# REVIEW OF SOLAR CELL

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Abstract: *The need for inexpensive, clean energy is increasing every day. As more and more countries develop and the world's population increases , the need to power the world increases .One of the most promising sources of energy for powering the planet is solar energy. Approximately 120,000 terawatts (TW) of solar energy strike the earth every day. Currently, only 0.05% of the world energy production is from solar energy. Because solar energy is relatively more expensive than conventional means of energy, such as coal and fossil fuels.*

Today: production Cost Of Electricity in $

2.1$	2.3$	3.6$	3.9$	5.5$	22$
Coal	nuclear	gas	oil	wind	solar
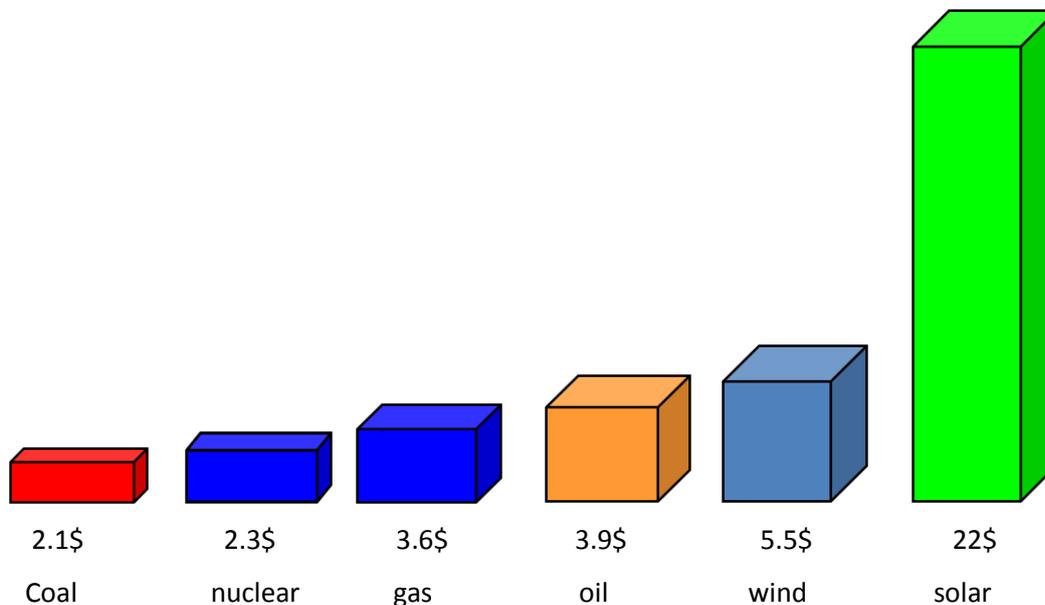
In order to overcome such high costs solar cell must either be made from cheaper material or become more efficient. The region between 400nm and 1100nm has the highest photon density in the am 1.5 solar spectrum. A material that cans absorb sunlight between 400nm and 1100nm would be the ideal absorber. Silicon and multijunction solar cells are very efficient at converting sunlight to electricity but they are competitive in price to fossil fuels.

A promising alternative to silicon and multijunction solar cells are dye sensitized solar cells (DSSC). DSSC have the potential to be as efficient as silicon solar cells, but at a fraction of the cost of silicon and multjunction solar cells.

The efficiency (η) of a DSSC is determined by the ratio of the power of the DSSC (PDSSC) to the power of incident light (Pin).The power of DSSC is determined by the short circuit current density (Jsc) open circuit voltage (voc) and fill factor (FF). The short circuit current density is given by the current measured at short circuit conditions or the current measured when there is zero applied voltage. The open circuit voltage is the voltage measured when the cell is at open circuit or the voltage that is applied to produce zero current. The fill factor is simply the ratio of the measured power of the solar cell from the current voltage curves to the maximal theoretical power of the solar cell. If recombination is high then the fill factor will be low and if there is little to no recombination the FF will be near unity, but in efficient solar cells the FF is ~ 0.6 -0.8. It can be concluded that by increasing the J_{sc}, V_{oc} or FF one can increase the η

η=PDSSC/Pin

=Jsc Voc FF/Pin

Consolidated tables showing an extensive listing of the highest independently confirmed efficiencies for solar cells and modules are presented. Highest confirmed "one-sun" cell and module results are reported in table I and II. Table I summarizes the best measurements for cells and sub modules, while Table II shows the best results for modules. The most important criterion for inclusion of results into the tables is that they must have been measured by a recognized test centre. A distinction is made between three different eligible areas: total area; aperture area and designated illumination area.

Table I. confirmed terrestrial cell and sub module efficiencies measured under the global AM1.5 spectrum (1000W/m ^{2}) at 25^0 C

Classification TestCentre[e]	Effic.[b] (%)	Area[c] (cm^2)	V_{oc} (v)	J_{sc} (mA/cm^2)	FF[d]	(and Data)
Silicon						
Si (crystalline)	25.0±0.5	4.00(da)	0.706	42.7	82.8	Sandia
Si (multicrystalline)	20.4±0.5	1.002(ap)	0.664	38.0	80.9	NREL
Si (thin film transfer)	16.7±0.4	4.017(ap)	0.645	33.0	78.2	FhG-ISE
Si (thin film submodule)	10.5±0.3	94.0(ap)	0.492	29.7	72.1	FhG-ISE
GaAs (thin film)	27.6±0.8	0.9989(ap)	1.107	29.6	84.1	NREL
GaAs (multicrystalline)	18.4±0.5	4.011(t)	0.994	23.2	79.7	NREL
InP (crystalline)	22.1±0.7	4.02(t)	0.878	29.5	85.4	NREL
Thin Film Chalcogenide						
CIGS (cell)	19.6±0.6	0.996(ap)	0.713	34.8	79.2	NREL
CIGS (submodule)	16.7±0.4	16.0(ap)	0.661	33.6	75.1	FhG-ISE

CdTe (cell)	16.7±0.5	1.032(ap)	0.845	26.1	75.5	NREL
CdTe (submodule)	12.5±0.4	35.03(ap)	0.838	21.2	70.5	NREL
Amorphous/nanocrystalline Si						
Si(amorphous)	10.1±0.3	1.036(ap)	0.886	16.75	67	NREL
Si(nanocrystalline)	10.1±0.2	1.199(ap)	0.539	24.4	76.6	JQA
Photochemical						
Dye sensetised	10.4±0.3	1.004(ap)	0.729	22	65.2	AIST
Dye sensetised (submodule)	9.9±0.4	17.11(ap)	0.719	19.4	71.4	AIST
Organic						
Organic polymer	8.3±0.3	1.031(ap)	0.816	14.46	70.2	NREL
Organic (sub module)	3.5±0.3	208.4(ap)	0.847	8.62	48.3	NREL
Organic (2-cell tandem)	8.3±0.3	1.087(ap)	1.733	8.03	59.5	FhG-ISE
Multijunction devices						
GaInP/GaAs/Ge	32.0±1.5	3.989(t)	2.622	14.37	85	NREL
GaAs/CIS(thin film)	25.8±1.3	4.00(t)	-	-	-	NREL
a-Si/μc-Si(thin film cell)	11.9±0.8	1.227	1.346	12.92	68.5	NREL
a-Si/μc-Si(thin film sub module)	11.7±0.4	14.23(ap)	5.462	2.99	71.3	AIST

[a] CIGS =CuInGa2; a-Si= amorphous silicon/ hydrogen alloy

[b] Effic.=efficiency

[c] (ap)=aperture area; (t)=total area; (da)=designated illumination area

[d] FF=fill factor

[e] FhG-ISE=Fraunhofer Institute for Solar Energiesysteme; JQA= Japan Quality Assurance; AIST=Japan

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Table II. Confirmed terrestrial module efficiencies measured under the global AM1.5 spectrum (1000W/m^2) at 25^0 C

Classification	Effic.[b] (%)	Area[c] (cm^2)	V_{oc} (v)	I_{sc} (A)	FF[d]	Test Centre (and Data)
Si (crystalline) Sandia	22.9±0.6	778(da)	5.6	3.97	80.3	
Si (large crystalline)	21.4±0.6	15780(ap)	68.6	6.293	78.4	NREL
Si (multicrystalline)	17.55±0.5	14701(ap)	38.31	8.94	75.3	ESTI
Si (thin film polycrystalline) Sandia	8.2±0.2	661(ap)	25	0.32	68	
CIGS	15.7±0.5	9703(ap)	28.24	7.254	72.5	NREL
CIGSS (Cd free)	13.5±0.7	3459(ap)	31.2	2.18	68.9	NREL
CdTe	10.9±0.5	4874(ap)	26.21	3.24	62.3	NREL

This context is focused on liquid redox electrolytes in dye – sensitized solar cells (DSCS). A liquid redox electrolyte as one of the key constitutes in DSCS typically consists of a redox mediator, additives and a solvent.

DEVELOPMENT OF SOLAR CELLS

Solar cells are   electrical devices that directly convert sunlight into electrically. Since the modern discovery of the silicon p-n junction PV devices (Solar Cells) , the global PV industry has experienced revolutionary developments and market growth. The solar industry has been the fastest growing renewable energy technology in recent years.

The first generations of solar cells from industrialization point of view are based on crystalline silicon. The manufacture of silicon – based solar cells involves high purity silicon, the manufacturing processes of which are extremely expensive. The high cost of the generation solar cells severely restricts their widespread application in the future.

The second generations of solar cells are normally referred to as thin film solar cells. Amorphous silicon , Cadmium telluride(CDTE) , Copper indium gallium selenide (CIGS) are the three most commonly used materials for the second generation solar cells to use far less materials required in a solar cells , which significantly reduce the production cost in contrast to the first generation solar cells are lower than the first generation solar cells.

Dye – sensitized solar cells were significantly improved in 1991. In contrast to conventional systems where the semiconductor takes both the function of light absorption and charge career transport, these two functions are separated in DSCs. The light absorption is performed by a monolayer of dye molecules attached to a mesoporous layer of a wide band gap semiconductor. Charge separation takes place at the semiconductor/dye interface. Charge carriers are transported in the conduction band edge (CB) of the semiconductor to the charge collector. DSCs are considered to be a technology between the second and third generation solar cells.

DYE-SENSITIZED SOLAR CELLS (DSCS)

DSC consists of three major components: semiconductor, sensitizer and electrolyte between two electrodes. The device generates electric power without suffering any permanent chemical transformation.
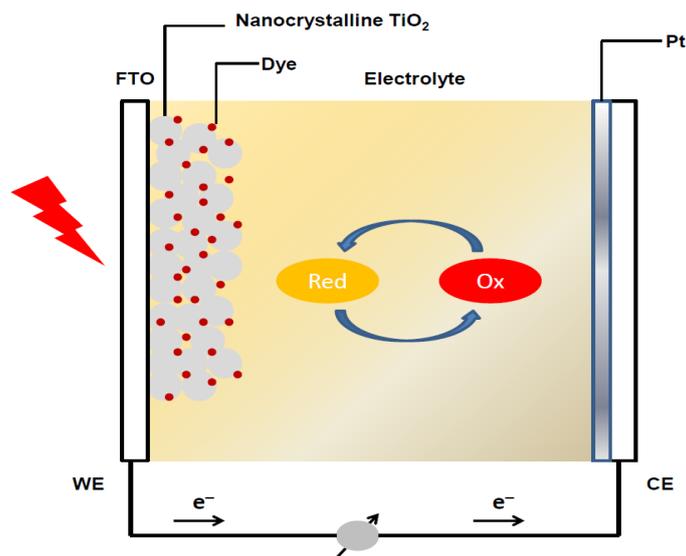
Schematic structure of a DSC

Working electrodes consists of a mesoporous layer of metal oxide semiconductor typically TIO_2, screen printed onto the conducting glass substrates, typically fluorine-doped tin oxide. The nanoparticle size is around 20 nm in diameter and typical film thicknesses are 10 μm. Liquid electrolytes consists of a redox couple and additives dissolved in a liquid solvent. Counter electrodes are prepared by depositing a thin layer of Platinum catalyst onto the fluorine-doped tin oxide.
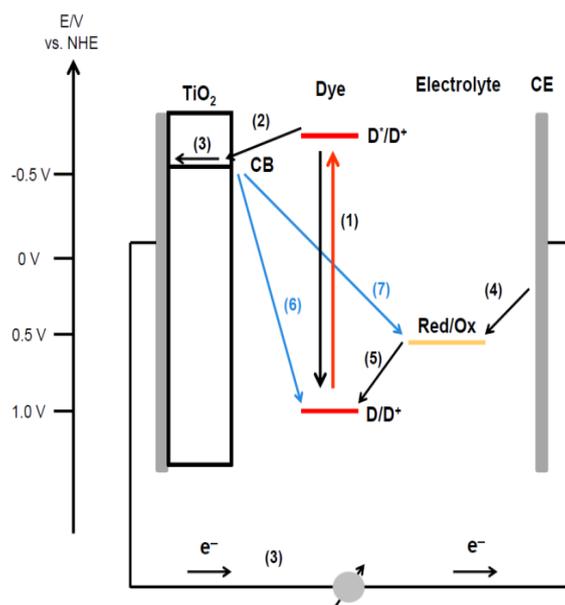

Operation principle in DSCs

Upon light irradiation, the monolayer of the sensitizer is photo excited. The excited electrons are injected into the conduction band in the TIO_2. The electrons penetrate through

the nanocrystalline TIO_2 film to the back contact of the conducting substrate and flow through an external circuit. The photovoltaic performance of liquid electrolyte- based DSCs depend strongly on the choice of electrolyte solvent. Organic solvent and ionic liquids are two major types of liquid electrolyte solvents.

A redox couple is the key component in a liquid electrolyte, assuming the tasks for dye regeneration and charge transport between the two electrodes, playing a circuit role in determining the photovoltaic performance of DSCs. Iodine/ triiodide has been used as a redox couple from the very beginning of DSC research. Organic sensitizes have attracted much attention in recent years due to their advantages, high molecular extinction coefficients, which allow DSCs to use thinner layer of TIO_2 film , thus leading to the improvements of charge collection efficiency. In addition to a redox couple , various additives i.e. specific cations or or compounds , are normally introduced into the liquid electrolytes. Two kinds of additives are typically employed in liquid electrolytes for DSCs. One class of additives in liquid electrolytes incorporates specific cations such as alkali cations or guanidium cations .Nitrogen –containing heterocyclic compound , such as 4-tert-butylpyridine is another class of the most frequently used additives .

Current – voltage measurement is the most important and conventional technique for the assessment of the photovoltaic performance. The most important photovoltaic parameter to evaluate the performance of DSC devices is the overall light-to-electricity conversion efficiency (η) , which is determined by the product of the short-circuit current density(Jsc), open –circuit voltage(Voc) and fill factor(FF) divided by the intensity of the incident light(Pin).
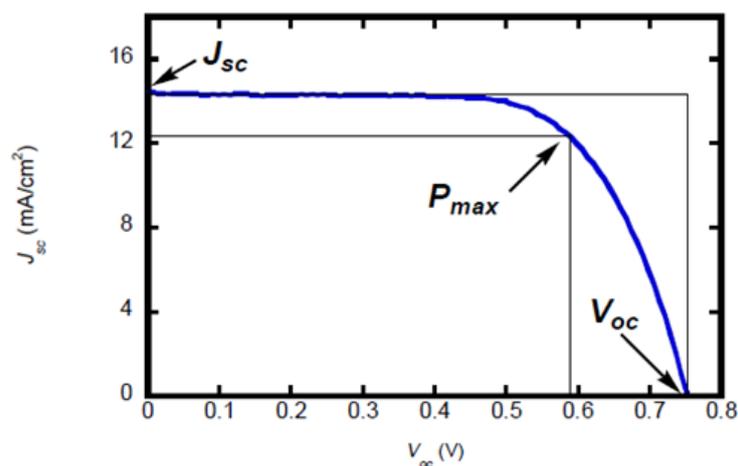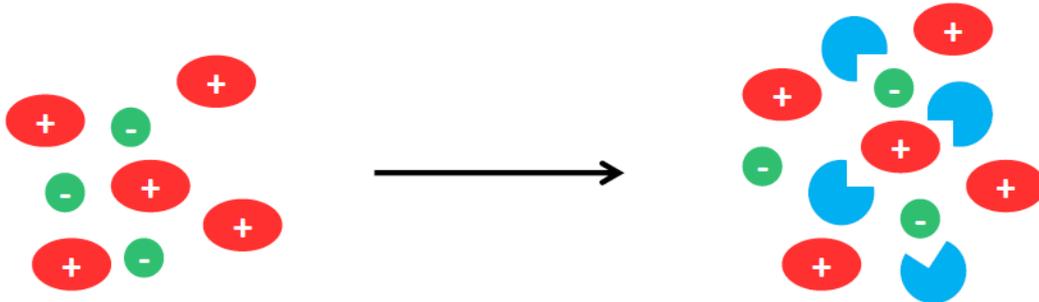

I-V characteristics of a DSC device

FF=Pmax/Jsc.Voc

η=Jsc.Voc.FF/Pin

Incompletely Solvated Ionic Liquids as Electrolyte Solvents

Mixtures between ionic liquids and molecular solvents exhibit interesting physical and chemical properties that deviate from their parent components. At low concentrations or molar ratios of the molecular solvent, the mixture in most aspects chemically behaves like an ionic liquid as long as the number of solvent molecules are insufficient to fully solvate the ions of the salt.

Conclusions

The influences of different cations of lithium, sodium and guanidinium in the electrolytes on the photovoltaic characteristics for DSCs have been investigated. Upon addition of cations into the reference electrolyte, short-circuit currents are all found to be significantly enhanced, largely due to the positive shift of the CB in the TiO_2, probably resulting in an increase of the electron injection yield from the excited state of the sensitizing dye to the CB of TiO_2. Different behaviors in the photovoltages are observed for different cations. The optimal overall conversion efficiency is obtained by the electrolyte with additional guanidinium cations, benefiting from the dual gains of both short-circuit current and open-circuit voltage relative to the reference electrolyte.

REFERENCES:

1. C. W. Bunn, "The lattice-dimensions of zinc oxide," Proc. Phys. Soc. London 47: 835,1935.

2. D. R. Lide (editor), CRC Handbook of Chemistry and Physics, CRC Press, New York, 73rd edition, 1992.

3. D. C. Look, "Recent advances in ZnO materials and devices," Mat. Sci. Eng. B. 80: 383, 2001.

4. D. C. Look, D. C. Reynolds, J. R. Sizelove, R. L. Jones, C. W. Litton, G. Cantwell and W. C. Harsch, "Electrical properties of bulk ZnO," Solid State Commun. 105: 399, 1998.

5. Y. Segawa, A. Ohtomo, M. Kawasaki, H. Koinuma, Z. K. Tang, P. Yu and G. K. L. Wong, "Growth of ZnO thin films by laser-MBE: Lasing of excitons at room temperature," Phys. Stat. Sol. 202: 669, 1997.

6. J. E. Nause, "ZnO broadens the spectrum," III-Vs Review 12: 28, 1999.

7. J. E. Nause, "Fluorescent substrate offers route to phosphor-free LEDs," Comp. Semicond. 11: 29, 2005.

8. S. O. Kucheyev, J. S. Williams, C. Jagadish, J. Zou, C. Evans, A. J. Nelson and A. V.Hamza, "Ionbeam-produced structural defects in ZnO," Phys. Rev. B 67: 094 115, 2003.

9. C. Coskun, D. C. Look, G. C. Farlow and J. R. Sizelove, "Radiation hardness of ZnO at low temperatures," Semicond. Sci. Technol. 19: 752, 2004.

10. S. O. Kucheyev, J. S. Williams and C. Jagadish, "Ion-beam-defect processes in group-III nitrides and ZnO," Vacuum 73: 93, 2004.

11. N. A. Spaldin, "Search for Ferromagenetism in transition-metal-doped piezoelectric ZnO," Phys. Rev. B 69: 125 201, 2004.

12. S. J. Pearton, D. P. Norton, K. Ip, Y. Heo and T. Steiner, "Recent advances in processing of ZnO," J. Vac. Sci. Technol. B 22: 932, 2004.

13. D. C. Look and B. Claflin, "P-type doping and devices based on ZnO," Phys. Stat. Sol. (b) 241: 624, 2004.

14. D. C. Look, B. Claflin, Y. I. Alivov and S. J. Park, "The future of ZnO light emitters," Phys. Stat. Sol. (a) 201: 2203, 2004.

15. S. B. Zhang, S. H. Wei and A. Zunger, "Intrinsic n-type versus p-type doping asymmetry and the defect physics of ZnO," Phys. Rev. B 63: 075 205, 2001.

16. A. F. Kohan, G. Ceder, D. Morgan and C. G. Van deWalle, "First-principles study of native point defects in ZnO," Phys. Rev. B 61: 15 019, 2000.

17. C. G. Van de Walle, "Hydrogen as a cause of doping in ZnO," Phys. Rev. Lett. 85: 1012, 2000.