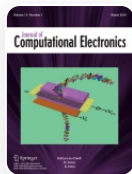


Performance analysis of different dielectrics for solar cells with TOPCon structure

Published: 19 February 2022

Volume 21, pages 471–490, (2022) Cite this article

**Journal of Computational Electronics**

Aims and scope

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Abstract

The performance of a TOPCon solar cell depends on the properties of the dielectric material through which tunneling takes place. Common dielectric material used with n-type Si wafer is SiO₂ due to its excellent passivation property for n-Si interface. Required thickness of SiO₂ is ≈1.5 nm, making its fabrication quite challenging. Moreover, recently p-type TOPCon solar cell has been proposed as an alternative to p-type PERC (p-PRC) structure. So, a dielectric

material different from SiO_2 may act as a better tunneling cum passivation layer for p-Si wafer. In this paper, various alternative tunneling/passivating dielectric layers like Si_3N_4 , Al_2O_3 , HfO_2 and ZrO_2 have been discussed. The cell performances as well as the critical dielectric thicknesses of all these materials have been simulated using the three-dimensional Sentaurus TCAD software. It has been found that the critical dielectric thickness for optimum cell performances depends strongly on the tunneling effective mass of the majority carriers, dielectric barrier at the dielectric/Si interface for the majority carriers and fixed charges in the dielectric. We have also used the simulation for an arbitrary generic dielectric and studied the dependence of its critical thickness (t_{critical}) on the three parameters mentioned above.

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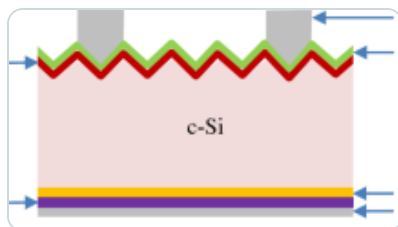
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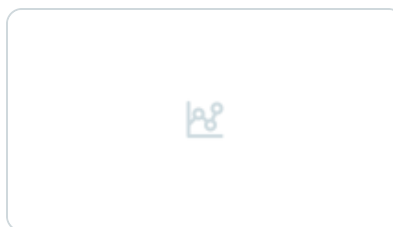
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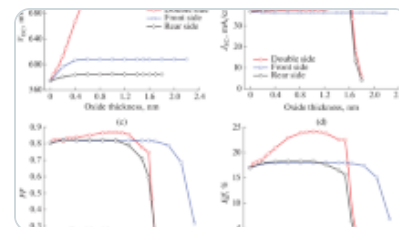
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References

1. Richter, A., Benick, J., Feldmann, F., Fell, A., Hermle, M., Glunz, S.W.: Sol. Energy Mater. Sol. Cells **173**, 96–105 (2017)
[Article](#) [Google Scholar](#)
2. Vossen R, et al.: Comparative study of differently grown tunnel oxides for p-type passivating contacts, 7th International Conference on Silicon Photovoltaics, SiliconPV 2017.
3. Feldman, F., Reichel, C., Müller, R., Hermle, M.: The application of poly-Si/SiO_x contacts as passivated top/rear contacts in Si solar cells. Sol. Energy Mater. Sol. Cells **159**, 265–271 (2017)
[Article](#) [Google Scholar](#)

4. Reichel, C., et al.: Interdigitated back contact silicon solar cells with tunnel oxide passivated contacts formed by ion implantation. 29th European Photovoltaic Solar Energy Conference and Exhibition
5. Peibst, R., Römer, U., Larionova, Y., Rienäcker, M., Merkle, A., Folchert, N., Reiter, S., Turcu, M., Min, B., Krügener, J., Tetzlaff, D., Bugiel, E., Wietler, T., Brendel, R.: Working principle of carrier selective poly-Si/c-Si junctions: Is tunnelling the whole story? Sol. Energy Mater. Sol. Cells **158**, 60–67 (2016)
[Article](#) [Google Scholar](#)
6. Tao, Y., Madani, K., Cho, E., Rounsaville, B., Upadhyaya, V., Rohatgi, A.: High-efficiency selective boron emitter formed by wet chemical etch-back for *n*-type screen-printed Si solar cells. Appl. Phys. Lett. **110**, 021101 (2017)
[Article](#) [Google Scholar](#)
7. Zhang, Z., Zeng, Y., Jiang, C.-S., Huang, Y., Liao, M., Tong, H., Al-Jassim, M., Gao, P., Shou, C., Zhou, X., Yan, B., Ye, J.: Carrier transport through the ultrathin silicon-oxide layer in tunnel oxide passivated contact (TOPCon) c-Si solar cells. Sol. Energy Mater. Sol. Cells **187**, 113–122 (2018)
[Article](#) [Google Scholar](#)
8. Zeng, Y., Tong, H., Quan, C., Cai, L., Yang, Z., Chen, K., Yuan, Z., Chung-Han, Wu., Yan, B., Gao, P., Ye, J.: Theoretical exploration towards high-efficiency tunnel oxide passivated carrier-selective contacts (TOPCon) solar cells. Sol. Energy **155**, 654–660 (2017)
[Article](#) [Google Scholar](#)
9. Li, Q., Tao, K., Sun, Y., Jia, R., Wang, S.M., Jin, Z., Liu, X.Y.: Replacing the amorphous silicon thin layer with microcrystalline silicon thin layer in TOPCon solar cells. Sol.

Energy **135**, 487–492 (2016)

[Article](#) [Google Scholar](#)

10. Tao, Y., Upadhyaya, V., Jones, K., Rohatgi, A.: Tunnel oxide passivated rear contact for large area n-type front junction silicon solar cells providing excellent carrier selectivity. AIMS Mater Sci **3**(1), 180–189 (2016)

[Article](#) [Google Scholar](#)

11. Feldmann, F., Bivour, M., Reichel, C., Hermle, M., Glunz, SW A passivated rear contact for high-efficiency *n*-type silicon solar cells enabling high V_{oc} AND $FF > 82\%$. 28th European Photovoltaic Solar Energy Conference and Exhibition.

12. vander Vossen, R., Master of Science Thesis at the Delft University of Technology, May 17, 2017.

13. Sentaurus, Synopsys TCAD software Release L-2017-09-SP2.

14. Perevalov, T.V., Shaposhnikov, A.V., Gritsenko, V.A., Wong, H., Han, J.H., Kim, C.W.: Electronic structure of α -Al₂O₃: Ab initio simulations and comparison with experiment. JETP Lett. **85**, 165–168 (2007)

[Article](#) [Google Scholar](#)

15. Monaghan, S., Hurley, P.K., Cherkaoui, K., Negara, M.A., Schenk, A.: Determination of electron effective mass and electron affinity in HfO₂ using MOS and MOSFET structures. Sol. State Elec. **53**, 438–444 (2009)

[Article](#) [Google Scholar](#)

16. Garcia, J.C., Lino, A.T., Scolfaro, L.M.R., Leite, J.R., Freire, V.N., Farias, G.A., da Silva, E.F.: Band structure derived properties of HfO₂ from first principles calculations. AIP Conf. Proc. **772**, 189–190 (2005)

[Article](#) [Google Scholar](#)

17. Cheynet, M.C., Pokrant, S., Tichelaar, F.D., Rouvière, J.: Crystal structure and band gap determination of HfO₂ thin films. J. Appl. Phys. **101**, 054101 (2007)

[Article](#) [Google Scholar](#)

18. Garcia, J. C., Scolfaro, L.M.R., Lino, A.T., Freire, V.N., Farias, G.A., Silva, C.C., Leite Alves, H.W., Rodrigues, S.C.P., da Silva Jr, E.F.: Structural, electronic, and optical properties of ZrO₂ from ab initio calculations. J Appl Phys **100**, 104103 (2006)

[Article](#) [Google Scholar](#)

19. Zheng, W., Bowen, K.H., Li, J., Dabkowska, I., Gutowski, M.: Electronic structure differences in ZrO₂ vs HfO₂. J Phys Chem A **109**(50), 11521–11525 (2005)

[Article](#) [Google Scholar](#)

20. Vitkavage, S. C., Irene, E.A., Massoud, H.: An investigation of Si-SiO₂ interface charges in thermally oxidized (100), (110), (111), and (511) silicon. J Appl Phys **68**(10), 5262–5272 (1990)

[Article](#) [Google Scholar](#)

21. Dauwe, S., Mittelstadt, L., Metz, A., Hezel, R.: Experimental evidence of parasitic shunting in silicon nitride rear surface passivated solar cells. Prog. Photovolt: Res. Appl. **10**, 271–278 (2002)

[Article](#) [Google Scholar](#)

22. Zhang, X.Y., Hsu, C.H., Lien, S.Y., Chen, S.Y., Huang, W., Yang, C.H., Kung, C.Y., Zhu, W.Z., Xiong, F.B., Meng, X.G.: Surface passivation of silicon using HfO_2 thin films deposited by remote plasma atomic layer deposition system. *Nanoscale Res. Lett.* **12**, 324 (2017)

[Article](#) [Google Scholar](#)

23. Zhang, X.Y., Hsu, C.H., Cho, Y.S., Lien, S.Y., Zhu, W.Z., Chen, S.Y., Huang, W., Xie, L.G., Chen, L.D., Zou, X.Y., Huang, S.X.: Simulation and fabrication of HfO_2 thin films passivating Silicon from a numerical computer and Remote Plasma ALD. *Appl. Sci.* **7**, 1244 (2017)

[Article](#) [Google Scholar](#)

24. Werner, F., Schmidt, J.: Manipulating the negative fixed charge density at the c-Si/ Al_2O_3 interface. *Appl. Phys. Lett.* **104**, 091604 (2014)

[Article](#) [Google Scholar](#)

25. Shin, W.J., Huang, W.-H., Tao, M.: Low-cost spray-deposited ZrO_2 for antireflection in Si solar cells. *Mater. Chem. Phys.* **230**(15), 37–43 (2019)

[Article](#) [Google Scholar](#)

26. Wan, Y., Bullock, J., Hettick, M., Zhaoran, X., Yan, D., Peng, J., Javey, A., Cuevas, A.: Zirconium oxide surface passivation of crystalline silicon. *Appl. Phys. Lett.* **112**, 201604 (2018)

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Acknowledgements

This work has been carried out under the project “DST-IEST Solar PV Hub Phase II” sponsored by Department of Science and Technology (DST), Government of India implemented at School of Advanced Materials, Green Energy and Sensor Systems (SAMGESS, IEST, Shibpur).

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Cite this article

Acharyya, S., Sadhukhan, S., Panda, T. *et al.* Performance analysis of different dielectrics for solar cells with TOPCon structure. *J Comput Electron* 21, 471–490 (2022).

<https://doi.org/10.1007/s10825-022-01866-0>

Received

14 December 2021

Accepted

26 January 2022

Published

19 February 2022

Issue Date

April 2022

DOI

<https://doi.org/10.1007/s10825-022-01866-0>

Keywords

[Solar cell](#)

[TOPCon](#)

[Tunneling](#)

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