Design optimization of Flexible Thin Film CIGS Solar Modules

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***Abstract:** The novel fabrication technology of Sunplugged CIGS solar cell/modules and their optimization related to the geometry of solar modules is presented here. The simulation was based on the real values of material parameters obtained from the company. Numerical optimisation of the CIGS solar modules, has shown that the change of the geometrical parameters (shape of the solar cell) as well as on the number of the cell/module influence strongly the output module efficiency. With COMSOL Multiphysics© the modeling of rectangular, circular and zigzag CIGS solar cell's has been done. The maximum efficiency was achieved for the zigzag shaped cells with the width of 4mm (13.30%).*

Introduction

Flexible thin film Copper Indium Gallium Selenide (CIGS) solar modules have many advantages compared to modules built on soda-lime glass substrate. They have excellent sensitivity on the broad radiation spectra and high ratio of delivered power to modul weight. Moreover, this type of solar modules are rather simple for the fabrication, having small cost of the watt-peak. Due to the flexible substrates, modules have light weight and are suitable for the implementation in custom designed products or even in the buildings skins.

The Sunplugged technology gives the opportunity to create various shapes & sizes of solar cells/modules. Here, we will present the vision of the Company and some first simulation results with the aim to maximize the output module efficiency and determine the efficiency dependence on the number of cells per module as well as on the cell shape.

Sunplugged CIGS Solar Cell Technology

Flexible thin film CIGS solar cell consists of the stainless steel substrate, the conductive layer from molybdenum, the absorber layer from $Cu(In, Ga)Se_2$, the buffer layer from CdS and the TCO (transparent conductive oxide) layer from ZnO:Al.

One core innovation of the Sunplugged technology is a flexible interconnecting scheme that allows the separation of all solar cell related processes from all processes related to the solar module production. This novel approach enables the flexible production of custom-made photovoltaic modules.

This approach cuts dramatically production costs, increases efficiencies and facilitates the flexible production of custom-made photovoltaic modules.

Sunplugged Vision

Sunplugged´s vision is to provide a new breed of Photovoltaic (PV) foil as a decentralized and sustainable source of energy which can be easily integrated into a multitude of devices,vehicles and building skins.

For these PV integrated product solutions are customisable shapes, sizes, colours, transparencies and specific electrical properties required, which have a decisive influence on the acceptance on the market.

In order to meet the requirements as expressed by architects and designers, Sunplugged´s approach is similar to that adopted by a tailor in the manufacture of bespoke "made-to-measure" garments.

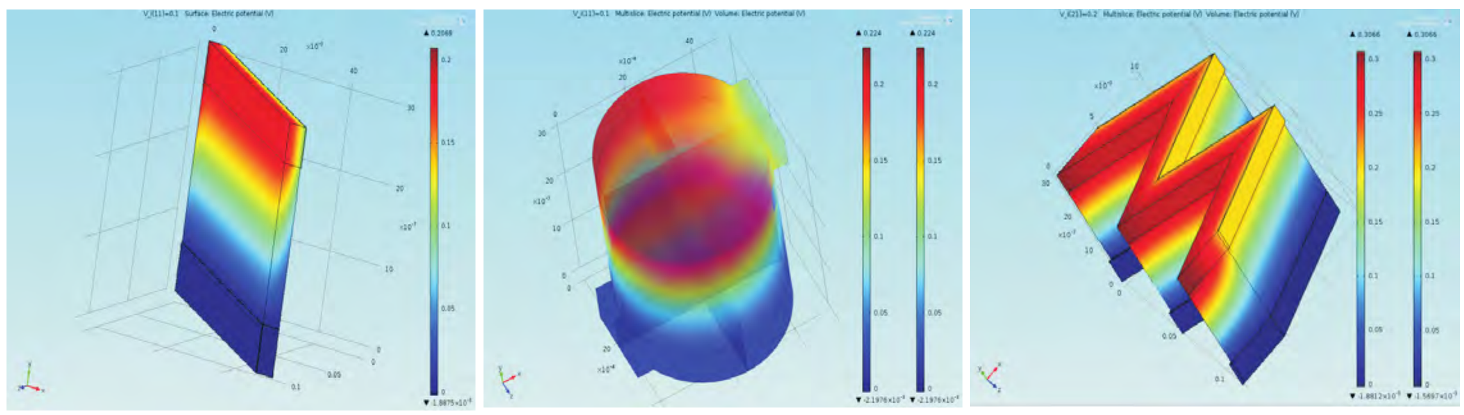
The fabric, or basic material, is an endless thin-film solar cell.This solar cell can be cut according to the size and shape stipulated by the user and a flexible interconnection can be applied "on-the-fly" to obtain the required electrical specifications. This innovative approach eliminates the confinements of mass-produced solar cells an offers an unknown freedom for solar powered products.

Modelling and Simulations

Modeling was done in COMSOL Multiphysics© based on partial differential equations and on finite element method solver. For the modeling of CIGS solar cells as a heterojunction diode, we have used a one diode model. The output current can be described with the following equation:

$$I = I_0\left(e^{\frac{V-IR_s}{AkT}} - 1\right) + \frac{V - IR_S}{R_{sh}} - I_L$$

The simulations were based on Sunplugged geometrical, optical and electrical parameters of solar cell. For the module optimization, TUW varied the size of the solar cells/modules, the number of cells per module and the size of interconnections.

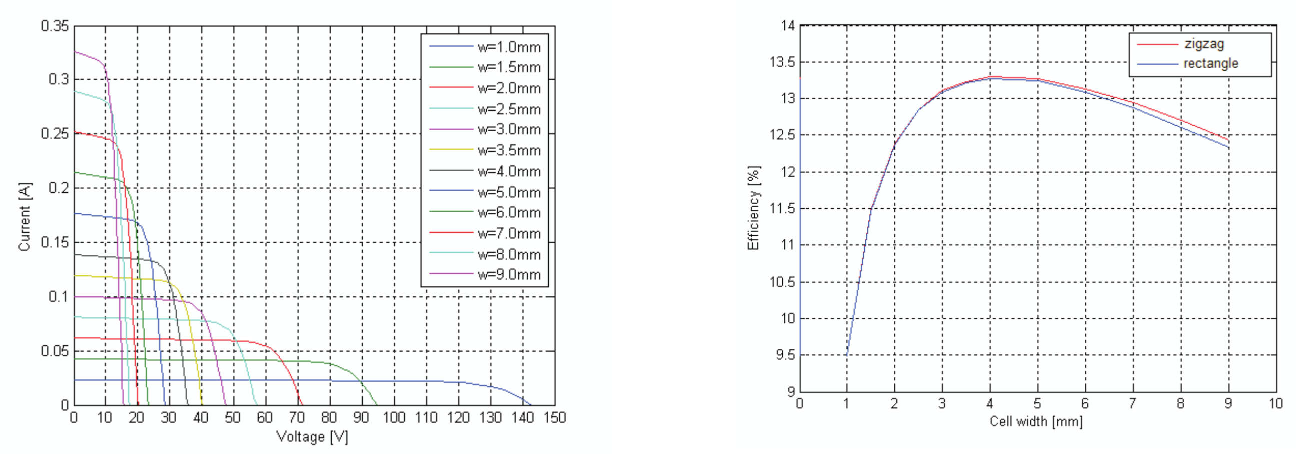


The figure presents the potential distribution in CIGS solar cell with Vcell = 0.1V and for: left: the rectangular, middle: the circular shape and right: zig-zag shape of a solar cell.

Discussion of Results

By changing the shape of CIGS solar cells, it has been shown that the maximal efficiency can be achieved with the cell width of 4mm (efficiency = 13.27%). For the smaller cell widths (<4mm), the module efficiency is increasing, because the increase in cell width reduces the relative area loss (on module level). For brighter cells (>4mm), the efficiency is reduced due to the growth of the series resistance (from serial interconnections).

The solar cell efficiency for the zigzag shape of the cell is higher than for the rectangular one. It can be explained by the fact that the current flows along the shortest path. Zigzag form offers shorter pathway than the rectangular shape in spite of the same cell width and the same relative loss area. The maximal simulated efficiency for the zigzag shape has been obtained with the cell width of 4mm (13.30%).



Left: I-V curves (output characteristics of modules) for different solar cell widths,
Right: module efficiency as a function of cell width for zigzag and rectangular cell shape.

Acknowledment

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