Thin-film $Cu(In,Ga)Se_2$ for flexible and lightweight photovoltaic applications

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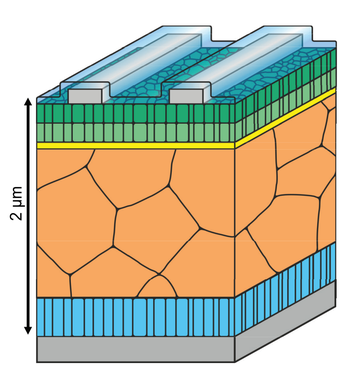
Empa
Materials Science and Technology

Research Focus

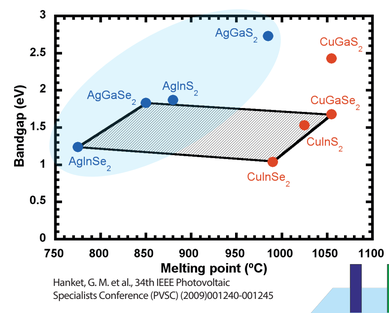
High performance $Cu(In,Ga)Se_2$ (CIGS) solar cells on flexible substrates



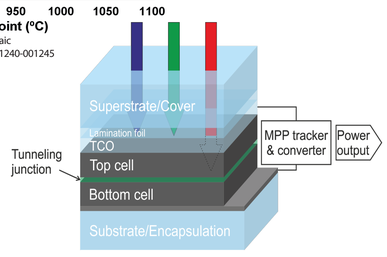
Advantages:
- Flexible, light weight (<2 kg/m² commercially available)
- Roll-to-roll processing
- Uniform appearance
- BIPV, mobility applications

Selected research activities

- High performance single junction devices
  - Process tailoring: composition, gradients, interfaces, doping
  - Flexible substrates
- Robust manufacturing processes
  - Relaxed processing requirements
    Thermal budget, process control, etc.
  - Simplified manufacturing processes
    Co-evaporation, doping, etc.
- Bottom cell for tandem devices
  - Low bandgap (1.0 eV for current matching)
  - Reduced surface roughness



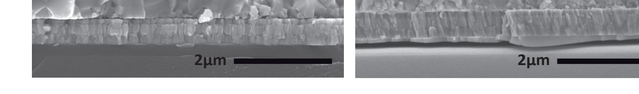
Hanket, G. M. et al., 34th IEEE Photovoltaic Specialists Conference (PVSC) (2009)001240-001245



Results

Lower deposition temperatures

Modified deposition process:
Precursor layer before coevaporation



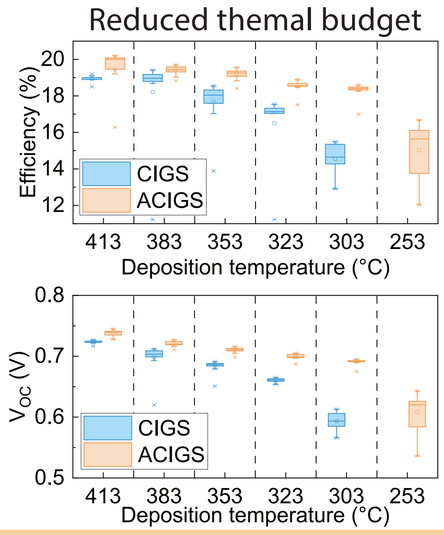
WHAT ARE WE INTERESTED IN ?

Robust processes, drastically reduced deposition temperatures

High performing devices

Possible new devices architectures

Wider processing window
Reduced themal budget



Improved microstructure with small Ag amount

- Improved morphology, larger grain size, increased efficiency
- Reduced thermal budget, wider process tolerances (T, dopants)
- Minimal requirements on hardware change

New efficiency record on flexible solar cells

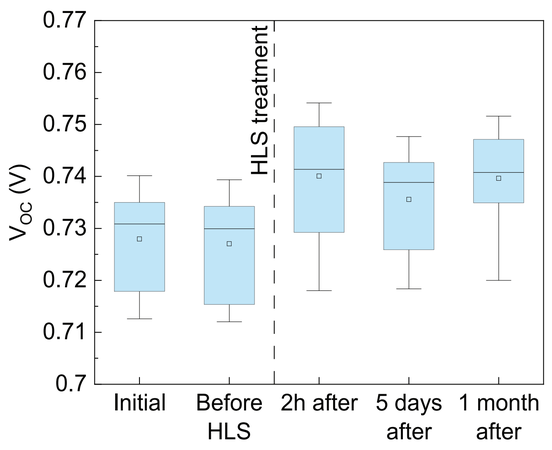
Thermal treatment on finished devices (heat light soaking)

- Improvements stable for months
- Evaluating industrialisation of findings

WHAT ARE WE INTERESTED IN ?

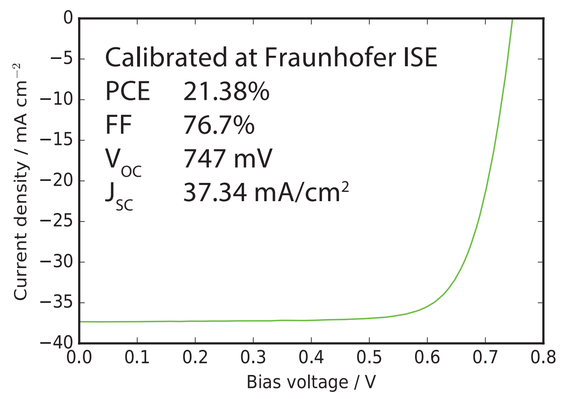
High power conversion efficiency for
- Increased energy production
- More profitable PV installations

Demonstrate technology potential



Increased device efficiency
- Increase in V_{OC} (higher doping density)
- Stable or slight improvement in FF, J_{SC}
- Slight negative impact on non-rad. recomb.

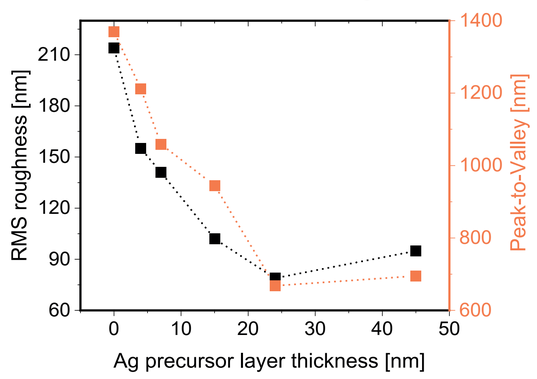
New record flexible CIGS solar cells



- New record efficiency: 21.4% for CIGS on flexible substrate
- Thermal treatment for :
  - improved V_{OC}
  - increased doping density

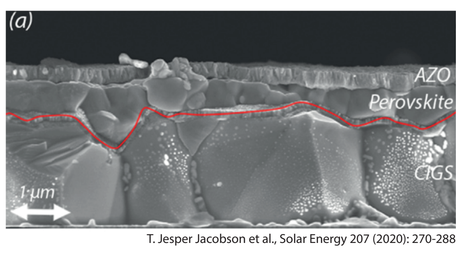
Roughness reduction for tandem device applications

Reduced surface roughness



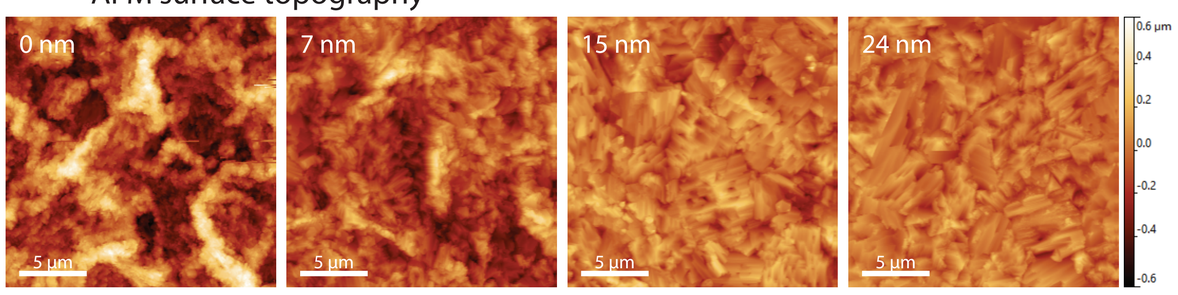
WHAT ARE WE INTERESTED IN ?

Reducing the surface roughness for 2-terminal perovskite-CIS tandem applications



T. Jesper Jacobson et al., Solar Energy 207 (2020): 270-288

AFM surface topography



- Better suitability for two-terminal tandem devices
- Facilitated conformal coverage for thinner buffer layers

Summary

- New record efficiency: 21.4% on CIGS solar cell on flexible substrate
- Modified CIGS absorbers with small Ag amount
  - Improved morphology, larger grain size for higher efficiency
  - High efficiencies retained at 100°C lower temperature than state-of-the-art (413°C to 303°C)
  - Wider processing windows (temperature, alkali)
  - Precursor layer method: minimal hardware and process modification
- Reduced surface roughness, in view of monolithic tandem devices

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