# Effective Bismuth Doping on CdTe Solar Cells

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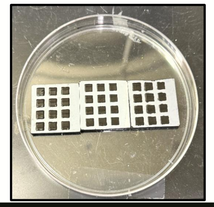
## 1. Motivation

With the growing global energy crisis, advancing renewable energy technologies is vital for ensuring a sustainable future for humankind. From house solar panels to large scale photovoltaic power stations, the role of solar power generation has become indispensable. Cadmium telluride (CdTe) solar cells offer low-cost production but face challenges such as limited efficiency, material scarcity, and potential environmental concerns.

## 2. Research Process

Bi-doped and undoped (CHT) CdTe solar cells were fabricated using a standard device process beginning with substrate cleaning in ammonium hydroxide and hydrochloric acid to remove contaminants and oxides. The Bi-doped samples were coated with a bismuth nitrate solution using a dynamic spin-coating method, while the CHT samples were left undoped for comparison. After coating, the Bi-doped films were annealed to activate the dopant and improve lattice incorporation. Both device types then received a brief HCl etch before depositing a carbon back contact. Then, silver was evaporated as the top contact and the completed devices were given a final low-temperature anneal. Finally, both samples were characterized using Photoluminescence (PL), Time-Resolved Photoluminescence (TRPL), External Quantum Efficiency (EQE), Capacitance–Voltage (CV), and Efficiency measurements.



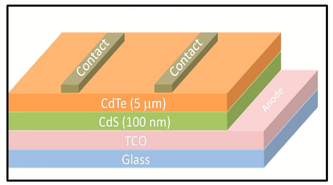
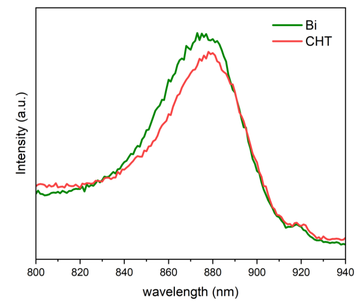


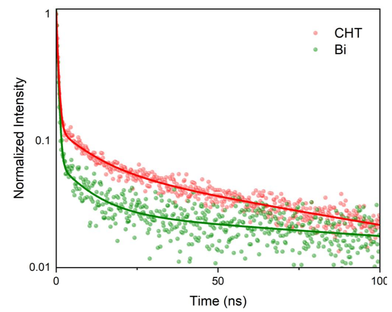

Fig 1. & Fig 2. overview of CdTe device structure

## 3. Results

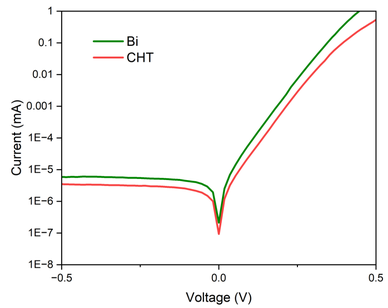
PL



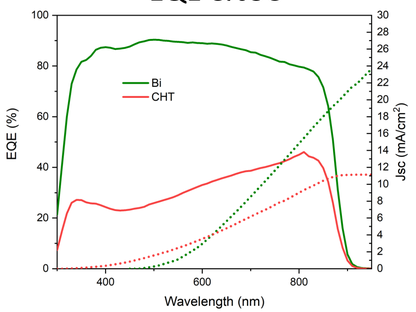

TRPL



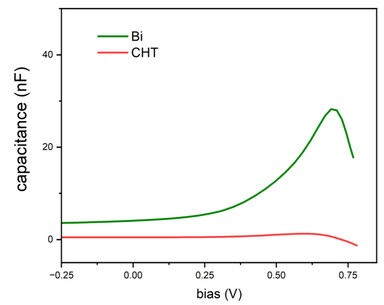

Dark IV



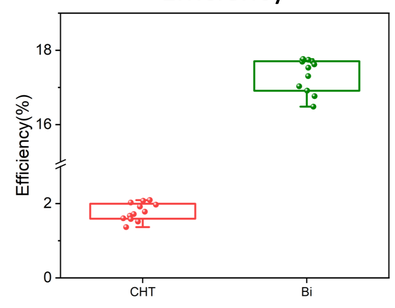

EQE & JSC




CV




Efficiency




## 4. Discussion

**PL & TRPL:** Bi-doped shows higher PL intensity but a faster TRPL decay. It indicates Bi reduces defects while enabling more efficient carrier extraction.
**Dark IV:** Bi-doped creates lower leakage current in the dark and behaves more like an ideal diode, showing that fewer defects allow unwanted current to flow.
**EQE&JSC:** Bi-doped shows higher EQE and larger JSC at all wavelength, which tells the Bi-doped material collects more of the generated carriers before they are lost to defects.
**CV:** The Bi-doped device shows higher capacitance, which means it has more charge in the absorber and better p-type doping.
**Efficiency:** Bi doping achieve dramatically higher and more consistent efficiencies. This improvement directly correlates with better carrier collection and reduced recombination losses, making the device works more effectively.

## 5. Conclusion

With these experimental results, future optimization of dopant concentration and processing conditions can be guided without needing extensive trial-and-error fabrication. This approach allows performance prediction and material improvement based on measurable optical properties for the development of higher-efficiency CdTe solar cells.

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