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(54) Title: METHOD FOR FABRICATION OF PHOTOVOLTAIC MODULES OF RATING 12-VOLT, 80-WATT INCORPORATING 72 ONE-THIRD CUT 156-MM SIZE MULTI CRYSTALLINE SILICON SOLAR CELLS

(57) Abstract: The method of fabrication of Photovoltaic modules of rating 12-volt 80 watt incorporating 72 one third cut 156 mm size multi crystalline silicon solar cells comprising the following steps; laser cutting of 156 mm full size solar cells into 2/3rd and 1/3rd portion; interconnection of solar cells and formation of a string; lamination of the interconnect solar cells and curing; framing, fixing of junction box and testing with a sun simulator; characterized in that the said Photovoltaic module comprises of 72 Nos. 1/3rd cut, 156 mm size solar cells, which are arranged for series connection of two sets of parallel strings of 2x18 nos. of such cells.

Claim:

WE CLAIM

1. The method of fabrication of Photovoltaic modules of rating 12-volt 80 watt incorporating 72 one third cut 156 mm size multi crystalline silicon solar cells comprising the following steps;
 - laser cutting of 156 mm full size solar cells into 2/3rd and 1/3rd portion;
 - interconnection of solar cells and formation of a string;
 - lamination of the interconnect solar cells and curing;
 - framing, fixing of junction box and testing with a sun simulator;characterized in that the said Photovoltaic module comprises of 72 Nos. 1/3rd cut, 156 mm size solar cells, which are arranged for series connection of two sets of parallel strings of 2x18 nos. of such cells.
2. The method as claimed in claim 1, wherein the formation of a string with the solar cells is made terminating in positive and negative output leads and their interconnection is done in lay up jig where phenyl Resin bonded cotton fibre (PRVCF) is provided.
3. The method as claimed in claim 1, wherein the said interconnection is made with tinned copper interconnects which are soldered on the front busbars of matched solar cells.
4. The method as claimed in claim 1, wherein the said lamination comprises of two layers, one layer comprising of Ethylene Vinyl Acetate (EVA) and high transmission tempered glass applied on one side and a second layer of combined Polyester and Poly Vinyl Fluoride based film applied on the other side of strung solar cells.
5. The method as claimed in claim 1, wherein the laminates, formed in the process of said lamination is framed with anodized aluminium edged frames.
6. The method as claimed in claim 1, wherein the said junction box is fixed for photovoltaic modules to be interconnected in the array and to the load.
7. The method as claimed in claim 1, wherein the said testing of Photovoltaic module, so framed, is done with a sun simulator, under simulated light for measuring the electrical power output.

Complete Specification:

TITLE: METHOD FOR FABRICATION OF PHOTOVOLTAIC MODULES OF RATING 12-VOLT, 80-WATT INCORPORATING 72 ONE-THIRD CUT 156-MM SIZE MULTI CRYSTALLINE SILICON SOLAR CELLS

FIELD OF INVENTION

The invention relates to the field of solar photovoltaic (PV) modules in general and to manufacture of solar photovoltaic modules with one third cut 156 mm size multi crystalline silicon solar cells in particular.

BACKGROUND OF THE INVENTION

The world top PV manufacturers have changed over to 156-mm multi / mono crystalline silicon solar cells from 125-mm size solar cells. This is due to the increase in power output to 3.6 - 3.7-watts (15% efficiency) per cell for 156-mm size cells from 2.3-watts per cell for 125-mm size cells. All the solar cell production machines have now been made for processing cells of 156-mm size. Hence, the production throughout increases by 60%, if 156-mm cells are processes as against 125-mm solar cells. The wafer manufacturers, in turn, have now changed over to 156-mm wafers. Hence, the availability of 125-mm wafers is becoming increasingly difficult, especially for multi-crystalline wafers. The PV module manufacturers, world-wide are now manufacturing PV modules using 156-mm size solar cells. Hence, it is important to develop modules using 156-mm solar cells for catering to the growing market.

Modules with full 36-nos. of 156-mm solar cells (each cell giving a power output of 3.6 to 3.7 watts) shall give a output in he range of 120 to 130-watts. For catering to the requirement of 75 to 80-watts PV modules (for stand-alone domestic / street lighting application), presently the modules are manufactured using 36-nos. of 125-mm mono / multi crystalline silicon solar cells (each cell giving a power output of 2.1 to 2.2 watts). As the availability of cells in 125-mm size is becoming difficult, a need is felt to develop 80-watts PV modules using 36-nos. of 156-mm cut solar cells. 156-mm full cells is required to be laser cut into 2/3rd and 1/3rd portions giving a power output of 2.4 watts and 1.2 watts respectively. 80-watts PV modules can be made straight away with 36 nos. of 156-mm 2/3rd cut cells in series configuration for 12-V application. In order to effectively utilize balance one-third cut cells, an alternative method of fabrication is invented by using 72-nos. of 156-mm one-third cut cells (with a power output of 1.2 watts) in series-parallel configuration for manufacture of 80-watts PV modules for 12-Volt application.

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

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

This patent describe 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 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 describe 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 72-nos. of one-third cut 156-mm multi-

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 describe 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 72-nos. of one-third cut 156-mm multi-crystalline silicon solar cells connected in series-parallel to obtain the required current and voltage.

Websites search :

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

To overcome the above drawbacks of the prior art, the following innovative remedial actions were under taken to improve it;

(a) to propose a method for replacing 36 nos. of 125-mm size solar cells with 72 nos. of one-third cut 156-mm size solar cells connected in series parallel configuration to get 12-volt and 80-watts power output.

(b) to propose a method for development of a Phenyl Resin Bonded Cotton Fibre (PRBCF) lay-up jig for interconnection of 72 - nos. of one-third cut 156-mm size solar cells.

(c) to propose a method for laser cutting of 156-mm full solar cells into two-third and one-third cut solar cells, so that 80 watts PV modules can be made straightaway with 36 nos. of 156-mm 2/3rd cut cells in series configuration for 12V application and to utilize effectively the balance 1/3rd cut cells for series connection of 2 sets of parallel strings (2*18 nos. of 156-mm 1/3rd cut cells).

BRIEF DESCRIPTION OF ACCOMPANYING DRAWING

The invention will now be described with the help of accompanying drawings which depict an exemplary embodiment of invention. However, there can be other embodiments all of which are deemed covered by the description.

Fig. 1: shows the Solar cell manufacturing process.

Fig. 2: shows the PV Module manufacturing process.

Fig. 3: shows PV modules made with 36-nos. of 125-mm size solar cells.

Fig. 4: shows full and cut 156-mm solar cells

Fig. 5: shows the lay-up jig with 72-nos. of 156-mm one-third cut solar cells.

Fig. 6: shows PV module made with 72-nos. of 156-mm one-third cut solar cells.

Fig. 7: shows the Current-Voltage characteristic curve of 80-watts PV modules made with 72-nos. of 156-mm size one-third cut solar cells.

As shown in Fig. 1, the sequential steps of solar cell production process starting from wafer comprises various steps like, precleaning of saw damage removal/degreasing, texturisation, diffusion for p-n junction formation, plasma etching for edge junction removal, anti reflection coating with Silicon Nitride, printing and drying, firing and testing under illuminated light and then classified into various bins as per the power output.

Fig. 2 shows the sequential steps of manufacturing Photovoltaic (PV) modules starting from solar cells, comprising of tabbing, stringing with interconnection of cells, transfer and inspection, lamination with Ethylene vinyl acetate and poly

vinyl based film in vacuum laminator, curing, edge trimming, framing of laminates in anodized aluminium edge frames, fixing of junction box for PV modules to be interconnected in an array and to the load and testing of such solar cells with a sun simulator for measurement of output power.

Fig. 3 shows the PV module of prior art having 36 Nos. 125 mm size mono/multi crystalline solar cells, which are not now available easily. To overcome the above draw back as in Fig. 3, full and cut 156 mm solar cells are introduced as shown

Fig. 4. 36 Nos. 156 size solar cells PV module has been developed for 75-80

watts PV modules, 156 mm size full cells is required to be laser cut into 2/3rd and 1/3rd portions. 80 watts PV modules can be made with 36 Nos. of 156 mm size 2/3rd cut cells in series configuration of 12-V application. To save the wastage, the balance as shown in Fig. 6, one third cut cells are utilized, by using 72 Nos. of 156 mm size solar cells in series-parallel configuration for manufacture of 80 watts PV modules for 12v-application, where cells are arranged for series connection of two parallel sets of 2x18 nos. of such solar cells. The said 72 Nos. 1/3rd cut 156 mm size cells are interconnected in string in lay up jig. (Fig. 5) on phenyl Resin Bonded Cotton Fiber (PRBCF).

A current-voltage characteristic curve for 80 watt PV modules (Fig. 6) is shown in Fig. 7, obtained from testing of the modules in a sun simulator under simulated light for measuring the electrical power output.

DETAILED DESCRIPTION OF THE INVENTION

According to this invention there is provided a method for manufacture 12-volt, 80-watt Photovoltaic (PV) modules incorporating 72 one-third-cut, 156-mm multi crystalline silicon solar cells (series connection of 2 sets of parallel strings of 2*18 nos. of 156-mm one-third cut cells).

Design and incorporate two parallel strings each containing 18 serially connected 156-mm one-third cut cells and two such sub-sets in series to get open-circuit voltage of 22-volts and power output of 80-watts.

A Phenyl Resin Bonded Cotton Fiber (PRBCF) lay-up jig having 72 slots for interconnecting the one-third cut cells and the sub-strings.

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

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 optimized 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 (POCl₃) 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. Buses (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 are 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 (Poly Vinyl Fluoride) 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 and thus laminate is formed. This makes the assembly resistant to moisture and environmental effects.

The laminate is framed with anodized 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 with a sun simulator, under simulated light for measuring the electrical power output.

Conventional 12-V, 80-W PV modules (Fig. 3) manufactured with 125-mm solar cells (36 cells of 2.2-watt in 9*4 configuration) have the overall dimension of 1203*528*38.5 mm³ with following electrical characteristics:

Open-circuit voltage (Voc) : 22 V, Short-circuit current (Isc): 5.0 A

Voltage at maximum power point (Vmp) : 17.5 V, Current at maximum power point (Imp) : 4.57 A.

The power output of 125-mm mono-crystalline or multi-crystalline solar cells range from 2.2 to as high as 2.4-watt. A typical module made with 36-nos. of 125-mm size solar cells (each of 2.2-watt) produces 80-watt power output. Similarly, a module fabricated with 36-nos. of 156-mm size solar cells (each of 3.6 watts) produces a power output of 120 to 130 watts. Hence, 156-mm solar cells is required to be cut to smaller size so as to suitable for delivering 80-watts power output. Two-third cut 156-mm cells shall give a power output of 2.4 watts and one-third cut cells, a power output of 1.2 watts approximately. It is derived that a module fabricated with 36-nos. of 156-mm two-third cut solar cells (each of 2.4 watts) produces a power output of 80-watts and a module fabricated with 36-nos. of 156-mm one-third cut solar cells (each of 1.2 watts) produces a power output of 40-watts. Hence, for utilizing 156-mm one-third cut cells for delivering 80-watts power output, two nos. of such 40-watt modules are required to be paralleled to realize 80 watts for 12-volt application. This concept is used here for manufacture of 12-V, 80- modules using 72 one-third cut solar cells. A picture of full and two-third cut and one-third cut 156-mm square multi crystalline silicon solar cell is shown in Fig. 4. 2 strings each of 18 one-third cut cells are paralleled and then connected in series with another set of 18*2 strings to realize the open-circuit voltage of 21-Volt, short-circuit current of 5.0-Amp and

power output in the range of 80 to 85 watts. The array design is of 18*4

configuration with an overall module size of 1023*663*38.5 mm³. The specially developed lay-up jig and the laminated 80-watt module are shown in Fig. 5 and Fig. 6 respectively.

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 (125-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 cells.

EXAMPLE

Few proto type PV modules of the new invention have been manufactured using 72-nos. of 156-mm one-third cut multi crystalline silicon solar cells.

Characteristics of a typical module measured using a Sun Simulator (Spire, 460i) are as given below.

MODULE SI.No. B711980

Open-circuit Voltage (Voc) 22.50 V

Short-circuit current (Isc) 5.33 A

Voltage at maximum power point (Voc) 18.15 V

Current at maximum power point (Voc) 5.12 A

Maximum Power output (Pmax) 92.85 W

Fill factor 0.77

Module efficiency 15.9%

Physical dimensions 1023*663*38.5 mm

Weight 7.5 Kg.

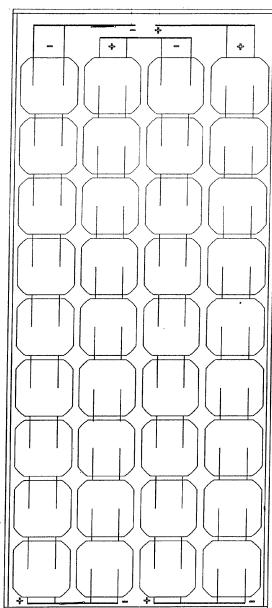


Fig. 3

80 WATTS PV MODULES WITH 36 NOS OF 125 mm SIZE SOLAR CELLS

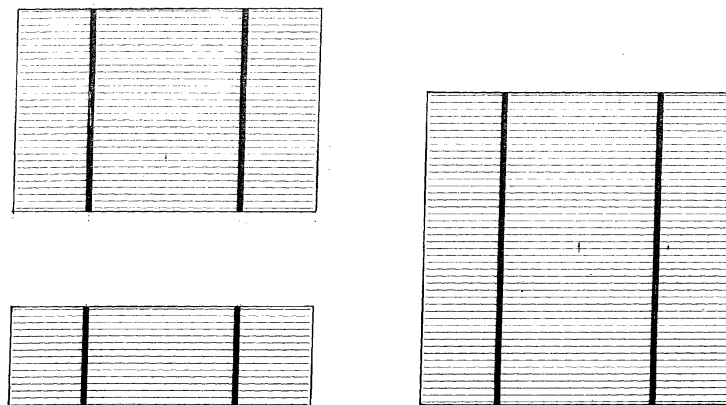


Fig. 4

156 mm FULL AND ONE-THIRD AND TWO-THIRD
CUT SOLAR CELL

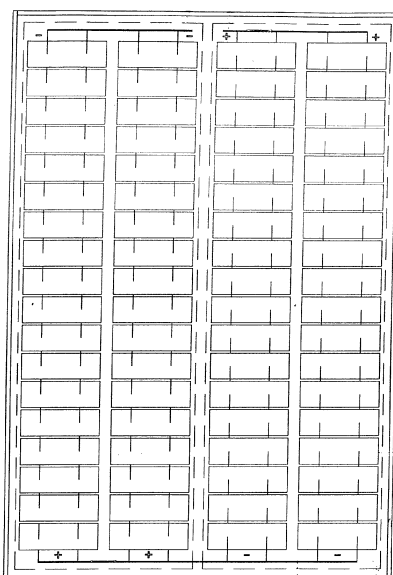


Fig. 6

80 WATTS PV MODULE MADE WITH 72 NOS.
OF ONE-THIRD CUT 156 mm SOLAR CELLS.

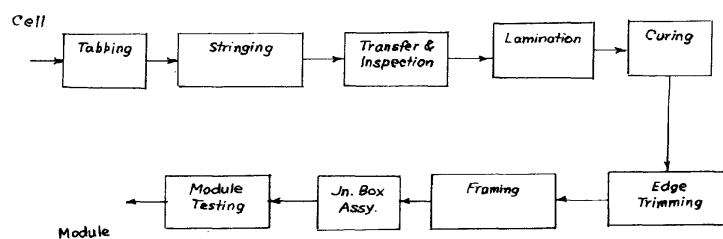


Fig. 2 PV module manufacturing process

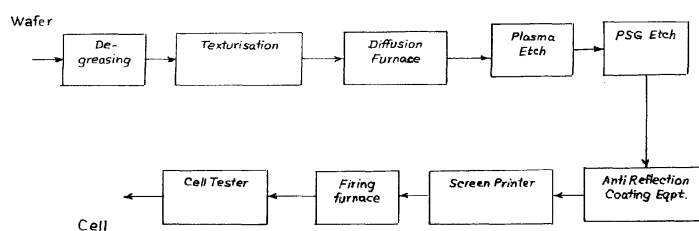


Fig. 1 Solar cell manufacturing process

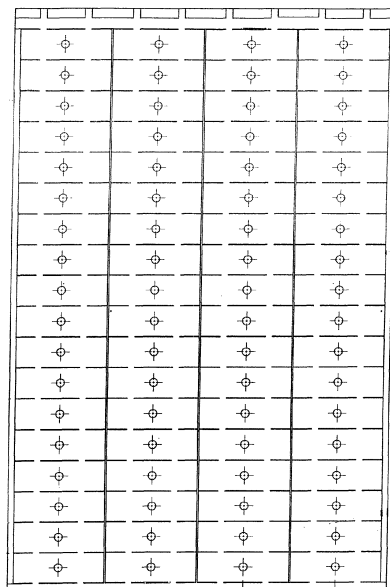


Fig. 5

LAY-UP JIG FOR 72 Nos. OF 156 mm
ONE-THIRD CUT SOLAR CELLS

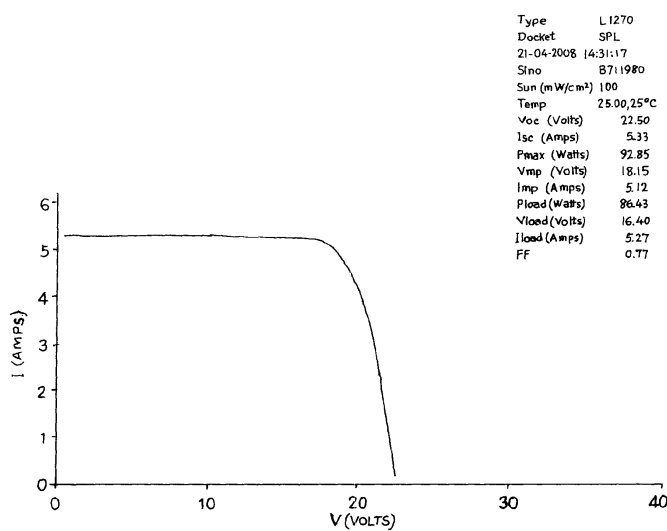


Fig. 7 current-voltage characteristic curve of 80-watts
PV module made with 72-Nos. of one-third cut
156 mm solar cells