SOLAR CELLS

INTRODUCTION

As fossil fuels continue to deplete, development and research in sustainable power generation like solar energy has become very important. Even though solar energy is always accessible, challenges arise because the power conversion from solar to electrical energy is not efficient. The energy payback time- that is the time taken for a device to generate as much energy as was needed to fabricate the device should also be acceptable. Above all, production cost should be low. Therefore, technological advancement, improvements in device design and choosing better materials are some ways by which we can reduce the cost of solar cell devices at the same time increasing its efficiency. In this text, operation of solar cells is examined, followed by a brief introduction of 3 interesting papers on solar cell development.

OPERATION OF SOLAR CELL

Solar cell is a photo diode. When light falls on it, electron hole pairs are generated in the n-side, the p-side and the depletion region. Due to the generated carriers, a current flows from n to p region which is I_{op}. As optical generation rate increases this current increases. This current adds to the normal reverse current of the diode. If we open circuit the photo diode a voltage less than contact potential V_o appears across the pn junction. This is V_{oc}.

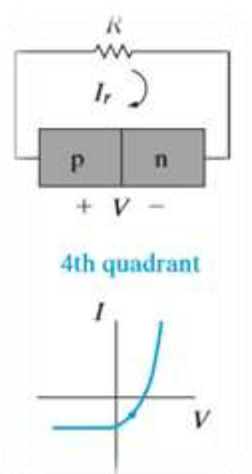


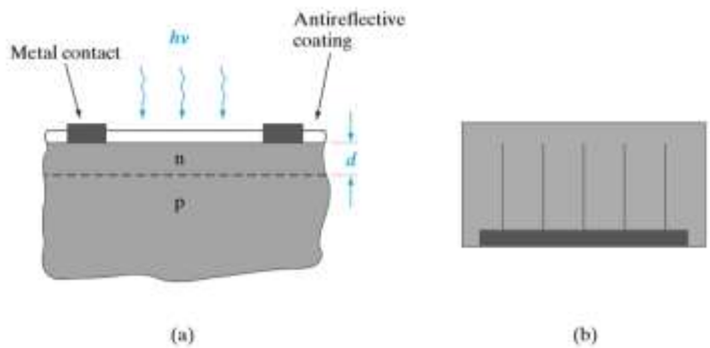
FIGURE 1 VOLTAGE IS POSITIVE, CURRENT IS NEGATIVE, CURRENT FLOWS INTO THE EXTERNAL CIRCUIT

$$Iop = qAgop(Lp + Ln + W)$$

$$Voc = \frac{kT}{q} \ln \frac{gop}{gth}$$

Where g_{th} = thermal generation rate and g_{op} = optical generation rate, L_p is diffusion length of holes in n region and L_n is diffusion length of electrons in p region and W is depletion region width.

V_{oc} and I_{op} are important parameters because they give the value of voltage and current obtained from a photo diode. In the 4th quadrant operation of the I-v curve. Applying a positive voltage to the device, we obtain a negative current, that is current is driven towards the load. Hence light energy gets converted to electrical energy. A typical design of a photo diode for a solar cell is as shown in figure 2. The depth d is kept less than L_p , so that holes generated holes generated near the surface to diffuse to the junction before they recombine. The area that faces the light is large, for



maximum exposure to the sun. Metal contacts are designed in such a way that there is minimum ohmic losses. The metal contact on the n region can be distributed like fingers as shown in figure 2 b, to reduce the ohmic loss as well maintain exposure to the light.

FIGURE 2 A- TYPICAL SOLAR CELL B- TOP VIEW OF N CONTACTS

Even though the currents obtained from a single cell is minimal, many cells add up to give appreciable outputs. Solar cells have established applications in powering satellites, powering remote locations and various consumer products like garden lights.

Fill factor is an important figure of merit for solar cell. The maximum power delivered to a load by the solar cell occurs when the product VI_r is a maximum. Calling these values of voltage and current V_m and I_m, we can see that the maximum delivered power illustrated by the shaded rectangle in Fig. 3 is less than the $I_{sc}V_{oc}$ product. The ratio I_mV_m / $I_{sc}V_{oc}$ is called the fill factor,

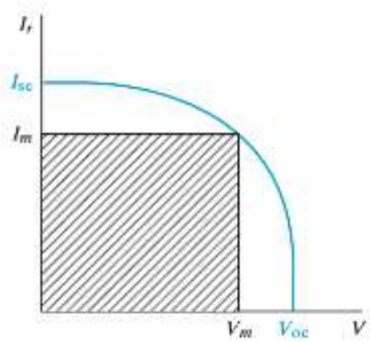


FIGURE 3 FILL FACTOR

Paper 1 - Perovskite Solar Cells: From Materials to Devices

There are two pathways one can take when increasing the productivity in solar cell production. One to manufacture solar cells from highly efficient resources like silicon, with low pay back time and very high cost. Or to compromise a little on efficiency to make cells with lower cost but with high numbers with a different material. Perovskite cell follow the second pathway and have shown superb power conversion efficiency (PCE) along with very low material costs. Solar cell efficiencies of devices using these materials have increased from 3.8% in 2009 to 25.2% in 2020 in single-junction architectures, and in silicon-based tandem cells, to 29.1% exceeding the maximum efficiency achieved in single-junction silicon solar cells. Perovskite solar cells are

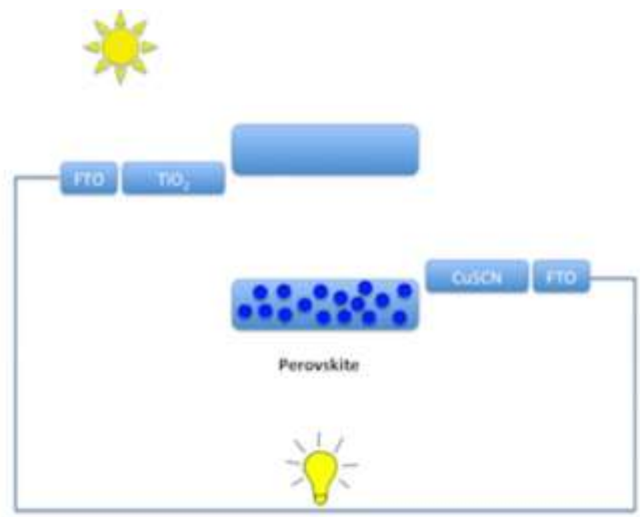


FIGURE 4 WORKING OF THE PEROVSKITE

therefore, currently the fastest-advancing solar technology. The key material for the perovskite solar cell are organometal hallides. When sunlight falls on the active perovskite, electron hole pair are generated, electron moves from Titatanium oxide to the FTO Anode and holes move from Copper thyocynate to FTO cathode. A big advantage perovskite PVs have over conventional solar technology is that they can react to various different wavelengths of light, which lets them convert more of the sunlight that reaches them into electricity.

Despite all this material has to offer, its commercialization still faces many challenges. The first challenge is toxicity due to PbI – lead iodide, it is one of the breakdown products of perovskite. Long term stability of perovskite solar cells is another big issue. Finding solutions to these problems, would be the concentration of future research studies in this field.

PAPER 2 - SENSITIZATION OF SILICON BY SINGLET EXCITON FISSION IN TETRACENE

The Shockley–Queisser limit refers to the maximum theoretical efficiency of a solar cell using a single p-n junction to collect power from the cell where the only loss mechanism is radiative recombination in the solar cell. It is between 29 and 33 percent depending on how we measure it. This paper details an experiment where solar cells were coated with a thin layer of tetracene, that effectively split incoming photons into two. This process is known as exciton fission and means that the solar cell is able to use high energy photons from the blue-green part of the visible spectrum.

Silicon solar cells generate an electric current by using incoming photons to knock electrons from the silicon into a circuit. Silicon’s bandgap corresponds to infrared photons, which carry less energy than photons in the visible part of the electromagnetic spectrum. Photons outside silicon’s bandgap essentially go to waste. But here’s where tetracene comes in: It splits blue-green photons into two “packets” of energy that are each equivalent to an infrared photon. So rather than each infrared photon knocking free one electron, a single photon in the blue-green spectrum can knock free two electrons. It’s essentially getting two photons for the price of one. This new cell represents a fundamentally new approach to a well-known truism in photovoltaics research: If you want to pass the Shockley-Queisser limit, you have to capture energy from a wider range of solar photons. While none of this is economically viable, the win here is the proof of concept. This is a fundamentally different approach from traditional photovoltaics

PAPER 3 - VERSATILE TERNARY ORGANIC SOLAR CELLS: A CRITICAL REVIEW

This paper presents a critical review of ternary organic cells. The power conversion efficiency (PCE) of organic solar cells (OSC) has increased in the past ten years from 4% up to 11%. Binary OSC and Tandem OSC were first developed. Ternary solar cells developed thereafter, enhancing photon harvesting using an additional layer. This layer can be a donor or acceptor layer. The third component could: (i) be fully embedded in a donor; (ii) be fully embedded in an acceptor; (iii) locate at the donor/acceptor interface; or (iv) form its own channels. This is demonstrated in the figure below.

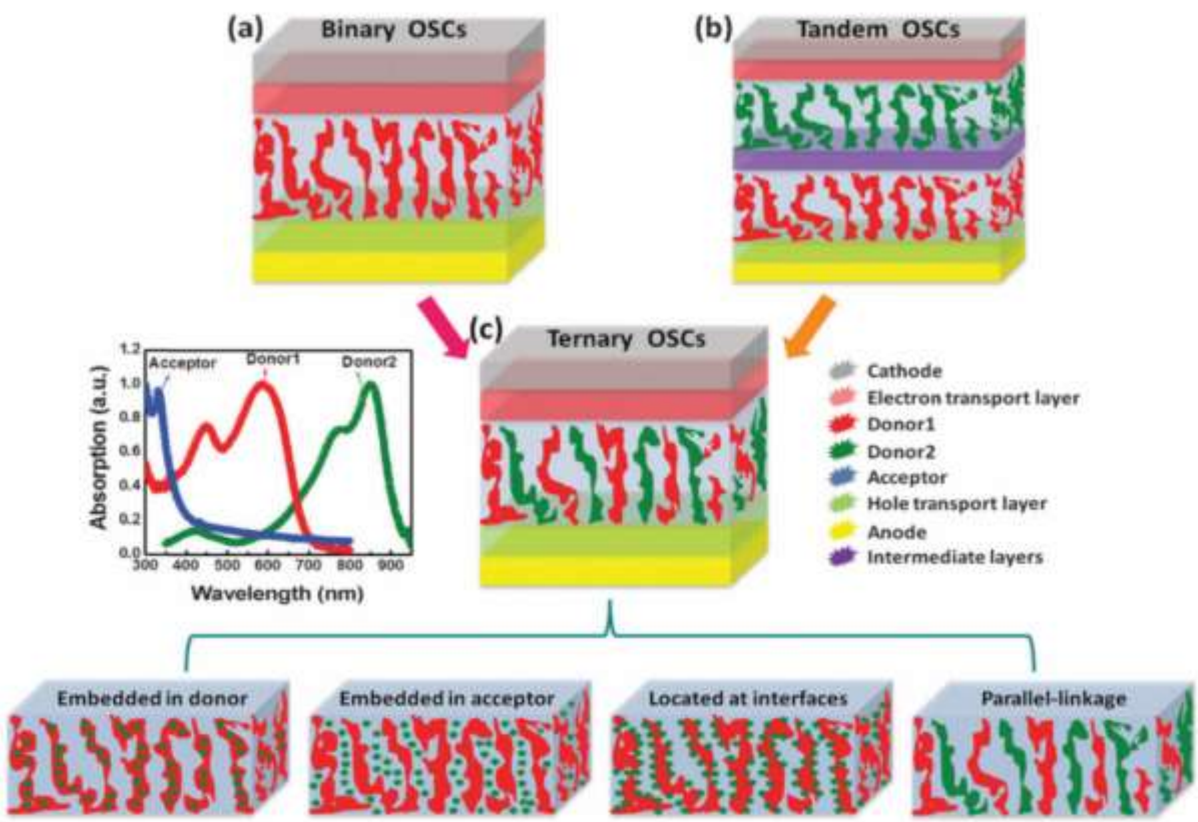


FIGURE 5 DIFFERENT ORGANIC SOLAR CELLS AND TYPES OF TERNARY OSCS BASED ON LOCATION OF THIRD LAYER

The ternary solar cells inherit the major advantages of single junction binary solar cells and tandem configuration solar cells. There are four fundamental principles in ternary solar cells: charge transfer, energy transfer, and parallel-linkage or alloy structure, which are closely related to the location of the third component in the ternary active layer.

This paper describes fundamental physical principles that govern the photovoltaic process in ternary solar cells and the corresponding characterization techniques, such as charge transfer, energy transfer, and parallel-linkage or alloy model. It summarizes the advantages of ternary solar cells, like efficient strategies for enhanced photon harvesting, phase and morphology adjustment, crystallinity forming and device stability. The current challenges and further prospects on ternary solar cells are also briefly analyzed in the last section of this paper.

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