

Supporting Information

Spectrometric Characterization for Triple-Junction Solar Cells

Johanna Aulich, David Chojniak, Alexander J. Bett, Marc Steiner, Florian Schindler,
Gerald Siefer, Martin C. Schubert, Jan Christoph Goldschmidt, Stefan W. Glunz.*

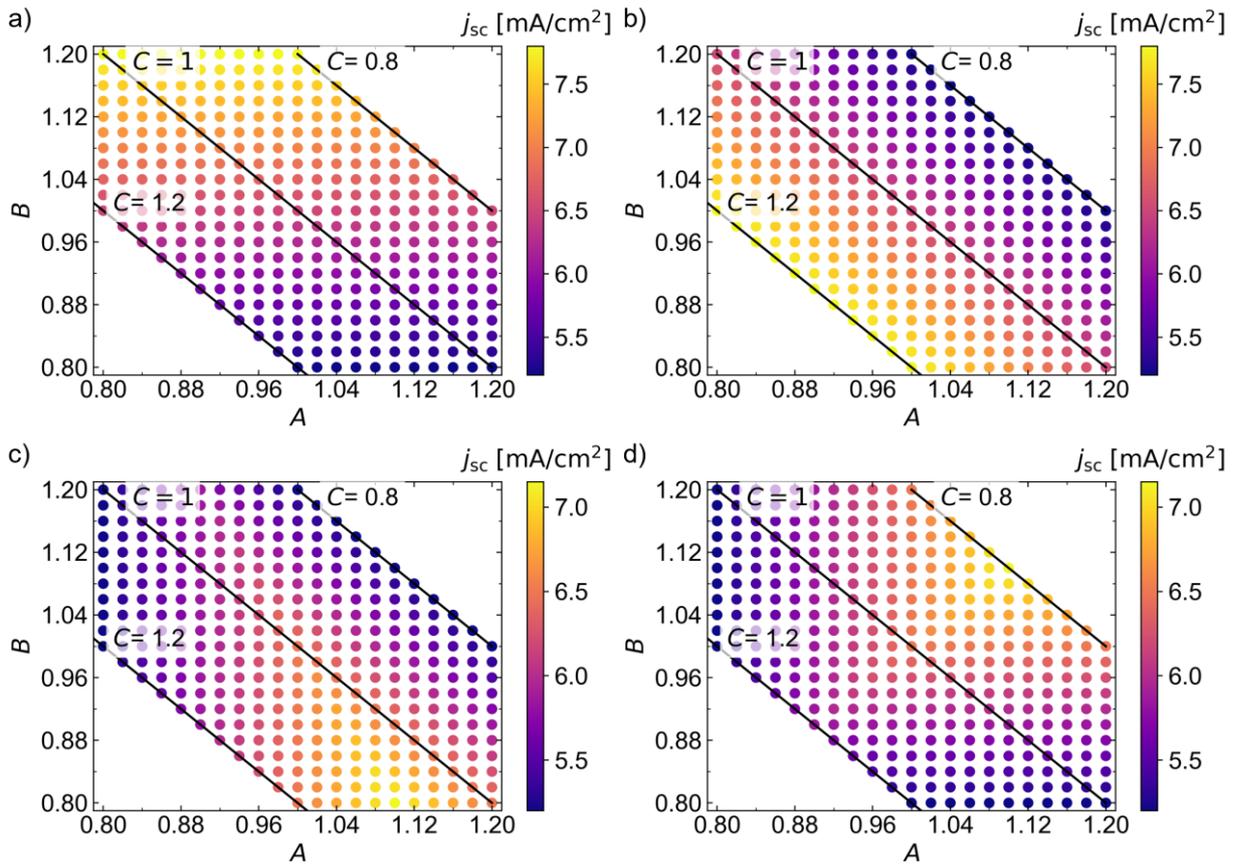


Figure S 1: Simulated spectrometric characterization results for difference current matching scenarios in addition to Figure 2. The metric parameters A , B and C are restricted to $x_{\min} = 0.8$ and $x_{\max} = 1.2$ and the step size is 0.02 . a) Strongly limiting middle-cell ($j_{\text{mid}} = 6.5 \text{ mA cm}^{-2}$, $j_{\text{top}} = j_{\text{bot}} = 13 \text{ mA cm}^{-2}$ under AM1.5g spectrum). The current matching point is outside the measurement area where only vertical lines are visible. b) Strongly limiting bottom-cell ($j_{\text{bot}} = 6.5 \text{ mA cm}^{-2}$, $j_{\text{top}} = j_{\text{mid}} = 13 \text{ mA cm}^{-2}$ under AM1.5g spectrum). The current matching point is outside the measurement area where only diagonal lines are visible. c) Limiting top- and bottom-cells ($j_{\text{mid}} = 13 \text{ mA cm}^{-2}$, $j_{\text{top}} = j_{\text{bot}} = 6.5 \text{ mA cm}^{-2}$ under AM1.5g spectrum). d) Limiting middle- and bottom-cells ($j_{\text{bot}} = 13 \text{ mA cm}^{-2}$, $j_{\text{top}} = j_{\text{mid}} = 6.5 \text{ mA cm}^{-2}$ under AM1.5g spectrum).

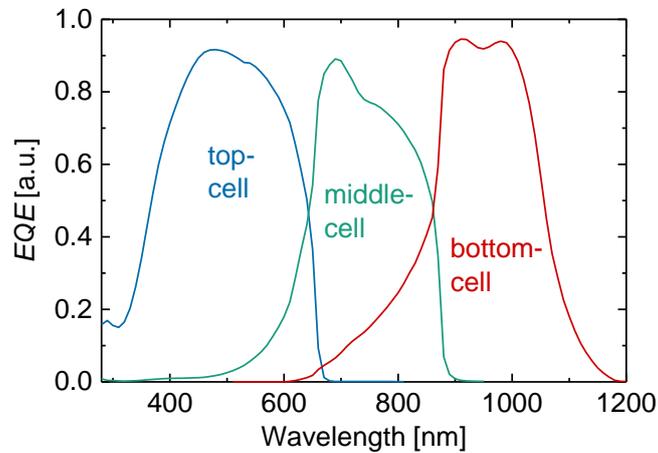


Figure S 2: Relative EQE of the 4 cm^2 GaInP/GaAs/Si triple-junction solar cell used for the spectrometric characterization in this work.

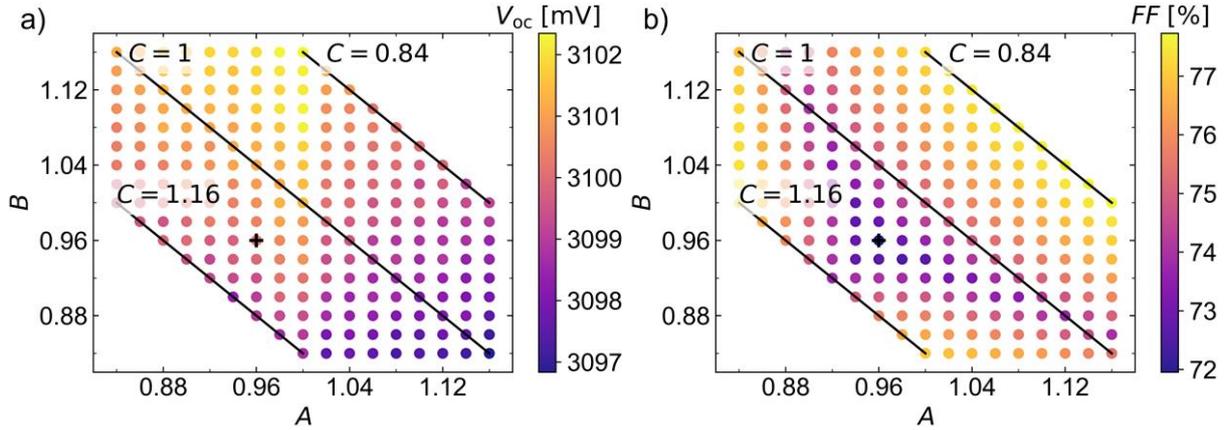


Figure S 3a) V_{oc} and b) FF obtained from the spectrometric characterization of the GaInP/GaAs/Si triple-junction solar cell. The V_{oc} is basically independent on the spectral condition. There is a slight variation of ~ 5 mV ($< 0.2\%$) which can be explained by different effective irradiances on the sub-cells and a slight variation of the temperature (< 1 K) during the ~ 8 hours of measurement. As expected, the FF shows a minimum at the spectral condition where the highest j_{sc} was measured.

Table S 1: Metric parameters of highest measured points and fitted current matching points of all spectrometric measurements performed within this work. For the first measurement, also the intersection points of the fits are listed (corresponding to the graphs in Figure 4) with the constant values for the fits in *italic*.

	<i>A</i>	<i>B</i>	<i>C</i>
Measurements with step size 0.02			
Highest measured point Measurement 1	0.960	0.960	1.080
Intersection point from fits for constant <i>A</i>	<i>0.960</i>	0.948	1.092
Intersection point from fits for constant <i>B</i>	0.955	<i>0.960</i>	1.085
Intersection point from fits for constant <i>C</i>	0.961	0.959	<i>1.080</i>
Current matching point Measurement 1	0.958	0.954	1.088
Highest measured point Measurement 2	0.960	0.960	1.080
Current matching point Measurement 2	0.961	0.953	1.086
Highest measured point Measurement 3	0.960	0.960	1.080
Current matching point Measurement 3	0.955	0.956	1.089
Measurements with step size 0.005			
Highest measured point Measurement 1	0.955	0.955	1.090
Current matching point Measurement 1	0.955	0.955	1.090
Highest measured point Measurement 2	0.960	0.955	1.085
Current matching point Measurement 2	0.956	0.954	1.090

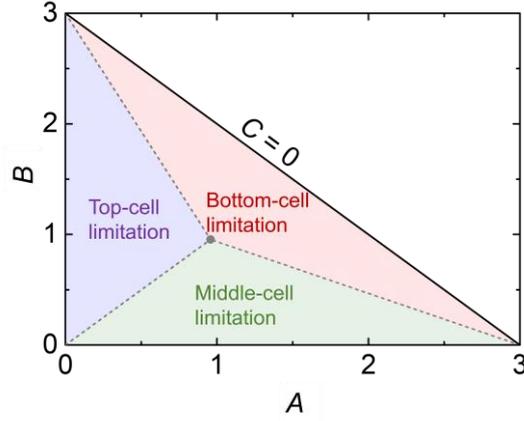


Figure S 4: Position of the three sections in the plane of measurement. The grey dot represents the fitted current matching point obtained from the result shown in Figure 3. The grey dashed lines from the current matching point towards the corners of the triangular measurement plane divide this plane in three sections. For spectral conditions in the blue, green and red shaded sections, the top-, middle- and bottom-cell is current limiting, respectively.

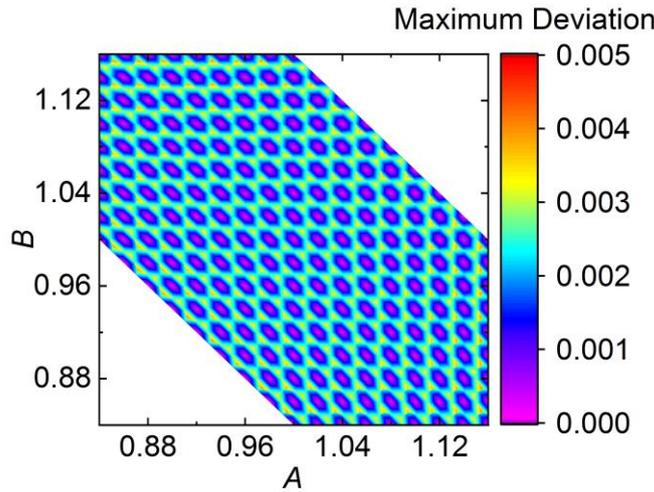


Figure S 5: Deviation of the current matching point determined by the linear fit method described in this paper from the real current matching point by simulation. To determine the deviation 250000 random points $[A, B, C(A, B)]$ in the measurement area have been considered as current matching points. For each of these points, the current densities under the reference spectrum have been determined and current densities of the sub-cells were calculated for all measurement points (step size 0.02 as in Figure 3) according to equations (4)-(6). The j_{SC} of the triple-junction solar cell was then obtained from $j_{SC} = \min(j_{top}, j_{mid}, j_{bot})$ for each measurement point. The described fitting procedure was applied to the measurement point with the highest j_{SC} to determine the parameters A_{Fit} , B_{Fit} and C_{Fit} of the current matching point. For each of the 250000 random points the maximum deviation $\max(|A_{Fit} - A|, |B_{Fit} - B|, |C_{Fit} - C|)$ is represented in the contour plot. The deviation is small in the proximity of the measurement points and increases to maximum values < 0.005 .

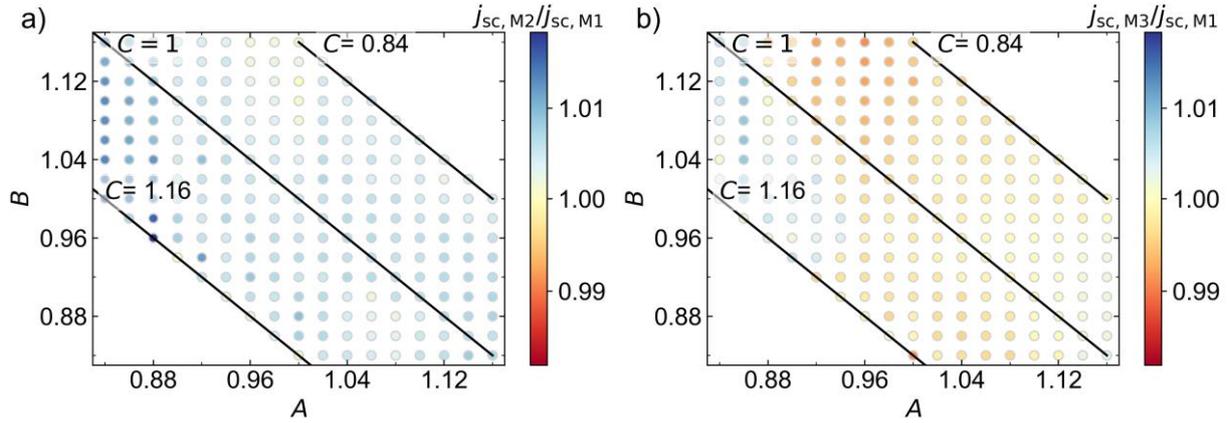


Figure S 6: Deviations of j_{sc} obtained from the a) second and b) third to the first spectrometric measurement of the GaInP/GaAs//Si triple-junction solar cell. All deviations are small ($\sim 0.5\%$ for most of the measurement points with a maximum of 1.8%)

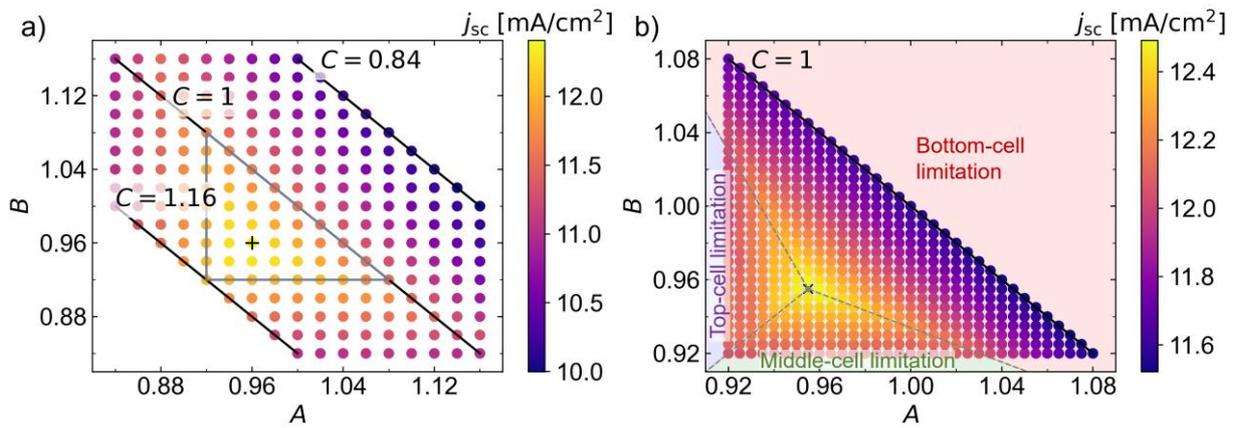


Figure S 7: a) j_{sc} obtained from spectrometric characterization (step size 0.02) represented in Figure 3 with selected area (grey triangle) around the current matching point for the finer spectrometric measurement shown in b). b) Result of the finer spectrometric measurement with step size of 0.005 around the current matching point. The point with highest j_{sc} is in good agreement with the calculated current matching point from the spectrometric measurement with step size of 0.02. The grey dashed lines from the current matching point towards the corners of the triangular measurement plane divide the plane in three sections. For spectral conditions in the blue, green and red shaded sections, the top-, middle- and bottom-cell is current limiting, respectively.