Challenges in PV Science , Technology and Manufacturing: A workshop on the role of theory, modeling, and simulation

Tech Session 1: Crystalline PV

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It's only a diode. How hard can it be?

A brief history our solar cell modeling and simulation

Our early work was motivated by Interdigitated Back Contact (IBC) cell design needs.

Original 1-D modeling was done to confirm what we thought we knew about solar cell operation.

The insight provided by the 1-D model was astonishing (east to us)

Simulation

The simulation is viewed a microscope that allowed us t
see" the inner working of the cell as a function of
concentration, spectrum, operating point and the design
parameters of the cell. We can view fields, recombinatio
ates, generation rates, minority and majority current
densities, spectral response, current-voltage
characteristics, efficiency and a number of other
parameters.

The above information allows for the rapid determination
of the factors which are limiting cell performance and for
he rapid evaluation of alternate cell and system designs

Where have theory, modeling and simulation been most effective in improving performance of crystalline PV

- Cell design

- Multi-junction cell design

- System design when the system involves lenses, mirrors and/or spectrum splitters
  Optimization of yearly electrical energy generation.

- The most effective use of modeling and simulation occurs when there is close, open and trusted collaboration between the modelers, the cell or system designers, the fabricators and testers.

What is the status of the field?

Single crystal silicon simulation is predictive

Many of the III-V's are predictive as single unction and monolithic multi-junction cells.

CIGS models are good

HIT cell models are under active development

What is the status of the field? (Cont.)

Amorphous silicon cell models are good

Cells that involve grain boundaries need more work - likely 2-D models.

Tunnel diode interface models may need more development particularly at high concentration insolatio and non-uniform illumination.

Monolithic multi-junction cells under non uniform high

What is the status of the field? (Cont.)

Parametrized simple models that are accurate over a wide range of concentrations and temperatures are needed for systems studies.

What are the fundamental and long-term challenges?

- Need better integration of cell models with:
  - Optical models (both ray tracing and Maxwell's Equations solvers)
  - Heat flow models
  - Process models- particularly for thin film cells

What are the fundamental and long-term challenges? (Cont.)

The very wide band gap materials become important when five or more junctions are involved. Very little work has been done to model such cells. Some of the wide band gap PV materials are piezoelectric i.e. GaN, and will need to incorporate polarization into Poisson's Equation.

Compared to Si-industry, are there TMS issues that make the problems uniquely challenging?

The interplay of optics, recombination and generation, majority and minority carrier flow, the need for very long lifetimes, the important effects of HSR, photon recycling and Auger recombination, make the models much more complex (and interesting).

What have been the roles of process and reliability modeling in crystalline PV?

Use of Supreme in early models

Some use of models to look at Stabler- Wronski effect o
cell performance

Did not have much impact at the time but demands or
reliability will call for reliable models. How confident are
of 25 year guarantees?

What is the role for TMS?

TMS already play a critical role in the **design of cells**. It enhances understanding. It identifies problem areas and speeds the development process by reducing the number of developmental runs needed.

It has proved to be critical in **system development** as well, particularly in concentrator systems using complex optics. It allows for the rapid evaluation of system trades, filter designs, dichroic mirror cut off wavelengths and sharpness, impact of tracking errors.

TMS informs designs that are intended to **maximize yearly electrical energy production** rather than

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