01	5.51E+01	2.27E-19	5.52E-21	-2.26E+01	-2.19E+01	2.19E+01

4. CONCLUSION

From this work, we have observed from the results that the conductivity of Gallium Arsenide is negative which varies asymptotically with temperature while that of silicon has a high conductivity at certain temperature and low conductivity at some other temperature. Invariably, it is generally noticed that the conductivity of these materials do not have a definite pattern with which they vividly vary with temperature and thus no notice of dependence of conductivity on temperature variation could be specifically identified.

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