Progress in PHOTOVOLTAICS

PROGRESS IN PHOTOVOLTAICS: RESEARCH AND APPLICATIONS
Prog. Photovolt: Res. Appl. 2016; **24**:905–913
Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/pip.2788

ACCELERATED PUBLICATION

Solar cell efficiency tables (version 48)

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ABSTRACT

Consolidated tables showing an extensive listing of the highest independently confirmed efficiencies for solar cells and modules are presented. Guidelines for inclusion of results into these tables are outlined, and new entries since January 2016 are reviewed. Copyright © 2016 John Wiley & Sons, Ltd.

KEYWORDS
solar cell efficiency; photovoltaic efficiency; energy conversion efficiency

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Received 10 May 2016; Accepted 20 May 2016

1. INTRODUCTION

Since January 1993, *Progress in Photovoltaics* has published six monthly listings of the highest confirmed efficiencies for a range of photovoltaic cell and module technologies [1–3]. By providing guidelines for inclusion of results into these tables, this not only provides an authoritative summary of the current state-of-the-art but also encourages researchers to seek independent confirmation of results and to report results on a standardised basis. In Version 33 of these Tables [2], results were updated to the new internationally accepted reference spectrum (International Electrotechnical Commission IEC 60904-3, Ed. 2, 2008), where this was possible.

The most important criterion for inclusion of results into the Tables is that they must have been independently measured by a recognised test centre listed elsewhere [1]. A distinction is made between three different eligible definitions of cell area: total area, aperture area and designated illumination area, as also defined elsewhere [1]. 'Active area' efficiencies are not included. There are also certain minimum values of the area sought for the different device types (above 0.05 cm^2 for a concentrator cell, 1 cm^2 for a one-sun cell and 800 cm^2 for a module).

Results are reported for cells, and modules made from different semiconductors and for sub-categories within each semiconductor grouping (e.g. crystalline, polycrystalline and thin film). From Version 36 onwards, spectral response information is included when available in the form of a plot of the external quantum efficiency (EQE) versus wavelength, either as absolute values or normalised to the peak measured value. Current voltage (IV) curves have also been included where possible from Version 38 onwards.

2. NEW RESULTS

Highest confirmed 'one sun' cell and module results are reported in Tables I and II. Any changes in the tables from those previously published [3] are set in bold type. In most cases, a literature reference is provided, which describes either the result reported, or a similar result (readers identifying improved references are welcome to submit to the lead author). Table I summarises the best reported measurements for cells and submodules, while Table II shows the best results for modules. Table III contains what might be described as 'notable exceptions'. While not

Table I. Confirmed terrestrial cell and submodule efficiencies measured under the global AM1.5 spectrum (1000 W/m^2) at 25°C (IEC 60904-3: 2008, ASTM G-173-03 global).

Classification	Efficiency (%)	Area (cm^2)	V_{oc} (V)	J_{sc} (mA/cm^2)	Fill factor (%)	Test centre (date)	Description
Silicon							
Si (crystalline cell)	25.6 ± 0.5	143.7 (da)	0.740	41.8[a]	82.7	AIST (2/14)	Panasonic HIT, rear junction [11]
Si (multicrystalline cell)	21.3 ± 0.4	242.74 (t)	0.6678	39.80[b]	80.0	FhG-ISE (11/15)	Trina Solar [21]
Si (thin transfer submodule)	21.2 ± 0.4	239.7 (ap)	0.687[c]	38.50[c]	80.3	NREL (4/14)	Solexel (35 μm thick) [22]
Si (thin film minimodule)	10.5 ± 0.3	94.0 (ap)	0.492[c]	29.7[c]	72.1	FhG-ISE (8/07)[e]	CSG Solar (<2 μm on glass) [23]
III-V cells							
GaAs (thin film cell)	28.8 ± 0.9	0.9927 (ap)	1.122	29.68[f]	86.5	NREL (5/12)	Alta Devices [24]
GaAs (multicrystalline)	18.4 ± 0.5	4.011 (t)	0.994	23.2	79.7	NREL (11/95)[d]	RTI, Ge substrate [25]
InP (crystalline cell)	22.1 ± 0.7	4.02 (t)	0.878	29.5	85.4	NREL (4/90)[d]	Spire, epitaxial [26]
Thin Film Chalcogenide							
CIGS (cell)	21.0 ± 0.6	0.9927 (ap)	0.757	35.70[g]	77.6	FhG-ISE (4/14)	Solibro, on glass [27]
CIGS (minimodule)	18.7 ± 0.6	15.892 (da)	0.701[c]	35.29[c]	75.6	FhG-ISE (9/13)	Solibro, 4 serial cells [28]
CdTe (cell)	21.0 ± 0.4	1.0623 (ap)	0.8759	30.25[d]	79.4	Newport (8/14)	First Solar, on glass [29]
CZTSSe (cell)	**9.8 ± 0.2**	**1.115 (da)**	**0.5073**	**31.95[i]**	**60.2**	**Newport (4/16)**	**IMRA Europe [4]**
CZTS (cell)	**7.6 ± 0.1**	**1.067 (da)**	**0.6585**	**20.43[i]**	**56.7**	**NREL (4/16)**	**UNSW [5]**
Amorphous/microcrystalline							
Si (amorphous cell)	10.2 ± 0.3[j]	1.001 (da)	0.896	16.36[d]	69.8	AIST (7/14)	AIST [30]
Si (microcrystalline cell)	11.8 ± 0.3[k]	1.044 (da)	0.548	29.39[g]	73.1	AIST (10/14)	AIST [31]
Perovskite							
Perovskite (cell)	**19.7 ± 0.6[l]**	**0.9917 (da)**	**1.104**	**24.67[i]**	**72.3**	**Newport (3/16)**	**KRICT/UNIST [6]**
Dye sensitised							
Dye (cell)	11.9 ± 0.4[m]	1.005 (da)	0.744	22.47[n]	71.2	AIST (9/12)	Sharp [32]
Dye (minimodule)	10.7 ± 0.4[m]	26.55 (da)	0.754[c]	20.19[c]	69.9	AIST (2/15)	Sharp, 7 serial cells [32]
Dye (submodule)	8.8 ± 0.3[m]	398.8 (da)	0.697[c]	18.42[c]	68.7	AIST (9/12)	Sharp, 26 serial cells [33]
Organic							
Organic (cell)	**11.2 ± 0.3°**	**0.992 (da)**	**0.780**	**19.30[i]**	**74.2**	**AIST (10/15)**	**Toshiba [7]**
Organic (minimodule)	9.7 ± 0.3°	26.14 (da)	0.806	16.47[c,g]	73.2	AIST (2/15)	Toshiba (8 series cells) [34]
Multijunction							
Five junction cell (bonded) (2.17/1.68/1.40/1.06/0.73 eV)	38.8 ± 1.2	1.021 (ap)	4.767	9.564	85.2	NREL (7/13)	Spectrolab [35]
InGaP/GaAs/InGaAs	37.9 ± 1.2	1.047 (ap)	3.065	14.27[p]	86.7	AIST (2/13)	Sharp [36]
GaInP/GaInAs/Ge; Si (minimodule)	**34.5 ± 2.0**	**27.83 (ap)**	**2.66/0.65**	**13.1/9.3**	**85.6/79.0**	**NREL (4/16)**	**UNSW/Azur/Trina [8]**
GaInP/GaAs (monolithic)	**31.6 ± 1.5**	**0.999 (ap)**	**2.538**	**14.18[i]**	**87.7**	**NREL (1/16)**	**Alta Devices [9]**
GaInP/Si (mech. stack)	29.8 ± 1.5[k]	1.006 (da)	1.46/0.68	14.1/22.7[b]	87.9/76.2	NREL (10/15)	**NREL/CSEM, 4-terminal [10]**
a-Si/nc-Si/nc-Si (thin film)	13.6 ± 0.4[j,k]	1.043 (da)	1.901	9.92[g]	72.1	AIST (1/15)	AIST [37]
a-Si/nc-Si (thin film cell)	12.7 ± 0.4%[j,k]	1.000(da)	1.342	13.45[d]	70.2	AIST (10/14)	AIST [30,31]

CIGS, $CuIn_{1-y}Ga_ySe_2$; a-Si, amorphous silicon/hydrogen alloy; nc-Si, nanocrystalline or microcrystalline silicon; CSTSS, $Cu_2ZnSnS_{4-y}Se_y$; CZTS, Cu_2ZnSnS_4; (ap), aperture area; (t), total area; (da), designated illumination area; FhG-ISE, Fraunhofer Institut für Solare Energiesysteme; AIST, Japanese National Institute of Advanced Industrial Science and Technology.

[a]Spectral response and current–voltage curve reported in Version 44 of these Tables.
[b]Spectral response and current–voltage curve reported in Version 47 of these Tables.
[c]Reported on a 'per cell' basis.
[d]Spectral responses and current–voltage curve reported in Version 45 of these Tables.
[e]Recalibrated from original measurement.
[f]Spectral response and current–voltage curve reported in Version 40 of these Tables.
[g]Spectral response and current–voltage curve reported in Version 46 of these Tables.
[h]Spectral response and current–voltage curve reported in Version 43 of these Tables.
[i]Spectral response and current–voltage curve reported in the present version of these Tables.
[j]Stabilised by 1000 h exposure to 1 sun light at 50 C.
[k]Not measured at an external laboratory.
[l]Not stabilised, initial efficiency. Reference 19 reviews the stability of similar devices.
[m]Initial performance (not stabilised). Reference 62 reviews the stability of similar devices.
[n]Spectral response and current–voltage curve reported in Version 41 of these Tables.
[o]Initial performance (not stabilised). References 63 and 64 review the stability of similar devices.
[p]Spectral response and/or current–voltage curve reported in Version 42 of these Tables.

Prog. Photovolt: Res. Appl. 2016; **24**:905–913 © 2016 John Wiley & Sons, Ltd.
DOI: 10.1002/pip

Table II. Confirmed terrestrial module efficiencies measured under the global AM1.5 spectrum (1000 W/m^2) at a cell temperature of 25°C (IEC 60904-3: 2008, ASTM G-173-03 global).

Classification	Efficiency (%)	Area (cm^2)	V_{oc} (V)	I_{sc} (A)	FF (%)	Test centre (date)	Description
Si (crystalline)	**23.8 ± 0.5**	**11562 (ap)**	**53.4**	**6.32[a]**	**81.6**	**AIST (1/16)**	**Panasonic (72 cells) [11]**
Si (multicrystalline)	**19.5 ± 0.4**	**15349 (ap)**	**41.53**	**9.299[a]**	**77.4**	**FhG-ISE (12/15)**	**Hanwha Q Cells (120 cells) [12]**
GaAs (thin film)	24.1 ± 1.0	858.5 (ap)	10.89	2.255[b]	84.2	NREL (11/12)	Alta Devices [38]
CdTe (thin film)	18.6 ± 0.6	7038.8 (ap)	110.6	1.533[a]	74.2	NREL (4/15)	First Solar, monolithic [39]
CIGS (Cd free)	17.5 ± 0.5	808 (da)	47.6	0.408[c]	72.8	AIST (6/14)	Solar Frontier (70 cells) [40]
CIGS (large)	15.7 ± 0.5	9703 (ap)	28.24	7.254[d]	72.5	NREL (11/10)	Miasole [41]
a-Si/nc-Si (tandem)	12.3 ± 0.3[e]	14322 (t)	280.1	0.902[f]	69.9	ESTI (9/14)	TEL Solar, Trubbach Labs [42]
Organic	8.7 ± 0.3[g]	802 (da)	17.47	0.569[c]	70.4	AIST (5/14)	Toshiba [34]
Multijunction							
InGaP/GaAs/InGas	**31.2 ± 1.2**	**968 (da)**	**23.95**	**1.506**	**93.6**	**AIST (2/16)**	**Sharp (32 cells) [13]**

CIGSS, CuInGaSSe; a-Si, amorphous silicon/hydrogen alloy; a-SiGe, amorphous silicon/germanium/hydrogen alloy; nc-Si, nanocrystalline or microcrystalline silicon; (t), total area; (ap), aperture area; (da), designated illumination area; FF, fill factor.

[a]Spectral response and/or current–voltage curve reported in the present version of these Tables.

[b]Spectral response and current–voltage curve reported in Version 41 of these Tables.

[c]Spectral response and/or current–voltage curve reported in Version 45 of these Tables.

[d]Spectral response reported in Version 37 of these Tables.

[e]Stabilised at the manufacturer to the 2% level following IEC procedure of repeated measurements.

[f]Spectral response and/or current–voltage curve reported in Version 46 of these Tables.

[g]Initial performance (not stabilised).

Table III. 'Notable exceptions': 'Top ten' confirmed cell and module results, not class records measured under the global AM1.5 spectrum (1000 Wm^{-2}) at 25°C (IEC 60904-3: 2008, ASTM G-173-03 global).

Classification	Efficiency (%)	Area (cm^2)	V_{oc} (V)	J_{sc} (mA/cm^2)	Fill Factor (%)	Test centre (date)	Description
Cells (silicon)							
Si (crystalline)	25.0 ± 0.5	4.00 (da)	0.706	42.7[a]	82.8	Sandia (3/99)[b]	UNSW p-type PERL top/rear contacts [43]
Si (large crystalline)	25.1 ± 0.5	151.88 (ap)	0.7375	40.79[c]	83.5	FhG-ISE (9/15)	Kaneka, n-type top/rear contacts [44]
Si (large crystalline)	25.2 ± 0.5	153.48 (t)	0.7370	41.33[c]	82.7	FhG-ISE (10/15)	Sunpower, n-type rear junction [45]
Cells (III-V)							
GaInP	20.8 ± 0.6[d]	0.2491 (ap)	1.4550	16.04[c]	89.3	NREL (5/13)	NREL, high bandgap [46]
Cells (chalcogenide)							
CIGS (thin film)	**22.3 ± 0.4**	**0.510 (da)**	**0.4219**	**39.38[e]**	**78.2**	**FhG-ISE (8/15)**	**Solar Frontier on glass [14]**
CIGSS (Cd free)	20.9 ± 0.7	0.5192 (ap)	0.6858	39.91[g]	76.4	FhG-ISE (3/14)	Showa Shell, on glass [47]
CdTe (thin film)	**22.1 ± 0.5**	**0.4798 (da)**	**0.8872**	**31.69[h]**	**78.5**	**Newport (11/15)**	**First Solar on glass [48]**
CZTSS (thin film)	12.6 ± 0.3	0.4209 (ap)	0.5134	35.21[g]	69.8	Newport (7/13)	IBM solution grown [15]
CZTS (thin film)	9.1 ± 0.2	0.2409 (da)	0.701	20.84[h]	62.5	AIST (12/14)	Toyota Central R&D Labs [49]
Cells (other)							
Perovskite (thin film)	**22.1 ± 0.7[i]**	**0. 046 (ap)**	**1.105**	**24.97[e]**	**80.3**	**Newport (3/16)**	**KRICT/UNIST [6]**
Organic (thin film)	11.1 ± 0.3[i]	0.159 (ap)	0.867	17.81[k]	72.2	AIST (10/12)	Mitsubishi Chemical [50]

CIGSS, CuInGaSSe; CZTSS, $Cu_2ZnSnS_{4-y}Se_y$; CZTS, Cu_2ZnSnS_4; (ap), aperture area; (t), total area; (da), designated illumination area; AIST, Japanese National Institute of Advanced Industrial Science and Technology; NREL, National Renewable Energy Laboratory; FhG-ISE, Fraunhofer-Institut für Solare Energiesysteme; ESTI, European Solar Test Installation.

[a]Spectral response reported in Version 36 of these Tables.

[b]Recalibrated from original measurement.

[c]Spectral response and current–voltage curves reported in Version 47 of these Tables.

[d]Not measured at an external laboratory.

[e]Spectral response and current–voltage curves reported in the present version of these Tables.

[f]Spectral response and current–voltage curves reported in Version 45 of these Tables.

[g]Spectral response and current–voltage curves reported in Version 44 of these Tables.

[h]Spectral response and/or current–voltage curves reported in Version 46 of these Tables.

[i]Stability not investigated.

[j]Korean Research Institute of Chemical Technology.

[k]Spectral response and current–voltage curves reported in Version 41 of these Tables.

conforming to the requirements to be recognised as a class record, the cells and modules in this Table have notable characteristics that will be of interest to sections of the photovoltaic community, with entries based on their significance and timeliness.

To encourage discrimination, Table III is limited to nominally 10 entries with the present authors having voted for their preferences for inclusion. Readers who have suggestions of results for inclusion into this Table are welcome to contact any of the authors with full details. Suggestions conforming to the guidelines will be included on the voting list for a future issue.

Table IV shows the best results for concentrator cells and concentrator modules (a smaller number of 'notable exceptions' for concentrator cells and modules additionally are included in Table IV).

Thirteen new results are reported in the present version of these Tables. The first new result in Table I is a new efficiency record for 1 cm^2 CZTSSe ($Cu_2ZnSnS_{4-y}Se_y$) solar cell. An efficiency of 9.8% has been measured by the Newport Technology and Applications Center for a cell with Se/(S + Se) ~65% fabricated at IMRA Europe using a wet process to deposit the active layer [4]. A second new result is 7.6% efficiency for a 1 cm^2 pure sulfide CZTS cell fabricated by the University of New South Wales (UNSW) and measured by the US National Renewable Energy Laboratory (NREL) with magnetron sputtering followed by sulfurisation used to form the active layer [5].

The third new entry is an improved result for an organic–inorganic lead halide perovskite cell of greater than 1 cm^2 area. An efficiency of 19.7% has been measured again at Newport for a 1 cm^2 perovskite cell fabricated by the Korean Research Institute of Chemical Technology (KRICT) in conjunction with the Ulsan National Institute of Science and Technology (UNIST) [6]. This is the efficiency as initially measured, with subsequent degradation not investigated. This

Table IV. Terrestrial concentrator cell and module efficiencies measured under the ASTM G-173-03 direct beam AM1.5 spectrum at a cell temperature of 25°C.

Classification	Efficiency (%)	Area (cm^2)	Intensity[a] (suns)	Test centre (date)	Description
Single cells					
GaAs	29.1 ± 1.3[b]	0.0505 (da)	117	FhG-ISE (3/10)	Fraunhofer ISE
Si	27.6 ± 1.2[d]	1.00 (da)	92	FhG-ISE (11/04)	Amonix back-contact [51]
CIGS (thin-film)	23.3 ± 1.2[b]	0.09902 (ap)	15	NREL (3/14)	NREL [52]
Multijunction cells					
GaInP/GaAs; GaInAsP/GaInAs	46.0 ± 2.2[f]	0.0520 (da)	508	AIST (10/14)	Soitec/CEA/FhG-ISE bonded [53]
GaInP/GaAs/GaInAs/GaInAs	45.7 ± 2.3[b]	0.09709 (da)	234	NREL (9/14)	NREL, 4 J monolithic [54]
InGaP/GaAs/InGaAs	44.4 ± 2.6[h]	0.1652 (da)	302	FhG-ISE (4/13)	Sharp, inverted metamorphic [55]
Minimodule					
GaInP/GaAs; GaInAsP/GaInAs	43.4 ± 2.4[b]	18.2 (ap)	340[j]	FhG-ISE (7/15)	Fraunhofer ISE (lens/cell) [56]
Submodule					
GaInP/GaInAs/Ge; Si	40.6 ± 2.0[i]	287 (ap)	365	NREL (4/16)	UNSW split spectrum [20]
Modules					
Si	20.5 ± 0.8[b]	1875 (ap)	79	Sandia (4/89)[k]	Sandia/UNSW/ENTECH (12 cells) [57]
Three junction	35.9 ± 1.8[l]	1092 (ap)	N/A	NREL (8/13)	Amonix [58]
Four junction	38.9 ± 2.5[m]	812.3 (ap)	333	FhG-ISE (4/15)	Soitec [59]
'Notable exceptions'					
Si (large area)	21.7 ± 0.7	20.0 (da)	11	Sandia (9/90)[i]	UNSW laser grooved [60]
Luminescent minimodule	7.1 ± 0.2	25(ap)	2.5[j]	ESTI (9/08)	ECN Petten, GaAs cells [61]

CIGS, $CuInGaSe_2$; (da), designated illumination area; (ap), aperture area; NREL, National Renewable Energy Laboratory; FhG-ISE, Fraunhofer-Institut für Solare Energiesysteme.

[a]One sun corresponds to direct irradiance of 1000 Wm^{-2}.

[b]Not measured at an external laboratory.

[c]Spectral response reported in Version 36 of these Tables.

[d]Measured under a low aerosol optical depth spectrum similar to ASTM G-173-03 direct[65].

[e]Spectral response and current–voltage curve reported in Version 44 of these Tables.

[f]Spectral response and current–voltage curve reported in Version 45 of these Tables.

[g]Spectral response and current–voltage curve reported in Version 46 of these Tables.

[h]Spectral response and current–voltage curve reported in Version 42 of these Tables.

[i]Determined at IEC 62670-1 CSTC reference conditions.

[j]Geometric concentration.

[k]Recalibrated from original measurement.

[l]Referenced to 1000 W/m^2 direct irradiance and 25°C cell temperature using the prevailing solar spectrum and an in-house procedure for temperature translation.

[m]Measured under IEC 62670-1 reference conditions following the current IEC power rating draft 62670-3.

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DOI: 10.1002/pip

was a very active category with improvements reported by two other groups beyond the previous 1 cm^2 cell record of 15.6% [3]. An improved efficiency of 18.2% was confirmed by the Japanese National Institute of Advanced Industrial Science and Technology (AIST) in October 2015 for a 1 cm^2 perovskite cell fabricated by the Japanese National Institute of Materials Science, while a value of 19.6% was confirmed by Newport in February 2016 for a 1 cm^2 perovskite cell fabricated by the École Polytechnique Fédérale de Lausanne. Again, these are efficiencies as initially measured, with subsequent degradation not investigated.

A fourth new result in Table I is the improvement of the efficiency of a 1 cm^2 organic solar cell to 11.2% for a cell fabricated by Toshiba and measured by AIST [7]. Again, this is an initial efficiency with stability not investigated.

A fifth new result in Table I relates to a four-junction, four-terminal, split-spectrum, one-sun minimodule based on the use of prismatic glass encapsulation to maintain close to standard angular response [8]. An efficiency of 34.5% was measured for a 28 cm^2 minimodule fabricated by the UNSW, Australia, consisting of a commercially available GaInP/GaInAs/Ge triple junction cell fabricated by Azur Space reflecting a band of near-infrared light to a silicon interdigitated back-contact cell fabricated by Trina Solar, with the performance measured by NREL.

The final new result in Table I is 31.6% efficiency for a 1 cm^2 area, two-junction, two-terminal monolithic one-sun tandem GaInP/GaAs cell fabricated by Alta Devices and again measured by NREL [9]. One correction to the table is inclusion of the Swiss Center for Electronics and Microtechnology (CSEM), Neuchatel, as a key partner in the record for a GaInP/Si mechanically stack cell included in the previous issue [3]. CSEM supplied the high-performance silicon cell in this 29.8% efficiency stack [10].

Three significant new module results are reported in Table II. Following the battle for supremacy for a large area crystalline-Si module reported in the previous version of these tables [3], Panasonic has seized the outright record for silicon module performance by fabricating a reasonably large-area 1.2 m^2 module with aperture area efficiency of 23.8% confirmed by AIST. This module uses the rear-heterojunction approach that earlier produced the record 25.6% efficient silicon cell [11].

An increase of 19.5% aperture area efficiency is also reported for a larger (1.5 m^2) multicrystalline module fabricated by Hanwha Q cells [12] and measured at the Fraunhofer Institute for Solar Energy Systems (FhG-ISE). The final new entry in Table I is the first confirmed module efficiency reported using monolithic triple-junction cells. A 31.2% aperture area efficiency is reported for a 968 cm^2 InGaP/GaAs/InGaAs module fabricated by Sharp [13] and measured by AIST. This is the highest confirmed efficiency for any one-sun photovoltaic module and the first one-sun module over 30% efficiency.

Three new results are reported as 'notable exceptions' in Table III. An efficiency of 22.3% has been confirmed for a small-area (0.5 cm^2) CIGS (CuInGaSe) cell fabricated by Solar Frontier and measured at FhG-ISE [14]. A very similar efficiency of 22.1% has also been measured for a similarly small (0.5 cm^2) CdTe cell fabricated by First Solar and measured at Newport [15]. An identical efficiency of 22.1% has also been measured for an even smaller 0.09 cm^2 mixed organic–inorganic lead halide perovskite cell fabricated by the Korean Research Institute of Chemical Technology and also measured at Newport [6]. This follows the slightly earlier measurement of 21.0% efficiency at Newport for a similarly sized perovskite cell fabricated by École Polytechnique Fédérale de Lausanne, which also surpassed the 20.1% record reported in the previous issue [3]. In all the aforementioned cases, cell area is too small for classification as an outright record. Solar cell efficiency targets in governmental research programmes generally have been specified in terms of a cell area of 1 cm^2 or larger [16–18]. Additionally, the perovskite cell efficiencies are initial efficiencies with the degradation of similar devices documented elsewhere [19].

A final new result in Table IV is a new efficiency level of 40.6% for a concentrator submodule of 287 cm^2 aperture area, measured in outdoor testing by NREL for a

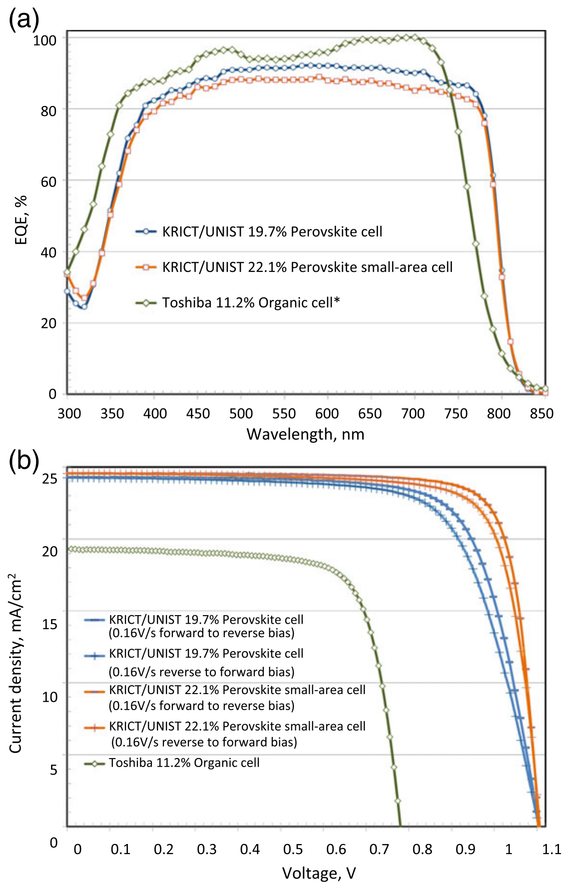

Figure 1. (a) External quantum efficiency (EQE) for the new perovskite and organic cell results reported in this issue (*normalised result). (b) Corresponding current density–voltage (JV) curves for the same devices.

287 cm^2 split-spectrum concentrator submodule fabricated by UNSW using commercial GaInP/GaInAs/Ge and Si cells manufactured by Spectrolab and SunPower, respectively [20].

The EQE spectra for the new perovskite and organic cell results reported in the present issue of these Tables are shown in Figure 1(a). Figure 1(b) shows the current density-voltage (JV) curves for the same device. For the perovskite devices, the JV curves are shown for a sweep rate of 0.16 V/s from both forward to reverse bias and in the opposite bias direction, showing a small hysteresis effect, although final efficiency values were determined after more exhaustive testing. Figure 2(a) shows the EQE for the new silicon and chalcogenide cell and module results, with Figure 2(b) showing their current density–voltage (JV) curves. Figure 3 shows the corresponding EQE and JV curves for the new multijunction cell and module results, together with JV results for the new small-area CdTe cell.

For the case of modules and tandem cells, the measured current–voltage data have been reported on a 'per cell' basis (measured voltage has been divided by the known or estimated number of cells in series, while measured current has been multiplied by this quantity and divided by the module area).

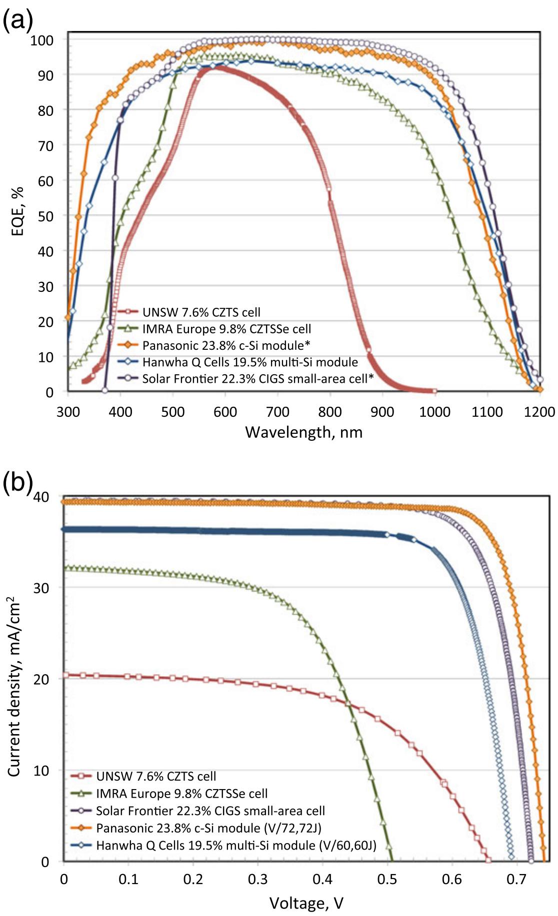

Figure 2. (a) External quantum efficiency (EQE) for the new silicon and chalcogenide cell and module results reported in this issue (*normalised result). (b) Corresponding current density–voltage (JV) curves.

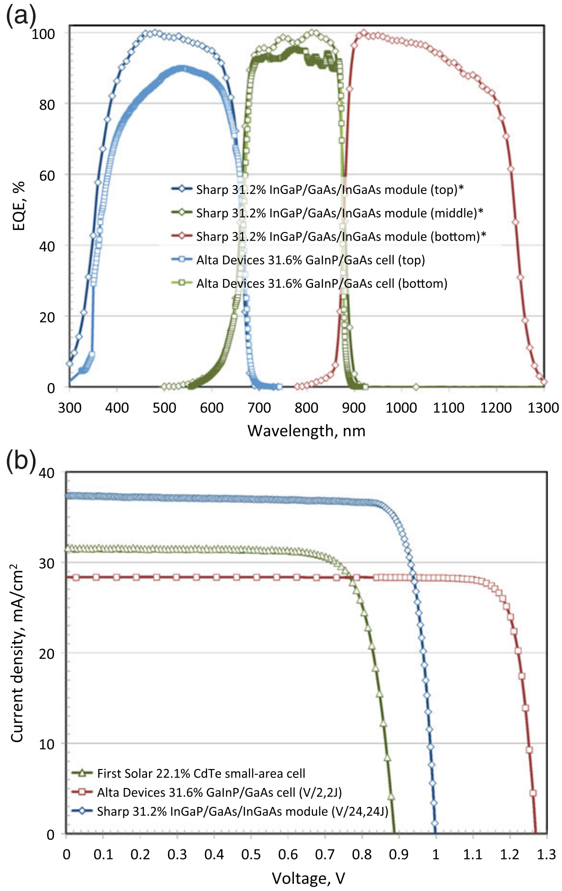

Figure 3. (a) External quantum efficiency (EQE) for the new multijunction cell and module results reported in this issue (*normalised result). (b) Corresponding current density–voltage (JV) curves together with that of the new CdTe small-area cell.

3. DISCLAIMER

While the information provided in the tables is provided in good faith, the authors, editors and publishers cannot accept direct responsibility for any errors or omissions.

ACKNOWLEDGEMENTS

The Australian Centre for Advanced Photovoltaics commenced operation in February 2013 with support from the Australian Government through the Australian Renewable Energy Agency (ARENA). The Australian Government does not accept responsibility for the views, information or advice expressed herein. The work by K. Emery was supported by the U.S. Department of Energy under contract no. DE-AC36-08-GO28308 with the National Renewable Energy Laboratory. The work at AIST was supported in part by the Japanese New Energy and Industrial Technology Development Organisation (NEDO) and by the Japanese Ministry of Economy, Trade and Industry (METI).

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