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(51) International Classifications: H01L 31/042

(54) Title: METHOD FOR DESIGNING AND MANUFACTURING PHOTOVOLTAIC MODULES OF RATING 12-VOLT, 120-WATT INCORPORATING 108 HALF-CUT 125-MM SIZE MONO CRYSTALLINE SILICON SOLAR CELLS

(57) Abstract: A new design is invented for fabrication of 12-volt, 120-watt photovoltaic modules incorporating 108 half-cut, 125-mm mono-silicon solar cells. The cell array utilizes 3 parallel strings of 36- solar cells. The module (size : 1239*789-mm²) is designed with standard lamination materials (high transmission tempered glass, Ethylene Vinyl Acetate encapsulant, Tedlar back sheet) and incorporates laser-cut high efficiency anti-reflection coated solar cells. In comparison to the conventional design using 36 solar cells of 156-mm size and 3.4-watt rating, the presently evolved design permits manufacture and application of 125-mm solar cells for realizing specific requirement of module and system voltage (12-V) at 120-watts power rating. To an extent, this versatile design helps to mitigate the short-supply of 156-mm silicon wafers and also, affords use of solar cell production equipment limited to 125-mm size.

Claim:

WE CLAIM

1. A method for fabricating 12-volt, 120-watt Photovoltaic (PV) modules incorporating 108 half-cut, 125-mm mono crystalline silicon solar cells.
2. A method as claimed in claim (1) wherein, replacement of 36 no. of 156-mm size solar cells with 108-nos. of half cut 125-mm size solar cells connected in series parallel configuration to get 12-volt and 120-watt power output.
3. A method as claimed in claim (1) and (2) wherein, development of a Phenyl Resin Bonded Cotton Fibre (PRBCF) lay-up jig for interconnection of 108-nos. of half-cut 125-mm size solar cells.
4. A method as claimed in claim (1), (2) and (3) wherein, laser cutting of 125-mm full solar cells into two half solar cells.
5. A method as claimed in claim (1), (2), (3) and (4) wherein, parallel connection of three solar cell strings of 36-half cut cells each.

Complete Specification:

HELP OF INVENTION

This invention relates to a method for fabrication of Photovoltaic (PV) modules of rating 12-volt, 120-watt incorporating 108 half-cut, 125-mm size mono crystalline silicon solar cells. The conventional 12-volt, 120-watt PV module incorporates 36 nos. of 156-mm size mono / multi-crystalline silicon solar cells.

Worldwide, there is a shift in PV module ratings from lower to higher power output. This is evidenced by the spurt in demand for higher-wattage modules for applications in stand-alone PV systems such as street lighting, domestic lighting as well as large Power Plants. Photovoltaic manufacturers have commercialized higher-rating PV modules with accompanying advantages of increased production throughput with high efficiency solar cells, improved system reliability and reduced maintenance cost.

The standard large power rating modules are; a) 160 to 185 watts manufactured using 72 nos. (24-V application) of 156-mm size solar cells, b) 120 to 130-watt modules manufactured using 36 nos. (12-V application) of 156-mm size solar cells. Solar cell size is a constraint for manufacturing 120-watt PV modules by manufacturers whose line can handle only 125-mm size wafers. To facilitate manufacture of 12-Volt, 120-watt PV modules using 125-mm size solar cells, an alternative design is required to be formulated. This invention is a configuration using 108 half-cut 125-mm size solar cells in series-parallel configuration. The

design concepts employed in manufacturing were: Production of high-efficiency ($\eta = 15\%$) solar cells using alkaline texturisation, diffusion, plasma edge junction removal, silicon-nitride anti-reflection coating, screen printing and firing. A graded- refractive index silicon nitride layer was deposited in-situ using Plasma Enhanced Chemical Vapour Deposition (PECVD) tube furnace process and a Back Surface Field (BSF) metalisation process applied to improve solar cell conversion efficiency; Design of suitable layout of PV modules and fabrication of the anodized aluminium frame with a special cross section for two screws at each corner and width of 50 mm for assembling and providing rigidity to the modules. The modules have been fitted with a junction box and clip-on connector cables.

Prior Art Search

A search was carried out to identify developments concerning PV modules of similar application. The following related patents were located.

1. WO/2004/038814 - Process for assembly of Photovoltaic Modules

This patent describes the interconnection of one cell to another by means of conducting glue or soldering paste, positioning of cells on a panel of suitable material, hot application of Ethylene Vinyl Acetate (EVA) and a sheet of glass to cover the panel. Whereas the present claim is for series-parallel interconnection of solar cell strings by means of copper interconnects and solar cells are laminated in a vacuum laminator.

2. WO/2007/053306 - Photovoltaic Modules and Interconnect methodology for fabricating the same.

In this patent, the front contacts and back contacts are accessible from the back side of same cell. Further, the photovoltaic cells are interconnected by interconnect leads that are coupled from a tab on the front contact point on the backside of a first photovoltaic cell to a back contact point on the backside of a second photovoltaic cell. Whereas in this patent, the photovoltaic cells used are of conventional type having front and back contacts on the front side and backside of the photovoltaic cell respectively. The cells are interconnected from front contact of one cell to back contact of next cell by means of soldering copper interconnects.

3. WO/2003/065392 - Photovoltaic Cell Interconnection

This patent describes photovoltaic modules which include photosensitized nano-matrix layer and a charge carrier media. The cells are interconnected in series and electrical connection layers each include conductive and insulative regions. Whereas the present invention uses 108-nos. of half cut conventional 125-mm mono crystalline silicon solar cells connected in series-parallel to obtain the required current and voltage.

4. WO/1994/027327 - Series Interconnected Photovoltaic Cells and method for making same.

This patent describes cells having a bottom electrode, a photoactive layer and a top electrode layer. Adjacent cells are connected in electrical series by way

of conductive-buffer line. Whereas the present invention uses 108-nos. of half cut conventional 125-mm mono crystalline silicon solar cells connected in series-parallel to obtain the required current and voltage.

Websites searched :

1. www.wipo.int/portal/index.html.en
2. www.ipo.gov.uk/
3. www.uspto.gov/patft/
4. strategis.ic.gc.ca/sc_mrksv/cipo/

OBJECTS OF THE INVENTION:

An object of this invention is to propose a method for fabrication of a 12-volt, 120-watt Photovoltaic (PV) module using 108 half-cut, 125-mm mono crystalline silicon solar cells.

Another object of this invention is to propose a method for replacing 36 nos. of 156-mm size solar cells with 108-nos. of half cut 125-mm size solar cells connected in series parallel configuration to get 12-volt and 120-watts power output.

Further object of this invention is to propose a method for development of a Phenyl Resin Bonded Cotton Fibre (PRBCF) lay-up jig for interconnection of 108-nos. of half-cut 125-mm size solar cells.

Yet another object of this invention is to propose a method for laser cutting of 125-mm full solar cells into two half solar cells.

Still another object of this invention is to propose a method for parallel connection of 3 strings 36-half cut cells each.

DESCRIPTION OF THE ACCOMPANYING DRAWINGS:



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Fig 1: shows the Solar cell manufacturing process.

Fig 2: shows the PV Module manufacturing process.

Fig 3: shows PV module made with 36-nos. of 156-mm size solar cells.

Fig 4: shows full and half-cut 125-mm cells.

Fig 5: shows the lay-up jig with 108-nos. of 125-mm half cut solar cells.

Fig 6: shows PV module made with 108-nos. of 125-mm half-cut solar cells.

Fig 7: shows the Current-Voltage characteristic curve of 120-watts PV module made with 108-nos. of 125-mm size half-cut solar cells.

DETAILED DESCRIPTION OF THE INVENTION:

According to this invention there is provided a method for manufacturing 12-volt, 120-watt Photovoltaic (PV) modules incorporating 108 half-cut, 125-mm mono crystalline silicon solar cells (parallel connection of 3 strings of 36-half cut cells each).

Design and incorporate three parallel strings each containing 18 serially connected 125-mm half cut cells and two such sub-sets in series to get open-circuit voltage of 22-volts and power output of 120-watts.

A Phenyl Resin Bonded Cotton Fibre (PRBCF) lay-up jig having 108 slots for interconnecting the half-cut cells and the sub-strings.

In the present invention, an engineering solution is applied to replace the conventionally used 156-mm size solar cells with 125-mm half cut solar cells.

Introduction :

Worldwide, there is a shift in PV module ratings from lower to higher power output. This is evidenced by the spurt in demand for higher-wattage modules for applications in stand-alone PV systems such as street lighting, domestic lighting as well as large Power Plants. Photovoltaic manufacturers have commercialized higher-rating PV modules with accompanying advantages of increased production throughput with high efficiency solar cells, improved system reliability and reduced maintenance cost.

The standard large power rating modules are ; a) 160 to 185 watts manufactured using 72 nos. (24-V application) of 125-mm size solar cells, b) 120 to 130-watt modules manufactured using 36 nos. (12-V application) of 156-mm size solar cells. Solar cell size is a constraint for manufacturing 120-watt PV modules by manufacturers whose line can handle only 125-mm size wafers. To facilitate manufacture of 12-volt, 120-watt PV modules using 125-mm size solar cells, an alternative design has been considered. This configuration uses 108 half- cut, 125-mm size solar cells in series-parallel configuration. The design concepts

employed in manufacturing were, production of high-efficiency ($\eta = 15\%$) solar cells using alkaline texturisation, diffusion, plasma edge junction removal, silicon-nitride anti-reflection coating, screen printing and firing. A graded-refractive index silicon nitride layer was deposited in-situ using Plasma Enhanced Chemical Vapour Deposition (PECVD) tube furnace process and a Back Surface Field (BSF) metalisation process applied to improve solar cell conversion efficiency. Anodized aluminium frame with a special cross section for two screws at each corner and width of 50 mm was used for assembling and providing rigidity to the modules. The modules have been fitted with a junction box and clip-on connector cables.

Design and development:

The process flow chart of solar cell is as given in Fig. 1. The process steps include the following :

1. Saw damage removal and texturisation
2. p-n junction formation by thermal diffusion
3. Edge junction removal by plasma etching
4. Phosphorous Silicate Glass (PSG) removal
5. Silicon Nitride Anti-Reflection Coating (ARC) by Plasma Enhanced Chemical Vapour Deposition (PECVD).
6. Metalisation and firing of contacts
7. Testing and classification of Solar Cells.

The as-cut p-type boron-doped CZ silicon wafers are chemically etched in concentrated alkali solution to remove saw damages followed by a dilute alkali

texturising step to form pyramid-like structures on the wafer. Process parameters such as alkali concentration, solution temperature and process time are optimised to get well-defined normal random pyramids which enhance the surface area of the wafer for greater light absorption and at the same time, facilitate total internal reflection of light.

A p-n junction is then formed on the textured silicon wafer through a high-temperature, solid- state diffusion process in a quartz furnace. In this process, phosphorous oxy-chloride (POCl_3) liquid dopant is deposited on the wafers and is driven in when a thin n-type layer is formed. The wafers are coin-staked and etched using freon-oxygen gas mixture in a dry plasma etch machine so as to remove the junction regions created on the edges. The wafers are then chemically etched to remove the oxides and phosphorous glass from the surface. A thin film of silicon nitride (anti-reflection coating) is deposited on the wafer to lower the reflection of light further and to passivate the solar cell against harmful environment such as humidity, ionizing radiation and reactive module lamination materials. The silicon nitride anti-reflection coating enhances the solar cell conversion efficiency by almost 1 %.

Front and back contacts on the wafer surface are established by screen printing a suitable metallic pastes on them. A fine-line grid pattern (Silver) is formed on the front side which is designed to reduce the contact resistance and at the same time increase the aperture for light absorption. Busbars (Silver-aluminium) are printed on the back side for facilitating solder contacts, and rest of the area is covered with aluminium paste to create the back surface field (BSF). The printed pastes are dried and sintered in an infra-red belt furnace where temperature and belt speed are optimized to achieve a sharp temperature profile. The cells are

then tested under illuminated light and classified into various bins as per the power output.

The flow chart of PV module fabrication process is shown in Fig. 2. The process steps include the following:

1. Interconnection of solar cells and formation of a string.
2. Lamination of the interconnected solar cells and curing.
3. Framing and junction box fixing
4. Testing with a Sun Simulator

Tinned copper interconnects are soldered on the front busbars of matched solar cells in terms of output current. These are strung together (front contact of one cell connected to the back contact of the next cell through the interconnects) in a specially designed lay-up jig, terminating in positive and negative output leads. The strung solar cell array is sandwiched between a layer of Ethylene Vinyl Acetate (EVA, a thermo plastic resin formulated with cross-linking additives) and a tempered glass superstrate with high transmission (91%) and low iron content on one side and a similar EVA layer and a Tedlar-Polyester-Tedlar PVF film as a substrate on the other. The entire assembly is bonded within a specially designed and developed vacuum laminator at high temperature and in vacuum. During this process, the EVA film melts and forms a bond between solar cells and glass on one side and solar cells and Tedlar on the other. This makes the assembly resistant to moisture and environmental effects. The laminate is framed with anodised aluminium edge frames so as to provide support and flexibility in mounting the PV modules at site as well as providing strength against high wind

velocity. A junction box is provided for enabling the PV modules to be interconnected in an array and to the load. The module is then tested under simulated light for measuring the electrical power output.

Conventional 12-V, 120-W PV modules (Fig. 3) manufactured with 156-mm solar cells (36 cells of 3.3 to 3.4-watt in 9*4 configuration) have the overall dimension of 1476*660*50 mm³ with following electrical characteristics:

Open-circuit voltage (Voc) : 22 V, Short-circuit current (Isc) : 7.5 A

Voltage at maximum power point (Vmp) : 17.5 V, Current at maximum power point (Up): 6.9 A.

The power output of 125-mm mono-crystalline or multi-crystalline solar cells range from 2.2 to as high as 2.5-watt. A typical module made with 36-nos. of 125-mm size solar cells (each of 2.3-watt) produces 80-watt power output. Similarly, a module fabricated with 36-nos. of 125-mm half cut solar cells produces a power output of 40 watts. It is derived that three 40-watt modules are required to be paralleled to realize 120 watts for 12-volt application. This concept is used here for manufacture of 12-V, 120-W modules using 108 half-cut solar cells. A picture of full and half-cut 125-mm mono pseudo square silicon solar cell is shown in Fig. 4. 3 strings each of 18 half-cut cells are paralleled and then connected in series with another set of 18*3 strings to realize the open-circuit voltage of 21-Volt, short-circuit current of 7.5-Amp and power output in the range of 120 to 125 watts. The array design is of 18*6 configuration with an overall module size of 1239*789*50 mm³. The specially developed lay-up jig and the laminated 120-watt module are shown in Fig. 5 and Fig. 6 respectively.

EXAMPLE:

Few PV modules of the present design have been manufactured using 108-nos. of 125-mm half cut high efficiency solar cells. Characteristics of a typical module measured using a Sun Simulator (Spire, 460i) are as given below.

Module SI. No. A100001

Open-circuit Voltage (Voc) 21.67 V

Short-circuit current (Isc) 7.75 A

Voltage at maximum power point (Voc) 17.35 V

Current at maximum power point (Voc) 7.04 A

Maximum Power output (Pmax) 122.18 W

Fill factor 0.73

Module efficiency 14.62 %

Physical dimensions 1239 * 789 * 50 mm

Weight 12 Kg.

These newly developed PV modules have met the design specification of voltage and power adequately. The current-voltage characteristics as measured using Sun Simulator is given in Fig. 7. The total area of the module remain almost same as that made with 36-cell (156-mm size) configuration. Out door performance tests have been carried out and the initial results indicate that the performance stability of these modules are well within acceptable limits, as already observed in the case of generic modules using similar solar cells.

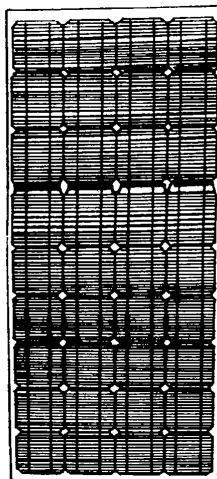


Fig. 3

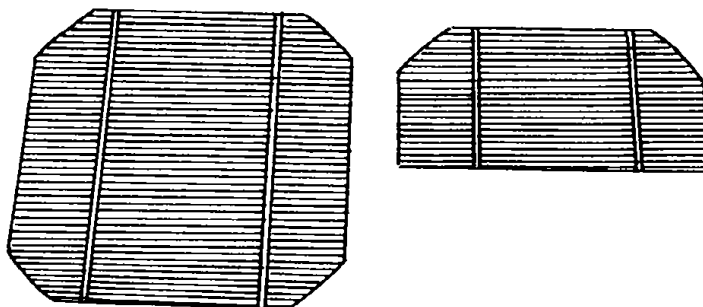


Fig. 4



Fig. 6

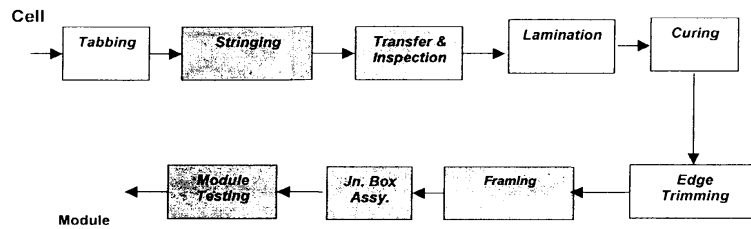


Fig. 2

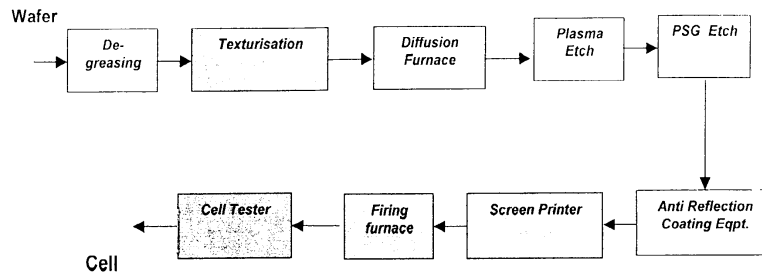


Fig. 1

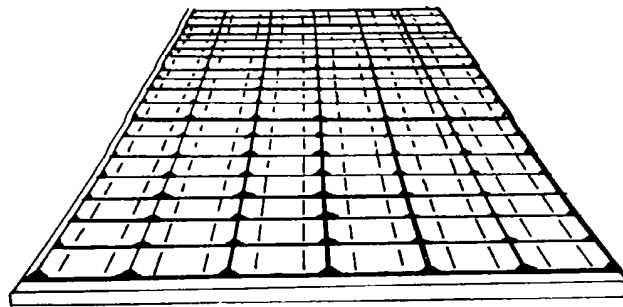


Fig. 5

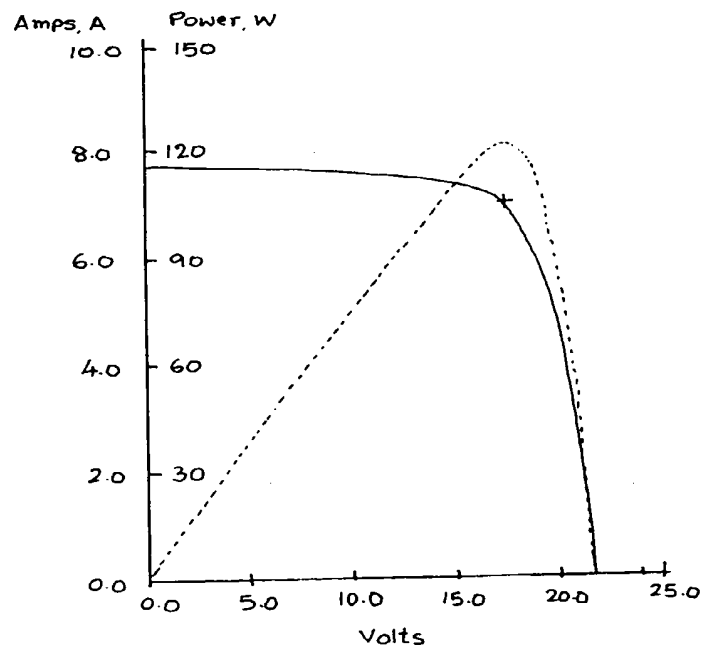


Fig. 7