Thin film silicon solar cells prepared at low deposition temperatures on transparent flexible substrates

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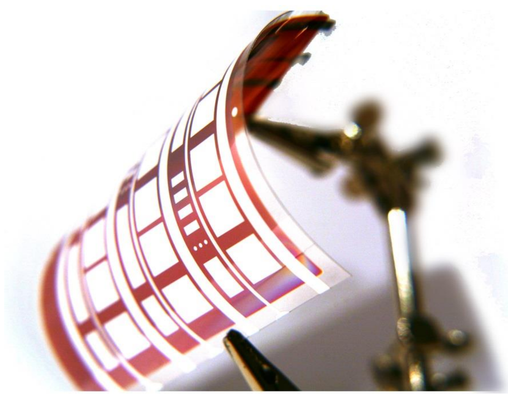
Motivation

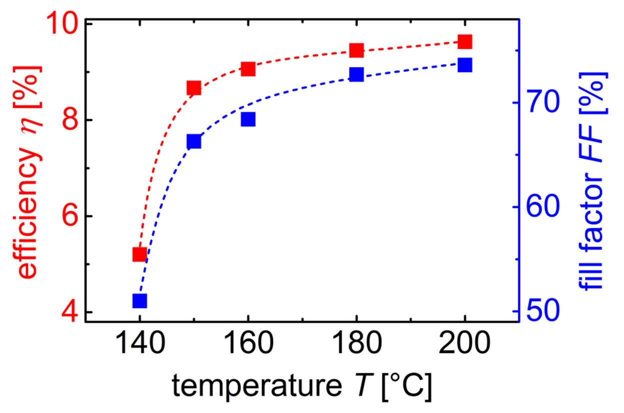
Advantages of flexible solar cells

- + High throughput by roll-to-roll fabrication
- + Use of low cost transparent plastic possible
- + Integration in various shapes and sizes
- + Lightweight
- + Compatible with known **thin-film silicon** technologies

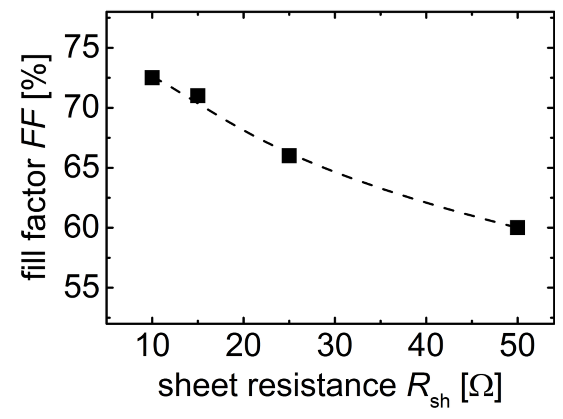


PET (Polyehtylenterephthalate): very low cost, but temperature sensitive

optimized low temperature (140°C) solar cells are needed



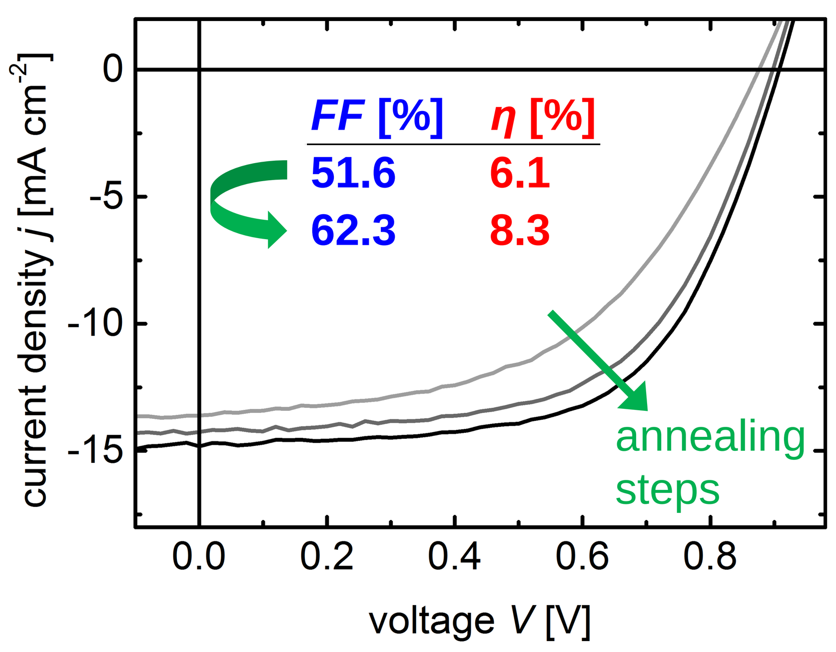
fill factor is reduced due to lower deposition temperature of a-Si:H layers

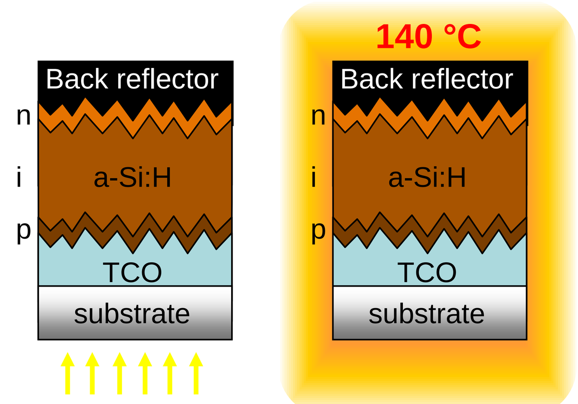


fill factor is reduced by high sheet resistance of low temperature TCO

Results: low temperature solar cells on glass substrates

Post deposition annealing (at 140°C) of low temperature a-Si:H solar cells

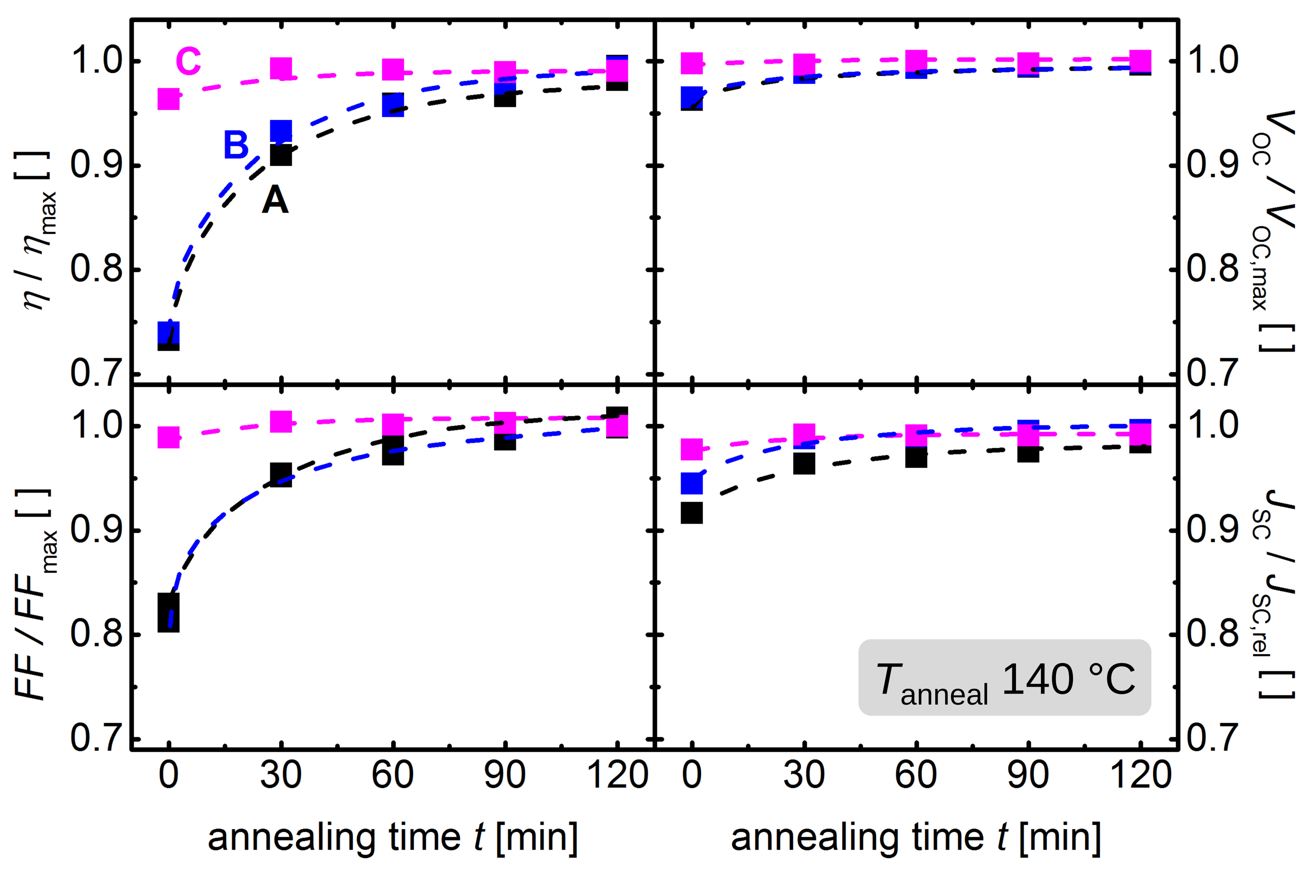




improves all *J-V* parameters

Effects of a-Si:H **layer temperature** on annealing behaviour

Sample	$T_{p\text{-layer}}$ [°C]	$T_{i\text{-layer}}$ [°C]	$T_{n\text{-layer}}$ [°C]
A	140	140	140
B	200	140	140
C	200	140	200

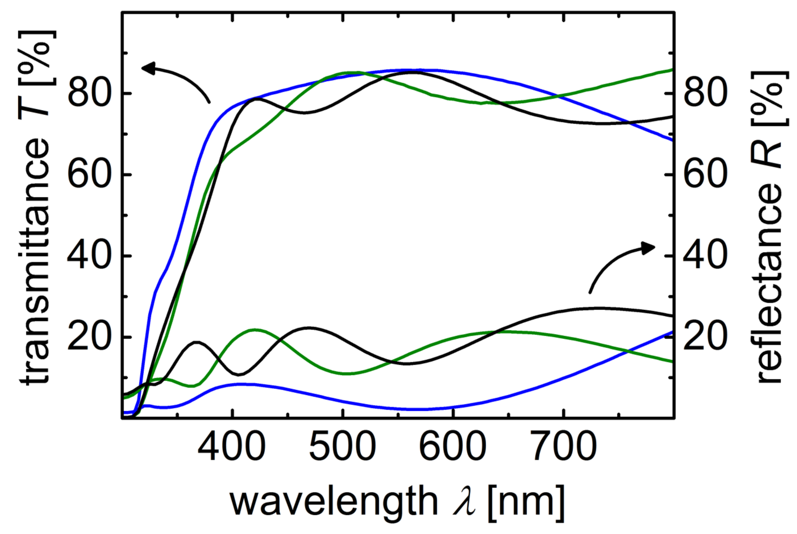


- ➢ No difference upon annealing between cells with p-layers at 140°C (**A**) and 200°C (**B**)
- ➢ Cell with high temperature n-layer shows best performance nearly from the beginning (**C**)
- ➢ Possible reasons: dopant activation, defect healing, hydrogen diffusion, diffusion at interfaces, …

Results: TCO development on foil substrates

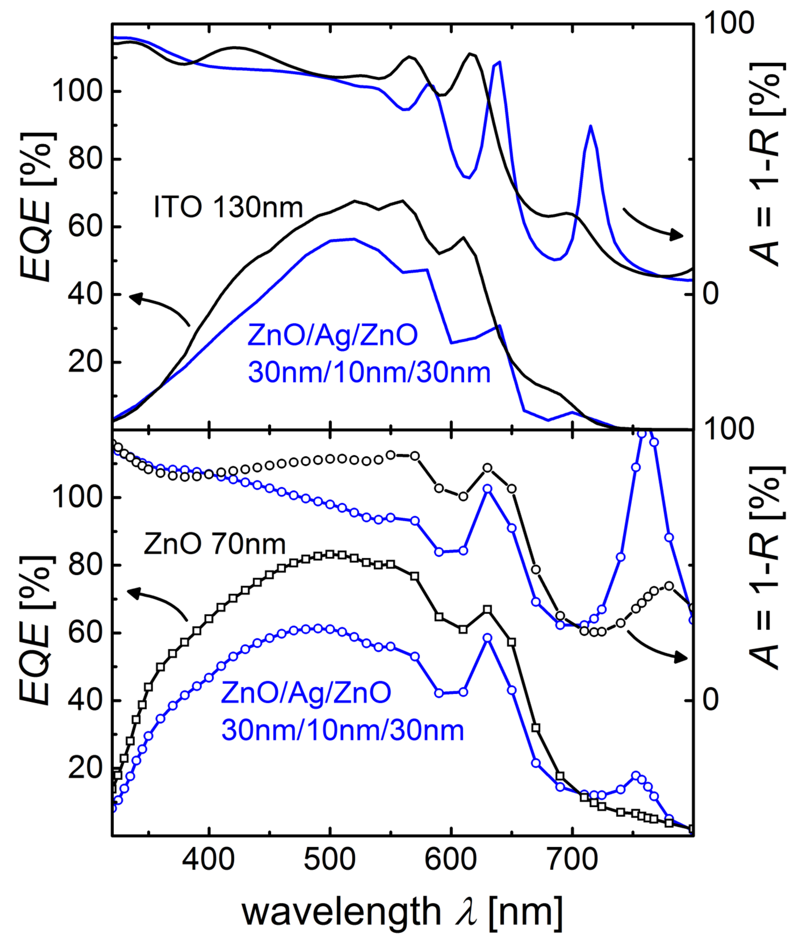
Different TCOs on foil substrates

	d_{TCO} [nm]	R_{sh} [Ω]
PET + ZnO/Ag/ZnO	70	6
PET + ITO_{R2R}	130	42
PET + ITO_{batch}	160	32



ZnO/Ag/ZnO layer stack shows best electrical and optical properties

Solar cells



Losses in EQE because of higher reflectance for ZnO/Ag/ZnO layer stack

Simulations (K. Ding) confirm that introduction of thin Ag layer increases reflectance of the solar cell

	η [%]	FF [%]	V_{oc} [mV]	J_{sc} [mA/cm²]
PET + ZnO/Ag/ZnO	4.1	56.4	875	8.4
PET + ITO_{R2R}	4.4	50.0	880	9.9
PET + ITO_{batch}	4.7	53.5	865	10.0

- ➢ ZnO/Ag/ZnO layer stack shows improved substrate properties, resulting in increased fill factor but lower *EQE*
- ➢ Simulation shows that Ag interlayer is responisble for increased cell reflection

Conclusion

- ➢ Performance of low temperature thin-film silicon solar cells can be improved by **post deposition annealing treatment** and **reduced sheet resistance of the TCO**
- ➢ Reasons for the improvement in solar cell performance upon annealing need to be further investigated in detail
- ➢ ZnO/Ag/ZnO layer stacks show promising electrical and optical properties as well as fill factor, but the thin Ag interlayer causes losses in short circuit current density

Publications:

K. Wilken, V. Smirnov et al, 40th IEEE Photovoltaic Specialists Conference (PVSC-40), Denver, USA, June 2014

Projects:

FlexSol (0325442D)

Gefördert durch: Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages