

Concepts for absorption enhancement in Chalcopyrite solar cells

M. Schmid, P. Andrä, P. Manley, B. Reinhold, G. Yin

Helmholtz-Zentrum Berlin
Nanooptical concepts for photovoltaics
Berlin, Germany



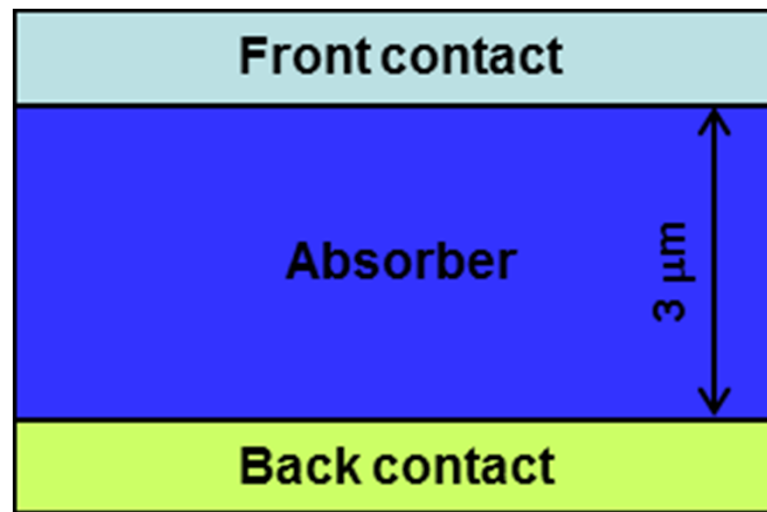
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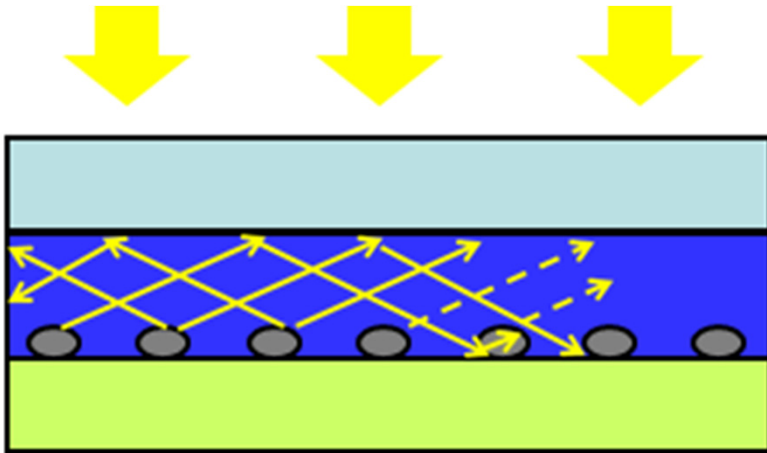
If you are interested in details, please refer to the publications indicated.

Thin film solar cells: important step forwards in decreasing material consumption



Example of Chalcopyrite solar cell
up to 21% lab scale efficiency

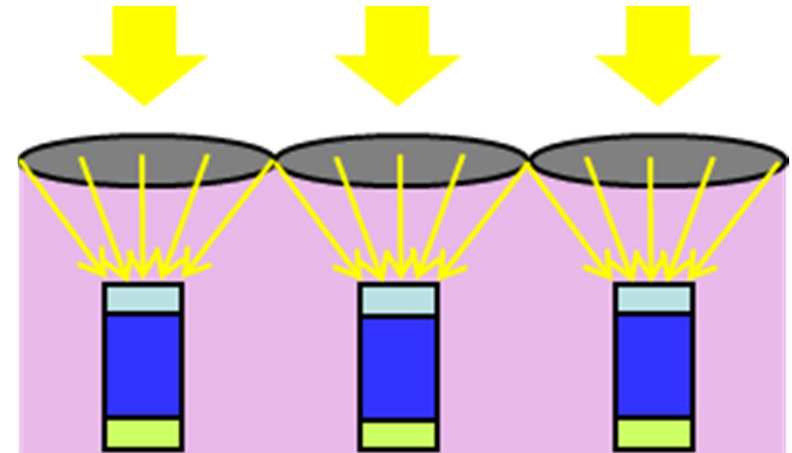
Ultra-thin film solar cells



Plasmonic and photonic
active nanoparticles

nanoscale

Micro-sized solar cells



Integrated micro-
concentrator optics

microscale

Lenses on the

- **Concepts for advanced CIGSe solar cells**
- **Plasmonic nanoparticles**
 - Fabrication and adaptation of Ag nanoparticles
 - Near-field investigations (SNOM)
 - Challenge of stable integration
- **Dielectric nanoparticles**
 - Metallic vs dielectric nanoparticles
 - Dielectric particles at front and back
- **Microoptical concepts**
 - From nano to micro
 - Microconcentrator solar cells

Nanoparticle fabrication and tuning:

- Different routes of fabrication
- Polydispersed particle distributions favorable due to broad-band resonance
- Fast simulation via statistical size distribution allows for tuning

[P. Manley et al., *in preparation*]

Near-field investigations:

- Reveal collective scattering behavior of dense random nanoparticle assemblies
- Point towards highly non-uniform generation rates

[M. Schmid et al., *J. Opt.*, **15**, 125001 (2013)]

Stable integration:

- Both passivation layers and shells can prevent diffusion and recombination
- Increased distance to absorber and fabrication challenging

[G. Yin et al., *in preparation*]

Metallic vs dielectric:

- Fundamental comparison for spherical particles shows equally strong scattering behavior
- Differences in near-field and directivity

[M. Schmid et al., *Nanoscale Res. Lett.*, **9**, 50 (2014)]

Dielectric particles in experiment:

- Stable integration at front and back interfaces
- Appearance of whispering gallery modes or antireflection-behavior depending on size

[G. Yin et al., *submitted*]

[C. van Lare, G. Yin et al., *in preparation*]

Nano to micro:

- Focusing behavior of dielectric spheres in accordance with ray tracing results for $r \gg \lambda$
- Large spheres / concentration ask for micro solar cells

[M. Schmid et al., *submitted*]

Microconcentrator solar cells:

- Micrometer-sized solar cells with good performance challenging
- Enhanced efficiency compared to planar reference possible under low concentration

[B. Reinhold et al., *submitted*]

Absorption enhancement in Cu(In,Ga)Se₂ solar cells

Microconcentrator solar cells:
highly promising for material saving
yet long way of development

Dielectric nanoparticles in ultra-thin solar cells:
successful experimental implementation
effects of resonant modes to be fully exploited

Plasmonic nanoparticles in ultra-thin solar cells:
great promises, particularly for random structures
but challenge of stable integration

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- core-shell particles

- XPS measurements

- CdS

- ZnO, grids

- CIGS for micro cells

- scribing

- Al₂O₃

- SNOM

- SNOM

- dielectric nanostructures

- nanoimprint and simulations

- FEM

