M. Khalili, H. Arabshahi, M. H. Tayarani and M. Bazrafshan / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 4, Jul-Aug 2013, pp.1636-1639

Comparison of Electron Mobility in Zno and Sic Semiconductors at Low Field by Solving Boltzmann Equation

[1]M. Khalili, [2]H. Arabshahi, [1]M. H. Tayarani and [1]M. Bazrafshan
[1]Physics Department, Higher Education of Khayyam, Mashhad,Iran
[2]Physics Department, Payam Noor University, Tehran, Iran

Abstract

In this article the electron mobility's in ZnO and SiC Semiconductors are calculated by solving Boltzmann equation using iteration model. The electron mobility is calculated as a function of temperature and ionized impurity in the ranges of 100k to 600k and $10^{16}$to 10^{18}cm^{-3}. The theoretical maximum motilities in ZnO, SiC at 300k are about275 and 7.35 cm^2.v^{-1}s^{-1}. We compare the results with experimental data and find reasonable correlation.

Keywords-*:* *Electron mobility; ZnO and SiC; Iteration Model.*

I. INTRODUCTION

Sic has a wide band gap of 3.2 eV and thus it is an applied semiconductors in the fabrication of electronic and photo electronic devices such as lasers and detectors which work in the range of Infrared spectrum . It is also useful in construction of transistors. There has been a great interest in the study of charge carrier transport of ZnO due to the wide band gap of 3.43 eV. Therefore Zink Oxide has become one of the most applied semiconductors in Light Emitting Diode (LED), Liquid crystal Detector (LCD) and Solar cells. The low -field electron mobility is one of the most important parameters that determine the performance of the field-effect transistor. The purpose of the present paper is to calculate electron mobility for various temperatures and ionized -impurity concentrations. The formulation itself applies only to the center of Γ valley conduction band. We have also considered band non-parabolicity and screening effects of free carriers on the scattering probabilities. All the relevant scattering mechanisms, including polar optic phonons, deformation potential, piezoelectric, acoustic phonons and ionized impurity Scattering The Boltzmann equation is solved iteratively for our purpose, jointly incorporating the effects of all the scattering mechanisms. This paper is organized as follows : Details of the iterative model of Boltzmann equation is presented in section II and the results of iterative calculations carried out on ZnO and SiC structures are interpreted in section III.

II. MODEL DETAILS

To calculate mobility, we have to solve Boltzmann equation to get the modified probability distribution function under the action of a steady electric field. Here we have adopted the iterative technique for solving the Boltzmann transport equation. Under the action of steady field, the Boltzmann equation for the distribution function can be written as

$$\frac{\delta f}{\delta t} + v.\nabla_r f + \frac{eF}{\hbar}.\nabla_k f = \left(\frac{\delta f}{\delta t}\right)_{coll} \qquad (1)$$

Where $\left(\frac{\delta f}{\delta t}\right)_{coll}$ represents the change f distribution function due to the electron scattering. In the steady-state and under application of uniform electric field the Boltzmann equation can be written as

$$\frac{e\vec{F}}{\hbar}.\vec{\nabla}_k f = \left(\frac{\delta f}{\delta t}\right)_{coll} \qquad (2)$$

Consider electrons in an isotropic, non-parabolic conduction band whose equilibrium Fermi distribution function is f_0 (k) in the absence of electric field. Note the equilibrium distribution f_0 (k) is isotropic in k space but is perturbed when an electric field is applied. If the electric field is small, we can treat the change from the equilibrium distribution function as a perturbation which is first order in the electric field. The distribution in the presence of a sufficiently small field can be written quite generally as

$$f(k) = f_0(k) + g(k)\cos(\theta) \qquad (3)$$

Whereθ is the angle between k and F and g(k) is an isotropic function of k, which is proportional to the magnitude of the electric field f(k) satisfies the Boltzmann equation 2 and it follows that :

$$\frac{eF\cos\theta}{\hbar}\frac{\delta f_0}{\delta k} = \int g'[S'_i(1-f_0) + S_i f_0]\cos\varphi\, d^3k - g\int[S_i(1-f'_0) + S'_i f'_0]d^3k' \qquad (4)$$

In general there will be both elastic and inelastic scattering proses. For example impurity scattering is elastic and acoustic and piezoelectric scattering are elastic to a good approximation at room temperature. However, polar and nonpolar optical phonon scattering are inelastic. Labeling the elastic and inelastic scattering rates with subscripts el and inlet respectively and recognizing that , for any process its$_{eli(}$k,k$^{'}$)=s$_{eli(}$k' ,k') equation 4 can be written as

$$g(k) = \frac{\frac{-eF}{\hbar}\frac{\delta f_0}{\delta k}\int \cos\varphi\, g'(k)[S'_{inel}(1-f_0)+S_{inel}f_0]d^3k'}{\int(1-\cos\varphi)S_{el}d^3k' + \int[S_{inel}(1+f'_0)+S'_{inel}f'_0]d^3k'} \qquad (5)$$

Note the first term in the denominator is simply the momentum relaxation rate for elastic scattering , equation 5 may be solved iteratively by the relation

$$g(k)[n] = \frac{\frac{-eF}{\hbar}\frac{\delta f_0}{\delta k}\int \cos\varphi\, g'(k)[n-1][S'_{inel}(1-f_0)+S_{inel}f_0]d^3k'}{\int(1-\cos\varphi)S_{el}\,d^3k'+\int[S_{inel}(1+f'_0)+S'_{inel}f'_0]d^3k'} \quad (6)$$

Where $g(k)[n]$ is the perturbation to the distribution function after the nth iteration. it is interesting to note that if the initial distribution is chosen to be the equilibrium distribution, for which $g(k)$ is equal to zero, we get the relaxation time approximation result after the first iteration. We have found that convergence can normally be achieved after only a few iterations for small electric fields. Once $g(k)$ has be evaluated to the required accuracy, it is possible to calculate quantities such as the drift mobility μ_e which is given in terms of spherical coordinates by

$$\mu_e = \frac{\hbar}{3m^*F}\frac{\int_0^\infty \left(k^3/1+2\alpha\varepsilon\right)g(k)dk}{3\int_0^\infty k^2 f_0 dk} \quad (7)$$

III. RESULTS

All structural and electrical parameters used to calculate the electron mobility is given in table 1. Figures 1 and 2 show changes the electron mobility function in terms of temperature in bulk ZnO and SiC at the electron concentration $10^{16}(cm^{-3})$

	ZnO	SiC
Density (kgm^{-3})	5600	3200
Longitudinal sound velocity v_s (ms^{-1})	6400	1373
Low- frequency dielectric constant ε_s	8.2	9.7
High-frequency dielectric constant ε_∞	3.7	6.5
Acoustic deformation potential (ev)	14	15
Polar optical phonon energy (ev)	0.072	0.12
Γ - valley effective mass (m^*)	0.25	0.28
Γ -valley nonparabolicity (ev^{-1})	0.312	0.32

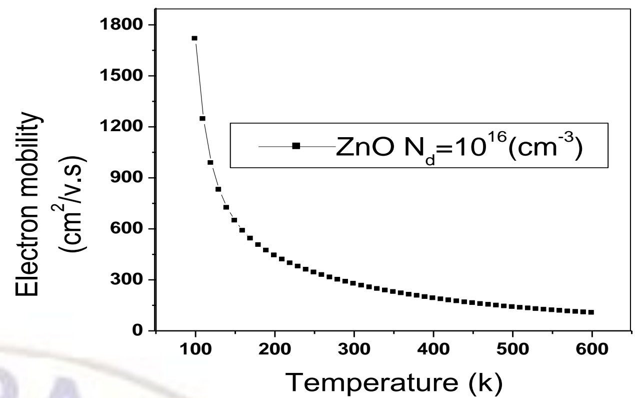

Fig 1. Changes the electron mobility function in terms of Temperature in bulk ZnO at the electron concentration

$10^{16}cm^{-3}$

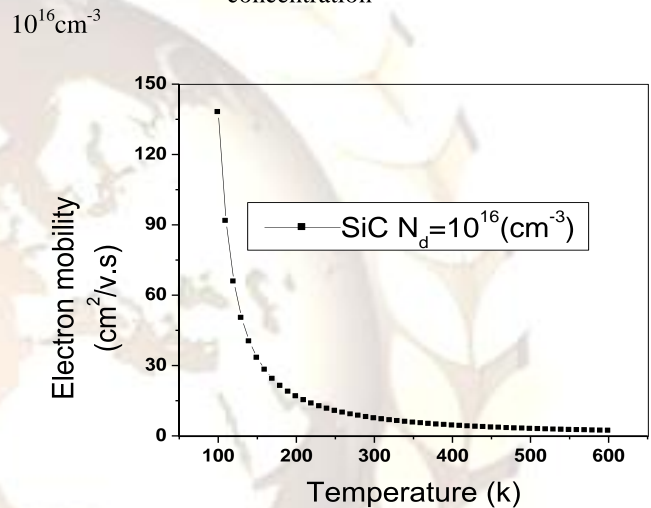

fig 2. Changes the electron mobility function in terms of Temperature in bulk SiC at the electron concentration $10^{16}cm^{-3}$

The electrons mobility decrease quickly by temperature increasing from 100 to 600k in bulk ZnO and SiC at the electron concentration of $10^{16}(cm^{-3})$.because temperature increasing causes increase of phonons energy too.so it causes a strong interaction between electrons and these phonons that its result is increase of electrons scattering rate and finally decrease of electrons mobility .

By comparing two figures 1 and 2 we can see that the electron mobility of ZnO is more than SiC. because increasing effective mass causes the decrease of acceleration and the time in which electrons are under the influence of impurity centers increase and as a result scattering would increase and mobility will decrease. Figures 3 and 4 show changes the electron mobility function in terms of electron concentration in bulks ZnO and SiC at temperature of 300k.

Figures 3 and 4 show that in both semiconductors ZnO and SiC mobility decrease by electrons

concentrations increasing because electrons increasing causes increase of ionized impurity centers in crystals that it causes electrons to be under the influence of the coulomb potential of these centers more frequently ,that its result is increase of electrons scattering rate and finally decrease of electrons mobility .

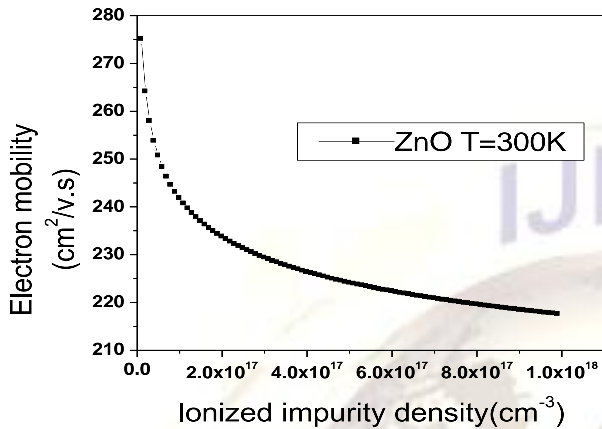

Fig 3. Changes the electron mobility function in terms of electron concentration in bulk ZnO and at temperature of 300k.

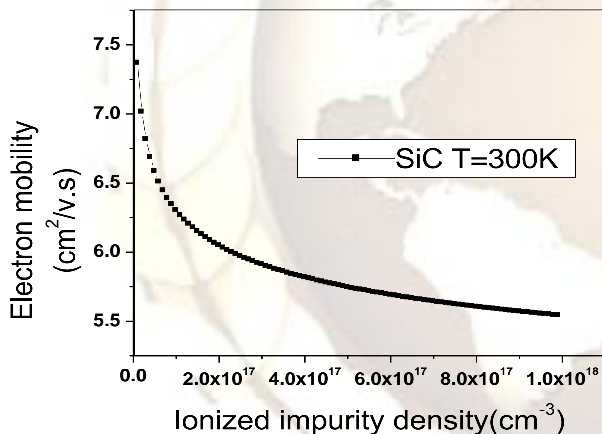

Fig 4. Changes the electron mobility function in terms of electron concentration in bulk SiC and at temperature of 300 K.

Figures 5 and 6 show changes the electron mobility function in terms of temperature in bulks ZnO and SiC at concentration of 10^{16}cm^{-3}, 10^{17}cm^{-3} , 10^{18}cm^{-3}. Figures 5 and 6 show that in both semiconductors ZnO and SiC mobility decrease by decrease by electrons concentration increasing from the rate of 10^{16}cm^{-3} to 10^{18}cm^{-3}.

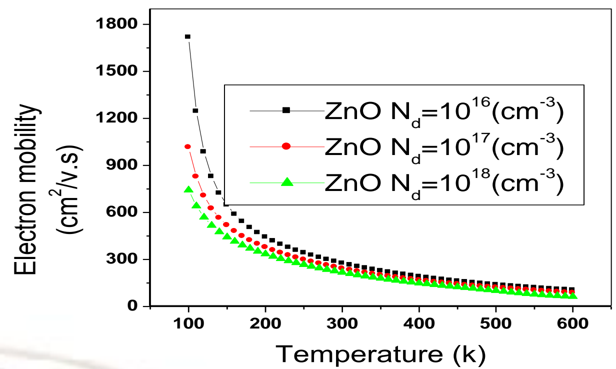

Fig 5. Changes the electron mobility function in terms of temperature in bulk ZnO at the different electron concentration.

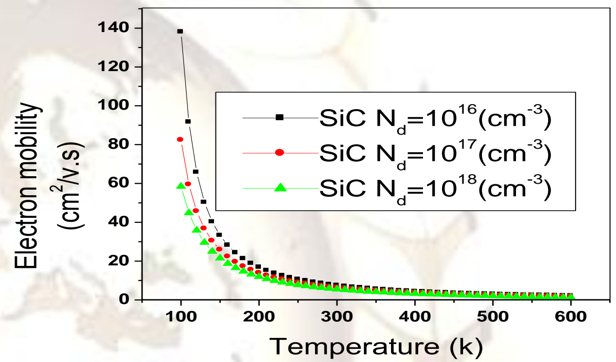

Fig 6. Changes the electron mobility function in terms of temperature in bulk SiC at the different electron concentration.

Figures 7 and 8 show changes the electron mobility function in terms of electron concentration in bulks ZnO and SiC in bulks ZnO and SiC at the different temperature (250k,300k,350k).
Figures 7 and 8 show that in both semiconductors ZnO and SiC mobility decrease by temperature increasing from 250k to 350k.

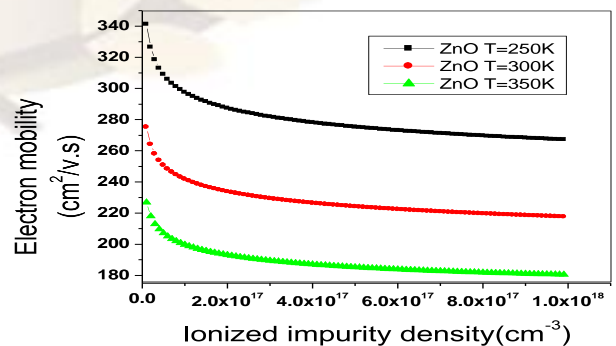

Fig 7. Changes the electron mobility function in terms of electron concentration in bulk ZnO at the different temperature.

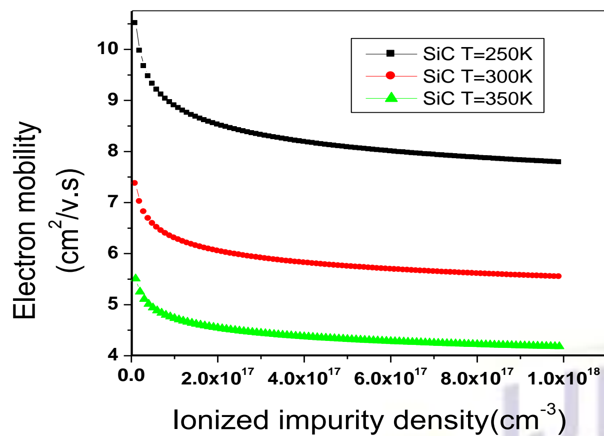

Fig 8. Changes the electron mobility function in terms of electron concentration in bulk SiC at the different temperature.

IV. CONCLUTION

Our calculation results show that the electron mobility decrease by electrons concentration increasing and the electron mobility decrease by temperature increasing .electron mobility ZnO more than SiC.

V. ACKNOWLEDGEMENT

I would like to thank A. Vatan-khahan and M. Ghafourian for their useful comments.

REFERENCES

[1] Vatan-khahan , M. H . Tayarani, , A.Saderemomtaz and H. Arabshahi, « Comparison of electron scattering mechanisims and electron mobility in AIN and GaN at low electric field application », Internatinal journal of scieence and Advanced Technology(ISSN 2221-8386),(july 2011),pp116-119.

[2] H. Arabshahi, A. Vatan- khahan and M. H. Tayarani ,"Comparision of low field electron transport properties in InN and GaN semiconductors by solving Boltzmann equation using iteration model",Internatonal journal of science and Advance Technology (ISSN 2221-8386),(2011),PP 6-11.

[3] H. Arabshahi , M. Reza Rokn –Abadi and F.Badieyan Bagh-siyahi,"Comparison of high field electron transport propertis in wurtzite phase of ZnO , GaN and SiC",Research journal of applied science5(3):215-220,2010

[4] H. Arabshahi,A. pashaei and M. H. Tayarani,"Comparison of low field electron transport propertiese in compounds of group sIII-V semiconductors by solving Boltzmann equation using iteration model", Internatinal journal of enigeering invention ,ISSN:2278-7461,(2012)PP:56-61