The Effect of Structural Modifications on the Efficiency of Thin-Film Tandem Solar Cells

Jay Lesny
TOHS AP Research STEM

Introduction

Electricity generation has become an issue as conventional sources of energy, such as oil, petroleum, coal, become depleted in the inner Earth (Hoekstra et al., 2014). As a result, many researchers are turning to renewable energy sources that are less harmful to the ecosystem, like solar energy (Twidell et al., 2015). Using the photovoltaic effect, scientists have developed solar cells which can convert the energy in sunlight to electricity (Zweibel, 1990). Factors that affect the power conversion efficiency of production include bandgap, open circuit voltage, closed circuit current, and fill factor. New photovoltaic research has also procured thin film cells, like CIGS, CdTe, and perovskite, and tandem cells, structures with sub-layers of solar cells (Jean et al., 2015).

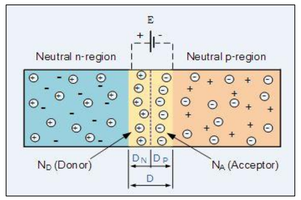

Figure 1. Diagram of a solar cell and how it works

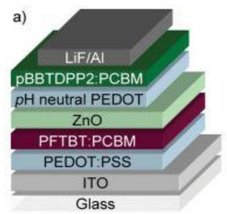

Figure 2. (Gilot et al., 2010) Image of a tandem solar cell

Purpose

The purpose of the study was to investigate solar cells and find which type of cell is most efficient. Higher efficiency results in lower cost, making solar energy more available to the public. This allows for reduced usage of energy sources that release waste detrimental to the environment.

Methods

Systematic Literature Review

- ScienceDirect, EbscoHost, JSTOR, NREL, DOE, IEEE, PlosOne, EngineeringVillage, Knovel, Reaxys, NCBI, PubMed, Google Scholar, and ResearchGate were researched for efficiency data
- Thin film tandem solar cells researched consist of CIGS-Perovskite 4T, Perovskite-Perovskite, and CdTe-Silicon
- Multicrystalline and monocrystalline silicon cells were researched as a control

Abstract

The effect of modifying solar cells into thin film tandem structures on the efficiency of photovoltaic technology was analyzed to discover whether they hold higher efficiencies of electrical energy production compared to silicon solar cells. Peer-reviewed articles that reported efficiencies and other variables on different types of cells were collected to conduct a statistical analysis test. Results showed that thin film tandem cells are not more efficient than silicon cells. These findings signify that silicon cells may be more beneficial than other types of cells when considering the amount of electricity generated, cost of electricity, and environmental impact of increased usage of renewable sources.

Research Question and Hypothesis

Research Question: Can solar cells' structure be manipulated into a type of thin film tandem cell to produce more efficient solar cells compared to silicon solar cells?
Alternative Hypothesis: Thin-film tandem solar cells are more efficient as compared to silicon solar cells.
Null Hypothesis: Thin film tandem solar cells are as or less efficient as silicon solar cells.

Results

P-values of t-Tests
CIGS-Perovskite 4T vs. Multicrystalline: .02173
CdTe/Si vs. Multicrystalline: .1952
Perovskite-Perovskite vs. Multicrystalline: .001349
CIGS-Perovskite 4T vs. Monocrystalline: .0001412
CdTe/Si vs. Monocrystalline: .4514
Perovskite-Perovskite vs. Monocrystalline: 5.883E-05

For the statistically significant results, under .05, the p-values were calculated in favor of the silicon solar cells because their average efficiency was higher.

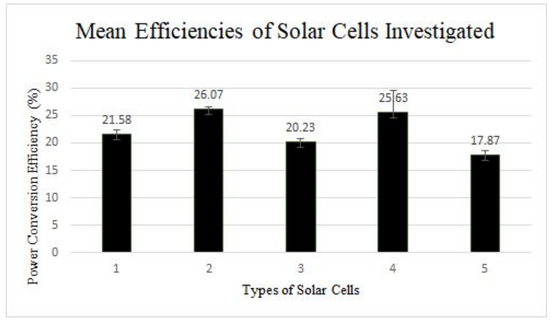

Figure 3. Graph of mean efficiencies. 1) Polycrystalline 2) Monocrystalline 3) CIGS/Perovskite 4T 4) CdTe/Silicon 5) Perovskite/Perovskite

Discussion

When comparing silicon cells to the tandem cells researched, it is evident that tandem cells do not have higher efficiencies on average. The reported p-values for Perovskite-Perovskite and CIGS-Perovskite 4T, which were less than .05 and in favor of silicon solar cells, indicate that both types of silicon cells are statistically proven to be more efficient. As for the CdTe/Si cells compared to the silicon cells, the p-values are greater than .05, showing no statistical difference in efficiency. With these results in mind, it is shown that none of the three tandem solar cells investigated have higher efficiencies than silicon cells. As a result, silicon solar cells generate more electricity and could therefore be more economically viable than tandem cells. Despite this being true, the potential of silicon to further grow as a material in the solar industry is minimal because of extensive research already done in the electronics industry. Consequently, other thin film materials have more potential to be more efficient because they are new to the photovoltaic industry, and therefore could be economically feasible for middle-class families in the future. Ultimately, this would provide greater benefits to the environment because of lessened dependence on harmful methods of electricity generation. This would also promote the flow of money in economy, positively affecting most people.

Conclusion

The systematic literature review provides strong evidence that thin film tandem cells are not more efficient than silicon cells. Peer-reviewed papers in this study support the null hypothesis, indicating silicon solar cells are better cells to use for solar energy purposes due to higher efficiencies. The findings suggest silicon cells are more efficient than tandem cells and therefore are better for energy generation when considering the amount produced.

Further Work

Research on different types of thin film solar cells could be conducted. Only three types of solar cells were able to be researched in the time span. Different types of tandem cells, like different types of two and four terminal solar cells, would be a possible research pathway. Comparing only three types of solar cells limits the entire field of possible materials and types of technology that could be researched, for example carbon quantum dots. Different variables affecting each of the solar cells also could be investigated, such as stability, size, doping concentration in the fabrication process, and manufacturing method.

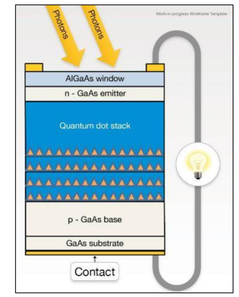

Figure 4. Image of a carbon quantum dot cell

Acknowledgements

Thank you to Mr. Koscher, Dr. Weber, Dr. Sharaf, Dr. Dolan, Mr. Rincon, and Dr. Malhotra for their continued assistance and support through the project.

References

Gilot J., Wienk, M. M., & Janssen, R. A. J. (2010). Optimizing polymer tandem solar cells. Advanced Energy Materials, 22(8), 67-71. Doi: 10.1002/adma.200902398
Guchhait, A., Dewi, H. A., Leow, S. W., Wang, H., Han, G., Suhaimi, F. B., ... Mathews, N. (2017). Over 20% efficient CIGS–perovskite tandem solar cells. ACS Energy Letters, 2(4), 807–812. Doi: 10.1021/acsenergylett.7b00187
Hoekstra, A. Y., & Wiedmann, T. O. (2014). Humanity's unsustainable environmental footprint. Science, 344(6188), 1114-1117. Doi: 10.1126/science.1248365
Jean, J., Brown, P. R., Jaffe, R. L., Buonassisi, T., & Bulovic, V. (2015). Pathways for photovoltaics. Energy Environ, 8, 1200-1219. Retrieved from https://pubs.rsc.org/en/content/
Twidell J, & Weir, T. (2015). Renewable energy sources. London, UK: Routledge.
Zweibel, K. (1990). Harnessing solar power: The photovoltaics challenge. New York, NY: Plenum Press.