Plagiarism Checker X - Report

Originality Assessment

4%

Overall Similarity

Date: May 1, 2023
Matches: 79 / 2017 words
Sources: 9

Remarks: Low similarity detected, check with your supervisor if changes are required.

Verify Report:
Scan this QR Code

978-602-50431-1-6/17/$31.00 ©2017 IEEE 57 3 2017 15th Intl. Conf. QiR: Intl. Symp. Elec. and Com. Eng Effect of Ge Mole Fraction on Current, Voltage and Electric Field Characteristics of High Doping Nanoscale Si1-xGex/Si P-N Diode Anak Agung Ngurah Made Narottama Electrical Engineering Politeknik Negeri Bali Denpasar, Indonesia narottama@pnb.ac.id 8 Anak Agung Ngurah Gde Sapteka Electrical Engineering Politeknik Negeri Bali Denpasar, Indonesia sapteka@pnb.ac.id Abstract—In this paper, we report the simulation of high doping nanoscale heterojunction diode, particularly Si1-xGex/Si p-n diode, using Cogenda Visual TCAD. In order to gain knowledge on electrical properties of this diode, we exhaustively simulate the effect of Ge mole fraction in SiGe material on current, voltage and electric field characteristics. The simulation covers Ge mole fraction of 0.2 to 0.7 in SiGe material as acceptor and Si material as donor. Both acceptor and donor have concentrations of 1020 per cm3 and areas of 10 × 10 nm2. Under forward bias voltage, higher Ge mole fraction will produce higher current. This phenomenon happens due to lower energy band gap at higher Ge mole fraction condition. Besides that, higher Ge mole fraction has lower energy difference between P side and N side of diode. According to the simulation result, Si0.8Ge0.2 has energy band gap about 0.8 eV, meanwhile Si0.3Ge0.7 has energy band gap about 0.5 eV. Lower energy band gap causes more electrons have enough energy to cross the junction. Meanwhile under reverse bias voltage, high doping nanoscale diode will produce infinitesimal current. At the junction, high doping nanoscale Si1-xGex/Si P-N diode also has lower electric field (measured at the center of diode) at higher Ge mole fraction. Under reverse bias voltage of -2 V, Si0.3Ge0.7 has maximum electric field about 5.89 × 106 V/m, meanwhile Si0.8Ge0.2 has maximum electric field about 6.17 × 106 V/m. We predict that Ge mole fraction has inversely proportional effect to the maximum electric field value. Therefore, we concluded that Ge mole fraction affects current, voltage and electric field characteristics of high doping nanoscale Si1-xGex/Si PN diode. Keywords— SiGe; Si; Ge; mole fraction; current; voltage; electric field; p-n diode; high doping; nanoscale; Cogenda Visual TCAD.

I. INTRODUCTION Effect of Ge mole fraction of SiGe device on current and voltage has been investigated by some researchers. H. J. Huang et al. examined about 1 forward and reverse bias characteristics of selective epitaxial growth SiGe/Si of 1000×1000 m 2 diode area with different Ge mole fraction. Higher current was obtained at higher Ge mole fraction [1,2]. A. Gupta et al. reported that in reverse bias, the junction capacitance of the SiGe diode is considerably less than that of the Silicon diode. Assuming that the difference in permittivity is small, the depletion width of the SiGe diode is therefore larger than that of the Silicon diode [3]. Other research shows that Ge mole fraction of SiGe diode also affect electric field. S. Banerjee et al. investigated about electric field profile at different current density of Si/Si0.9Ge0.1 heterojunction DDR IMPATT [4]. J.Y. Li and J.C. Sturm observed the effect of Ge fraction on high field band to band tunneling in P +-SiGe/N+-SiGe junction [5]. SiGe diode fabrication has been conducted by some researchers using various techniques. E.V. Jelenkovic et al. demonstrated the formation of SiGe(P+)-Si(N) diode fabricated by co-sputtering and post-deposition annealing. SiGe film was deposited and in-situ by RF magnetron 2 co-sputtering on oxidized and bare silicon wafer. Nominal thickness of the film was 20 nm and 500 nm [6]. Another technique to prepare SiGe layer is using chemical vapor deposition [7,8]. Here, we report the effect of Ge mole fraction on current, voltage and electric field characteristics of high doping nanoscale Si1-xGex/Si P-N diode by simulation using Cogenda Visual TCAD, a semiconductor simulator software provides by Cogenda Pte Ltd. Due to the critical thickness constrain caused by Si and Ge lattice mismatch [9], this report will be limited to the Ge mole fraction of 0.7. II. METHODOLOGY We simulate the Si1-xGex/Si p-n diode using Cogenda Visual TCAD. As an acceptor (P side), the Si1-xGex has an area of 10 × 10 nm 2. Similarly to Si, as a donor (N side), has an area of 10 × 10 nm 2. The simulation of P-N diode is shown in Fig. 1. Both acceptor and donor have concentrations of 1020/cm 3. Here we simulate and analyze current, voltage and electric field of Si 1xGex/Si p-n diode with Ge mole fraction from x = 0.2 to 0.7.

58 Fig. 1. P-N diode simulation using Cogenda Visual TCAD. III. RESULT We simulate

current-voltage characteristics of high doping nanoscale Si1-xGex/Si P-N diode under forward bias from 0 to 1 V and reverse bias from 0 to -2 V with variation of Ge mole fraction from x = 0.2 to 0.7. The results are shown in Fig. 2 and 3. Under forward bias condition, the Ge mole fraction of Si1xGex/Si P-N diode affects the current. For Ge mole fraction of x=0.7, the diode begins to conduct at V 0.57 Volt, meanwhile for Ge mole fraction of x=0.2, the diode starts to conduct at V 0.9 Volt. Under reverse bias condition, the Ge mole fraction of Si1xGex/Si P-N diode also affects the current. Although it produces infinitesimal current, higher Ge mole fraction will produce higher current. Fig. 2. Current-Voltage characteristic under forward bias. Fig. 3. Current-Voltage characteristic under reverse bias. From Fig. 2 and Fig. 3, high doping nanoscale Si1-xGex/Si PN diode 1 can be used as a rectifier with higher Ge mole fraction will produce higher current. We also simulate electric field of high doping nanoscale Si1xGex/Si P-N diode under reverse bias voltage = -2 V with variation of Ge mole fraction from x = 0.2 to 0.7. The results are shown in Fig. 4 and Table 1. As stated in Table I, Ge mole fraction of Si1-xGex/Si P-N diode affects the electric field. At the junction, higher Ge mole fraction will produce lower maximum electric field. Fig. 4. Electric field characteristic under reverse bias.

59 TABLE I. GE MOLE FRACTION AND MAXIMUM ELECTRIC FIELD Ge Mole Fraction Max. Electric Field (V/m) Si0.8Ge0.2 6.17×106 Si0.5Ge0.5 5.99×106 Si0.3Ge0.7 5.89×106 IV. DISCUSSION As shown in Fig. 2 under forward condition, high doping nanoscale Si1-xGex/Si P-N diode will provide higher current with higher Ge mole fraction. This is consistent with result obtained by Huang et al. [1, 2] and Li et al. [5]. As stated by other papers, lower energy band gap achieves at higher Ge mole fraction condition [10-13]. Energy band gap (Eg) is energy difference between the bottom of conduction band (Ec) and the top of valence band (Ev); Hence, lower energy band gap causes more electrons having 9 enough energy to cross the junction from n+ side to p+ side. According to Srinivasan et al ., increases Ge mole fraction will decrease Kelvin resistance [14]. Therefore, higher Ge mole fraction will produce higher current. Using the result of

quantitative data from simulation using Cogenda Visual TCAD, we draw the energy band diagram of high doping nanoscale Si1xGex/Si P-N diode as shown in Fig. 5. Under forward bias voltage = 1 V, for Si0.3Ge0.7, it has Eg 0.5 eV, meanwhile for Si0.8Ge0.2, it has Eg 0.8 eV. Under reverse bias condition, as shown in Fig. 3, high doping nanoscale Si1-xGex/Si P-N diode will provide higher leakage current with higher Ge mole fraction. This fact is observed due to lower electric field 1 at the junction of diode with higher Ge mole fraction as shown in Fig. 4 and Table I. This is also consistent with other papers [1, 2]. Using the result of quantitative data from simulation, we draw the energy band diagram of high doping nanoscale Si1-xGex/Si P-N diode under reverse bias voltage = -2 V as shown in Fig. 6. Fig. 5. Energy band diagram under forward bias. Fig. 6. Energy band diagram under reverse bias. As shown in Fig 4, the maximum electric field has inversely proportional value with Ge mole fraction of high doping nanoscale Si1-xGex/Si P-N diode. Higher Ge mole fraction will produce lower electric field peak. This fact is consistent with Banerjee et al . [4]. According to quantitative data from simulation using Cogenda Visual TCAD, we predict that Ge mole fraction has linear effect on maximum electric field value of high doping nanoscale Si1-xGex/Si P-N diode as shown in Fig. 7. Under reverse bias voltage = -2 V, for Si0.3Ge0.7, it has maximum electric field 5.89 × 106 V/m, meanwhile for Si0.8Ge0.2, it has maximum electric field 6.17 × 106 V/m. Fig. 7. Effect of Ge mole fraction on maximum electric field.

60 V. CONCLUSION We have already simulated the effect of Ge mole fraction from x=0.2 to x=0.7 in SiGe material on current, voltage and electric field characteristics of high doping nanoscale Si1-xGex/Si P-N diode using Cogenda Visual TCAD. It can be concluded that under forward bias voltage, higher Ge mole fraction will produce higher current. This phenomenon happens due to lower energy band gap at higher Ge mole fraction condition. Under reverse bias voltage, the diode will provide higher leakage current with higher Ge mole fraction. This fact is observed due to lower energy band gap at higher Ge mole fraction condition and also lower maximum electric field 1 at the junction of

diode with higher Ge mole fraction. We predict that Ge mole fraction has inversely proportional effect to the maximum electric field value of the diode.

ACKNOWLEDGMENT We would like to thank to QiR 2017 committee and peer reviewers for their work to improve and publish this paper.

REFERENCES [1] H. J. Huang, K.M. Chen, C.Y Chang, and T.Y. Huang," Electrical and compositional properties of Co-Silicided shallow P+-N junction using SiCapped/Boron-doped Si1-xGex layer deposited by UHVCME", Journal of Electrochemical Society, vol. 148, No. 3, pp. G126-131, 2001. [2] H. J. Huang, K.M. Chen, C.Y. Chang, T.S. Chao, and T.Y. Huang, "Electrical properties of shallow P+-N junction using Boron doped Si1xGex layer deposited by ultra high vacuum chemical molecular epitaxy", Journal of Applied Physics, vol. 89, No. 9, pp. 5133-5137, May 2001. [3] A. Gupta et al., "Characterization of Germanium implanted Si1-xGex layer", Journal of Electronic Materials, vol. 22, no. 1, pp.125-128, 1993. [4] S. Banerjee, T. Sarkar, D. Sanyal, P. Barmon, and D. Das, "Effect of mobile space charge in Si/Si0.9Ge0.1 heterojunction double drift IMPATT oscillator at w-band window frequqency", 5 IOSR Journal of Electronics and Communication Engineering, vol. 9, issue 23, pp. 41-47, May-June 2014. [5] J. Y. Li and J. C. Sturm, "The effect of Ge fraction on high-field band-toband tunneling in p+-SiGe/n+-SiGe junction in forward and reverse bias", IEEE Transactions On Electron Devices, vol. 60, no. 8, pp. 2479-2484, August 2013. [6] E.V. Jelenkovic et al., "SiGe-Si 2 junctions with Boron-doped SiGe films deposited by co-sputtering", Solid-State Electronics, vol. 50, pp. 199-204, 2006. [7] Y. Bogumilowicz et al., "Chemical vapour etching of Si, SiGe and Ge With HCl; Application to the formation of thin relaxed SiGe buffers and to the revelation of threading dislocations", Semiconductor Science and Technology, vol. 20, pp. 127-134, 2005. [8] M. Okada et al., "Epitaxial growth of heavily B-doped SiGe Films and interfacial reaction of Ti/B-doped SiGe bilayer structure using rapid thermal processing", Thin Solid Films, Vol. 369, pp. 130-133, 2000. [9] K-H. Kao et al., Compressively strained SiGe band-to-band-tunneling model calibration based on P-I-N diodes and prospect of strained SiGe tunneling field effect transistors", Journal of Applied Physics, Vol. 116, No. 214506, pp. 1-11,

2014. [10] T-J King, J.P. McVittie, K.C. Saraswat, and J.R. Pfiester, “Electrical properties of heavily doped polycrystalline Silicon-Germanium film”, 6 IEEE Transactions On Electron Devices, Vol. 41, No. 2, pp.228-232, 1994. [11] L. K. Orlov et al., “Multilayer strained Si/SiGe structure: fabrication problems, interface characteristics, and physical properties”, Optoelectronics Review, vol. 11, no. 2, pp. 169-174, 2003. [12] B. Obradovic, R. C. Bowen, and M. S. Rodder, “Band-to-band tunneling in Ge-rich SiGe devices”, 4 IEEE Electron Device Letters, vol. 35, no. 4, pp. 473-475, April 2014. [13] G. Abstreiter, “Physics and perspectives of Si/Ge heterostructures and superlattices”, Physica Scripta, vol. T.49, pp. 42-45, 1993. [14] G. Srinivasan et al., “Tungsten 7 Silicide contacts to polycrystalline Silicon and Silicon-Germanium alloys”, Materials Science and Engineering B, Vol. 114, pp. 223-227, 2004.

Sources

1	https://wiki.analog.com/university/courses/electronics/text/chapter-5	INTERNET	1%
2	https://www.sciencedirect.com/science/article/pii/S0038110106000098	INTERNET	1%
3	http://bertalya.staff.gunadarma.ac.id/Publications/files/5771/Prosiding 2 Bertalya An Analysis.pdf	INTERNET	<1%
4	https://mtlsites.mit.edu/users/alamo/pdf/2014/RJ-147 paper.pdf	INTERNET	<1%
5	https://journalseeker.researchbib.com/view/issn/2278-2834	INTERNET	<1%
6	https://www.eecg.utoronto.ca/~sorinv/papers/ElectronDEvices_feb06.pdf	INTERNET	<1%
7	https://www.sciencedirect.com/science/article/abs/pii/S0921510704003125	INTERNET	<1%
8	https://www.datadikti.com/dosen/anak-agung-ngurah-gde-sapteka/d4-teknik-otomasi/politeknik-negeri-bali/1/	INTERNET	<1%
9	https://testbook.com/question-answer/the-forbidden-energy-band-gap-in-conductors-semic--5caddb58fdb8bb74c49d480d#:~:text=In a semiconductor, there exists a finite but,the energy gap and enter the conduction band.	INTERNET	<1%

EXCLUDE CUSTOM MATCHES	ON
EXCLUDE QUOTES	OFF
EXCLUDE BIBLIOGRAPHY	OFF