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REGULAR ARTICLE

A Simulation Study on the Performance of Double Gate Junctionless Field Effect Transistor for Doping Concentration Variation

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We report here a study on doping concentration variation on Double Gate Junctionless Field Effect Transistor. Doping concentration for the device is varied from 10^{10}/cm^3 to 10^{19}/cm^3 and their transfer characteristics and output characteristics were investigated for drain section voltages with 0.1 V, 0.5 V and 1 V. At 1 V drain voltage with doping level 10^{19} cm^{-3} a drain current of 1.7 mA has been obtained. Furthermore various electrical parameters like on current, I_{ON} to I_{OFF} ratio, subthreshold swing, threshold voltages are investigated. At 10^{19} cm^{-3} and drain potential 1 V current in body is 1.9 mA. On the other hand subthreshold swing obtained at 10^{19} cm^{-3} with a drain potential 1 V is 79 mV/Decade. The simulation is done with the help of Cogenda Visual TCAD simulator. By increasing doping concentration better control over drain current can be obtained. Better on current can be achieved at higher doping variation.

Keywords: Junctionless, Field effect, DGJLFET, Doping, Threshold voltage, Subthreshold swing.

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1. INTRODUCTION

Semiconductor device is now a days very important for the development of the technology. As the technology is improving the fundamental device i.e. transistor in VLSI field also decreasing in its size so that performance of the device can be ameliorated. The device FET (Field Effect Transistor) [1-3] in its miniature size shows Short Channel Effects (SCE). Due to SCE, Drain Induced Barrier Lowering can be seen in the device. Therefore, to reduce SCE in the device Silicon on Insulator device (SOI) and high K device technology are used. But all this devices has junction. As the device is very small, so it is actually challenging to sustain the doping concentration level within junctions. Moreover this type of device shows heat dissipation and fabrication becomes difficult. Therefore, 2009 Collinge et al. [4] introduced a novel device which is known as Junctionless Field Effect Transistor (JLFET) [5-19]. This device is lack of any junctions and therefore a uniformly doping level can be maintain throughout the source, channel and drain sections. JLT is easy to fabricate and is highly scalable. This device can be operating by considering the work function dissimilarity in the middle of metal and body of the device. The device shows full depletion during off state condition. On the other hand the depletion reduces during on state condition.

In the presented work a N channel Junctionless Field Effect Transistor has been used for study purpose. In the study different variation of doping concentration has been considered. Doping variation is done from 10^{10}/cm^3 to 10^{19}/cm^3. For the work with different doping, transfer characteristics and output characteristics are studied. Different electrical identifications such as on current, I_{ON} to I_{OFF} ratio, Subthreshold swing and Threshold voltages are investigated. Lightly doped de-vice such as 10^{10}/cm^3 can be considered as undoped device.

2. DEVICE SET-UP

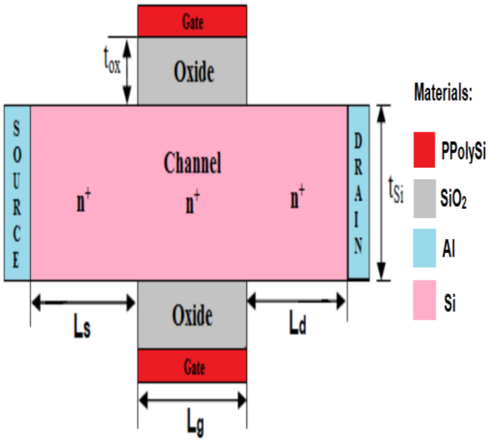

Fig. 1 – N channel Double Gate JLFET

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Fig. 1 indicates schematic figure of N channel Double Gate Junctionless Field Effect Transistor. Table 1 shows different device specifications required for simulation process. The Simulation process is performed with the help of TCAD simulator. P Polysilicon is the material used for gate material. Source and drain section are considered Aluminum material. Oxide layer is considered with SiO_2 material. The substrate of the device is considered with Silicon material.

Table 1 – Device Specifications

№	**Device Specifications**	**DGJLFET**
1	Substrate doping concentrations (N_d)	10^{10} cm $^{-3}$, 10^{11} cm $^{-3}$, 10^{12} cm $^{-3}$, 10^{13} cm $^{-3}$, 10^{14} cm $^{-3}$, 10^{15} cm $^{-3}$, 10^{16} cm $^{-3}$, 10^{17} cm $^{-3}$, 10^{18} cm $^{-3}$, 10^{19} cm $^{-3}$
2	Body thickness (t_{si})	10 nm
3	Oxide Thickness (t_{ox})	3 nm
4	Gate Work Function ($ø_M$)	5.4 eV
5	Upper Gate Section (L_g)	10 nm
6	Lower Gate Section (L_g)	10 nm
7	Source Section (L_s) and Drain Section (L_d)	10 nm

3. RESULT AND DISCUSSION

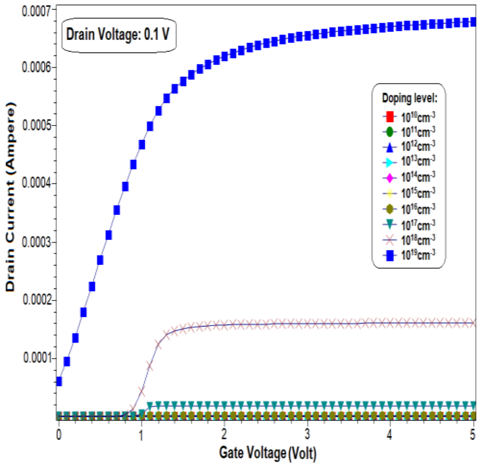

Fig. 2 – Drain Current Vs Gate to Source Voltage at drain voltage 0.1 V

Fig. 2 shows transfer characteristics of the DGJLFET with a drain section potential of 0.1 V for different doping concentrations. Doping level is within the span between 10^{10} cm $^{-3}$ to 10^{19} cm $^{-3}$. It has been observed from the figure that during undoped or low doping concentration drain current is very low. Higher drain current is observed at 10^{19} cm $^{-3}$. During low doping characteristics shows a negative resistance behavior as there is no enough carrier to raise the body current.

Fig. 3 depicts transfer characteristics of the device with drain voltage of 0.5 V for different doping concentrations. Here also doping level varies in between 10^{10} cm $^{-3}$ to 10^{19} cm $^{-3}$. 1.6 mA drain current is observed for 10^{19} cm $^{-3}$ concentrations.

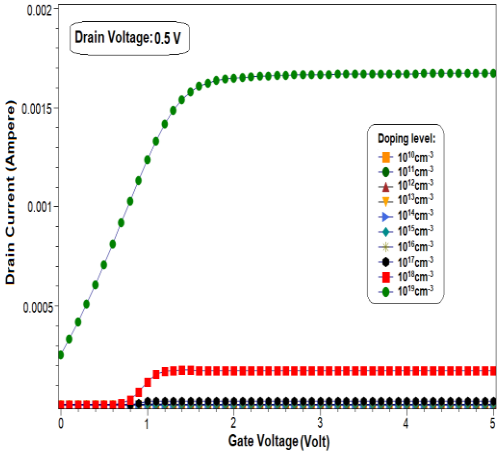

Fig. 3 – Drain Current Vs Gate to Source Voltage at drain voltage 0.5 V

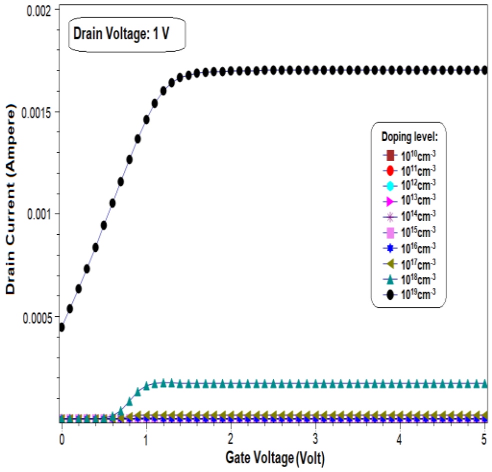

Fig. 4 – Drain Current Vs Gate to Source Voltage at drain voltage 1 V

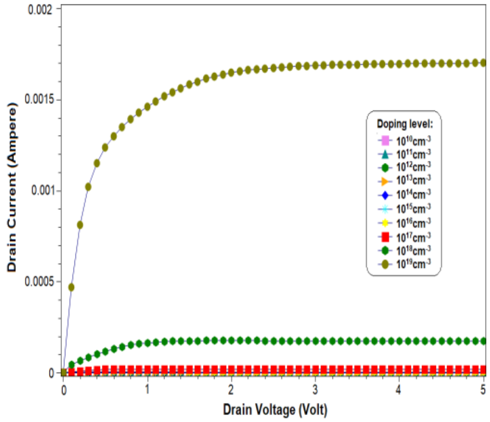

Fig. 5 – Drain Current Vs Drain to Source Voltage at gate voltage 1 V

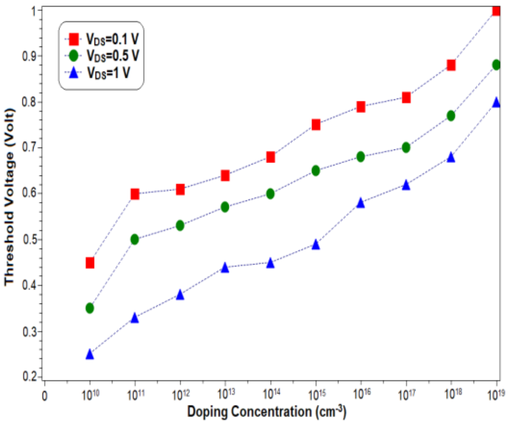

Fig. 6 – Threshold Voltage variation with Doping Concentration

Fig. 4 depicts transfer characteristics of the DGJLFET with drain voltage of 1 V for different doping concentrations. Here doping level ranges in between 10^{10} cm^{-3} to 10^{19} cm^{-3}. 1.7 mA drain current is observed for 10^{19} cm^{-3} concentrations.

Fig. 5 indicates output characteristics of DGJLFET with a gate voltage of 1 V for different doping concentrations. Doping variations ranges in between 10^{10} cm^{-3} – 10^{19} cm^{-3}. From illustration it has been observed that from doping level 10^{10} cm^{-3} – 10^{17} cm^{-3} bodies current level is very low. A higher level of body current is observed at doping level 10^{19} cm^{-3} which is 1.6 mA.

Fig. 6 indicates threshold voltage variation for different doping concentrations at drain section potentials of 0.1 V, 0.5 V and 1 V respectively. Doping concentration variation has been done from 10^{10} cm^{-3} – 10^{19} cm^{-3}. From figure it can be illustrate that if doping concentration increases threshold voltages also increasing. For lower value of drain voltage higher threshold voltage is observed as drain induced barrier lowering (DIBL) is less.

Fig. 7 shows on current variation for different doping concentrations at drain zone potentials of 0.1 V, 0.5 V and 1 V respectively. From plotted graph it can be illustrate that on current is very small up to doping level of 10^{17} cm^{-3}. On current is higher for higher drain potentials as DIBL increases with increase in drain potential.

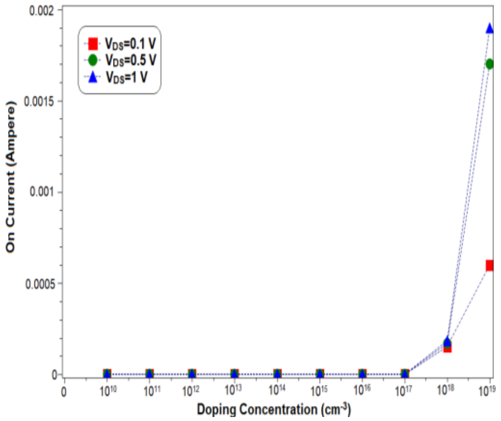

Fig. 7 – On Current variety with Doping Concentration

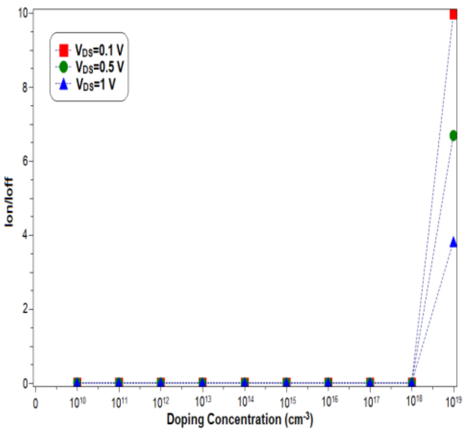

Fig. 8 – I_{ON}/I_{OFF} Vs Doping Concentration

Fig. 8 shows on I_{ON} to I_{OFF} ratio variation for different doping concentrations at drain section potentials of 0.1 V, 0.5 V and 1 V respectively. The on current off current ratio is higher for lower drain voltages as off current is higher for higher drain voltages as leakage is high.

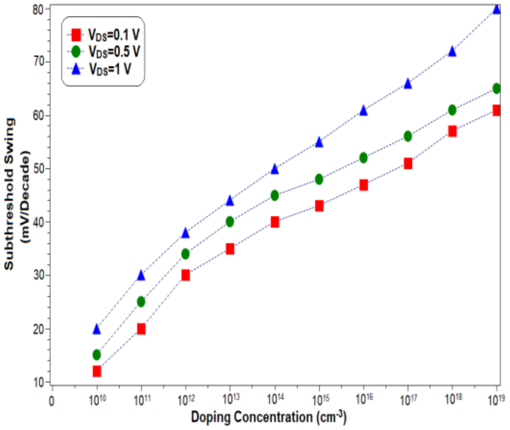

Fig. 9 – Subthreshold Swing variety with Doping Concentration

Fig. 9 indicates Subthreshold Swing variation for different doping concentration levels at distinct drain potentials (0.1 V, 0.5 V and 1 V). It has been observed that for higher drain voltages subthreshold swing is increasing as DIBL is high.

4. CONCLUSION

In the presented work an analysis has been done with different doping concentrations on DGJLFET. Doping level varies from 10^{10} cm^{-3} – 10^{19} cm^{-3}. The Simulation for the study has been done using Visual TCAD simulator. Drain current variety with respect to input voltage i.e. gate voltage has been observed for drain section potentials 0.1 V, 0.5 V and 1 V. In all cases a higher drain voltage has been observed at 10^{19} cm^{-3} doping level. Drain current 0.6 mA, 1.6 mA and 1.7 mA has been observed for 10^{19} cm^{-3} at drain voltages 0.1 V, 0.5 V and 1 V respectively. Output characteristics at gate voltage 1 V has been observed in the analysis. Various electrical parameters threshold voltage, on current, I_{ON} to I_{OFF} ratio and subthreshold swing are analyzed for different doping concentration levels. The fabrication and characteristics study for different doping level for DGJLFET is the future development of the present work.

REFERENCES

1. S. Migita, Y. Morita, T. Matsukawa, M. Masahara, H. Ota, *IEEETrans. Nanotechnol.* **13** No 2, 208 (2014).
2. C.-W. Lee, A. Afzalian, N.D. Akhavan, R. Yan, I. Ferain, J.-P. Colinge, *Appl. Phys.Lett.* **94** No 5, 053512 (2009).
3. R. Rios, et al., *IEEE Electron Device Lett.* **32** No 9, 1170 (2011).
4. J.P. Colinge, H.W. Lee, A. Afzalian, N.D. Akhavan, R. Yan, I. Ferain, P. Razavi, B. O'Neill, A. Blake, M. White, A.M. Kelleher, B. McCarthy, R. Murphy, *Nature Nanotechnology* **5**, 225 (2010).
5. J.P. Colinge, A. Kranti, R. Yan, C.W. Lee, I. Ferain, R. Yu, N.D. Akhavan, P. Razavi, *Solid- State Electronics* **65–66**, 33 (2011).
6. E. Gnani, A. Gnudi, S. Reggiani, G. Baccarani, *IEEE Transactions on Electron Devices* **58** No 9, 2903 (2011).
7. A.K. Raibaruah, K.C.D. Sarma, *IEEE International Conference on Computational Performance Evaluation* (ComPE) (2020).
8. A.K. Raibaruah, K.C.D. Sarma, *Silicon* **14** No 2, 711 (2022).
9. A. Gnudi, S. Reggiani, E. Gnani, G. Baccarani, *IEEE Electron Dev. Lett.* **33** No 3, 336 (2012).
10. A. Gnudi, S. Reggiani, E. Gnani, G. Baccarani, *IEEE Trans. Electron Dev.* **60** No 4, 1342 (2013).
11. A.K. Raibaruah, A. Talukdar, K.C.D. Sarma, *IEEE International Conference on Computational Performance Evaluation* (ComPE) (2020).
12. A.K. Raibaruah, K.C.D. Sarma, *IEEE Delhi Section International Conference on Electrical, Electronics and Computer Engineering* (DELCON) (2022).
13. J.P. Colinge, C.W. Lee, A. Afzalian, N. Dehdashti, R. Yan, I. Ferain, P. Razavi, B. O'Neill, A. Blake, M. White, A.M. Kelleher, B. McCarthy, R. Murphy, *IEEE International SOI Conference* (2009).
14. K.C.D. Sarma, S. Sharma, *J. Comput. Electron.* **14** No 3, 717 (2015).
15. C.H. Park, M.D. Ko, K.H. Kim, R.H. Baek, C.W. Sohn, C.K. Baek, S. Park, M.J. Deen, Y.H. Jeong, J.S. Lee, *Solid-State Electron.* **73**, 7, (2012).
16. T.K. Chiang, *IEEE Trans. Electron Dev.* **59** No 9, 2284 (2012).
17. C. Li, Y. Zhuang, S. Di, R. Han, *IEEE Trans. Electron Dev.* **60** No 11, 3655 (2013).
18. A. Talukdar, A.K. Raibaruah, K.C.D. Sarma, *Procedia Comput. Sci.* **171**, 1053, (2020).
19. J.P. Durate, M.S. Kim, S.J. Choi, Y.K. Choi, *IEEE Trans. Electron Dev.* **59** No 4, 1008 (2012).

Моделювальне дослідження ефективності безперехідного польового транзистора з подвійним затвором для зміни концентрації легування

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Стаття стосується дослідженню зміни концентрації домішки на безперехідному польовому транзисторі з подвійним затвором. Концентрація легування для пристрою варіювалася від 10^{10}/см^3 до 10^{19}/см^3, а їх характеристики передачі та вихідні характеристики були досліджені для напруг секції стоку з 0,1 В, 0,5 В та 1 В. При напрузі стоку 1 В з рівнем легування 10^{19} см$^{-3}$ отримано струм стоку 1,7 мА. Крім того, досліджуються різні електричні параметри, такі як струм, співвідношення I_{ON}/I_{OFF}, підпорогове коливання, порогові напруги. При 10^{19} см$^{-3}$ і потенціалі стоку 1 В струм в корпусі становить 1,9 мА. З іншого боку, підпорогове коливання, отримане при 10^{19} см$^{-3}$ з потенціалом витоку 1 В, становить 79 мВ/декаду. Симуляція виконується за допомогою симулятора Cogenda Visual TCAD. Збільшуючи концентрацію легування, можна отримати кращий контроль над струмом стоку. Краще значення струму можна досягти при вищій варіації легування.

Ключові слова: Безперехідний, Ефект поля, DGJLFET, Легування, Порогова напруга, Підпорогове коливання.