CdTe Solar Cell Design & Manufacture for Large Scale, Grid-Connected Systems

Student C

3.003 Engineering the Future of Solar Electricity

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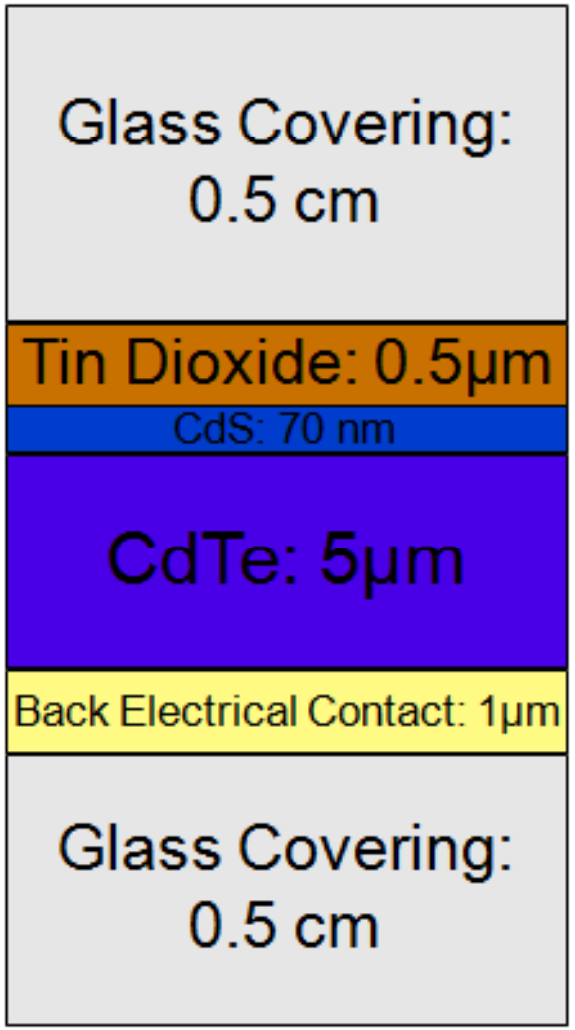
Annual Installed Grid-Connected PV Capacity by Sector: red – nonresidential; blue – residential; yellow – utility (Sherwood 2009)

Graphs removed due to copyright restrictions. Please see Fig. 1 and Fig. 2 in Sherwood, Larry. "U.S. Solar Market Trends 2008." Interstate Renewable Energy Council, July 2009.

Capacity of Annual US PV Installations by Grid-Connected (red) and Off-Grid (blue) (Sherwood 2009)

CdTe Solar Cell Design

- CdTe band gap energy = 1.47 eV (direct)
  - CdS band gap energy = 2.42 eV
- P-n junction: CdTe (p-type) & CdS (n-type)
- Anti-reflective coating: Tin dioxide (n = 2.00)
- High absorption coefficient allows for scaling to thin film
- Low thermal conductivity ensures steady efficiency on hot days
- Glass coverings provide for physical protection and a streamlined manufacturing process



Proposed schematic for CdTe cell

PC1D Simulation

- Paramaters:
  - 100 sq. cm area
  - Modified GaAs file
  - CdTe thickness: 5 micrometers
  - Anti-reflective coating

coating layer	thickness (nm)	index of refraction
1	10000	1.52
2	500	2.00
3	70	2.51

RESULTS

Short-circuit Ib: -2.933 amps

Max base power out: 2.234 watts

DEVICE

Device area: 100 cm^2

No surface texturing

No surface charge

Front surface optically coated

No Exterior Rear Reflectance

No internal optical reflectance

Emitter contact enabled

Base contact enabled

No internal shunt elements

REGION 1

Thickness: 5 µm

Material modified from gaas.mat

Carrier mobilities from internal model

Dielectric constant: 10.9

Band gap: 1.47 eV

Intrinsic conc. at 300 K: 2.59×10^{6} cm^{-3}

Refractive index: 2.67

Absorption coeff. from internal model

No free carrier absorption

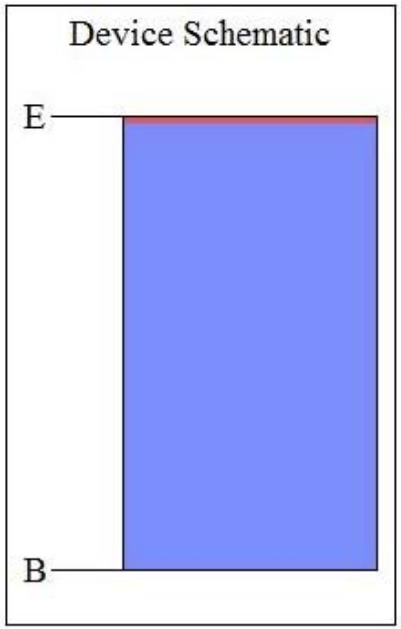
P-type background doping: 1×10^{16} cm^{-3}

1st front diff.: N-type, 1×10^{19} cm^{-3} peak

No 2nd front diffusion

No rear diffusion

Bulk recombination: $\tau_n = \tau_p = 0.01$ µs



Readings from the PC1D Simulation

Concerns

- Toxicity issues: cadmium
- Materials scarcity: tellurium: Every GW of PV capacity produced requires 93 metric tons of tellurium (assuming 10% efficiency and 100 W per sq. meter output)
  - Possible 859 – 1716 metric tons available annually
  - Additional estimated 24,000 metric tons of tellurium in US reserves

Photo of Solarpark Wietramsdorf
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CdTe PV system
(http://agmetalminer.com/2008/08/15/introducing%E2%80%A6-cadmium-telluride-solar-panels/)

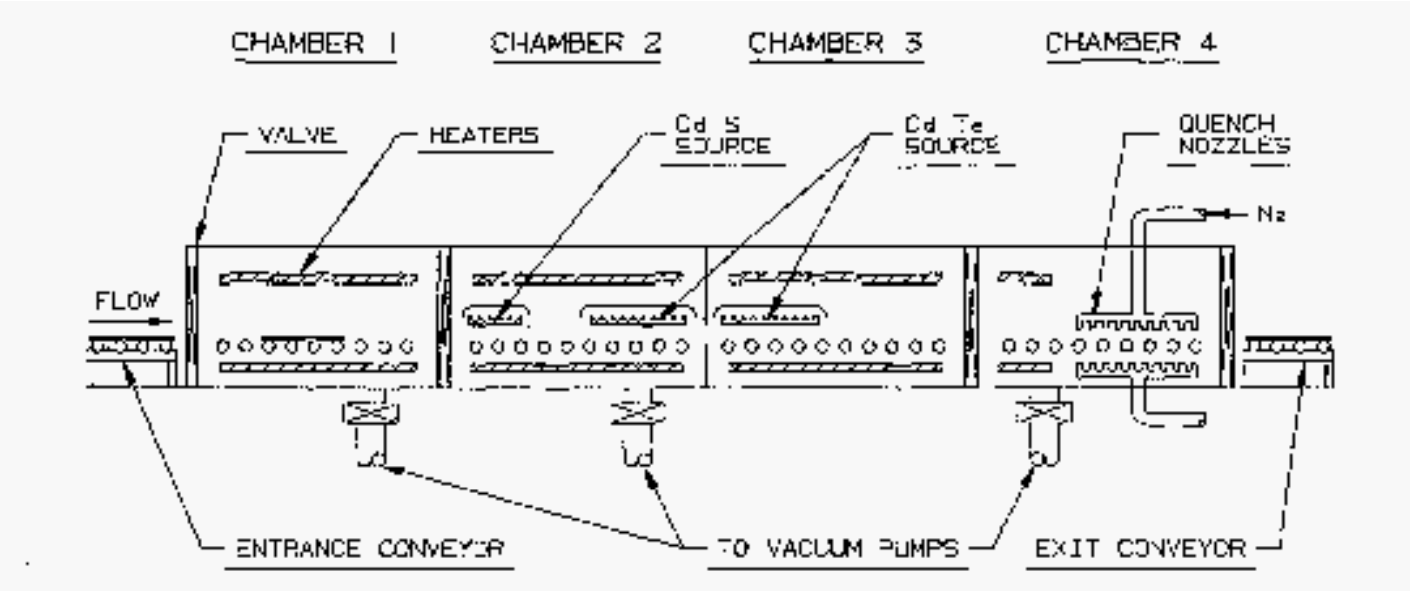
Manufacturing Process

Photo of Abound Solar's Longmont, CO production facility removed due to copyright restrictions.

Vapor Deposition onto glass covering

- High level of automation possible
- Manufacturing cost: < $1/W
- ~ 2 hours to create 1 module

Inside look of Abound Solar 's factory (http://earth2tech.com/2009/04/14/new-name-same-ambition-abound-solar-hot-on-first-solars-heels/)



Schematic of the conveyor for vapor deposition (Nolan and Meyers 1993)

Production Projections

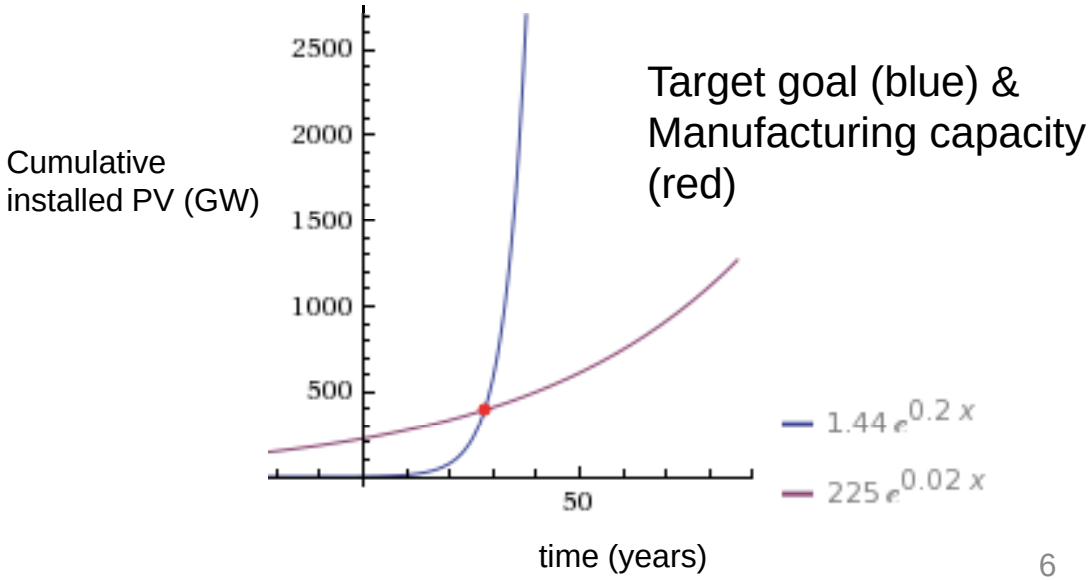
CdTe factories in the US: 223 MW – FirstSolar; 65 MW (only currently operating; 200 MW are possible) – Abound Solar

Mean growth rate for factory additions: 60%

- Assume 20% growth rate: f(t) = 0.288 exp(0.2t) (GW)
  - Cumulateive installed PV: g(t) = 1.44 exp(0.2t)
  - Goal: 225 GW from solar possible in 28 years
    - Assumption: amount of CdTe cells produced in the US equals the number of CdTe cells available to and bought by US consumers

Photo of FirstSolar plant in Kulim, Malaysia removed due to copyright restrictions.

FirstSolar factory in Malaysia (http://www.siteselection.com/features/2009/sep/Malaysia)



Conclusion

- Expansion of large scale, grid-connected PV systems can drastically increase the percent of energy use derived from solar power.
- For an increased use of grid-connected PV systems, it is necessary to lower costs by improving cell efficiency and decreasing manufacturing costs.
- The continued growth of manufacturing capacity within the US is vital for a movement away from the energy crisis and toward energy independence and environmentally-conscious living.

3.003 Principles of Engineering Practice

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