Fiber Optics in Solar Energy Applications

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Devices for Renewable Energy
ECE 4803
11/09/2015

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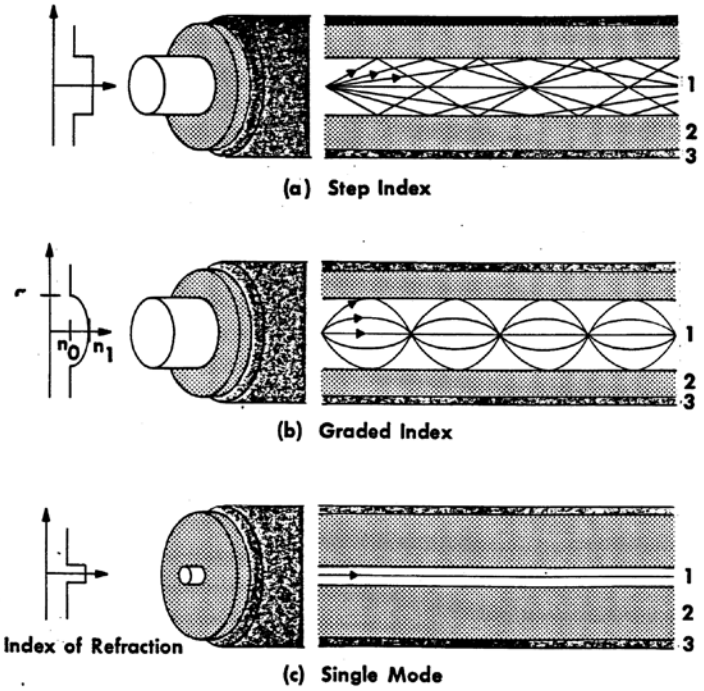
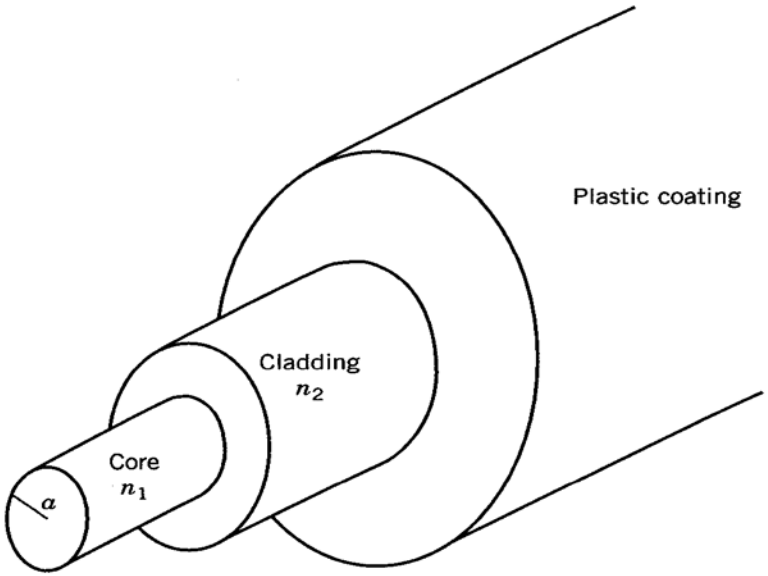
Environmental Motivations

- **Exposure to the Elements**
  - **Beyond the Rooftop**
    - Malleable across multiple applications
    - Roof appearance/durability uncompromised
  - **Subsurface Systems**
    - Cheaper to manufacture and maintain
    - Shading

Optical Fiber

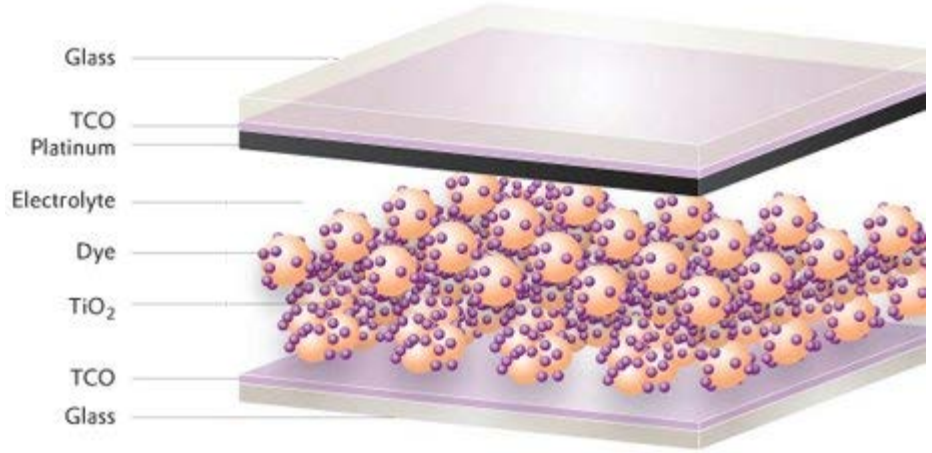
- **Ideal Medium for Guiding Coupled Light**
  - Index of Refraction: n1 > n2





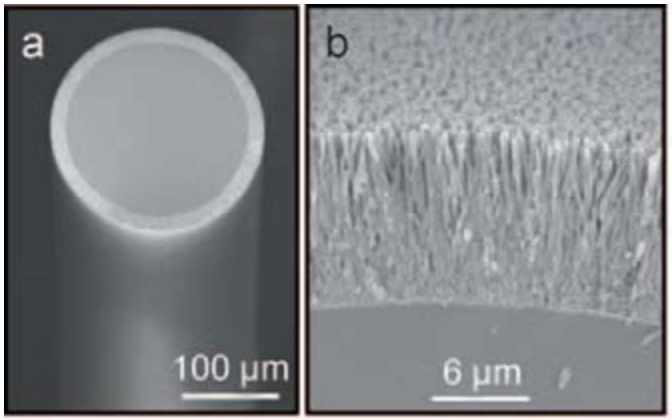
Dye-Sensitized Solar Cells

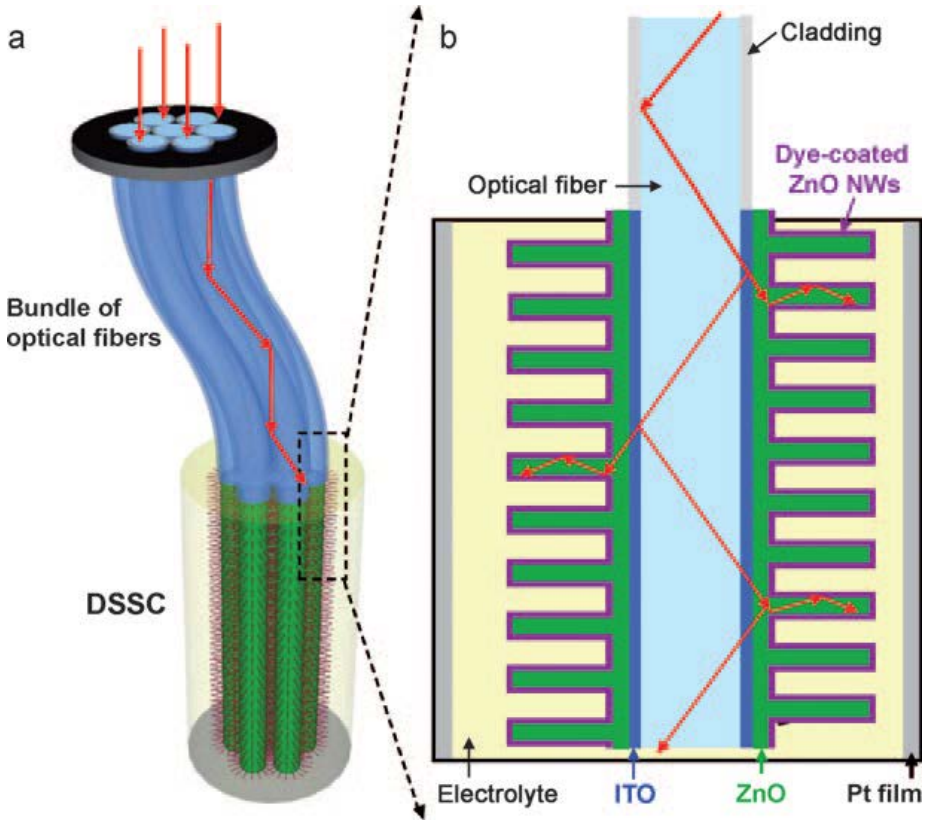
- **Invented in 1991 by Professor Michael Graetzel**
  - Also called “GCells”
- **Exceptionally Large Spectral Range**
  - Capable of capturing sunlight and ambient light (UV to near IR)
- **AM 1.5 Efficiency of 10%**



Nanowire Hybrid Structure

- **ZnO Nanowires**
  - Chemically grown normal to fiber
  - ITO Conductor
    - Change in index of refraction
- **Effective Surface Area**
  - Increased drastically with reflection
  - Unaltered carrier path length

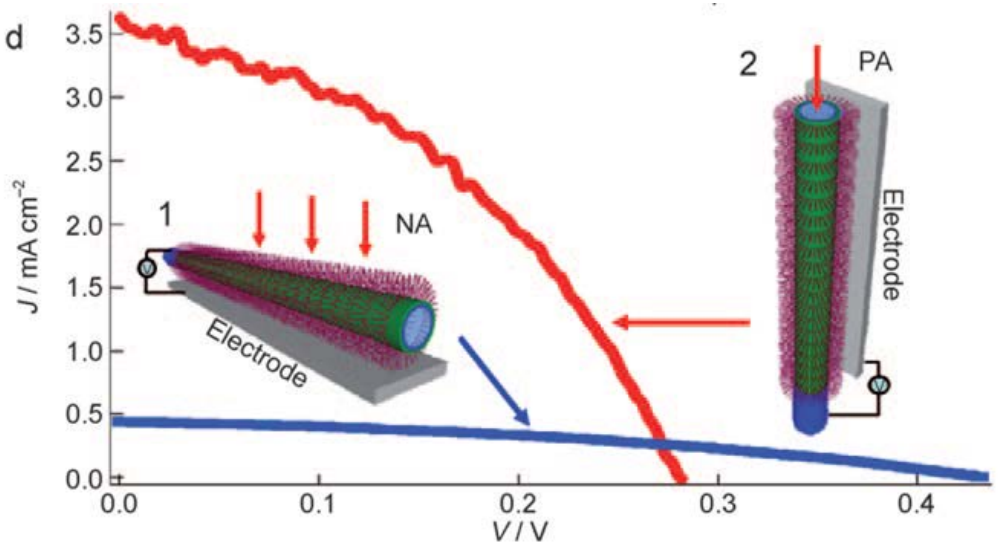




Experimental Results

- **Under one full-sun (AM 1.5) Illumination**

- $\eta = \mathrm{FF} \times V_{\mathrm{OC}} \times J_{\mathrm{SC}} / P_{\mathrm{in}}$



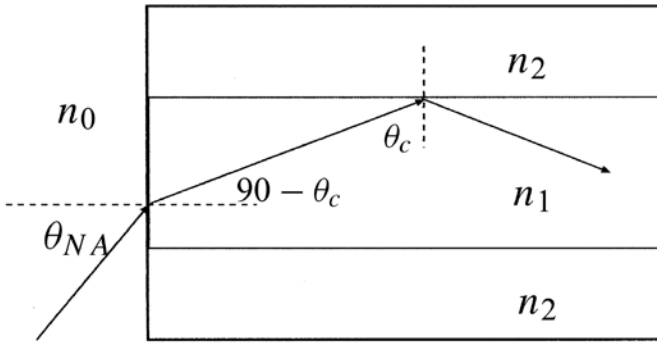
Normal Axis	Parallel Axis
• Jsc = 0.44 mA/(cm^2) • Voc = 0.433 V • FF = 0.375 • Efficiency = 0.071%	• Jsc = 3.73 mA/(cm^2) • Voc = 0.283 V • FF = 0.414 • Efficiency = 0.44%

Advantages

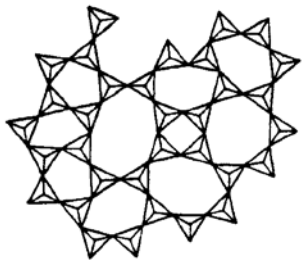
- **Remote Functionality with High Mobility**
- **Potentially Low Manufacturing Cost**
  - **Large Dynamic Range**
    - From below 1 sun to more than 10 suns
    - Diffuse light
  - **3D DSSC Processing**
    - Chemical synthesis at low temperatures
    - Environmentally friendly and biologically safe materials

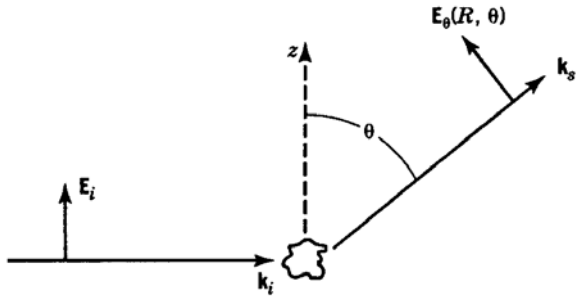
Challenges/Limitations

- **Angle of Incidence**
  - Snell's Law
- **Bending Loss**
- **Rayleigh Scattering**



$$\text{Numerical Aperture} \equiv \sin\theta_{NA} = (1/n_0)\sqrt{n_1^2 - n_2^2}$$





Future Work

- **Fiber Configuration**
  - Distribute bundled fiber networks to maximize coupling efficiency
  - Scalability
- **Fiber Type Performance**
  - Quartz optical fiber vs. polymer fiber
- **Vary Dyes and Surface Coating Material**
  - Dielectric / protective coatings for increased lifetime

References

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