Numerical Modelling of Tandem Solar Cells

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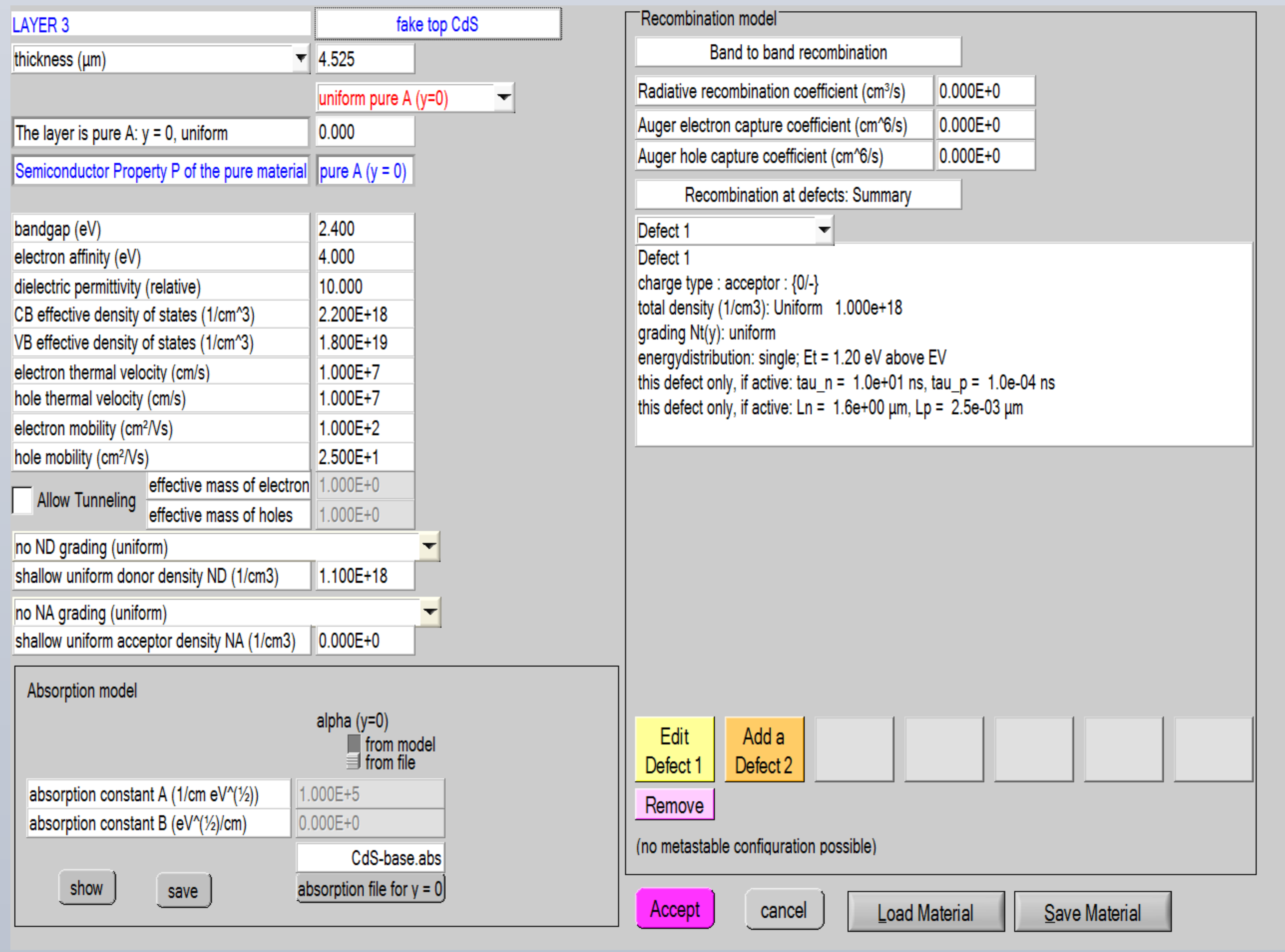
Abstract

In this work, Solar Cell Capacitance Simulator (SCAPS-1D), a software primarily developed to analyze single-junction devices, was used to effectively model photovoltaic thin-film multi-junction solar cells. The tandem configuration in this study consists of a modified cadmium telluride based top cell which uses n-MZO (magnesium doped zinc oxide) as an emitter layer (as opposed to n type cadmium sulfide) and a silicon-based bottom cell with n type silicon as an emitter layer. Parameters including the thickness of the emitter and absorber layers were varied to improve the open circuit voltage to 1.4 V, short circuit current to 24.5 mA/cm2, fill-factor to 85.9%, and overall efficiency of the device to 28.8%. This numerical work supports the study of tandem-devices and their potential to optimize efficiency by making use of the entire spectrum of solar irradiation.

Introduction

- Solar cells convert the sun's energy directly into electrical energy. This conversion is called photovoltaics.
- In order to conduct experiments on different potential solar-cell layer materials, simulations are performed beforehand to estimate what width the materials should be made.

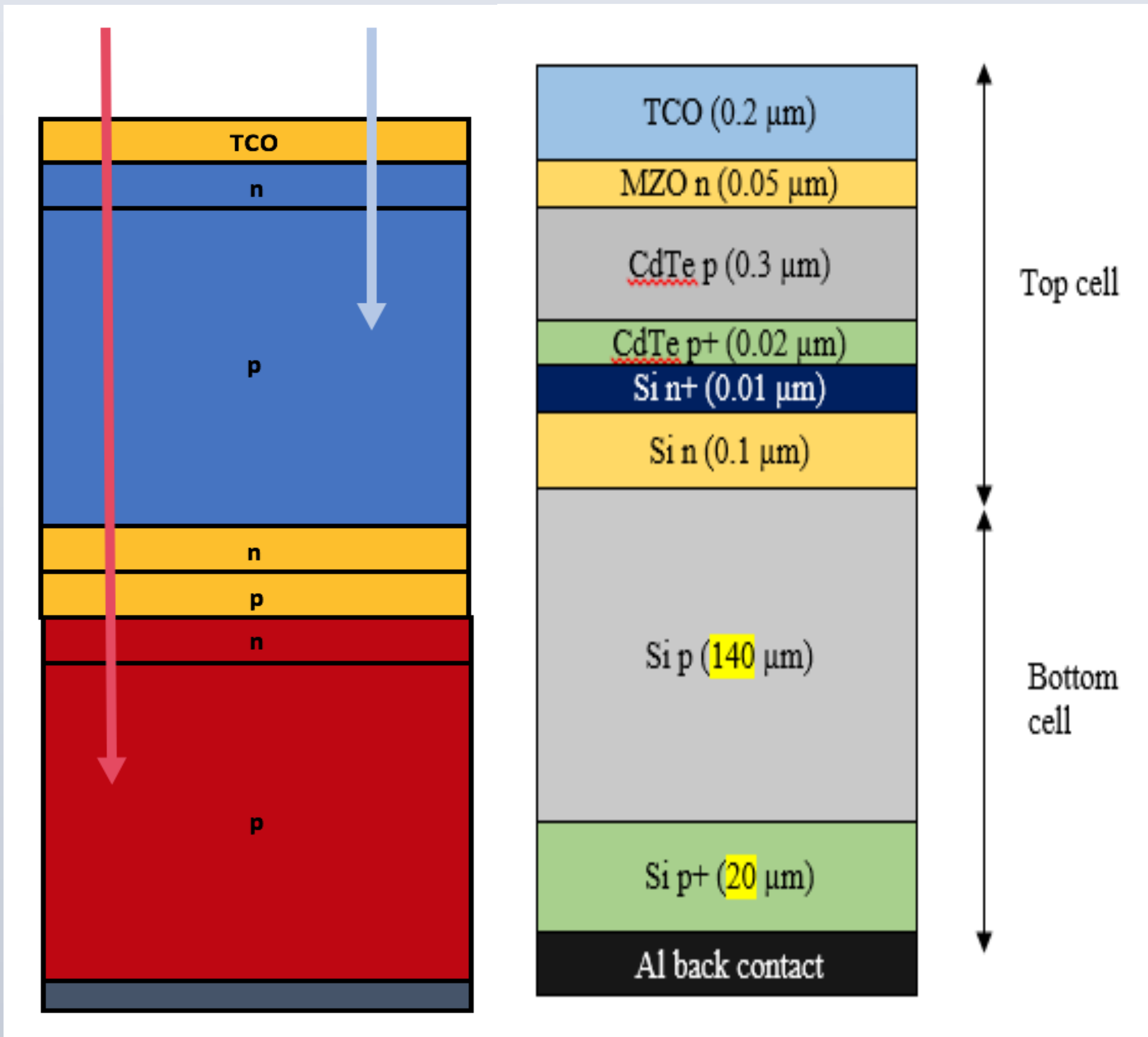


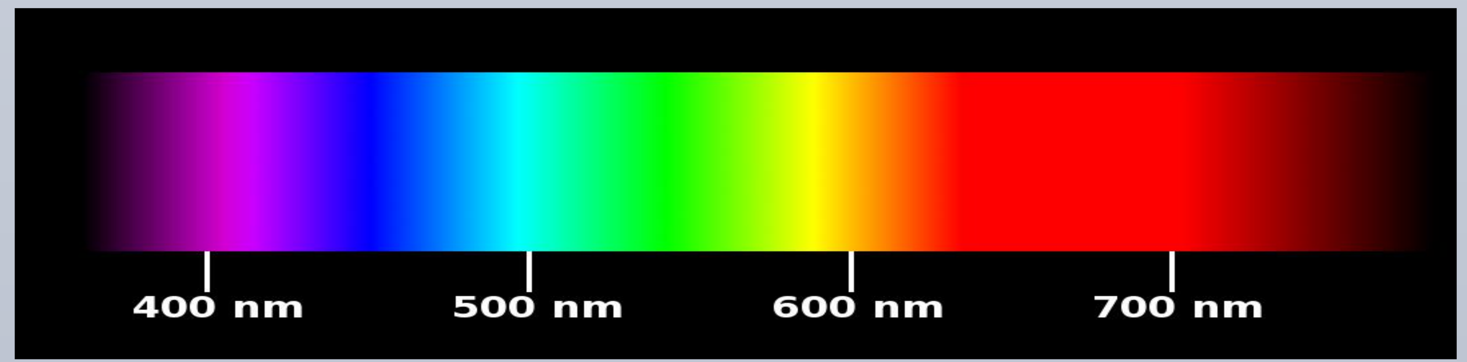
SCAPS-1D

- Solar Cell Capacitance Simulator (SCAPS) is a one-dimensional solar software developed at the Department of Electronics and Information Systems (ELIS) of the University of Gent, Belgium.

Tandem Solar-Cells

- The amount of energy that can be converted using a single-junction solar cell is dependent upon the band-gap of the layers.
- Different materials have different band gaps, thus different configurations absorb energy from different parts of the electromagnetic spectrum.
- In an effort to maximize the amount of energy being absorbed by and converted from light, the idea of multi-junction solar cells has been created.
- By having two cells in tandem with one another, a cell can convert energy from light at different wavelengths.





The simulated tandem cell consists of:

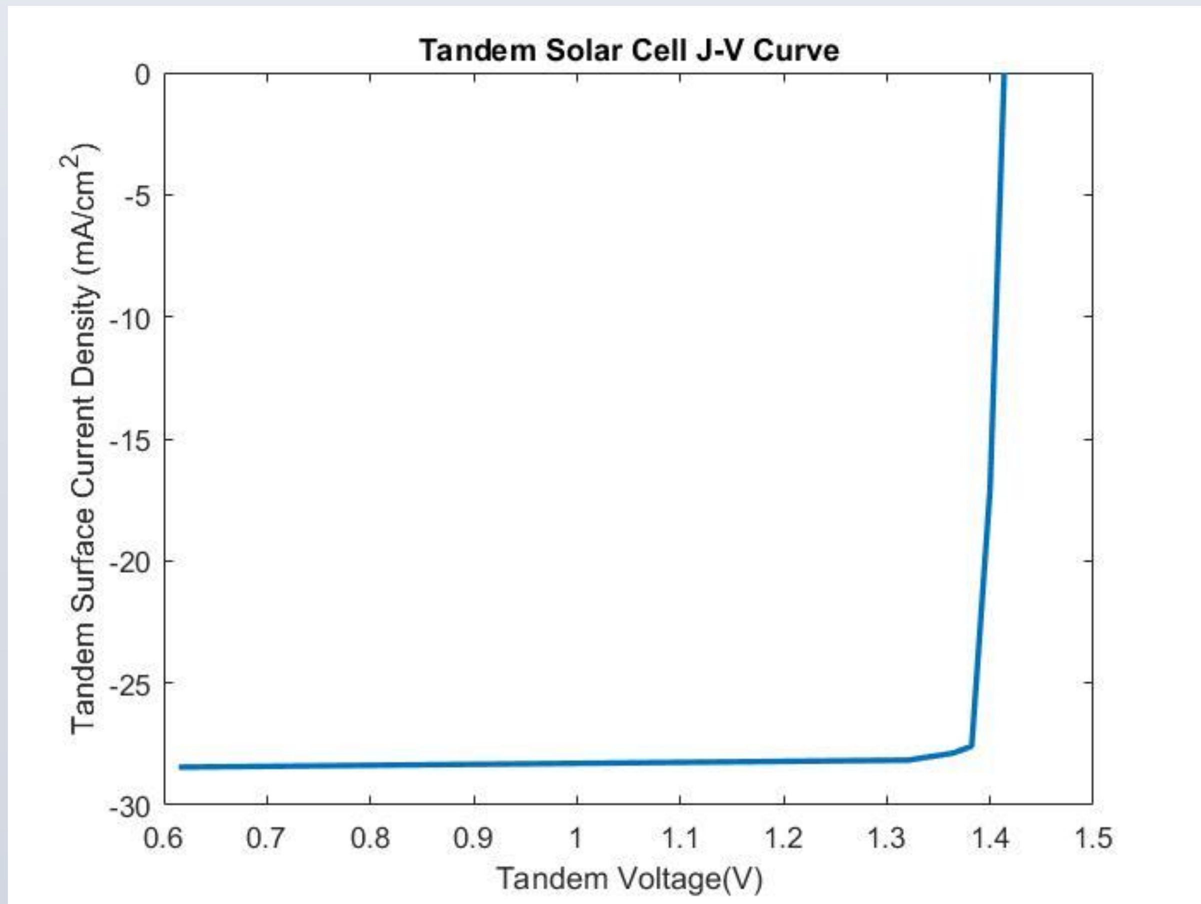
- Cadmium Telluride-based top cell with a magnesium doped zinc-oxide replacement for the standard cadmium sulfide based n-type layer
- Silicon-based bottom cell

Parameters

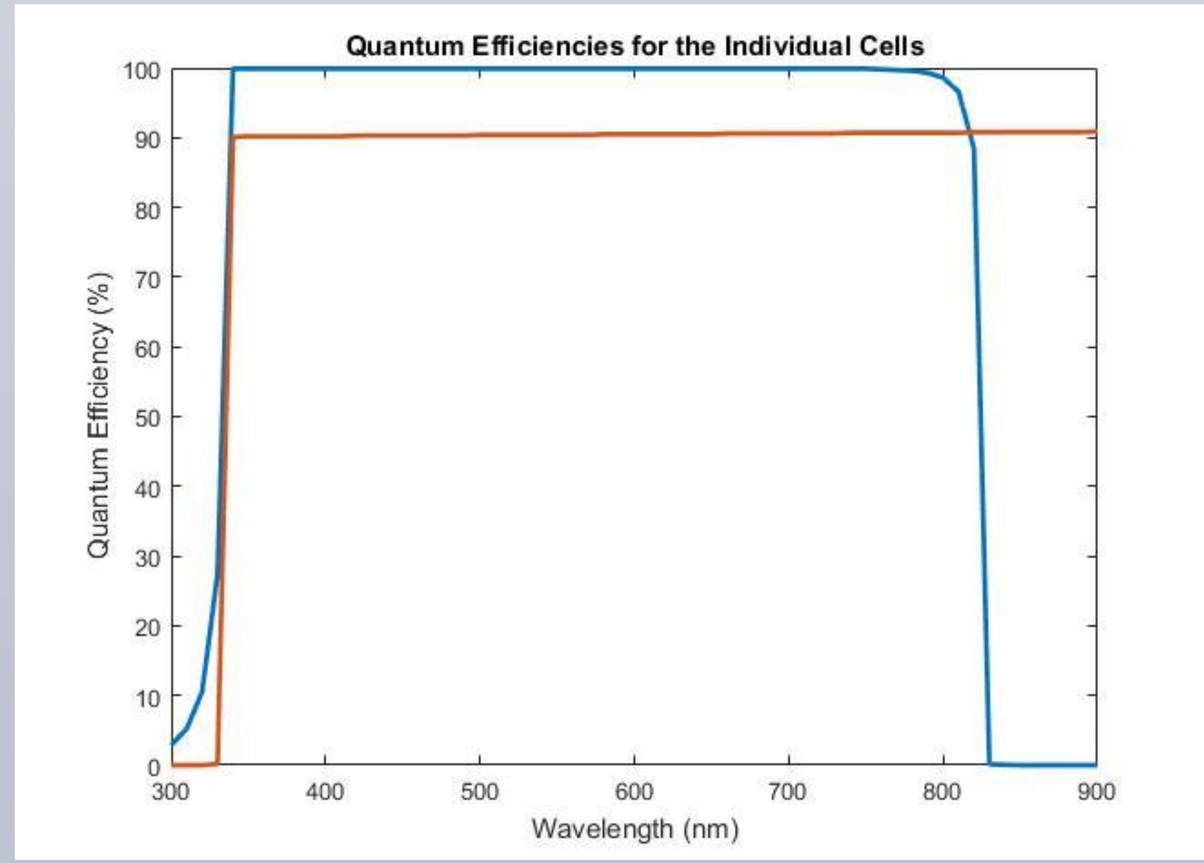
. Table 1: Input parameters for SCAPS-1D simulation

Parameters	TCO	n MZO	p CdTe	p+ CdTe	n+ Si	n Si	p Si	p+ Si
Thickness, (µm)	0.5	0.05	2.0	0.02	0.01	0.1	140.0	20.0
Dielectric ratio, ($\varepsilon/\varepsilon_0$)	9.00	9.00	9.40	9.40	11.9	11.9	11.9	11.9
Electron mobility, µN (cm^2/Vs)	5.0E+1	1.0E+2	3.2E+2	3.2E+2	1.35E+3	1.35E+3	1.35E+3	1.35E+3
Hole mobility, µP (cm^2/Vs)	2.5E+1	2.5E+1	4.0E+1	4.0E+1	4.5E+2	4.5E+2	4.5E+2	4.5E+2
Acceptor concentration, (cm^{-3})	-	1	1.0E+15	2.10E+20	-	-	1.0E+16	1.0E+19
Donor concentration, (cm^{-3})	5.0E+20	1.0E+17	1	-	1.1E+19	1.0E+16	-	-
Band gap, E_g (eV)	3.7	3.7	1.5	1.5	1.12	1.12	1.12	1.12
Density of states, NC (cm^{-3})	2.2E+20	2.2E+17	8.0E+17	7.5E+17	2.8E+19	2.8E+19	2.8E+19	2.8E+19
Density of states, NV (cm^{-3})	1.8E+19	1.8E+18	1.8E+19	1.8E+19	1.04E+19	1.04E+19	1.04E+19	1.04E+19
Electron affinity, χ (eV)	3.7	3.7	1.5	1.5	1.12	1.12	1.12	1.12

Results



- The shapes of the plots illustrate that SCAPS can be used to effectively model multi-junction solar cells.



- Open circuit voltage V_{oc} = 1.4 V
- Short circuit current J_{sc} = 24.5 mA/cm^2
- Fill-factor FF= 85.9%
- Overall Efficiency= 28.8%.