FAKULTÄT FÜR PHYSIK
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Cloaced grids on solar cells
(Getarnte Kontakte auf Solarzellen)

Bachelorarbeit
von

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Titelbild

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Karlsruhe, den 20.04.2016, _____

Lukas Powalla

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Karlsruhe, den 20.04.2016, _____

Prof. Dr. Martin Wegener

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1. Introduction

During the last few years, the efficiency of solar cells could be raised significantly through research and development on different aspects of the solar cell. Besides reducing electrical losses and improving the materials used in solar cells (such as the material for the semiconductor), we can also try to improve optical properties of the solar cell. On the one hand-side, it is important to reduce reflections and on the other hand-side, it is important to guide as much light as possible to the optical active areas. One issue concerning this is cloaking the contact fingers and bus-bars on solar cells to guide the light, which would have hit the contact grid on solar cells, to the optical active areas. This can be used to enhance the efficiency of solar cells.

With my Bachelorthesis, I want to investigate in the two dimensional design of a surface to get the contact-fingers and the bus-bars cloaked. It is important to cover a as large as possible angular-acceptance as well al a as homogeneous as possible light distribution on the active area of the solar cell. The design we want to concentrate on is a Polymer structure (n=1.5), which should have the right refraction-properties. In this Bachalorthesis, we will not take reflection into account. First, I want to design a continuous solution in two dimensions based on a given one dimensional solution. [SWG+15] Second, I want to try to find an optical design based on Fresnel-optics to cloak the contact-fingers and the busbars. In the end, I want to design a meta-material to cloak the contact fingers and the busbars and compare it with the first two designs..

2. Description of the Problem

2.1. state of the art

In order to improve the optical properties of solar cells a lot of research has been done. It is important to minimise reflections on the sunny side of the solar cell and in addition to that it is also important to guide as much light as possible to the optical active areas of the solar cell. Reflected light and light that hits the contact grid and the busbar is lost.

The question I want to deal with in my Bachelorthesis is how to minimise light that hits the contact grid and the busbar. You can reach this by either decreasing the contact grid and the busbars. This can be reached through using back contact solar cells [KB06] emitter wrap through solar cells [GSB92].

Another approach is to design the sun-side of the solar cell in a way that the light in the end hits the optical active area.

3. Simulations for continuous surface design

3.1. blending of the two one dimensional solutions

3.2. Simulation rectangular unit cell

3.3. Simulation squared unit cell

4. Simulations for Fresnel design

5. Simulations for meta-surface design

5.1. construction of the meta-surafce design

5.2. Simulation for rectangular unit cell

5.3. Simulation for squared unit cell

6. Conclusions

Appendix

A. First Appendix Section

Wonderful Appendix!

Bibliography

[BEK09] Boca, Andreea, Kenneth M Edmondson und Richard R King: *Prismatic covers for boosting the efficiency of high-concentration PV systems.* In: *Photovoltaic Specialists Conference (PVSC), 2009 34th IEEE*, Seiten 000131–000136. IEEE, 2009.

[GSB92] Gee, James M, W Kent Schubert und Paul A Basore: *Emitter wrap-through solar cell.* In: *Presented at the 23rd Institute of Electrical and Electronics Engineers (IEEE) Photovoltaic Specialists Conference, Louisville, KY, 10-14 May 1993*, Band 1, Seiten 10–14, 1992.

[KB06] Kerschaver, Emmanuel Van und Guy Beaucarne: *Back-contact solar cells: A review.* Progress in Photovoltaics: Research and Applications, 14(2):107–123, 2006.

[MSE+16] Mayer, Frederik, Robert Schittny, Amos Egel, Andreas Niemeyer, Jan Preinfalk, Ulrich Lemmer und Martin Wegener: *Cloaking Contacts on Large-Area Organic Light-Emitting Diodes.* Advanced Optical Materials, 2016.

[SWG+15] Schumann, Martin F, Samuel Wiesendanger, Jan Christoph Goldschmidt, Benedikt Bläsi, Karsten Bittkau, Ulrich W Paetzold, Alexander Sprafke, Ralf B Wehrspohn, Carsten Rockstuhl und Martin Wegener: *Cloaked contact grids on solar cells by coordinate transformations: designs and prototypes.* Optica, 2(10):850–853, 2015.

[YC14] Yu, Nanfang und Federico Capasso: *Flat optics with designer metasurfaces.* Nature materials, 13(2):139–150, 2014.

[YGK+11] Yu, Nanfang, Patrice Genevet, Mikhail A Kats, Francesco Aieta, Jean Philippe Tetienne, Federico Capasso und Zeno Gaburro: *Light propagation with phase discontinuities: generalized laws of reflection and refraction.* science, 334(6054):333–337, 2011.

[ZWG90] Zhao, J, A Wang und MA Green: *An optimized prismatic cover design for concentrator and nonconcentrator solar cells.* Journal of applied physics, 68(3):1345–1350, 1990.