How to Interconnect III-V/Si Tandem Solar Cells for Maximum Module Efficiency

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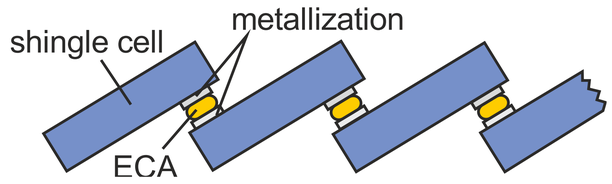
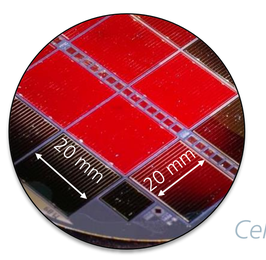
Motivation

- III-V/Si-based tandem solar cells enable maximum efficiencies of currently up to 36.1%[1], while potentially offering higher long-term stability compared to perovskite-Si-based tandem solar cells
- Shingling allows omitting cell gaps and shading losses due to ribbons/wires and thus, maximizing the active area [2]

→ Low cell-to-module losses for III-V/Si solar cells can be realized using the shingling approach



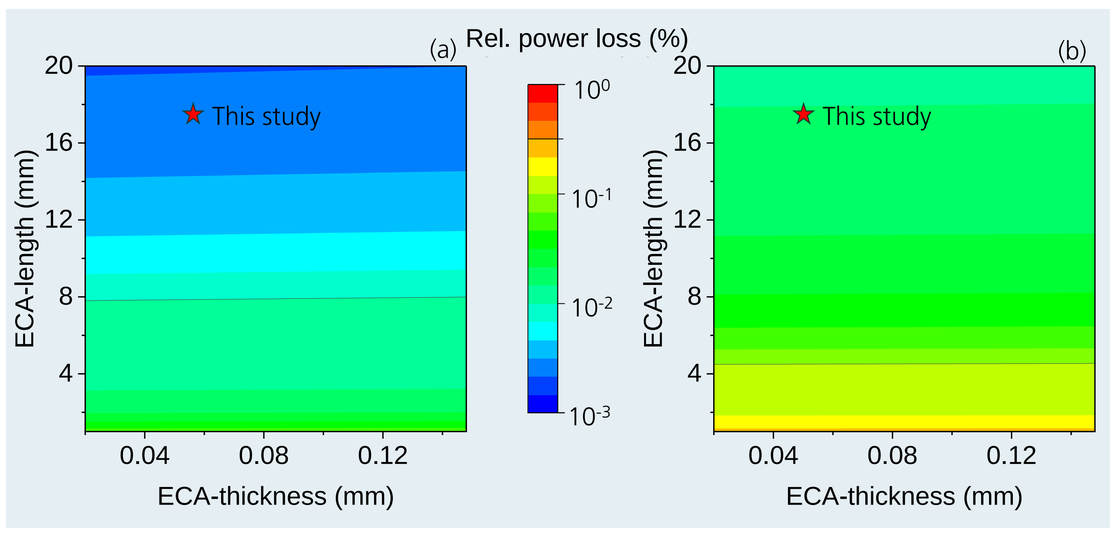
Sketch of shingled solar cell interconnection [3]



Cells used in this study

Analytical calculation of cell to string losses

- Contact and volume resistance of the used ECA was measured on a stacked Greek cross like configuration according to [4]
  - $\rho_{contact}$ = 0.24 ± 0.16 mΩ · cm²
  - ρ_{volume} = 0.49 ± 0.21 Ω · cm
- Assumptions
  - 0.3 mm wide ECA line
  - I_{sc} = 47 mA
- High measurement error → Evaluation of best- and worst-case scenario
- Interconnection resistance calculation: $R_{\mathrm{int}} = \frac{\rho_{\mathrm{volume}} \cdot t_{ECA}}{A_{\mathrm{contact}}} + 2 \cdot \frac{\rho_{\mathrm{contact}}}{A_{\mathrm{contact}}}$ [5]
- Power loss estimation: $P_{\mathrm{loss}} = n_{\mathrm{strings}} \cdot n_{\mathrm{joints\ per\ string}} \cdot R_{\mathrm{int}} \cdot I^2_{\mathrm{string}}$



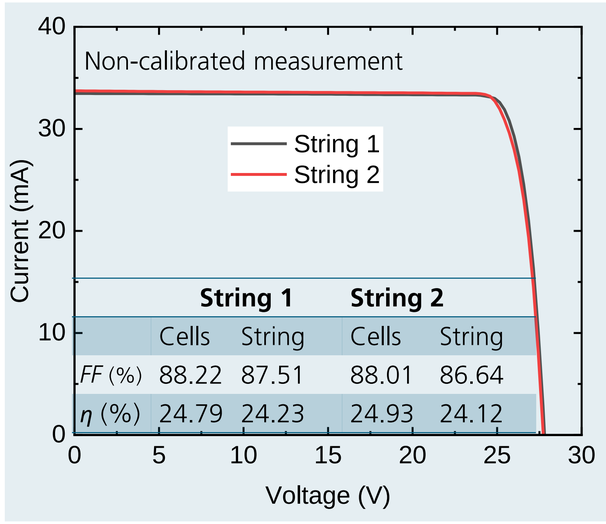
Relative module power losses due to interconnection. (a): worst case, (b): best case

Results

- Interconnection losses are almost independent from the ECA thickness due to low volume resistivity
- Worst case scenario: min. 8 mm ECA length required for $P_{\mathrm{loss,\ rel.}} < 0.01\%$

String and module validation

- Two 9-cell strings produced using a prototype shingle stringer from M10
- Aim: Determination of interconnection losses through *IV* characterization
- String *IV* measurements compared to expected values based on cell data



	String 1		String 2	
	Cells	String	Cells	String
FF (%)	88.22	87.51	88.01	86.64
η (%)	24.79	24.23	24.93	24.12

IV characterization of two III-V/Si shingle strings

Results

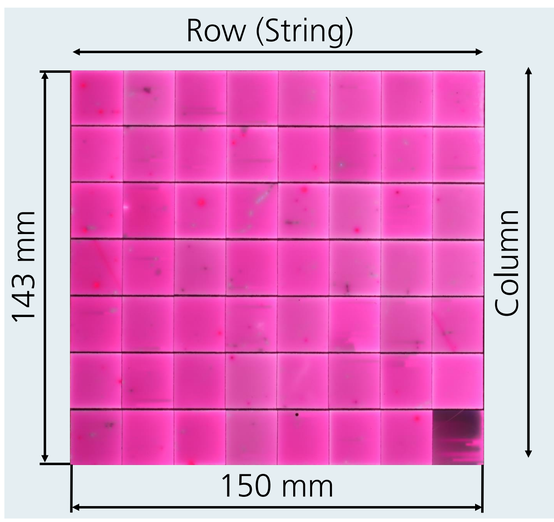
- $\Delta FF < 1.5\%_{abs}$: No significant R_{int}
- String 2: Local shunt due to contacting

Top cell EL: String 1 @ I_{sc} (35 mA)

Top cell EL: String 2 @ I_{sc} (35 mA)

Module production and characterization

- Production in glass/backsheet configuration on an industrial laminator (Bürkle)
- Active module area: 214.36 cm²



Top cell module electrolumenescence image at I_{sc} (320 mA)

Demonstrator module

- Cell efficiency η_{cell} = (31.86 ± 0.20)%
- ECA length: 18 mm
- String gap: 0.5 mm
- Parallel interconnection in each column

Next steps

- Calibrated *IV* characterization

Summary

- ECA characterization enables power loss prediction < 0.01% with optimized interconnection geometry
- 9-cell strings show ΔFF <1.5%, confirming minimal interconnection losses
- 7×8 shingle module with 214 cm² module area successfully demonstrated

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Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

This research was funded by German Federal Ministry for Economic Affairs and Climate Action under the project "Mod30plus" (Grant number 03EE1160A).