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Experiment of Open-circuit Voltage in "EPH 2 Advanced Photovoltaics Trainer" Laboratory and Types of PV Cell

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Abstract — *Types of solar panels, their operating modes, the impact of external displays on solar panels are studied in this article.*

Keywords — PV cell; monocrystalline solar cells; polycrystalline solar cells; amorphous silicon cell; irradiance;

Introduction

Solar cells can be divided into three groups based on raw material:

- Monocrystalline
- Polycrystalline
- Thin-film

Thin-film cells include those made of amorphous silicon and other materials like cadmium-telluride (CdTe), copper-indium-diselenide (CIS) and gallium-arsenide (GaAs). Silicon solar cells have prevailed so far in practice.

Monocrystalline solar cells

Highly pure silicon melt is used to grow mono-crystals in the form of round silicon blocks. A mono-crystal's lattice has an entirely homogeneous structure. The silicon block is sawed into wafers each 200 to 300 µm thick. To optimize utilization of the solar module's surface, the round cells are cut into square ones. A cell's side usually has a length of 152 mm. The final phase of manufacture involves doping followed by installation of contact surfaces and an anti-reflective layer.

Mono-crystalline solar cells manufactured on an industrial scale have an efficiency of 15 - 18%, the highest among the variety of solar cells presently available [1]. However, monocrystalline solar cells require more energy and time to manufacture compared with polycrystalline solar cells. (Fig 1.)

Fig. 1. Monocrystalline solar cells

Polycrystalline solar cells

Highly pure silicon melt also serves as the initial material for polycrystalline cells. However, these cells are manufactured not by growing mono-crystals, but through controlled cooling of the silicon melt in square-shaped moulds. During cooling, the crystals arrange themselves in an irregular pattern resulting in an iridescent surface typical of polycrystalline solar cells. (Fig.2.) The square silicon blocks are then sawed into wafers with a thickness of 200 to 300 µm. The final phase of manufacture involves doping followed by installation of contact surfaces and an anti-reflective layer. This layer gives the solar cell its characteristic blue sheen, blue being least reflective and most absorptive to light. Polycrystalline solar cells have an efficiency of 13 to 16%[2].

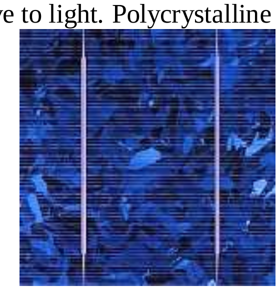

Fig.2. Polycrystalline solar cells

Amorphous silicon cell

The expression amorphous is derived from Greek (**a**: without; **morphé**: form). In physics, substances whose atoms form irregular patterns are termed amorphous. Atoms arranged in ordered patterns are said to be crystalline.

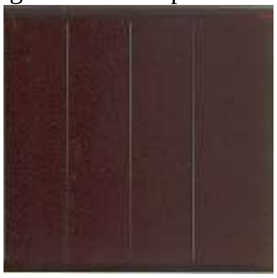

Fig.3. Amorphous silicon cell

To manufacture amorphous solar cells, silicon is vapour-deposited on a carrier, e.g. glass. The vapour-deposited silicon layer has a thickness of 0.5 to 2 µm. Besides lowering silicon consumption, this also dispenses with elaborate sawing of silicon blocks. However, amorphous solar cells only have an efficiency of 6 to 8%.

Copper-indium-diselenide cell (CIS)

Instead of silicon, this type of cell employs thin films comprising copper, indium and selenium. The cell has a black surface allowing it to absorb nearly 99% of the incident light. Manufacture takes place in a vacuum chamber where the materials are applied to a carrier at a temperature of 500°C[3].

The table below provides an overview of the various modules' efficiencies and surface areas required to generate a power of 1 kWp.

Table 1:

Raw material	**Module efficiency in %**	**Area in m^2**
Monocrystalline	15-18	7-9
Polycrystalline	13-16	8-9
Amorphous	6-8	13-20
Copper-indium-diselenide	10-12	9-11

Open-circuit voltage of a PV cell

As the largest voltage occurring across the terminals of a PV cell, the open circuit voltage U_{OC} is important in dimensioning subsequent circuits (e.g. inverters) [4]. This voltage is measured without any load being connected to the PV cell. (Fig.4.)

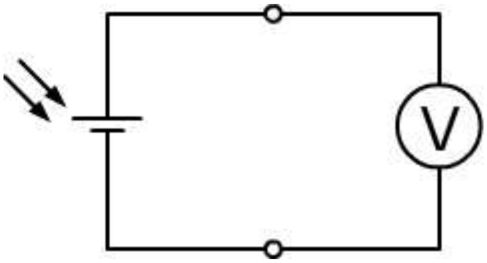

Fig.4. Open-circuit voltage of a PV cell

The semiconductor material making up the PV cell decisively determines the voltage produced by the cell. The factors mentioned next influence the open-circuit voltage.

- Irradiance
- Angle of incidence
- Temperature

Irradiance

The next diagram illustrates the dependency of open-circuit voltage on irradiance.

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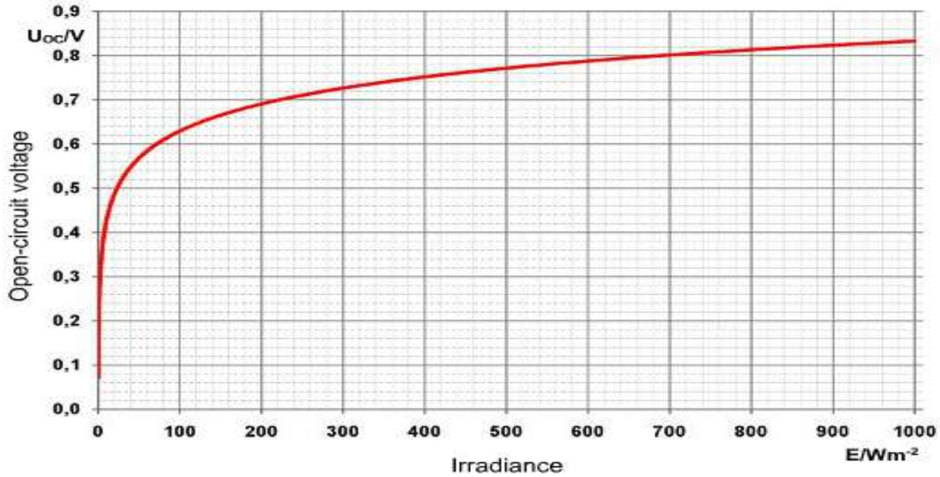

Fig.5. Solar irradiance

Obviously, the open-circuit voltage is not a linear function of the irradiance. The voltage approaches its maximum level already at low irradiances. When installing PV cells on roofs, you should therefore bear in mind the cells' ability to produce substantial voltages even under overcast skies[5].

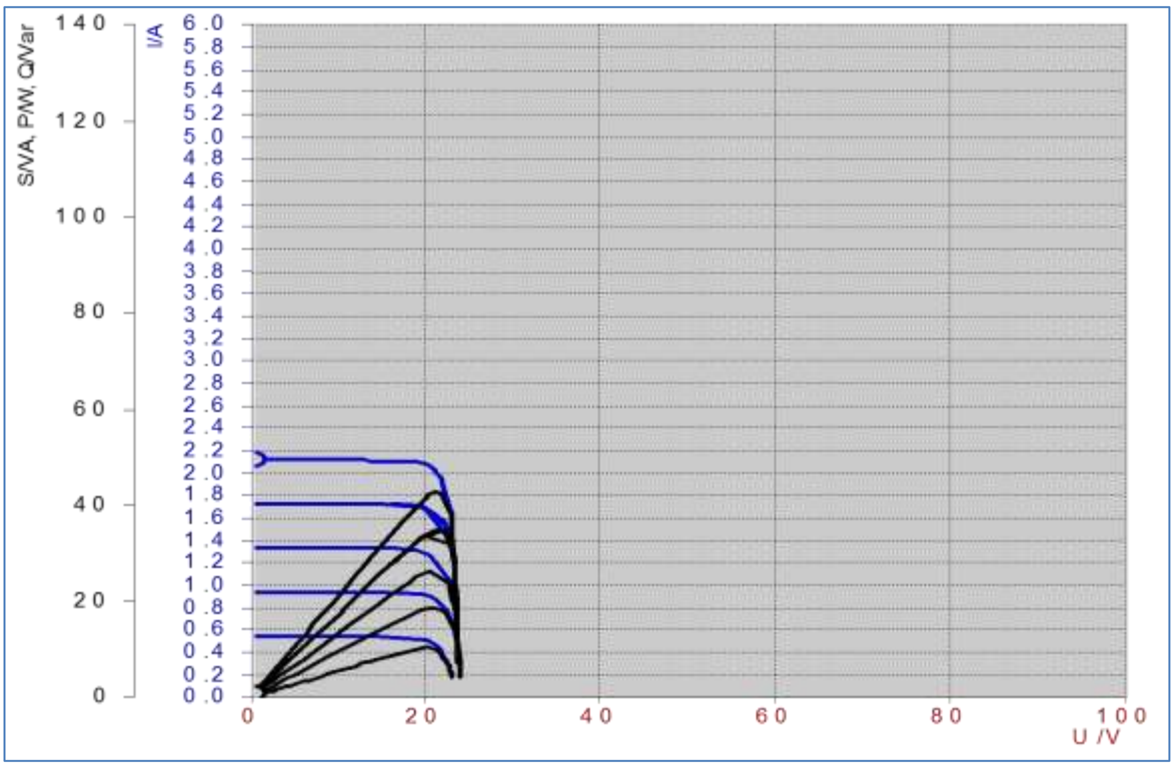

Fig.6. V-I characteristics of a PV cell EPH 2

Angle of incidence

Measurements of the dependency of open-circuit voltage on angle of light incidence show that this voltage is maximized when the light impinges perpendicularly.

Temperature

A PV cell's open-circuit voltage has a negative temperature coefficient, i.e. as a PV cell or module warms up (e.g. on exposure to light), its open-circuit voltage drops. As an outcome of this temperature dependency, the PV cell's open-circuit voltage is at its highest at low (winter) temperatures

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In this experiment, we will use an analog/digital multimeter to examine the dependency of a solar module's open-circuit voltage V_{OC} on irradiance.

Fig.7. "EPH 2 ADVANCED PHOTOVOLTAICS TRAINER"

On the sun position emulator, set the sun and panel angles to 0°, and the elevation angle to 90°. The halogen lamp should then be positioned perpendicularly over the solar module.

We should set irradiance values for the subsequent measurements, move the dimmer's slide control in quarterly steps. This results in five different positions for the control, the lowest irradiance corresponding to position 0/4, the highest to 4/4.

Set the irradiances as indicated in the table below, measure the solar module's corresponding open-circuit voltages and enter their values in the table[6].

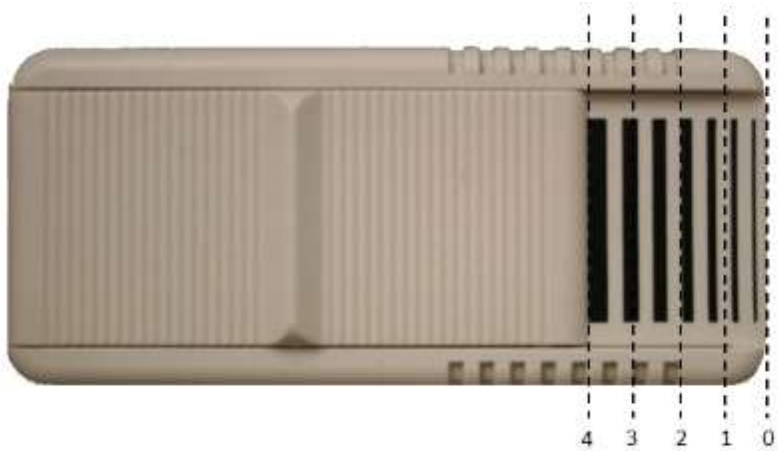

Fig.8. Dimmer's slide control

Open-circuit voltage U_{OC} is the maximum voltage at the solar elements output that occurs at zero current through the solar elements. Open-circuit voltage voltage corresponds to the forward displacement of the p-n junction, and depends on its saturation current and light current. The result of the experiment, conducted in the "EPH 2 Advanced photovoltaics trainer" laboratory, is presented in 4 - 5 pictures.

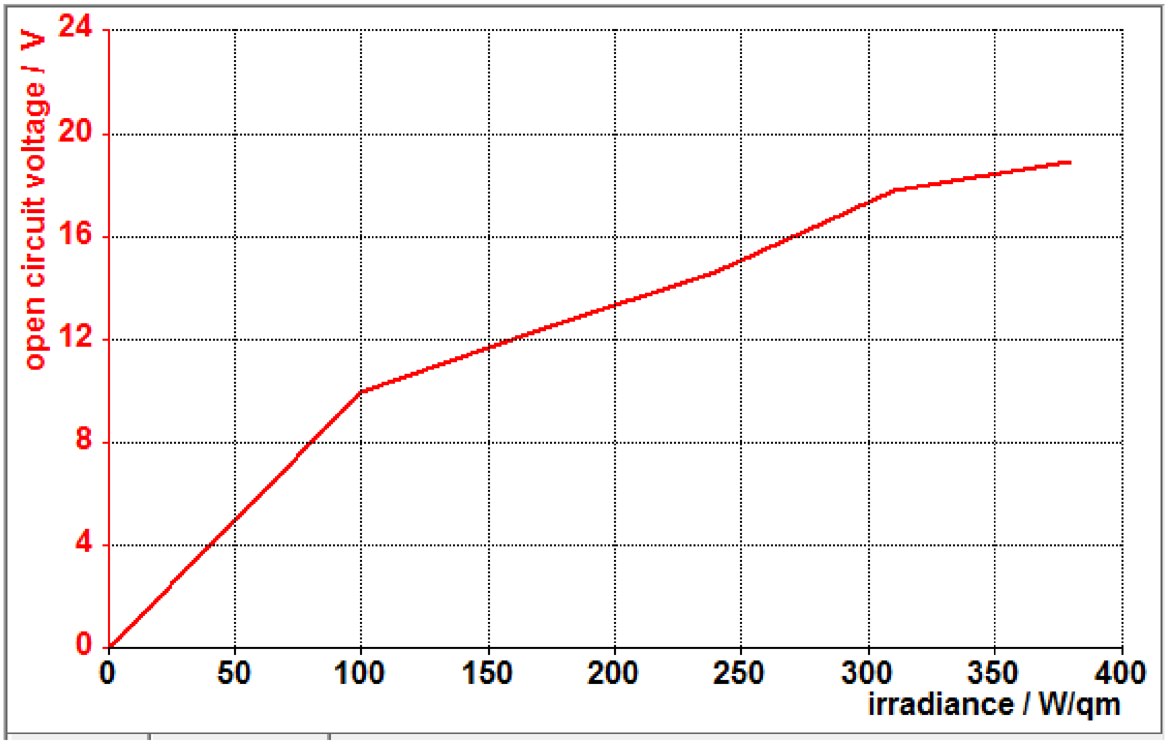

Fig.9. Diagram of Open-circuit voltage dependence on irradiation

position of dimmer	irradiance [W/qm]	open circuit voltage [V]
	0	0.00
0/4	100	10.00
1/4	170	12.40
2/4	240	14.60
3/4	310	17.80
4/4	380	18.90

Fig.10. Graph of Open-circuit voltage dependence on irradiation

The research results allow us to make a reasonable conclusion about the quality of the solar panel and the feasibility of using it for connecting of a solar battery, with subsequent use as part of a charger, etc.

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