



Building an All-Sulfide $\text{TaS}_2/\text{Cu}_2\text{-II-Sn-S}_4/\text{CdS}$ Solar Cell and Putting it on Silicon

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Publication date:
2020

Document Version
Publisher's PDF, also known as Version of record

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Citation (APA):
Crovetto, A., Assar, A., Nielsen, R., Hansen, O., Seger, B., Chorkendorff, I., & Vesborg, P. (2020). *Building an All-Sulfide $\text{TaS}_2/\text{Cu}_2\text{-II-Sn-S}_4/\text{CdS}$ Solar Cell and Putting it on Silicon*. Poster session presented at American Physical Society March Meeting 2020, Denver, United States.

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Building an All-Sulfide $\text{TaS}_2/\text{Cu}_2\text{II-Sn-S}_4/\text{CdS}$ Solar Cell and Putting it on Silicon

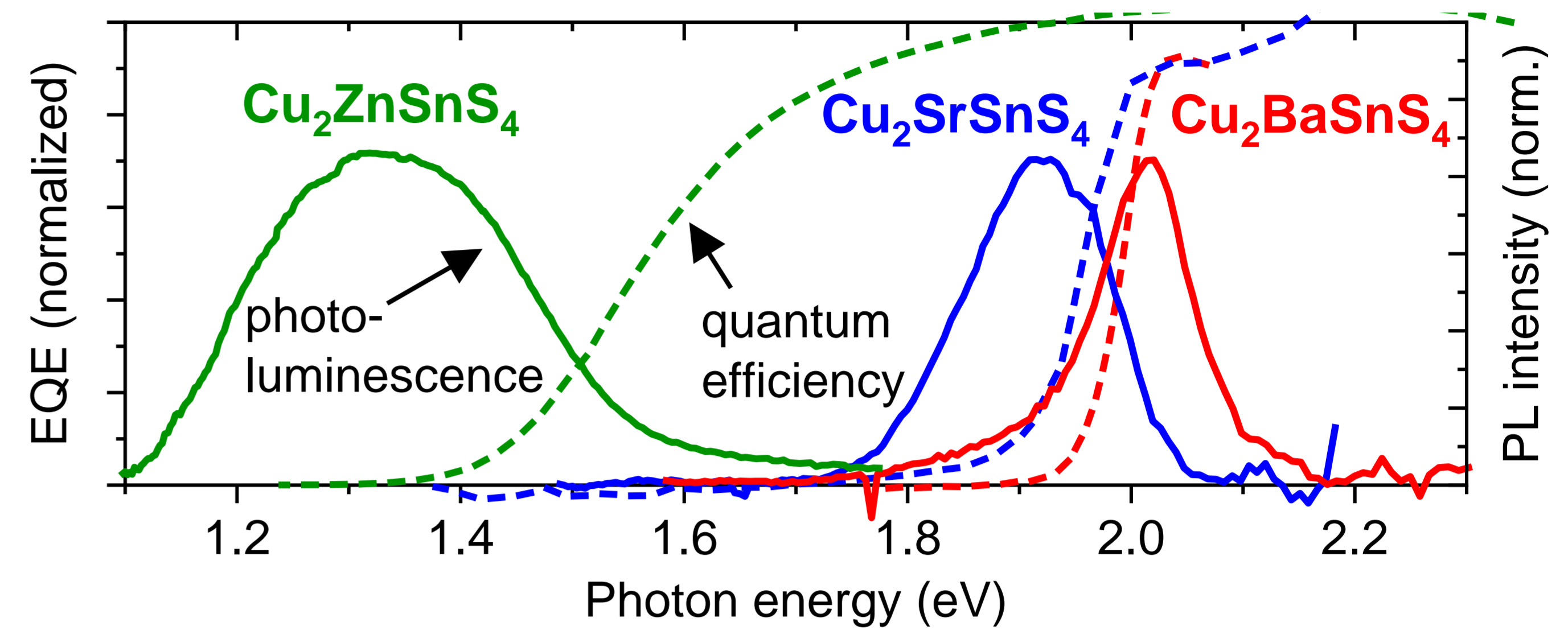
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$\text{Cu}_2\text{II-Sn-S}_4$ photoabsorbers

- $\text{Cu}_2\text{ZnSnS}_4$ is earth-abundant and non-toxic but it suffers from tail states and defects
- When replacing **Zn** (Group IIB) with **Sr** or **Ba** (Group IIA):
 - Band gap increases from 1.5 eV to 2.0 eV
 - Less tail states. Smaller photoluminescence - band gap shift

$\text{Cu}_2\text{SrSnS}_4$ and $\text{Cu}_2\text{BaSnS}_4$: ideal top absorbers for tandem solar cells?

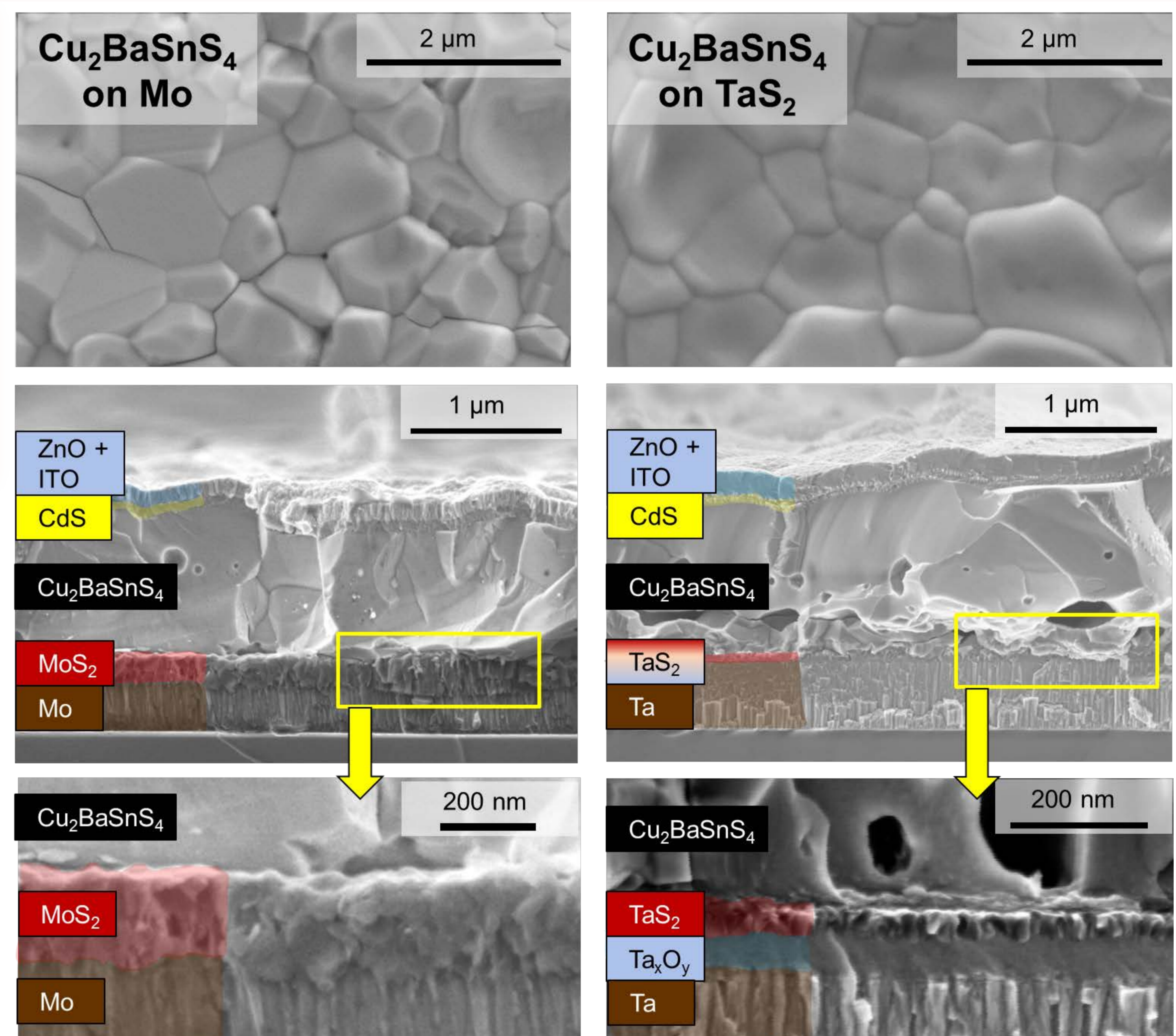
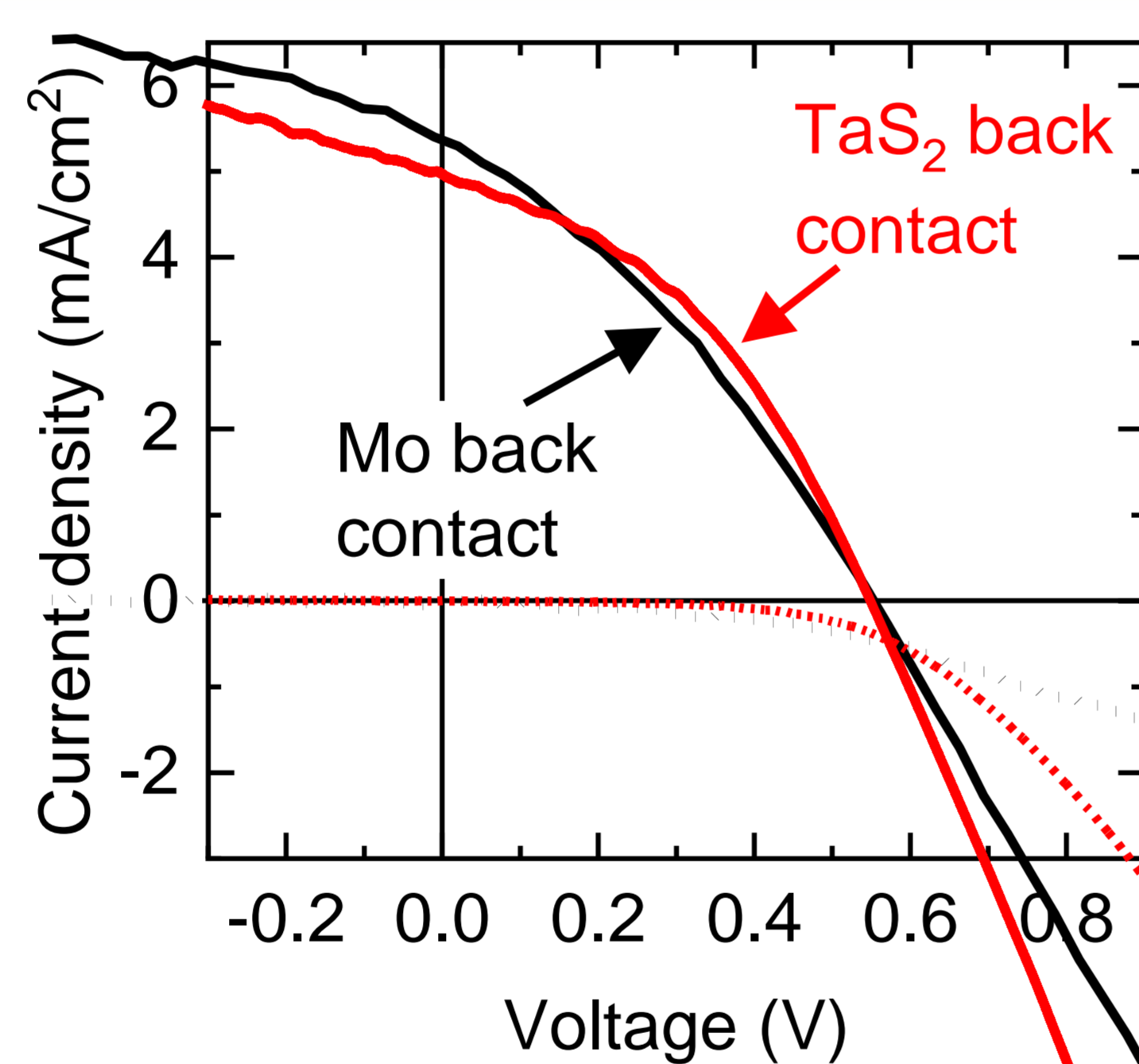


Single-junction cells with a TaS_2 back contact

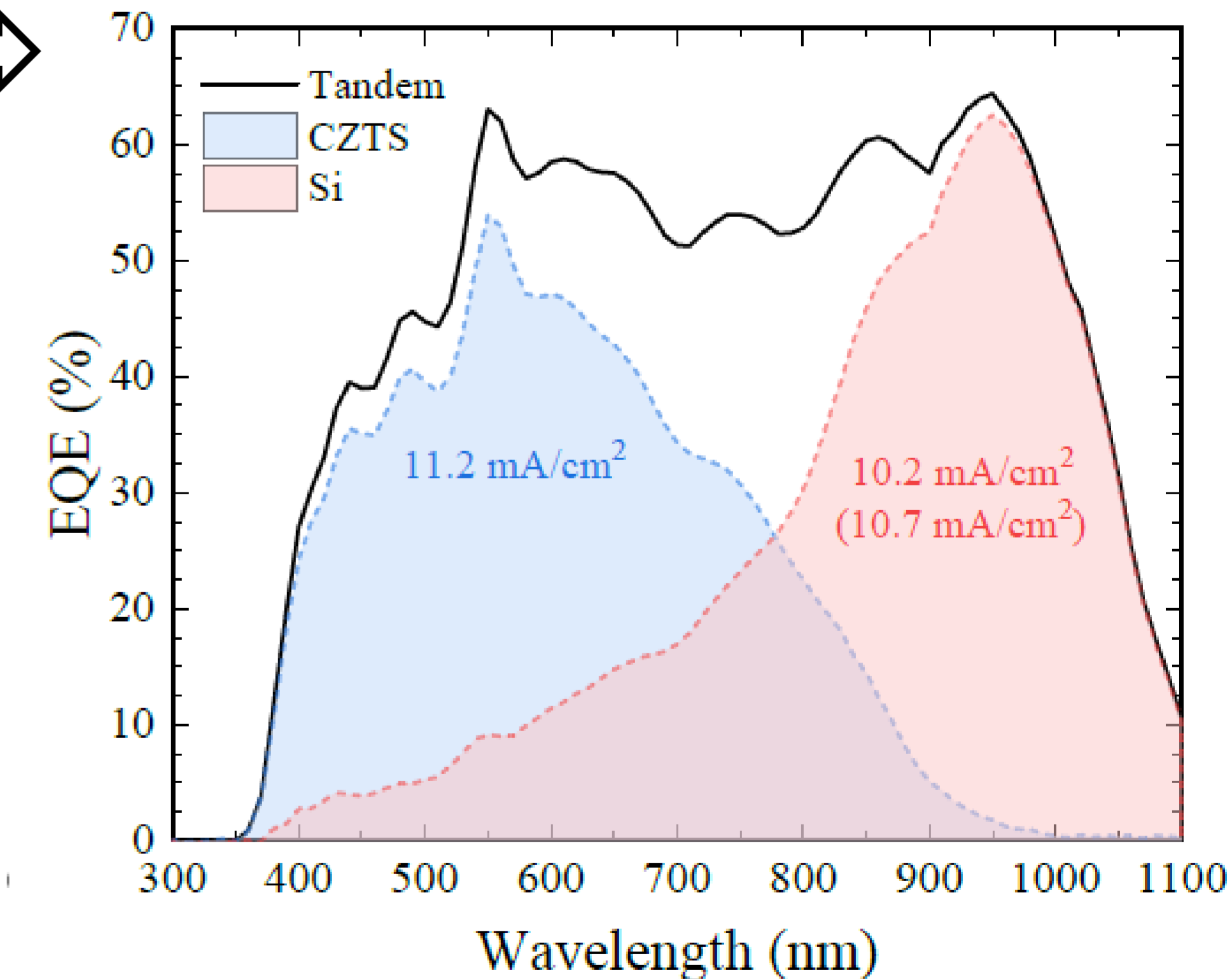
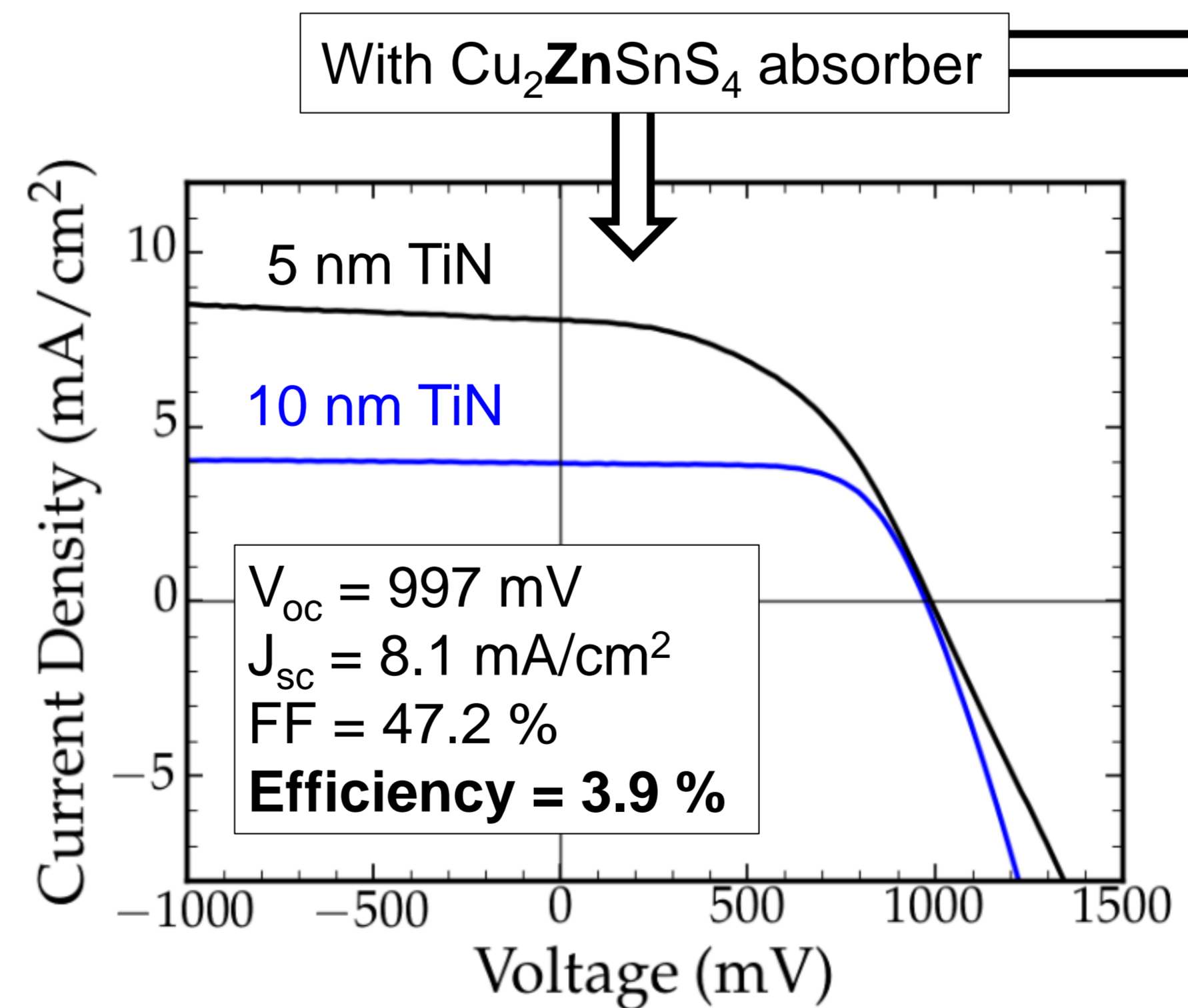
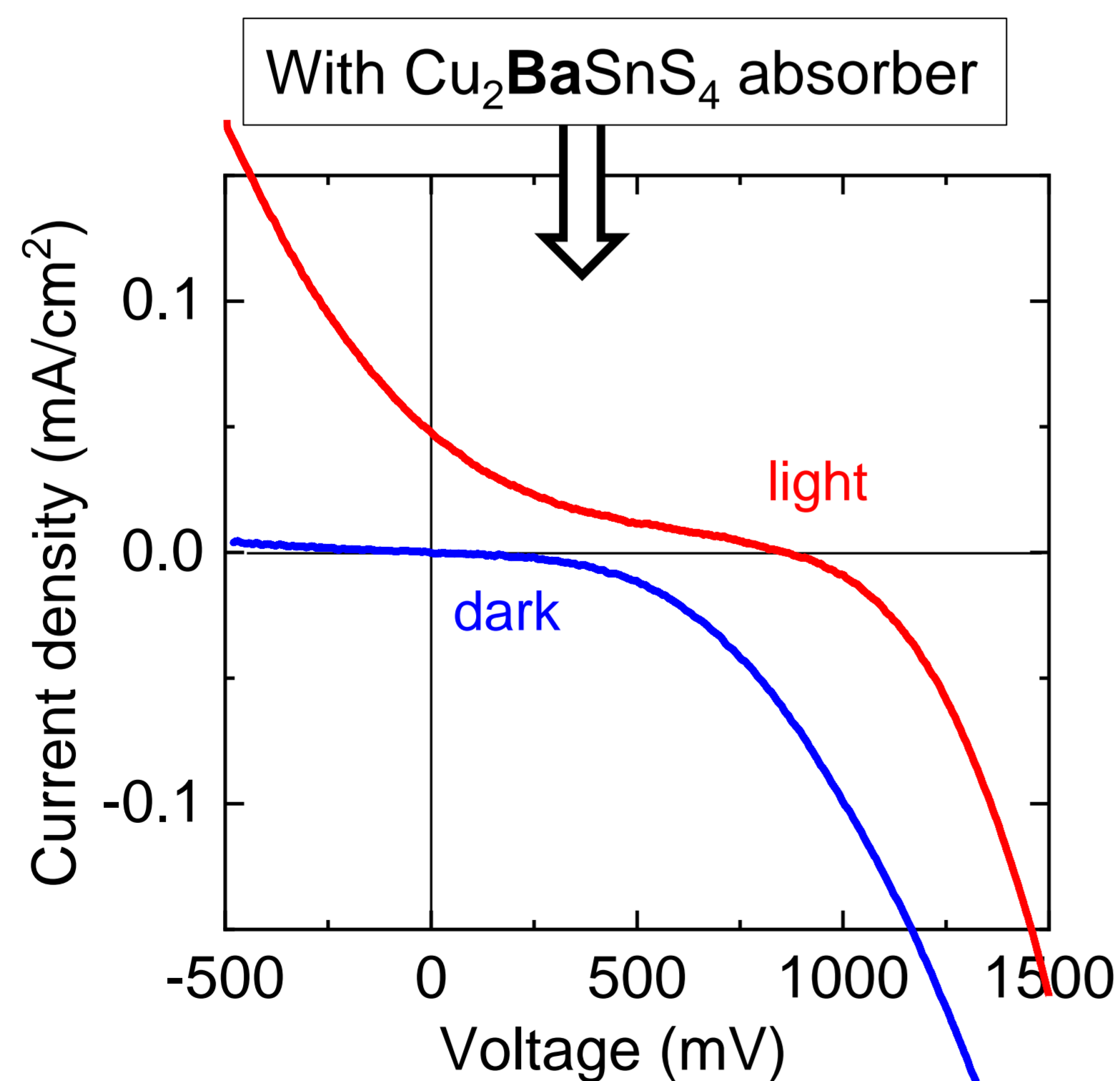
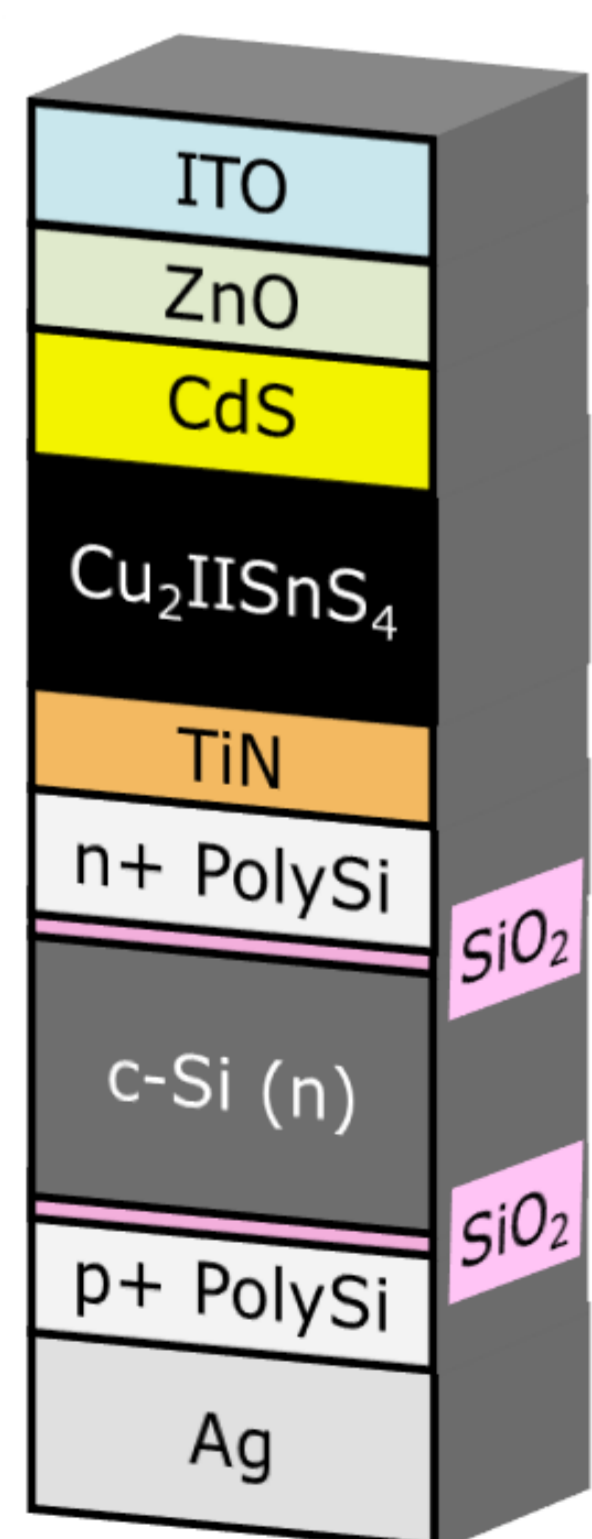
- Mo is the standard hole contact in CuInSe_2 -inspired cells. However:
 - Wider band gap absorbers require a higher work-function hole contact
 - The interfacial MoS_2 layer has a lower band gap than $\text{Cu}_2\text{SrSnS}_4$ and $\text{Cu}_2\text{BaSnS}_4$ → losses are likely
- TaS_2 is a high work-function (5.2 eV) **metallic** compound, which forms naturally when the absorber is deposited on Ta
- $\text{Cu}_2\text{BaSnS}_4$ efficiency **improved** with a TaS_2 back contact!

Fabrication

- Co-sputtering of **oxide** ($\text{Cu}_2\text{IISnO}_4$) precursors from metal targets
- Sulfurization at **520-550°C** in H_2S
- For tandem cells: 5-10 nm **TiN** recombination layer by ALD



Tandem cells (monolithic) with a TiN barrier layer



Conclusion

- $\text{Cu}_2\text{SrSnS}_4$ and $\text{Cu}_2\text{BaSnS}_4$ are promising top absorbers for tandem solar cells
- TaS_2 is the first successful example of a transition metal chalcogenide hole contact in solar cells!
- Monolithic tandem cells with $\text{Cu}_2\text{IISnS}_4$ on silicon are possible
 - ✓ **3.9%** tandem efficiency (world record) with minimal sulfurization damage to the silicon cell

More details

- A. Crovetto et al., *ACS Appl. Energy Mater.* **2**, 7340 (2019)
- Hajjafarassar, Martinho et al., *Sol. Energy Mater. Sol. Cells*, submitted

Acknowledgments

This work was supported by VILLUM Fonden (grant no. 9455) and the Innovation Fund Denmark (grant no. 6154-00008A). This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 840751.



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