

Interface modification by atomic layer deposition on highly pure Sb_2S_3 based solar cells

Pascal Büttner, Florian Scheler, Craig Pointer, Dirk Döhler, Elizabeth R. Young,
Ignacio Mínguez-Bacho, Julien Bachmann

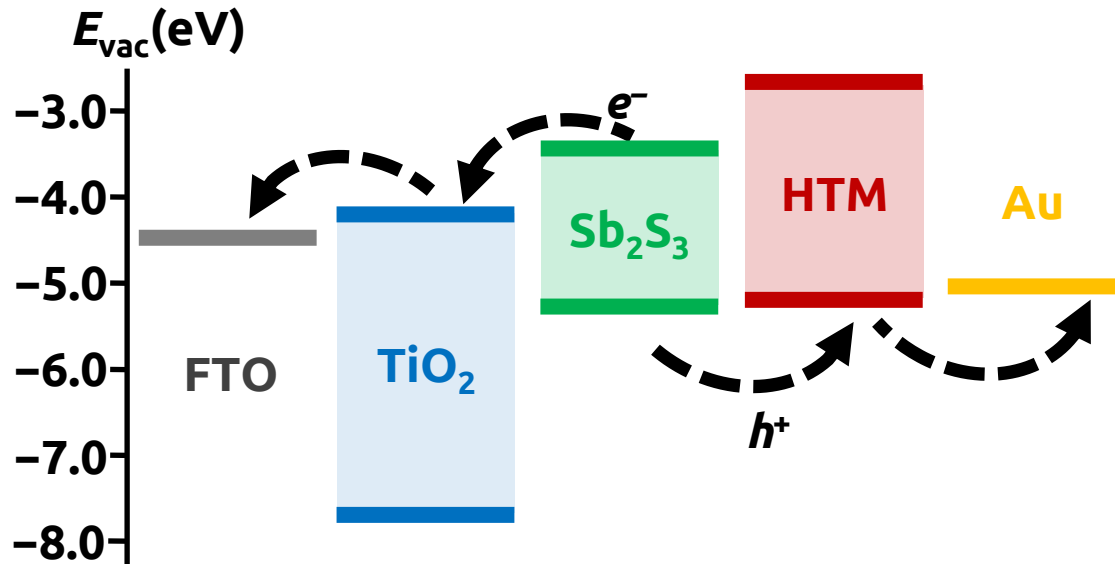
Friedrich-Alexander-Universität Erlangen-Nürnberg
Chemistry of Thin Film Materials



Sb₂S₃ is an excellent material as extremely thin absorber (ETA) in solar cells

Bandgap: ~1.7 eV

Absorption coefficient: 10⁴ - 10⁵ cm⁻¹

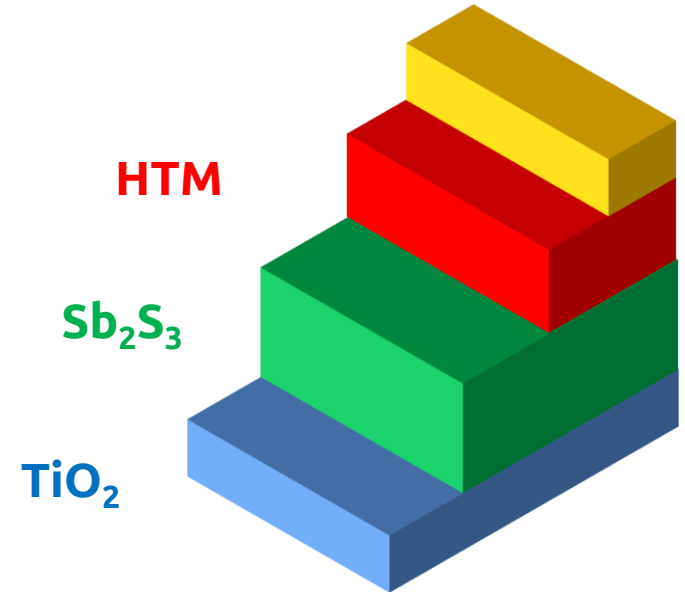
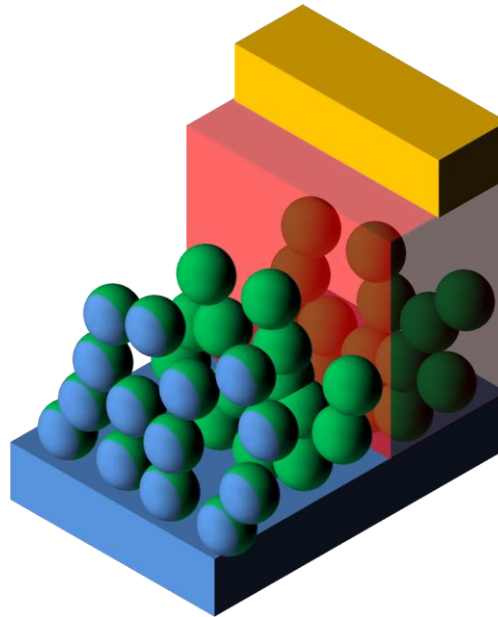


Mesoporous TiO_2

Planar geometry

Solution-based processes:

- Antimony oxide
- Charge carrier traps



We use **Atomic Layer Deposition of Sb_2S_3** to coat TiO_2 surfaces

Advantages

Conformal coating on any surface

Uniform thickness

Pure and stoichiometric Sb_2S_3 [3,4]

Limitation

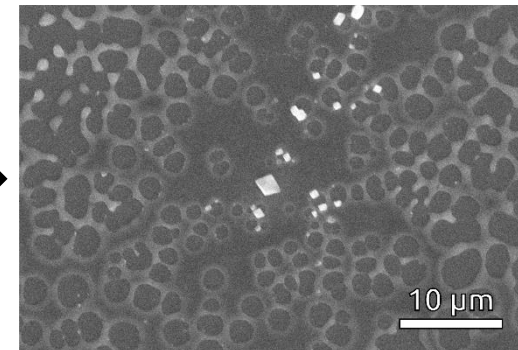
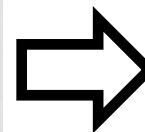
Poor adhesion between Sb_2S_3 and TiO_2

Dewetting of Sb_2S_3

ZnS to avoid dewetting of Sb_2S_3



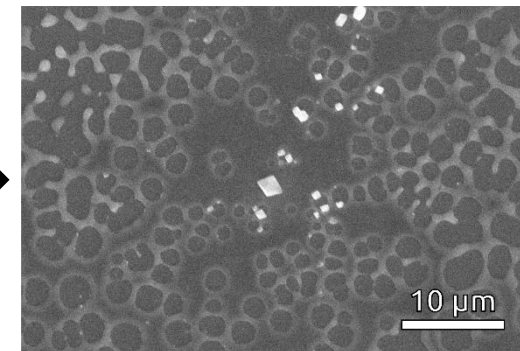
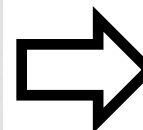
300 °C



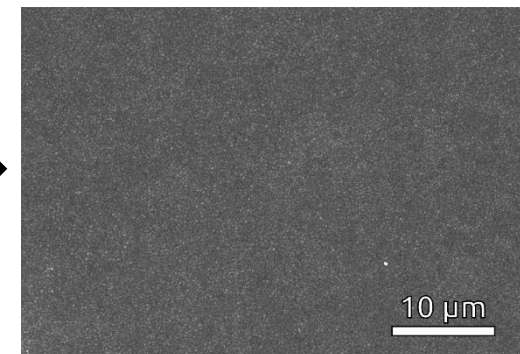
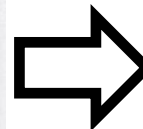
ZnS to avoid dewetting of Sb_2S_3

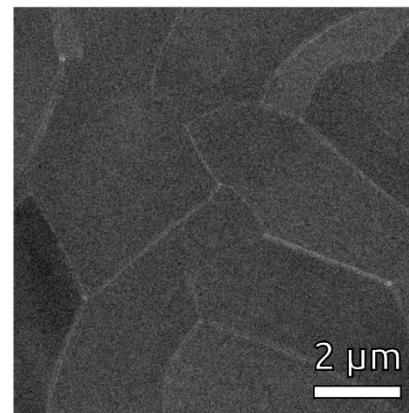
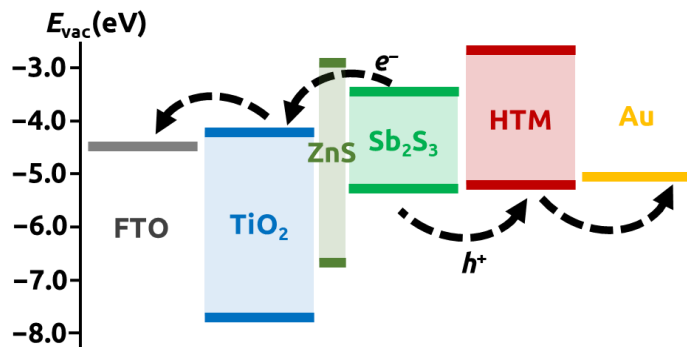
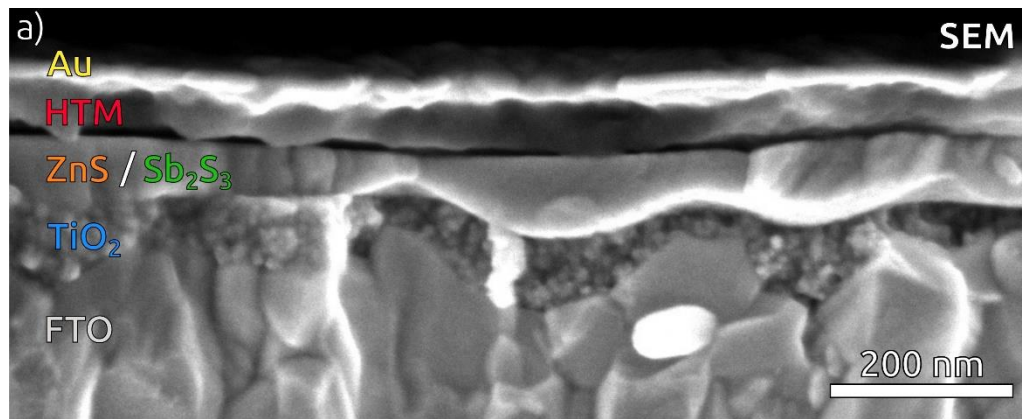
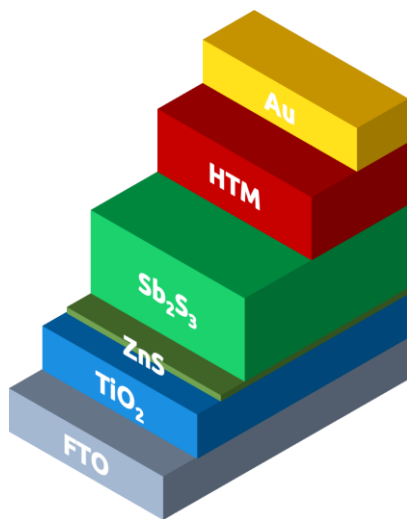


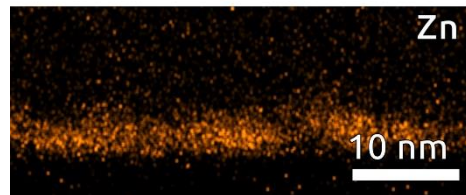
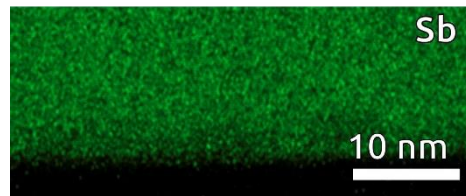
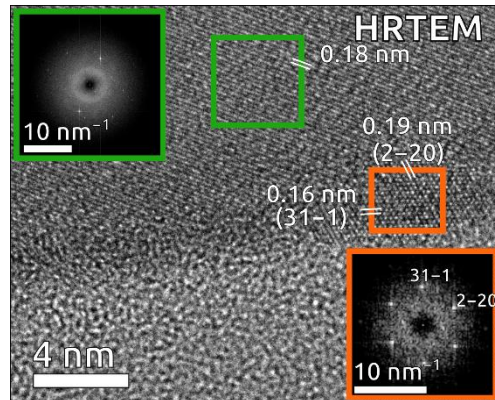
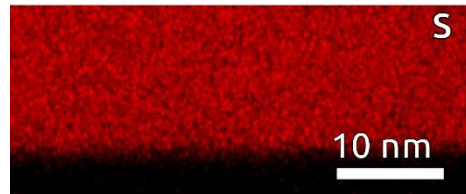
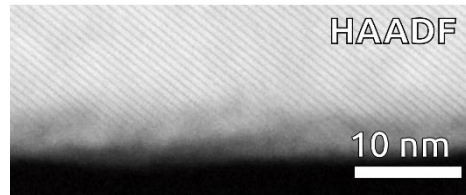
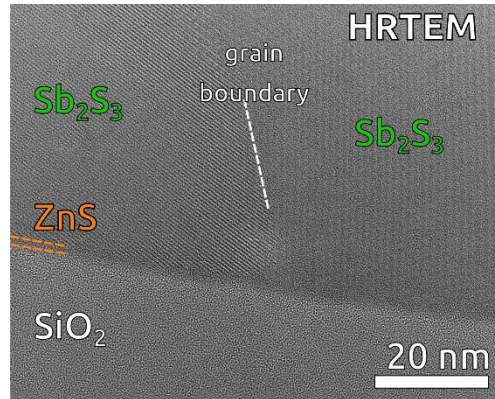
300 °C



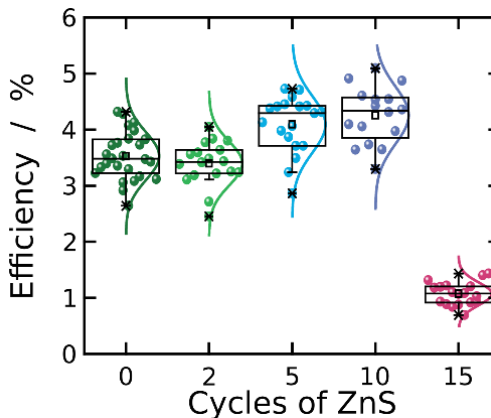
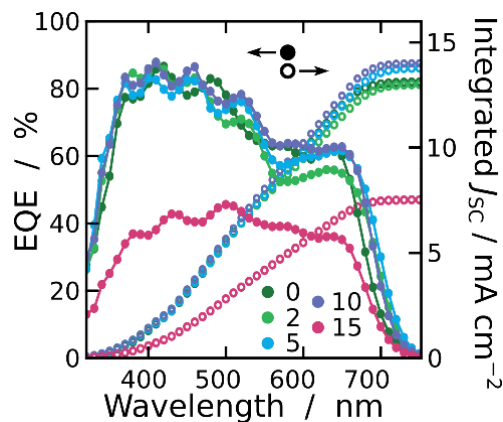
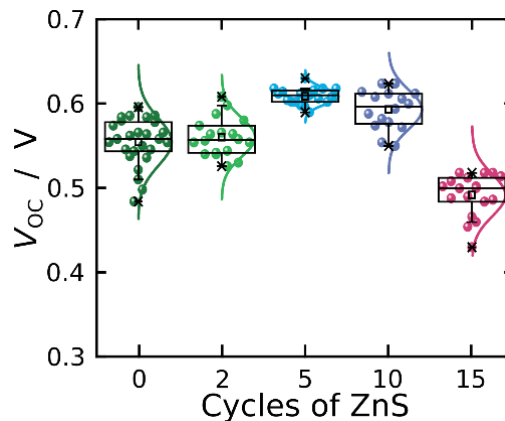
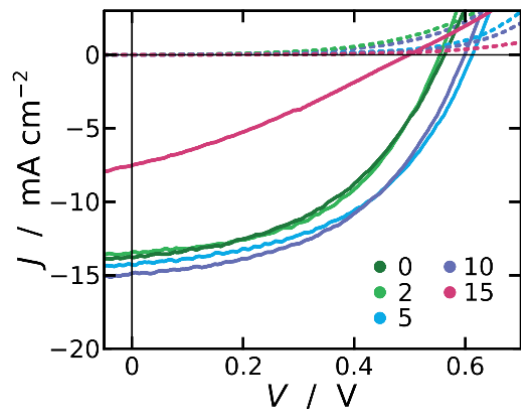
300 °C







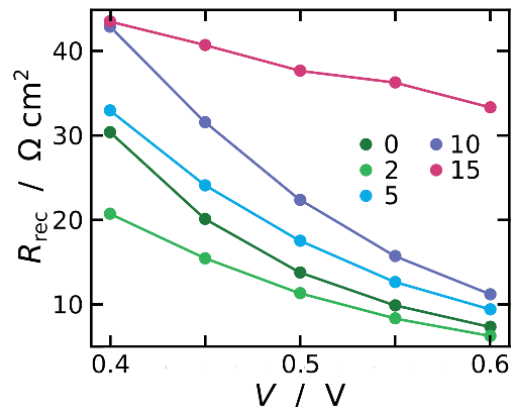
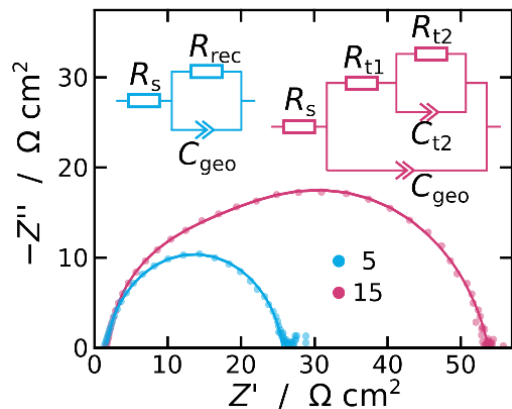
- ZnS remains as a layer after annealing
- Stibnite structure for Sb_2S_3 and zinc blende structure for ZnS



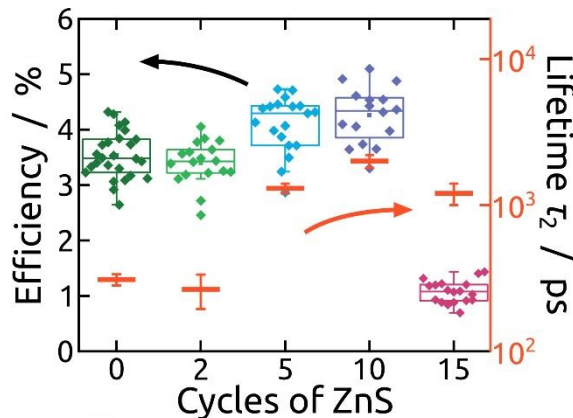
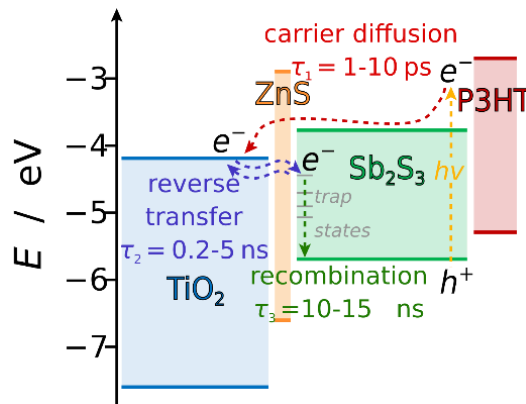
ZnS cycles	Thickness / nm
2	0.2
5	0.5
10	1.0
15	1.5

- **Monotonic improvement of the PV performance from 0 to 1.0 nm ZnS.**
- **Drastic drop of performance for 1.5 nm ZnS due to low current density and fill factor.**

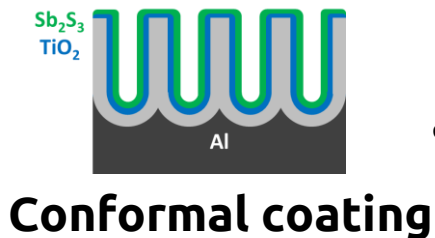
Impedance spectroscopy



Transient absorption

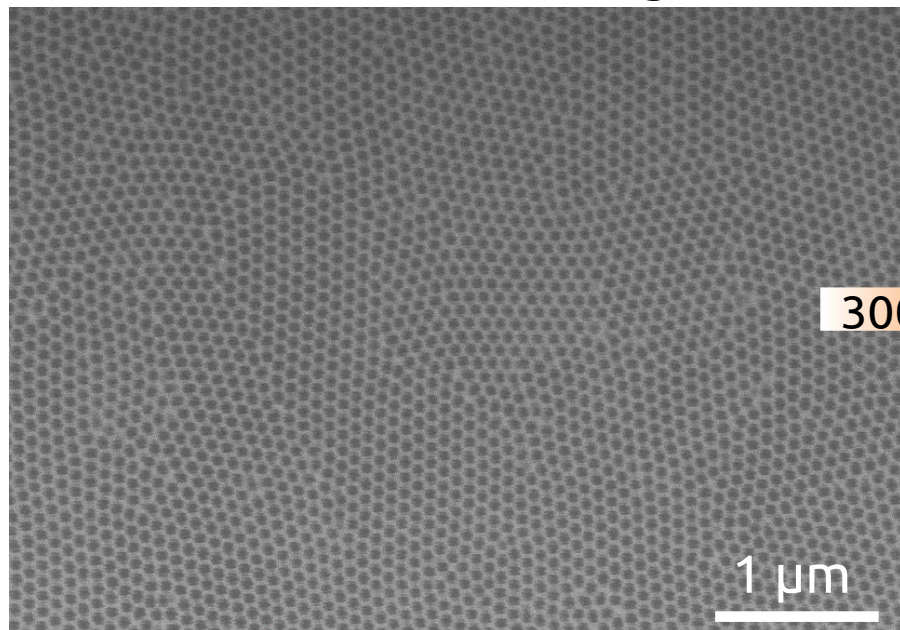


- ZnS0-10 recombination limited behaviour
- ZnS15 devices are transport limited
- Lifetimes estimated by transient absorption follow a similar trend as the efficiencies

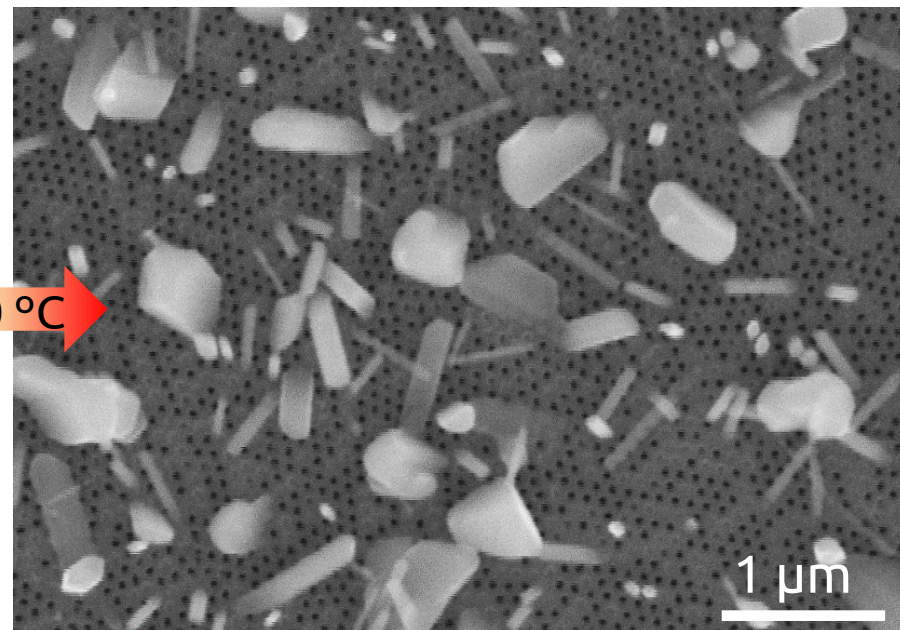


Nanoporous anodic
alumina coated with
 Sb_2S_3 by ALD

Dewetting

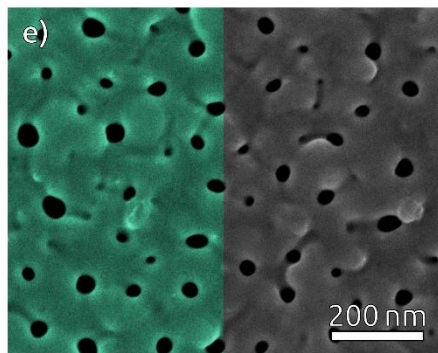


300 °C

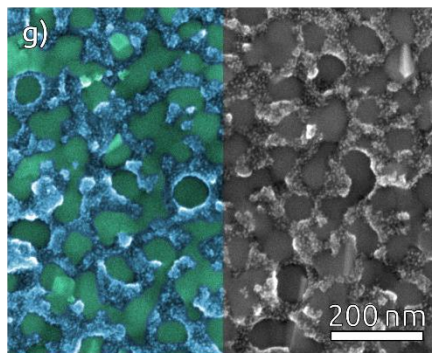


Anodic TiO₂ nanotubes coated with ultrathin ZnS and Sb₂S₃ by ALD

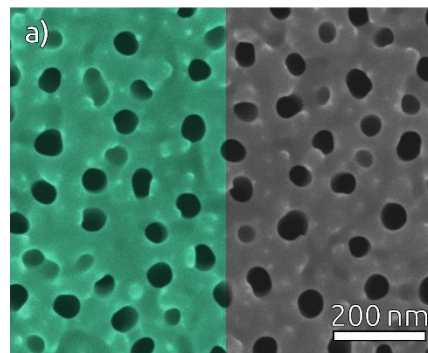
15 nm Sb₂S₃, as grown



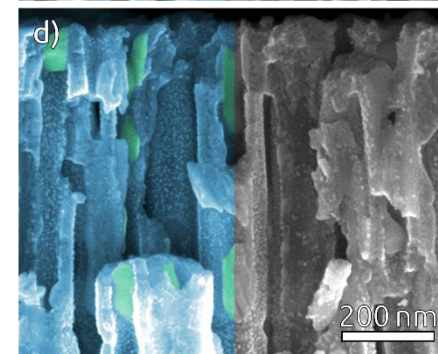
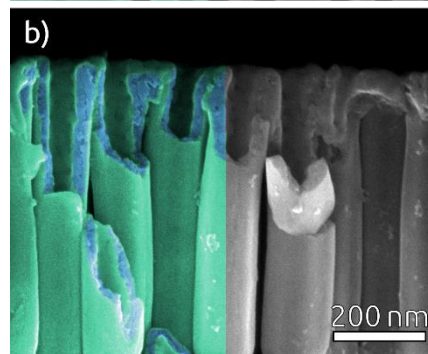
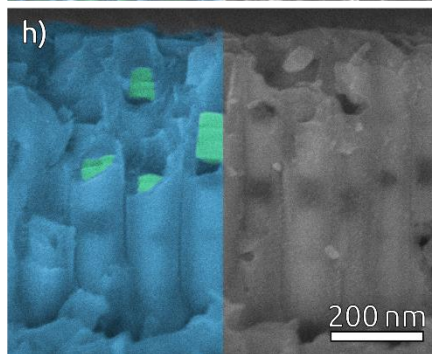
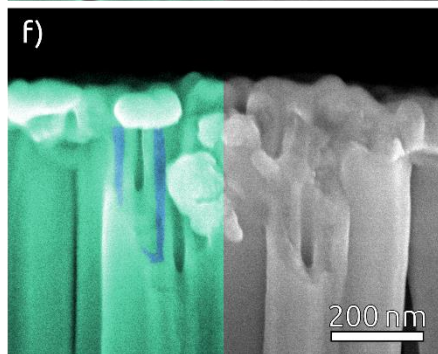
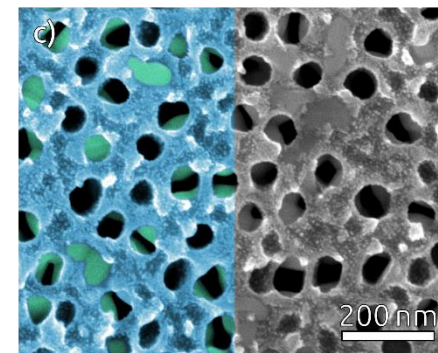
15 nm Sb₂S₃, annealed

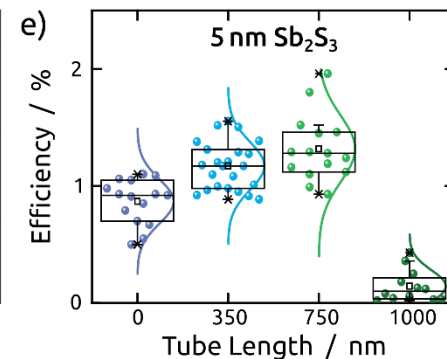
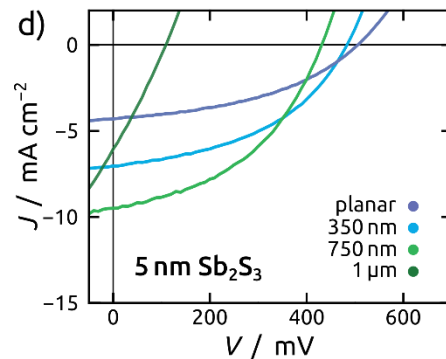
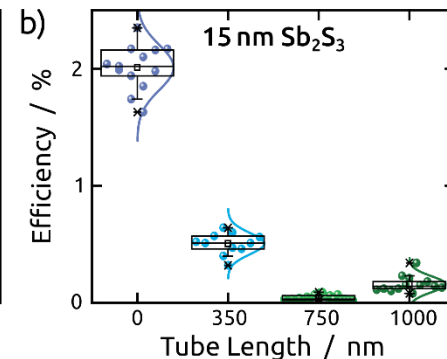
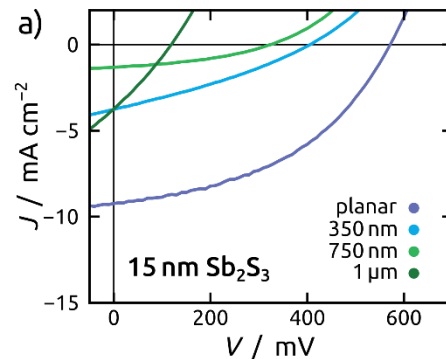
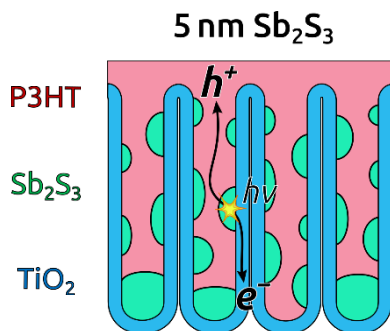
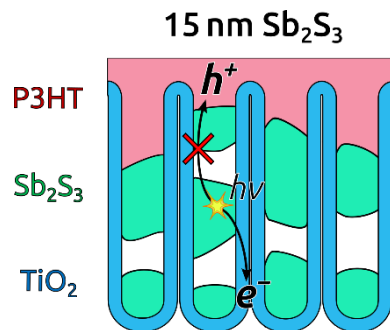
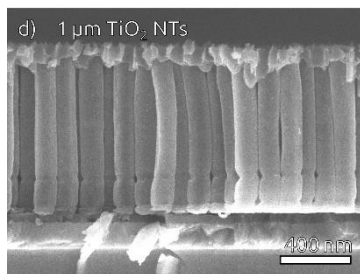
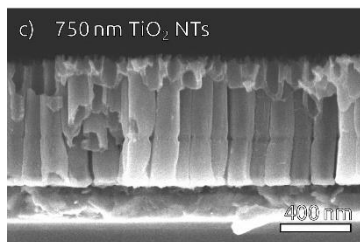
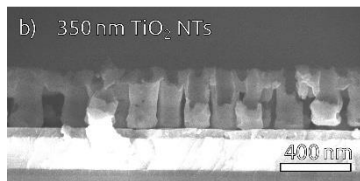
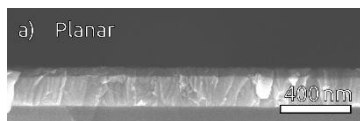


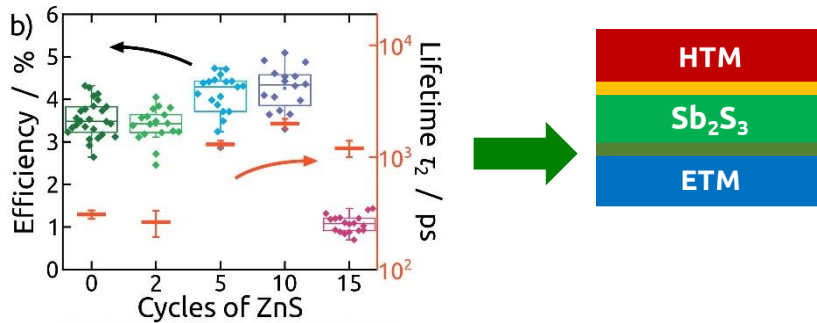
5 nm Sb₂S₃, as grown

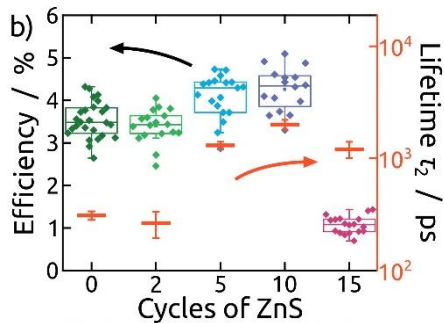


5 nm Sb₂S₃, annealed

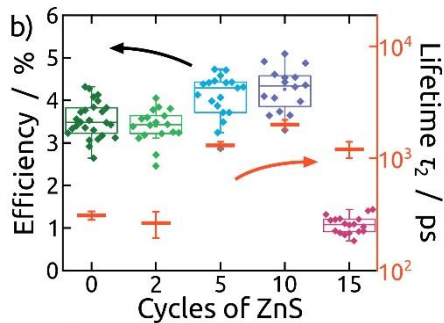




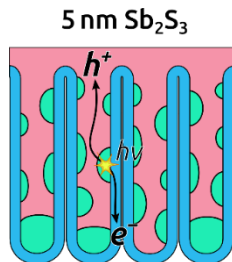
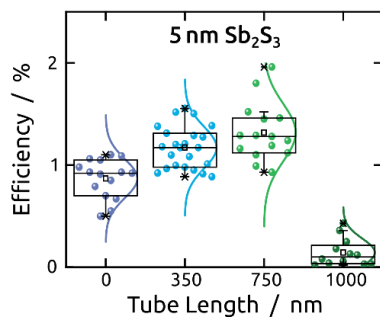


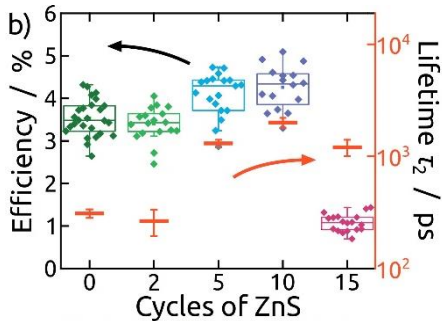


ALD based surface modification
of the Sb_2S_3 /HTM interface

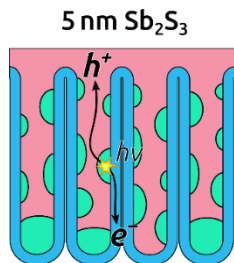
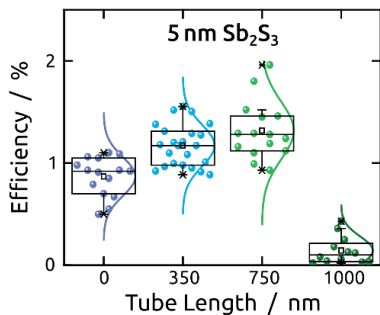


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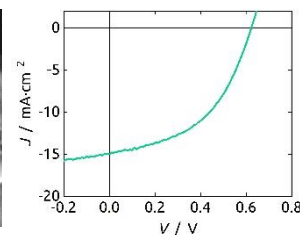
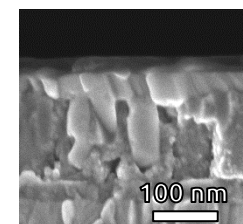
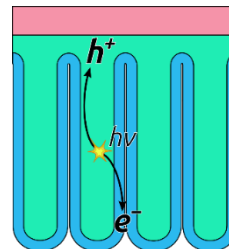
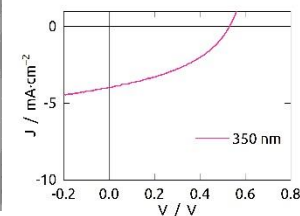
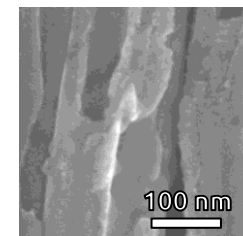
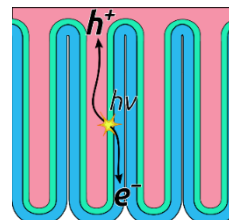


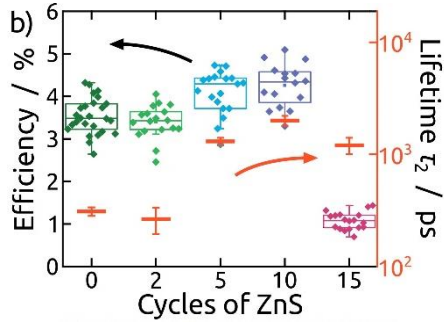


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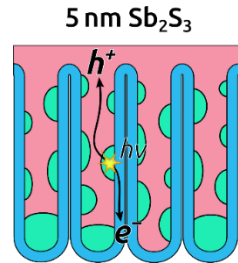
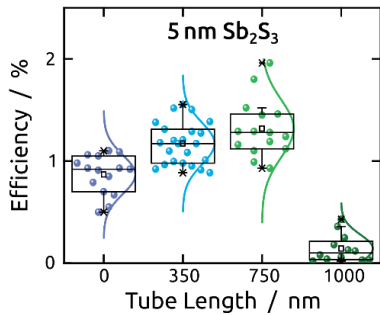


Conformal and continuous coating of Sb_2S_3 via ALD

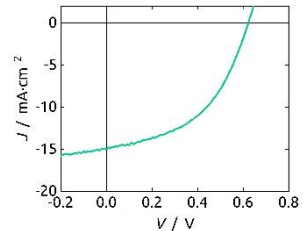
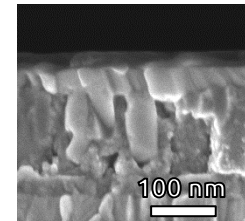
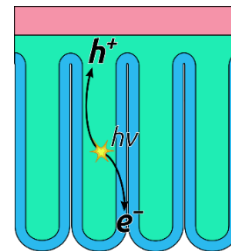
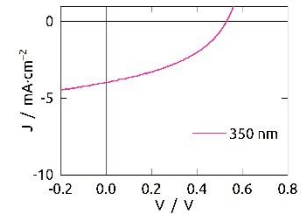
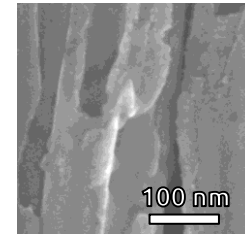
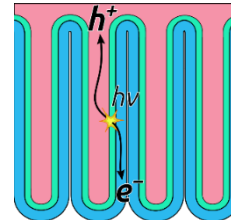




← ALD based surface modification of the Sb_2S_3 /HTM interface



Conformal and continuous coating of Sb_2S_3 via ALD



Exploit ultrathin layers deposited via ALD to mitigate interfacial recombination in other chalcogenides

Consolidator
Grant, 'Solacylin'
647281



European Research Council
Established by the European Commission

Prof. Julien Bachmann



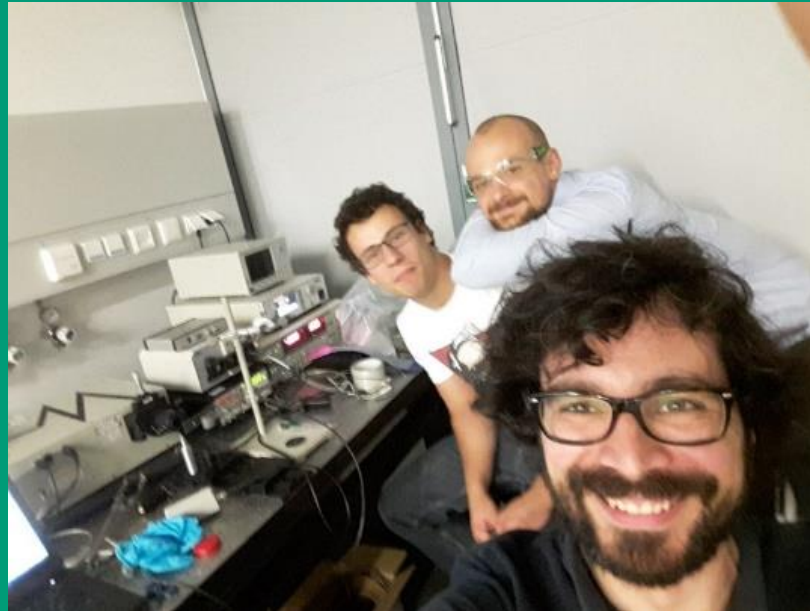
**Prof. E.
Young**






Marie Skłodowska-
Curie Actions.
Individual Fellowship
'Hybricyl' 795716

Pascal Büttner
Dirk Döhler
Florian Scheler



ignacio.minguez@fau.de



The background is a grayscale micrograph showing a textured surface with a central dark, pointed feature. The surface has a pattern of irregular, interconnected lines, possibly representing a biological or material structure. A scale bar is located in the bottom right corner.

Thank you for your attention!

ignacio.minguez@fau.de

2 μm