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Research Paper

Correlation between the Power Output and Exposure to Sunlight of a Solar Panel

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Abstract: *The degree of dependence of power delivered by a solar panel on input solar irradiance was examined with a 10watt polycrystalline silicon (Si) solar panel and a 10watt polycrystalline gallium Arsenide (GaAs) solar panel, each at a fill-factor of 0.7.The research was carried out at Ilesa city located at coordinates 7037'0"N $4^0$43'0^0E / 7.61667^0N4.71667^0E, in Osun State of Nigeria. The research experiment was carried out from December 10^{th} to 23^{rd}, 2013 and March $10^{th}$to 23^{rd}, 2014. Average solar isolation figure for Ilesa measured in kWh/m^2/day onto a solar panel where the angle is adjusted each month to get optimum sunlight is 4.44 in March and 5.0 in December.The solar panels were hindered by different quantities of dust particles from receiving the appropriate sunlight. The particles used are sieved fine mud dust used in the following concentrations: 0.0ml, 2.5ml, 5.0ml, 7.5ml, 10.0ml, 12.5ml and 15ml respectively to shield the surface of the panels from normal exposure to the rays of sunlight. Measurements were taken of short circuit current (I_{sc}) and open circuit voltage (V_{oc}) values at intervals 1hour from 10.00am and 5.00pm.The output power and percentage power loss were calculated. The results show that the effect of any shielding the surface of a solar panel from receiving sunlight in appropriate abundance is vital. At 0.0ml dust particles on the surface of the solar panels, that is, when the surfaces are free from dust particles, the power loss is 0.00%. The percentage power loss rose from 0.00% to as high as 71.69% in polycrystalline silicon solar panel and 75.35% in polycrystalline GaAs solar panel during December, 2013 as the shielding dust particles volume rose up to15.0ml. Also, in March, 2014 the percentage power loss rose from 0.00% to as high as 71.94% with polycrystalline silicon solar panel and 75.60% with polycrystalline GaAs solar panel. These high values of power loss in both panels and periods of experimental investigation, suggest that the surface of solar panels should be kept free of dust particles or any* *other materials that can cause a shield or prevent the solar panels from receiving optimum sunlight at a time.*

Keywords: Polycrystalline, gallium, arsenide, silicon and particles.

Introduction

Solar cells constitute a critical technology for overcoming global environmental and energy problems. The invention of the p-n junction in 1949 formed the basis of the discovery of the crystalline Si solar cell by Pearson in 1954. Since then, solar cells have been developed and produced with polycrystalline silicon, CdTe and GaAs. Needless to mention, remarkable progress has been made in past four decades. Megawatt solar power generating plants have been built, solar cells are being combined with building materials, and very recently the first solar-cell-powered plane demonstrated a transcontinental flight across the United States. Applications of solar cell are now an important and integral part of our daily lives, ranging from calculators and wristwatches to solar powered irrigation systems. Over 95% of solar cells in production are silicon based (Bhattacharya, 2010).

The energy output from the sun is primarily electromagnetic radiation, which covers the spectral range of 0.2 to 3.0 μm. The radiation reaching Earth is scattered and absorbed in the atmosphere and the intensity is dependent on angle of incidence. Depending on this angle, the intensity can vary between 500 and 1000 W/m^2. The power level of the solar spectrum in outer space, where there is no absorption of radiation, is 140mW/cm^2.This is commonly termed the air-mass-zero (AM0) spectrum. On Earth at sea level, with the sun at zenith, the power level is reduced to nearly 100mW/cm^2. This is the AM1 spectrum. At an angle of incidence that results in twice the path length through the atmosphere, the power level drops to approx. 80mW/cm2 and the corresponding spectrum is termed AM2. The conversion of radiation energy into electrical energy is, in general, the photovoltaic effect. The most important photovoltaic device is the solar cell. The primary requirement for a material to be applicable to solar cells is a band gap matching the solar spectrum with high mobility and lifetime of the charge carriers. These conditions exist in GaAs and many other group III-V compounds (J.L. Shay et al, 1975).

Solar energy: The most efficient and reliable alternative source of electricity to hydro-electric and oil fired power supply. This research examines the quality, reliability and efficiency of two inorganic solar cells - a 10W polycrystalline silicon solar panel (PsSp) and a 10W gallium arsenide (GaAs) solar panel both with a fill-factor of 0.7. They were positioned and rotated to have optimum irradiation at each experimental measurement at a good location in Ilesa. The method used involves direct exposure of the solar panels to sunlight for a length of time (6hours, 10a.m to 4p.m) daily for ten consecutive days, between 10^{th} and 19^{th} day of a month for 1year with readings taken at interval of 1hour. The results of the research indicate that the energy conversion efficiency of each of the panels used is high, and also the power output is stable and steady, reliable, safer and economically viable. From the research, the conversion efficiency of silicon based solar panel is 31.1% and that of GaAs solar panel is 25.2%. These are high values, which can be improved if more cells are combined to form a multijunction panel, as seen in multijunction tandem solar panel with increased maximum thermodynamic achievable efficiencies of 50%, 56% and 72% for stacks of 2, 3 and 5(Familusi T.O. et al, 2014).

A very simple experiment that allowed measurement of important photovoltaic parameters and the plot of I-V characteristic curve of a solar cell by college students in an introductory physics course was demonstrated in the Department of Physics, Monash University, Australia. The cell fill-factor and light conversion efficiency were determined (Michael J Morgan, Greg Jakovidis and Ian McLeod, 1991).

A research work that was focused on the optimization of metal back reflectors of thin-film solar cells was carried out and it was discovered theoretically that the conversion efficiency can be improved through the insertion of intermediate energy band in the fundamental energy gap. The theoretical aspect of intermediate band photovoltaic devices was investigated and the predicted high efficiency was confirmed by drift-diffusion modelling. A practical way to spectrally decoupling absorption spectrum was proposed, and the practicability of intermediate band concept was assessed and compared to experimental work (Albert S.L., 2010).

Under varying atmospheric conditions on the site of Algiers, global solar radiation incident on solar cells was simulated using a spectral transmittance model. The effect of changes in total intensity and spectral distribution on the short circuit current and efficiency of different kinds of solar cells (amorphous, monocrystalline and multicrystalline) was examined. The results show a reduction in the short circuit current due to increasing turbidity. It is 4.41%, 4.79%, and 7.34% under global radiation for mono-crystalline, multicrystalline and amorphous silicon cells respectively (Chegaar M., Mialhe P., 2008).

The dye-sensitized solar cells (DSC) provide a technically and economically credible alternative concept to present day p–n junction photovoltaic devices. In contrast to the conventional systems where the semiconductor assume both the task of light absorption and charge carrier transport the two functions are separated here. Light is absorbed by a sensitizer, which is anchored to the surface of a wide band semiconductor. Charge separation takes place at the interface via photo-induced electron injection from the dye into the conduction band of the solid. Carriers are transported in the conduction band of the semiconductor to the charge collector. The use of sensitizers having a broad absorption band in conjunction with oxide films of nanocrystalline morphology permits to harvest a large fraction of sunlight. Nearly quantitative conversion of incident photon into electric current is achieved over a large spectral range extending from the UV to the near IR region. Overall solar (standard AM 1.5) to current conversion efficiencies (IPCE) over 10% have been reached. There are good prospects to produce these cells at lower cost than conventional devices. Here we present the current state of the field, discuss new concepts of the dye-sensitized nanocrystalline solar cell (DSC) including heterojunction variants and analyze the perspectives for the future development of the technology (Michael G., 2003).

The methods for evaluating the atmospheric turbidity parameters, introduced by the present author in 1929-30, are subjected to a critical examination. A method first suggested by M. HEROVANU (1959) is here simplified and expanded, and used for deriving the named parameters in adherence to a procedure described by the present author in a previous paper in this journal (1961). The procedure is applied to the pyrheliometric observations at Potsdam in 1932-36, published by HOELPER (1939) A comparison between the frequency distribution of the coefficient of wave-length dependence a at the high level station Davos and the low level station Potsdam gives results which are discussed in detail. In all the figures of the present paper, where the turbidity coefficients occur, they are multiplied by lo3 (ANDERS A., 1963).

The maximum power delivered by a solar panel was determined from its voltage and current and the curve of the result was illustrated as a function of time. With conclusion that solar power is neat and reliable (Gerald & Scott, 2010.).

This research work verified the effect of dust deposit on energy conversion efficiency of solar panels. The research was carried out at Ilesa, Osun State of Southern Western Nigeria. The major aim of the research is to determine the percentage of power reduction in power output of a solar panel when operating with dust deposit on its surface. The research examined the effect of varying quantity of dust particles deposit on a 10watt polycrystalline silicon solar panel with a fill-factor of 0.7. The research experiment was carried out between December 10th and 23rd, 2013. The dust deposit concentrations of sieved fine mud dust used on the solar panel are 0.0ml, 2.5ml, 5.0ml, 7.5ml, 10.0ml, 12.5ml and 15ml respectively in the experiment with the measurement of short circuit current (I_{sc}) and open circuit voltage (V_{oc}) values at intervals 1hour from 10.00am and 6.00pm taken.

Materials and Method

The materials used in this research include a 10 watts polycrystalline silicon and a 10 watt polycrystalline gallium arsenide solar panels, both of 350x250x25 mm^3 dimension, sieved fine mud dust particles, solar charge controller, battery with battery heads, connecting cable and multimeter. The research experiment used the mud dust in sub-quantities like 0.0ml, 2.5ml, 5.0ml, 7.5ml, 10.0ml, 12.5ml and 15.0ml evenly spread to cover the surface of the solar panel with the connection well-made and the solar panel positioned directly facing up to receive sunlight. Each sub-quantity was experimented twice in each of the period of the experiment, December 2013 and March 2014.The measurements were taken of the values of open circuit voltage and short circuit current between10.00a.m and 5.00p.m at intervals of 1hour. The measured values short circuit current and open circuit voltage were used to determine the corresponding power output for each panel. The output power and percentage power loss were calculated.

Results and Discussion

Table 1a: Measured short circuit current (I_{sc}) values for polycrystalline Si and GaAs Solar Panels within the Hours of 10am and 5pm daily from 10th to 23rd of December, 2013

Day/ Period	11am	12pm	1pm	2pm	3pm	4pm	5pm	Av(Isc)	Dust Vol.
10^{th}	0.38.0.31	0.51,0.41	0.72,0.58	0.79,0.64	0.79,0.64	0.78,0.63	0.37,0.30	0.62,0.54	0.0ml
11^{th}	0.38,0.31	0.51,0.41	0.72,0.58	0.79,0,64	0.79,0,64	0.78,0.63	0.37,0.30	0.62,0.54	
12^{th}	0.37,0.30	0.49,0.39	0.70,0.56	0.76,0.62	0.76,0,62	0.75,0.60	0.36,0.29	0.60,0.48	2.5ml
13^{th}	0.37,0.30	0.49,0.39	0.70,0.56	0.76,0.62	0.76,0,62	0.75,0,60	0.36,0.29	0.60,0.48	
14^{th}	0.33,0.27	0.42,0.32	0.68,0.52	0.68,0.54	0.69,0.54	0.67,0.52	0.32,0.26	0.54,0.42	5.0ml
15^{th}	0.33,0.27	0.42,0.32	0.68,0.52	0.68,0.54	0.68,0.54	0.67,0,52	0.32,0.26	0.54,0.42	
16^{th}	0.29,0.22	0.38,0.29	0.63,0.50	0.63,0.49	0.62,0.49	0.60,0.47	0.28,0.22	0.49,0.38	7.5ml
17^{th}	0.29,0.22	0.38,0.29	0.63,0.50	0.63,0.49	0.62,0.49	0.60,0.47	0.28,0.22	0.49,0.38	
18^{th}	0.27,0.20	0.36,0.26	0.54,0.47	0.55,0.41	0.55,0.41	0.54,0.41	0.26,0.19	0.44,0.31	10.0ml
19^{th}	0.27,0.21	0.36,0.26	0.54,0.47	0.55,0.41	0.55,0.41	0.54,0.41	0.26,0.19	0.44,0.31	
20^{st}	0.23,0.17	0.31,0.22	0.46,0.39	0.47,0.36	0.47,0.36	0.47,0.36	0.23,0.17	0.38,0.29	12.5ml
21^{nd}	0.23,0.17	0.31,0.22	0.46,0.39	0.47,0.36	0.47,0.35	0.47,0.36	0.23,0.17	0.38,0.29	
22^{nd}	0.20,0.13	0.27,0.19	0.39,0.32	0.42,0.34	0.42,0.32	0.42,0.34	0.19,0.12	0.33,0.25	15ml
23^{rd}	0.20,0.13	0.27,0.19	0.39,0.32	0.42,0.34	0.42,0.32	0.42,0.34	0.19,0.12	0.33,0.25	

Table 1b: Measured short circuit current (I_{sc}) values for polycrystalline Si and GaAs Solar Panels within the hours of 10am and 5pm daily from 10th to 23rd of March, 2014

Day/ Period	11am	12pm	1pm	2pm	3pm	4pm	5pm	Av(Isc)	Dust Vol.
10th	0.34,0.28	0.45,0.36	0.64,0.51	0.70,0.57	0.70,0.57	0.69,0.56	0.33,0.27	0.55,0.48	0.0ml
11th	0.34,0.28	0.35,0.36	0.64,0.51	0.70,0,57	0.70,0.57	0.69,0.56	0.33,0.27	0.55,0.48	
12th	0.33,0.27	0.44,0.35	0.62,0.50	0.68,0.55	0.67,0,49	0.67,0.53	0.32,0.26	0.53,0.43	2.5ml
13th	0.33,0.27	0.44,0.35	0.62,0.50	0.68,0.55	0.67,0,49	0.67,0.53	0.32,0.26	0.53,0.43	
14th	0.29,0.24	0.37,0.28	0.60,0.46	0.60,0.50	0.61,0.48	0.60,0.46	0.28,0.23	0.48.0.33	5.0ml
15th	0.29,0.24	0.37,0.28	0.60,0.46	0.60,0.50	0.60,0.48	0.60,0.46	0.28,0.23	0.48,0.37	
16th	0.26,0.20	0.34,0.26	0.56,0.44	0.56,0.44	0.55,0.44	0.53,0.42	0.22,0.18	0.44,0.34	7.5ml
17th	0.26,0.20	0.34,0.26	0.56,0.44	0.56,0.44	0.55,0.44	0.53,0.42	0.22,0.18	0.44,0.34	
18th	0.24,018	0.32,0.23	0.48,0.37	0,48,0.37	0.49,0.36	0.48,0.36	0.20,0.15	0.39.0.28	10.0ml
19th	0.24,0.18	0.32,0.23	0.48,0.37	0.48,0.37	0.49,0.36	0.48,0.36	0.20,0.15	0.39,0.28	
20st	0.20,0.15	0.28,0.20	0.41,0.35	0.42,0.32	0.42,0.32	0.42,0.32	0.18,0.13	0.34,0.26	12.5ml
21nd	0.20,0.15	0.28,0.20	0.41,0.35	0.42,0.32	0.42,0.32	0.42,0.32	0.18,0.13	0.34,0.26	
22nd	0.18,0.12	0.24,0.17	0.35,0.28	0.37,0.30	0.37,0.30	0.37,0.30	0.13,0.10	0.29,0.22	15ml
23rd	0.18,0.12	0.24,0.17	0.35,0.28	0.37,0.30	0.37,0.30	0.37,0.30	0.13,0.10	0.29,0.22	

Tables 2a and 2b: Truth tables for dust volume, short circuit current (I_{sc}) and open circuit voltage (V_{oc}) measured of the experimental verification

a. December, 2013

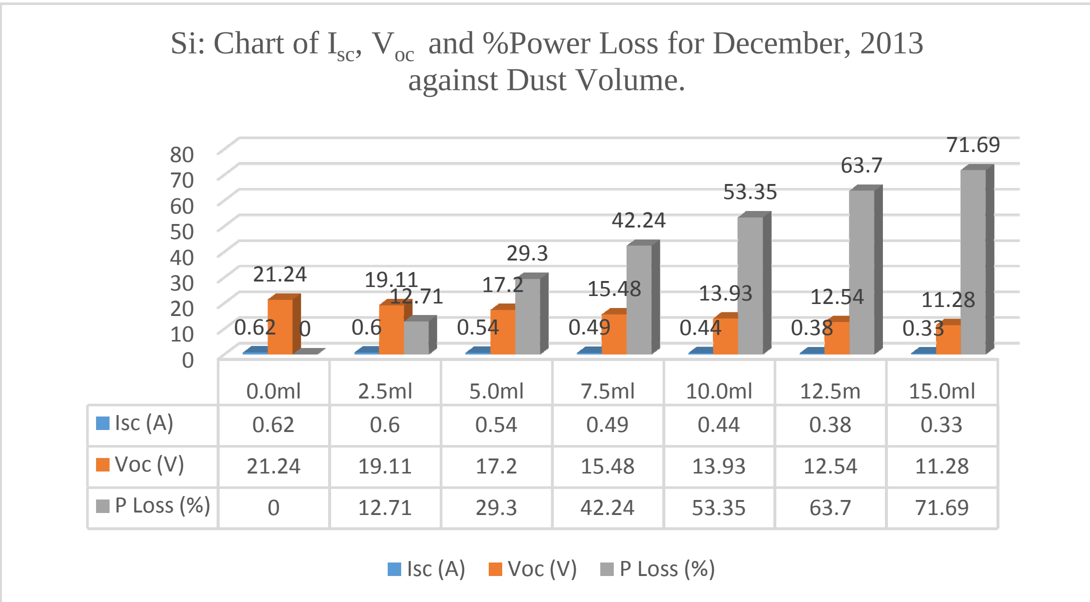
Si					GaAs				
Dust vol.	**I_{sc} (A)**	**$V_{oc\ (V)}$**	**P (W) = IV**	**P Loss (%)**	**Dust vol.**	**I_{sc} (A)**	**$V_{oc\ (V)}$**	**P (W) = IV**	**P Loss (%)**
0.0ml	0.62	21.24	13.14	0.00	0.0ml	0.54	17.20	9.29	0.0
2.5ml	0.60	19.11	11.47	12.71	2.5ml	0.48	15.48	7.43	20.02
5.0ml	0.54	17.20	9.29	29.30	5.0ml	0.42	13.93	5.85	37.03
7.5ml	0.49	15.48	7.59	42.24	7.5ml	0.38	12.54	4.77	48.66
10.0ml	0.44	13.93	6.13	53.35	10.0ml	0.31	11.28	3.50	62.33
12.5m	0.38	12.54	4.77	63.70	12.5m	0.29	10.16	2.95	68.25
15.0ml	0.33	11.28	3.72	71.69	15.0ml	0.25	9.14	2.29	75.35

b. March, 2014

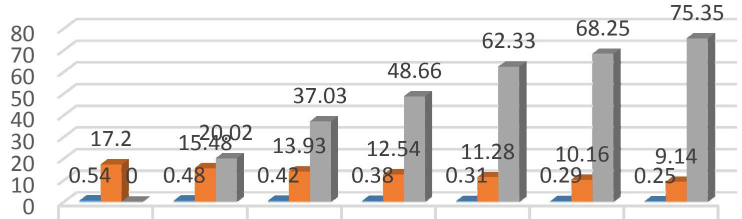
Si						GaAs				
Dust vol.	**I_{sc} (A)**	**$V_{oc\ (V)}$**	**P(W) = IV**	**% P Loss**		**Dust vol.**	**$I_{sc\ (A)}$**	**$V_{oc\ (V)}$**	**P (W) = IV**	**% P Loss**

0.0ml	0.55	18.86	10.37	0.00		0.0ml	0.48	15.28	7.33	0.00
2.5ml	0.53	16.97	8.84	14.75		2.5ml	0.43	13.75	5.91	19.37
5.0ml	0.48	15.27	7.33	29.32		5.0ml	0.37	12.37	4.58	37.52
7.5ml	0.44	13.75	6.05	41.66		7.5ml	0.34	11.14	3.79	48.30
10.0ml	0.39	12.37	4.82	53.52		10.0ml	0.28	10.02	2.81	61.66
12.5m	0.34	11.14	3.79	63.45		12.5m	0.26	9.02	2.35	67.94
15.0ml	0.29	10.02	2.91	71.94		15.0ml	0.22	8.12	1.79	75.60

From the tables it can be observed that there exists a unidirectional correlation among the input irradiance, that is, level of exposure of solar panels to sunlight, short circuit current Isc, open circuit voltage Voc and output power. It is therefore true to have it put that the consumable (output) power from a solar panel is a function of the input solar irradiance. The results show that the effect of any shielding the surface of a solar panel from receiving sunlight in appropriate abundance is vital. At 0.0ml dust particles on the surface of the solar panels, that is, when the surfaces are free from dust particles, the power loss is 0.00%. The percentage power loss rose from 0.00% to as high as 71.69% in polycrystalline silicon solar panel and 75.35% in polycrystalline GaAs solar panel during December, 2013 as the shielding dust particles volume rose up to15.0ml. Also, in March, 2014 the percentage power loss rose from 0.00% to as high as 71.94% with polycrystalline silicon solar panel and 75.60% with polycrystalline GaAs solar panel. These high values of power loss in both panels and periods of experimental investigation, suggest that the surface of solar panels should be kept free of dust particles or any other materials that can cause a shield or prevent the solar panel from receiving optimum solar sunlight at a time.



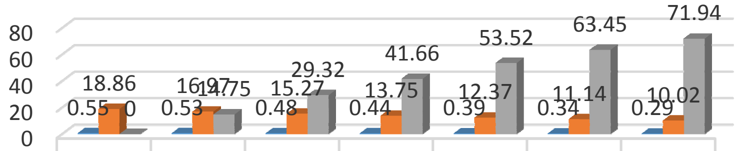
GaAs: Chart of Isc, Voc and %Power Loss for December, 2013 against Dust Volume



	0.0ml	2.5ml	5.0ml	7.5ml	10.0ml	12.5m	15.0ml
Isc (A)	0.54	0.48	0.42	0.38	0.31	0.29	0.25
Voc (V)	17.2	15.48	13.93	12.54	11.28	10.16	9.14
P Loss (%)	0	20.02	37.03	48.66	62.33	68.25	75.35

Isc (A) Voc (V) P Loss (%)

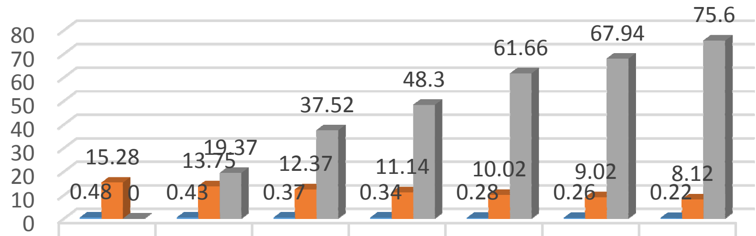
Si: Chart of Isc, Voc and % Power Loss for March, 2014 against Dust Volume.



	0.0ml	2.5ml	5.0ml	7.5ml	10.0ml	12.5m	15.0ml
Isc (A)	0.55	0.53	0.48	0.44	0.39	0.34	0.29
Voc (V)	18.86	16.97	15.27	13.75	12.37	11.14	10.02
% P Loss	0	14.75	29.32	41.66	53.52	63.45	71.94

Isc (A) Voc (V) % P Loss

GaAs: Chart of Isc, Voc and % Power Loss for March, 2014 against Dust Volume.



	0.0ml	2.5ml	5.0ml	7.5ml	10.0ml	12.5m	15.0ml
Isc (A)	0.48	0.43	0.37	0.34	0.28	0.26	0.22
Voc (V)	15.28	13.75	12.37	11.14	10.02	9.02	8.12
% P Loss	0	19.37	37.52	48.3	61.66	67.94	75.6

Isc (A) Voc (V) % P Loss

Conclusion and Recommendation

The results show that the effect of any shielding the surface of a solar panel from receiving sunlight in appropriate abundance is vital. At 0.0ml dust particles on the surface of the solar panels, that is, when the surfaces are free from dust particles, the power loss is 0.00%. The percentage power loss rose from 0.00% to as high as 71.69% in polycrystalline silicon solar panel and 75.35% in polycrystalline GaAs solar panel during December, 2013 as the shielding dust particles volume rose up to15.0ml. Also, in March, 2014 the percentage power loss rose from 0.00% to as high as 71.94% with polycrystalline silicon solar panel and 75.60% with polycrystalline GaAs solar panel. These high values of power loss in both panels and periods of experimental investigation, suggest that the surface of solar panels should be kept free of dust particles or any other materials that can cause a shield or prevent the solar panels from receiving optimum sunlight at a time.

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