History, Evolution, and Future of PV Cells

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ECG 646: PHOTOVOLTAIC DEVICES AND SYSTEMS

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01 – HISTORY

Early Discoveries

1839
The first observation of the photovoltaic effect by French physicist Alexander Edmund Becquerel.

1875–1880
Professor William Grylls Adams and student Richard Evans Day discover light-generated electricity independent of thermally generated electricity, led to the development of Selenium solar cells with 1-2% efficiency.

1883
American inventor Charles Edgar Fritts constructs a solar module from selenium-coated copper and a thin layer of gold, efficiency of around 1%.

1904
Albert Einstein's work on the photoelectric effect puts light energy and PV effects into a new perspective understandable in scientific terms.

1923
Albert Einstein awarded Nobel Prize for his work on photoelectricity.

Advancements Over Time

1954

New Jersey's Bell Telephone Laboratories releases silicon solar cell with 6% efficiency, with believed capability of 10% with no extra innovation required. (Price at the time was $300/watt)

1956

Toys and radios begin implementation of photovoltaic technology for powering electronics inside.

1960–1970

Space programs begin relying more heavily on solar power for satellites as efficiency increases to 14%, still too expensive for residential use.

1970–1980

Dr. Elliot Berman designs a cheap solar module manufacturing technique bringing the price of solar power down to just $20/watt, paving the way for applications on the ground.

02 – EVOLUTION

Types of Solar Cells Today

Low Efficiency, Low Price

- **Dye-Sensitized Solar Cells**
  - 12% Efficiency (2020)
- **Organic Solar Cells**
  - 15.6% Efficiency (2019)
  - 17.4% Efficiency (2020)
  - Extremely low cost (ranging between $50-$140/m^2)

Mid-Efficiency, Mid-Price

- **Thin-Film Cadmium Telluride Cells**
  - 22.1% Efficiency (2020)
- **Polycrystalline Cells**
  - 22.8% Efficiency (2020)
- **Thin-Film CIGS Cells**
  - 23.4% Efficiency (2020)
- **Unstabilized Perovskite Cells**
  - 25.2% Efficiency (2020)
- **Monocrystalline Cells**
  - 26.1% Efficiency (2020)

High Efficiency, High Price

- **Tandem Perovskite Cells**
  - 28% Efficiency (2020)
- **Gallium Arsenide Cells**
  - 30% Efficiency (2020)
  - Most commonly used in spacecraft
- **Multi-Junction Cells**
  - 39% Efficiency (2020)

Roadblocks and Tradeoffs

- High efficiency cells tend to have longer manufacturing processes, increasing the price.
  - Scientists and engineers at NREL are hard at work trying to decrease the manufacturing time required for a multi-junction cell while maintaining its outstanding efficiency.
- Reflected sunlight is wasted, causing efficiency to be lower than expected in most cells.
  - Roughening or "texturizing" cell surface drastically decreases reflectivity and increases absorption of light, increasing efficiency [9].
    - This process is expensive.
  - Bifacial solar modules have been invented and use the top face to absorb direct sunlight and the bottom face to absorb reflected sunlight [10].

03 - FUTURE

Future Work and Innovation

- Development of a new, faster process for multi-junction cell manufacturing which will maintain efficiency [8].
- Implementation and further development/dependence upon organic photovoltaic solar cells [1].
  - Current cell efficiency has reached a maximum of 13.2%.
  - Greater than 5000-hour initial unencapsulated lifetime.
  - Simple, cheap manufacturing process.
  - Absorbers available in different colors.
  - Diversity of organic materials can be used to construct the cells.
- Bifacial solar panels and innovative installation techniques to absorb the greatest possible amount of the sun’s energy in a given area [10].

Conclusions

- Scientists and engineers at the NREL and other labs in the USA and worldwide are hard at work preparing for the increased demand for a solar powered world in the decades to come [1].

- Many types of cells (slide 7) saw increases in efficiency rating from 2019 to 2020 and will likely continue to improve in the coming years [3].

- Most cell types and processes can be improved with time without the need for more innovation, and the cap for improvement is set by thermodynamic limitations rather than cell technology limitations.

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