

## EE580 – Solar Cells Todd J. Kaiser

- Lecture 10
- Summary

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## Summer 2010 Class

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### Solar Cell Operation

The diagram shows a cross-section of a solar cell with an n-type emitter and a p-type base. Light enters from the left through an antireflection coating. An electron-hole pair is created in the depletion region. The electric field separates the charges, with electrons moving toward the front contact and holes toward the rear contact. An external load is connected between the contacts, and the text notes that electrons recombine with holes in the load, delivering power.

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### Photovoltaic Effect

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### Efficiency

The flowchart starts with 100 mW of incident light. 21 mW is lost to below-bandgap absorption and 31 mW to excess photon energy lost as heat. This leaves 48 mW available. From this, 1.1 V is available (with 0.6 V open circuit voltage) and 44 mA current is available (with 28 mA short circuit current). Losses from recombination and optical losses reduce the available energy. Series resistance losses further reduce the fill factor to 0.7. The final cell output is 14 mW (23 mW in the laboratory), representing 14% efficiency for commercial cells and 23% for laboratory cells.

- Over half of energy lost initially due to mismatch in photon energy and gap energy
- Trade off between EHP recombination and optical absorption (thickness of cell)
- Almost half of potential lost to recombination

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### Photovoltaic Myth #1

- Solar modules consume more energy for their production than they ever generate.
  - Most frequent argument and just as incorrect
  - Monocrystalline silicon energy payback is 7.3 years (1998)
    - Lifetime of 25-30 years will generate over 3 times the energy of production
  - Thin-film modules energy payback is 1.5 years (1998)

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### Photovoltaic Myth #2

- PV produces more greenhouse gases than it saves
  - Same argument as energy production
  - Greenhouse gas recovery time range between 2.4 – 3.6 years

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### Photovoltaic Myth #3

- Grid-connected PV requires lots of back-up fossil power plants
  - PV energy production coincides largely with peak demand
  - Wind can meet some needs. It has a different and partly opposite time dependence
  - Smart Grid will become widespread in the future. Demand control can be adapted.

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### Photovoltaic Myth #4

- Photovoltaics is too expensive
  - Indeed it is expensive but this is a transitory situation
  - Prices continue to fall
  - PV is long lived, reliable & unlimited potential
  - Long term benefits undeniable

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### Photovoltaic Myth #5

- PV is not ready for marketing, more research is required
  - Improvements of technology is stimulated by interactions with markets
  - Market driven improvements continues
    - Example: cell phones, digital cameras, laptops
  - Lower costs will materialize with feedback from markets and technology improvements

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### Photovoltaic Myth #6

- PV only makes sense in high insolation areas
  - Certainly true that PV modules can produce twice as much energy in high desert areas
  - But larger transmission costs and transmission losses
  - Distributed systems remove costs of transmission and metering, transmission losses, administration and taxes

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### Photovoltaic Myth #7

- PV involves toxic materials
  - Minimal toxic materials in silicon solar cells, but used in the purification and processing
  - The silicon purification technology is well controlled based on decades of experience from the integrated chip industry
  - Future recycling of modules will further reduce environmental impact

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## Photovoltaic Myth #8

- PV consumes valuable land area
  - Large projects use land that is not suitable for other applications
  - There is still a huge supply of unused roof, building, facade, and sound barrier space

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## Photovoltaic Myth #9

- PV competes for roof space with thermal collectors
  - Without question PV modules and solar thermal use the same southern roof space
  - Thermal collectors need only limited space due to higher efficiency (~70%)
    - For hot water 1 m<sup>2</sup> / person
  - Space heating only needed in winter
  - Thermal insensitive to partial shading → use in shadowing areas

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## Final Report

- Introduction
- Fabrication Processes and Theory
- Fabrication Sequence
- Solar Cell Theory of Operation
- Experimental Results
  - IV curve
  - Fill factor
  - Maximum Power
- Recommendations
  - Lecture Modifications
  - Laboratory Modifications
- Summary & implementation into your curriculum

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