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HIGH EFFICIENCY DOUBLE SIDED SOLAR CELLS *

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ABSTRACT

Silicon technology state of the art for single crystalline was given to be limited to less than 20% efficiency. A proposed new form of photovoltaic solar cell of high current high efficiency with double sided structures has been given. The new forms could be $n^{++}pn^{++}$ or $p^{++}np^{++}$ double side junctions. The idea of double sided devices could be understood as two solar cells connected back–to–back in parallel electrical connection, in which the current is doubled if the cell is illuminated from both sides by a V–shaped reflector. The cell is mounted to the reflector such that each face is inclined at an angle of 45° to each side of the reflector. The advantages of the new structure are:

a) High power devices.

b) Easy to fabricate.

c) The cells are used vertically instead of horizontal use of regular solar cell which require large area to install. This is very important in power stations and especially for satellite installation.

If the proposal is made real and proved to be experimentally feasible, it would be a new era for photovoltaic solar cells since the proposal has already been extended to even higher currents. The suggested structures could be stated as:

$$n^{++}p\,n^{++}V\;p^{++}n\,p^{++};\;n^{++}pn^{++}V\;n^{++}p\,n^{++}OR\;p^{++}n\,p^{++}V\;p^{++}\;np^{++}\;.$$

These types of structures are formed in wedged shape to employ indirect illumination by either parabolic; conic or V–shaped reflectors. The advantages of these new forms are low cost; high power; less in size and space; self concentrating; ... etc.

These proposals if it happens to find their ways to be achieved experimentally, I think they will offer a short path to commercial market and would have an incredible impact on solar cell technology and applications.

INTRODUCTION

Semiconductors are potentially useful materials to those engaged in developing semiconductor devices. The structural properties of these materials provide tools in analyzing, evaluation and designing new devices made of crystalline, polycrystalline and amorphous; single or compound semiconductors. Consequently some of these materials have recieved considerable attention due to their usefulness in wide range of device applications. In order to successfully employ these materials, it is necessary to understand the basic concepts and their structures and to have precise and detailed knowledge of their material parameters. Intensified research activities in the field of compound semiconductors have been established due to the improvement in crystal growth technology. Recent comparison of the solar cell performance of various materials such as single crystalline, polycrystalline and amorphous silicon was given by the author elsewhere [1].

Silicon solar cells have good potential in terrestial and space power generation due to their high energy conversion efficiencies and also their well established technology. The obstacle to the widespread use of solar cell systems has been and still will be the high costs. New technologies to enhance the efficiency of silicon solar cells, such as concentration of sunlight, back surface field, double anti-reflection coatings, surface passivation and back surface illumination have been introduced recently. In spite of the considerable amount of effort being spent during the last thirty years for developing silicon solar cells and modifications, still the limiting factors on cell efficiency to–date make it a hard task to break the efficiency barrier of $\geq$ 20% which is mainly due to the recombination loss mechanisms that sets a limit for silicon technology.

The delayed progress may be due to diverting the attention from deploying current techniques effectively and exploring new techniques.

Previously several double drift diodes were proposed by Seddik and Haddad [2] where various device structures were analyzed and proved to deliver high power and efficiency. A review of the technology of multiple solar cells including Schottky barrier [3,4], hetero–junction [5,6], pin/pin cascade [7–11] and $p^{+}pnn^{+}$ [12] solar cells have demonstrated high conversion efficiency. These solar cells consist of multiple layers semiconductors arranged electrically and optically in series which represent a high voltage solar cells.

DOUBLE SIDED SOLAR CELLS

A new cell structure called "double drift – double sided illumination" solar cell is proposed here. The device is either $n^{+}pn^{+}$ or $p^{+}np^{+}$ which represents a double junction cells connected in parallel back–to–back to deliver high currents. The efficiency, with double sided illumination provided by a V–shaped reflector to illuminate both sides of the cell, would be expected to reach up to 35–40%.

Despite the maturity of theoretical modeling and the applications of new technologies such as back surface field, surface passivation, double anti–reflection coatings, back surface illumination,... etc., the current 20% efficiency barrier due to recombination loss mechanisms is a limiting factor for silicon technology.

To overcome the current problems, double drift devices ought to be designed to break the 20% efficiency barrier. The drawback of using double sided illumination employing a V–shaped reflector, resulted in a reduced light intensity compared to direct radiations, however, this task was tested and found to be still over 50% increase in efficiency relative to single cell. The advantages of the new structures proposed here are:

1. High current devices (two cells connected in parallel)
2. High efficiency (expected efficiency up to 40%)
3. Simple structures to fabricate by conventional diffusion methods. Diffusion masks are not needed since the double sided of the wafer would be difused to make the n^+ or p^+ regions and then the contact windows are etched through the SiO_2 anti–reflecting layers.

It should be noted here that the higher efficiencies could be achieved by using double anti–reflecting layers as well as irregular flat V–shaped mirror reflectors, as shown in Fig.1.

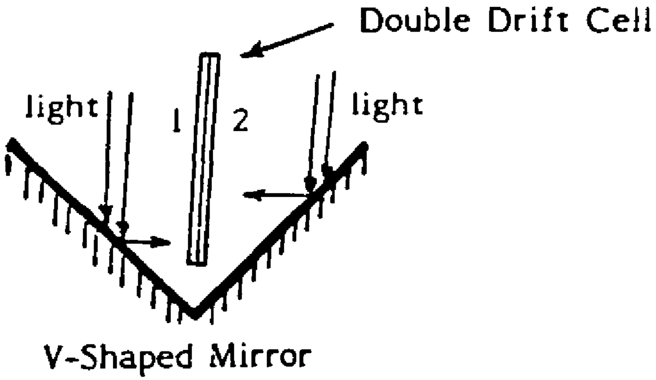

Fig.1. Double drift solar cell with a V–shaped reflector.

The figure shows how two solar cells connected back–to–back are illuminated experimentally after mechanical fastening of the given silicon cells supplied by Sargent–Welch Corporation of Canada each of which has an area of $2\,cm \times 2\,cm$ and of the form p^+pn^+/n^+pp^+. The contact leads of n^+–regions were connected together. The equivalent circuit and the I–V curves are shown in Fig.2 and Fig.3.

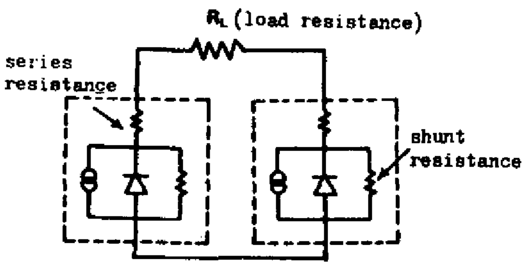

Fig.2. Equivalent circuit of double drift solar cell.

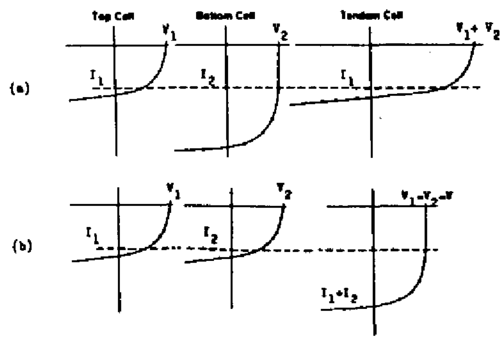

Fig.3. I–V curves for single cells and tandem structures,

(a) I–V curves of two single cells and tandem sum voltages (the current is limited to I_1) series connection.

(b) I–V curves of two single cells and tandem sum currents (the voltages are the same) parallel connection.

It should be noted that the cell was illuminated on both faces, i.e. the two cells such that the V–shaped reflector faces were inclined 45° on each surface of the cell.

An improvement of almost 50% increase in efficiency of the single cell was achieved, with the limited facilities available.

The scheme proposed here ought to be sponsored and fabricated with the up–to–date technology available today in order to obtain the expected efficiency. This scheme is easy to fabricate and expected to double the output current and thus double the power and efficiency. The idea of double drift devices could be extended to even higher power solar cells. A new form could be developed to be equivalent to four cell in the shape of a wedge. It could even go far to have two wedges and illuminated by a parabolic, conic or V–shaped reflectors to deliver high current equivalent to eight single cells connected together. Fig.4 shows the equivalent circuit of the wedged cell.

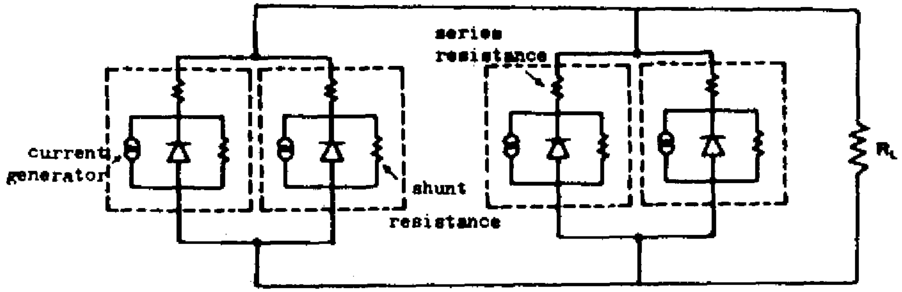

Fig.4. Equivalent circuit of the wedged double drift solar cell illuminated with V–shaped mirror reflector.

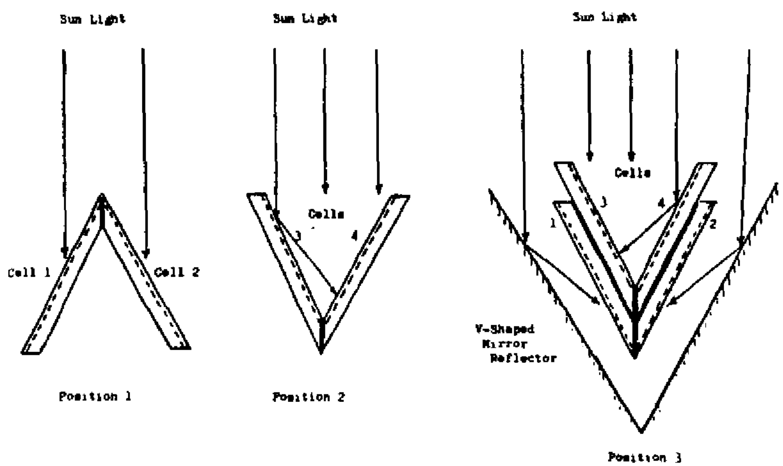

Fig.5. Mechanical wedged silicon cells and combination with V–shaped mirror reflector.

Each of the positions 1 and 2, in Fig.5, are equivalent to the circuit shown in Fig.4. However, position 3 is equivalent to double the circuit which is expected to deliver as much current as eight single solar cells.

The idea would be very useful when the horizontal area available is limited as in the case of central city buildings, satellites and space vehicles in which case vertical installation as our scheme propose would be most appropriate.

CONCLUSION

The potential for high current–high efficiency solar cell "double–sided" and wedged–type has been given and viewed. The double–sided solar cell break the limited efficiency barrier imposed by the silicon properties. The advantages of these new structures introduce the vertical eraction facility which would have an enormous impact on the photovoltaic applications in city buildings and similar systems. The interconnection flexibility offered in the wedged double faced cell have given the scheme a powerful stand in future applications. In addition, self–concentration of the cell may be considered an improvement in the cell design.

Finally, I think it would be a strong Arab contribution if it is fully realized through sponsoring the proposal by one of our firms. If it is successfully developed, it would be practically a new era of photovoltaic technology.

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