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A REVIEW

Effect of temperature on solar cell with reference to electrical parameters

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ABSTRACT

The performance and overview use of solar cell is expressed in this research paper electric parameters are studies with reference to temperature variation. The variation in comparative effects the parameters like, open circuit voltage (V_{OC}), short circuit current density (J_{SC}), fill factor (FF) and efficiency (η), of solar cells based on semiconductor materials such as Ge, Si, CdTe, GaAs, InP and Cds, all these parameters has been investigated in the temperature range 275-525K. Results shows that all electrical parameters of solar cell such as open circuit voltage (V_{OC}), short circuit current density (J_{SC}), fill factor (FF) and efficiency (η) have changed with temperature variation. As well as the changes in these, parameters in terms of temperature value have been obtained. Results shows that change in temperature effects the current of cells.

Key Words : Open circuit voltage, Short circuit current density, Fill factor, Efficiency, Solar cell, Temperature

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Photovoltaic cell commonly called as solar cell is an optical electronic device that converts solar energy into electric energy (Settino *et al.*, 2018). Solar light absorbed by the cell produces a voltage and current to generate electric power. The whole exercise is dependent on the material which can absorb the light and may rays an electron to a light energy electron from the solar cell to its external circuit (Pandey and Agrawal, 2012 and Abdallah and Nijmeh, 2004). IV group elements of periodic table or a combination of III and IV group and a combination of group II and VI are susseptable for this purpose. The sun rays of all spectrum ranging radio wave to gamma rays are used in the exercise.

When the solar cells are exposed to sunlight the electron become excited from balance band to conduction band this phenomenon creates charge particle that are called holes. In PV cell the upper layer (n-type) is of crystalline silicon covered with phosphorus with 5 balance electron while the lower layer (p-type) is doped with boron which was 3 balance electron by bringing n and p-type semi conductors together p-n junction starts creating an electric field with in the solar cell. The balance electron jumper to conduction band and initiates a current coming-out from the solar cells (Zeyghami *et al.*, 2015 and Choubey *et al.*, 2012).

The solar cell parameters such as open circuit voltage (V_{OC}), short circuit current density (J_{SC}), fill factor (FF) and efficiency (η) have been discussed. The open circuit voltage is temperature dependent. The short circuit current increases proportionally with temperature (Rana, 2013).The fill factor and efficiency which depends on open circuit voltage and short circuit current follows these temperature variations. The temperature change affects these parameters and hence, the performance of solar cells (Bagher *et al.*, 2015).

Temperature variation on solar cell with reference to electrical parameters:

A solar cell is made of p-n junction of semi conductors which converts solar energy directly into electricity (Peplow, 2014). The study of the behaviour of solar cells with temperature (T) is important as, in terrestrial applications, they are generally exposed to temperatures ranging from 15ºC (275L) to 35ºC (325K) and to even higher temperatures in space and concentrator system (Tsoutsos *et al.*, 2005). The performance of a solar cell is determined by the parameters, *viz.*, open circuit voltage (V_{OC}), short circuit current density (J_{SC}), fill factor (FF) and efficiency. The temperature variation effects these parameters and hence, the performance of solar cells (Yadav and Kumar, 2015). The diode parameters of solar cells, *i.e.*, reverse saturation current density (J_0) and ideality factor (n) along with series resistance (R_S) and shunt resistance (R_{SH}) control the effect of temperature on V_{OC}, FF and n of the solar cell (Tobnaghi *et al.*, 2013). It has been shown earlier that V_{OC} decreases with increasing T (Wysocki and Rappaport, 1960). Both FF and n decrease with increase in temperature and efficiency degradation is mainly due to decrease in V_{OC} (Fan, 1986).

The current density voltage (J-V) characteristics of p-n junction. Solar cells under steady state illumination can most simply be described using single exponential model as:

$$J = J_{ph} + J_o\,(e^{qv/nkj} - 1) \quad .... (1)$$

where, J_{ph} represents the photo generated current density, v is the terminal voltage, k is the Boltzmann constant and n is the ideality factor. The short circuit current density, J_{sc} depends on the given solar spectral irradiance and is given by:

$$Jsc = q\int_{hv=Eg}^{\infty} \frac{dN_{ph}}{dhv}.d(hv) \quad ....(2)$$

The variation in J_{sc} with temperature for solar cells based on Ge, Si, InP, GaAS, CdTe and CdS is presented in Fig.1. As can be seen in figure, J_{sc} increases with increasing temperature whereas it decreases with increasing bandgap. It can be seen from Table 1. That, for solar cells based on Si, GaAS, InP and CdTe, variation in short circuit current density with temperature is primarily due to the change in bandgap with temperature (Henry, 1980).

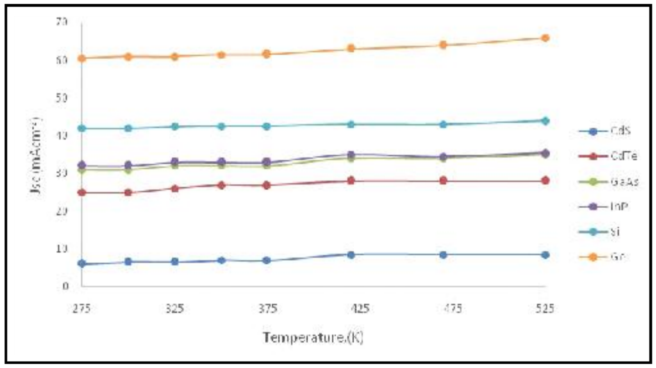

Fig. 1 : Variations of short-circuit current density (J_{SC}) with temperature for different solar cell materials

The open circuit voltage is the maximum voltage available from a solar cell eq. (1) at J = 0 yields the expression for V_{oc} as :

$$V_{oc} = KT / q\ In\ (J_{sc} / J_o + 1) \quad ....(3)$$

where, $J_{sc} \approx J_{ph}$, V_{oc} is related to J_{sc} and J_o and hence, to Eg. For a high V_{oc}, a low J_o is absolutely necessary.

The variation in the open circuit voltage for solar cells based on Ge, Si, InP, GaAS, CdTe and CdS in the temperature range 275 – 525 K is shown in Fig. 2. Open

Table 1 : Values of short-circuit current density (J_{SC}) for different solar cell materials at various temperatures

Temperature	CdS	CdTe	GaAs	InP	Si	Ge
275	6	25	31	32	42	60.5
300	6.5	25	31	32	42	61
325	6.5	26	32	33	42.5	61
350	7	27	32	33	42.6	61.55
375	7	27	32	33	42.6	61.6
420	8.5	28	34	35	43	63
470	8.5	28	34	34.5	43	64
525	8.5	28	35	35.5	44	66

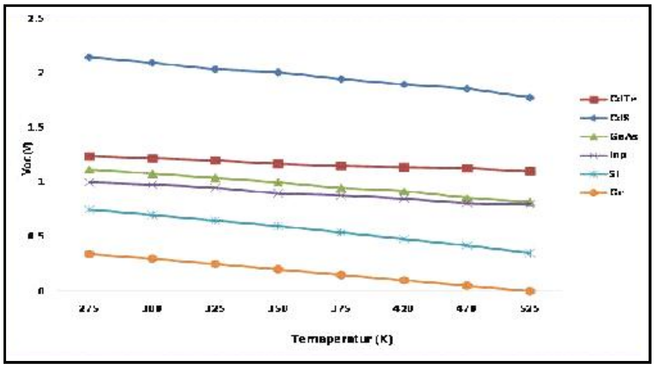

Fig. 2 : Variations of open-circuit voltage (V_{OC}) with temperature for different solar cell materials

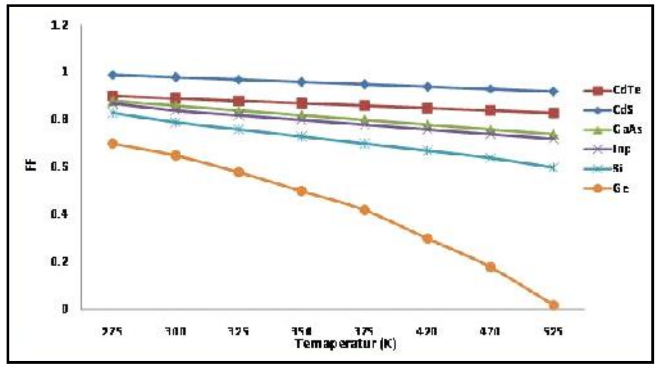

Fig. 3 : Variations of fill factor (FF) with temperature for different solar cell materials

Table 2 : Values of open-circuit voltage (V_{OC}) for different solar cell materials at various temperatures

Temperature	CdS	CdTe	GaAs	InP	Si	Ge
275	2.15	1.24	1.12	1	0.75	0.34
300	2.1	1.22	1.08	0.98	0.7	0.3
325	2.04	1.2	1.04	0.95	0.65	0.25
350	2.01	1.17	1	0.9	0.6	0.2
375	1.95	1.15	0.95	0.88	0.54	0.15
420	1.9	1.14	0.92	0.85	0.48	0.1
470	1.86	1.13	0.86	0.81	0.42	0.05
525	1.78	1.1	0.82	0.8	0.35	0

Table 3 : Values of fill factors (FF) for different solar cell materials at various temperatures

Temperature	CdS	CdTe	GaAs	InP	Si	Ge
275	0.99	0.9	0.88	0.87	0.83	0.7
300	0.98	0.89	0.86	0.84	0.79	0.65
325	0.97	0.88	0.84	0.82	0.76	0.58
350	0.96	0.87	0.82	0.8	0.73	0.5
375	0.95	0.86	0.8	0.78	0.7	0.42
420	0.94	0.85	0.78	0.76	0.67	0.3
470	0.93	0.84	0.76	0.74	0.64	0.18
525	0.92	0.83	0.74	0.72	0.6	0.02

Table 4 : Values of efficiency of short-circuit current density (J_{SC}) for different solar cell materials at various temperatures

Temperature	Ge	Ge	Ge	Si	Si	Si
275	14.9	12.9	10.9	31.8	28.8	26.8
300	12.4	10.4	8.4	29	26	24
325	9.5	7.5	5.5	26	23	21
350	7.45	5.45	3.45	23	20	18
375	4.9	2.9	1.4	20.5	17	115
420	2.9	0	0	17.99	14	12
470	1	0	0	15.4	11	9
525	0	0	0	12.8	8	6

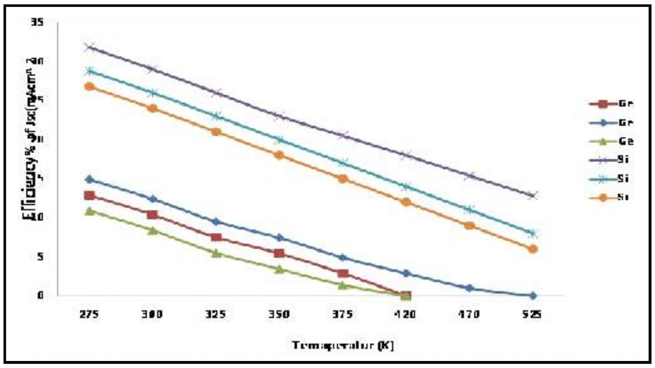

Fig. 4 : Variations of efficiency of short-circuit current density (J_{SC}) with temperature for different solar cell materials

circuit voltages shown in Fig. 2 are determined from the calculated J_{sc} and J_o using eq.3 for case (III) only. Table 2 lists the values of V_{oc} calculated for three cases at 298K described above.

Fill factor is defined as the maximum power output (P_{max}) at the maximum power point to the product of the open circuit voltage and short circuit current density and can be expressed as :

$$FF = \frac{P_{max}}{V_{oc} J_{sc}} \quad \text{....(4)}$$

Green gave an expression for the calculation of FF to an excellent accuracy,

$$FF = V_{oc} - \frac{V_{oc} + 0.72}{V_{oc}} + 1 \quad \text{....(5)}$$

where, $V_{oc} = \left(\frac{V_{oc}}{V_{th}}\right)$ is defined as 'normalized V_{oc}'.

The efficiency of a solar cell is the ratio of the power output corresponding to the maximum power point to the power input and is represented as :

$$\eta = \frac{V_{oc} . J_{sc} . FF}{P_{in}} \quad \text{....(6)}$$

where, P_{in} is the intensity of the incident radiation efficiency is calculated at each temperature using eq. 6 corresponding to the calculated V_{oc}, J_{sc} and FF at each temperature.

Conclusion:

The solar cell performance is dependent on their output parameters such as output voltage, current, fill factor and efficiency varies on the temperature. Changes the temperature dependence of performance electrical parameters, V_{oc}, J_{sc}, FF and n, of solar cells based on Ge, Si, CdTe and Cds has been investigated in the temperature range 275-525K.

The maximum achievable V_{oc}, J_{sc}, FF and n of solar cells, calculated for Am 1.5G and AMO, are nearly the same as in this literature. With increasing temperature, reverse saturation current increasing and, therefore, V_{oc} decreases which decreases the fill factor and hence the efficiency of the solar cell. Therefore, the tendency of V_{oc} to decrease and J_{sa} to increase with increasing temperature in the solar cells results in a decrease in the efficiency with increasing temperature.

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