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(54) MOUNTING CLAMP AND MOUNTING CLAMP CONFIGURATION FOR PHOTOVOLTAIC MODULE INSTALLATION

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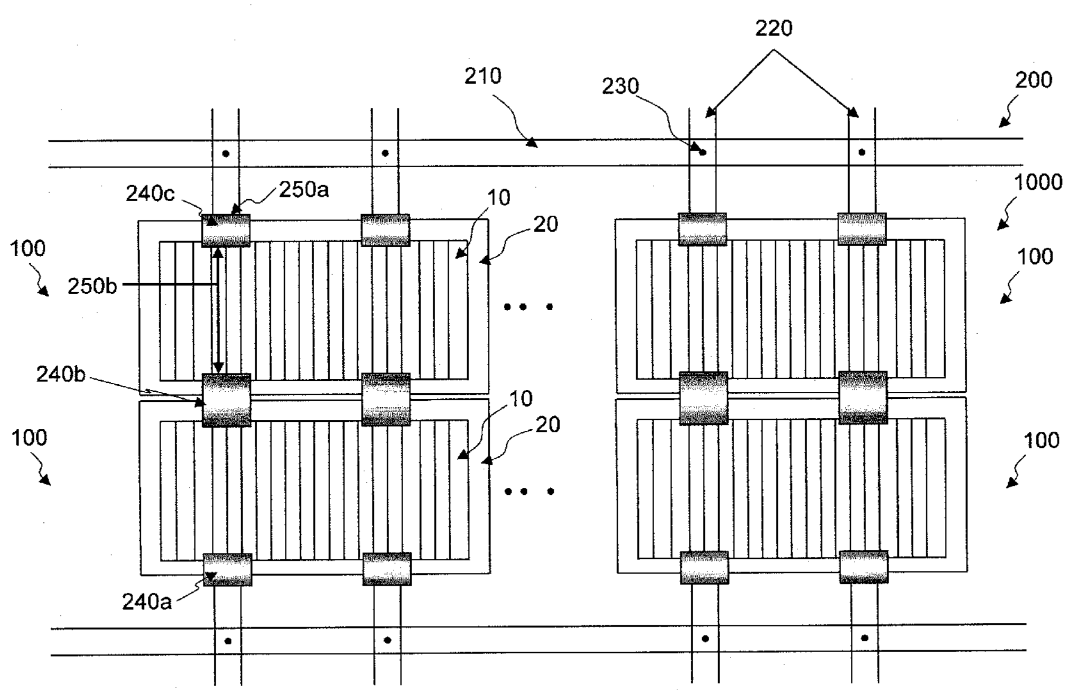
USPC **248/226.11**; 29/428

(57) **ABSTRACT**

Disclosed are photovoltaic module mounting assemblies with mounting clamps for connecting multiple photovoltaic modules into a photovoltaic array. One embodiment of the mounting assembly includes mounting clamps that are positioned on the mounting assembly parallel to the scribe lines of the module. Another embodiment of the mounting assembly uses mounting clamps that are configured to hold a portion of the module at a predetermined distance away from the photovoltaic cells of the module.



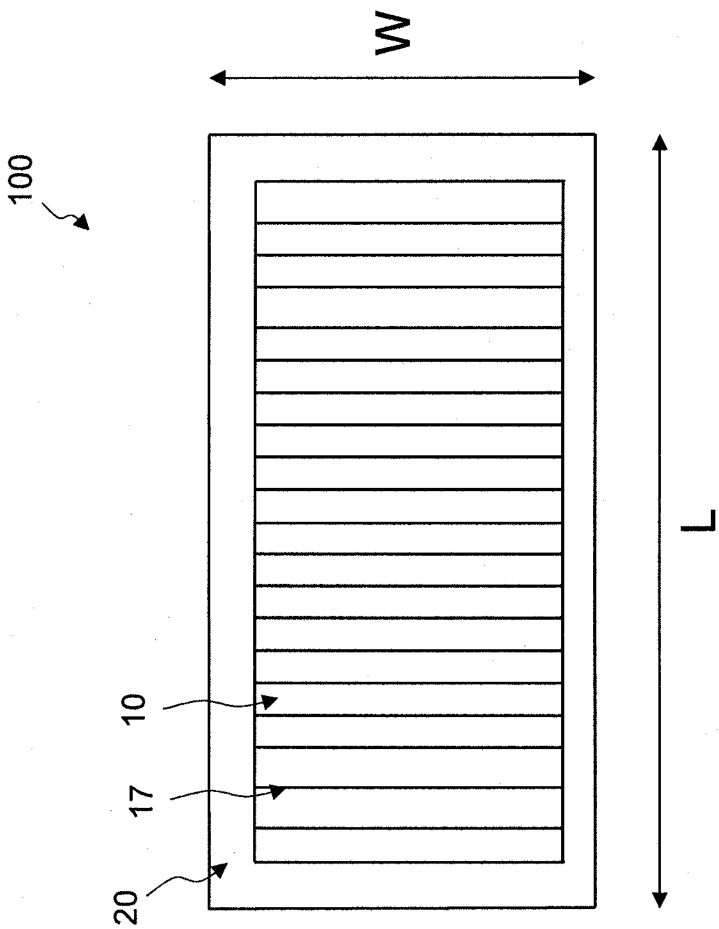


Figure 1A

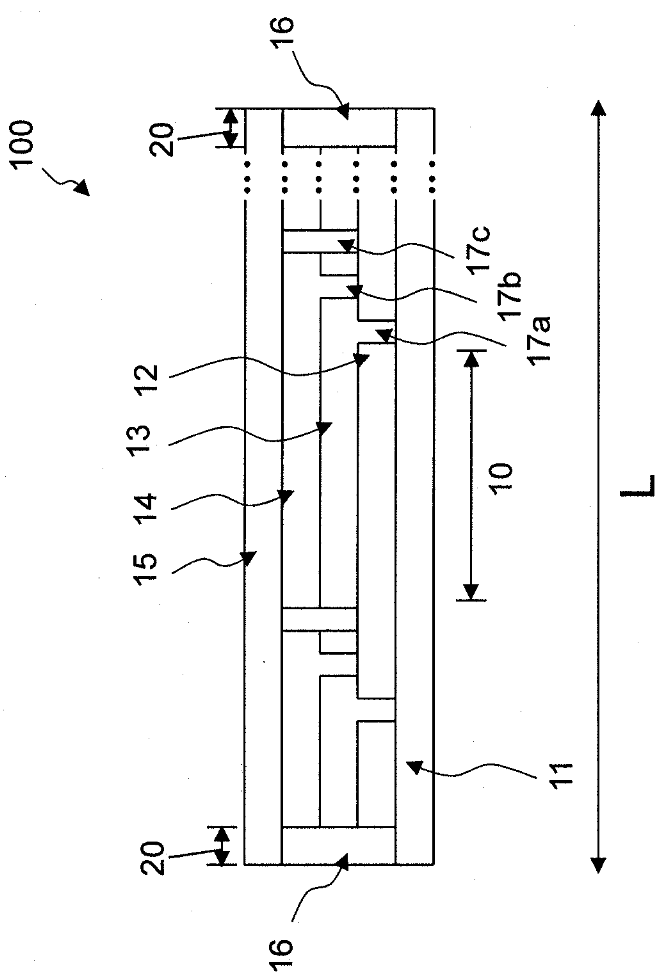


Figure 1B

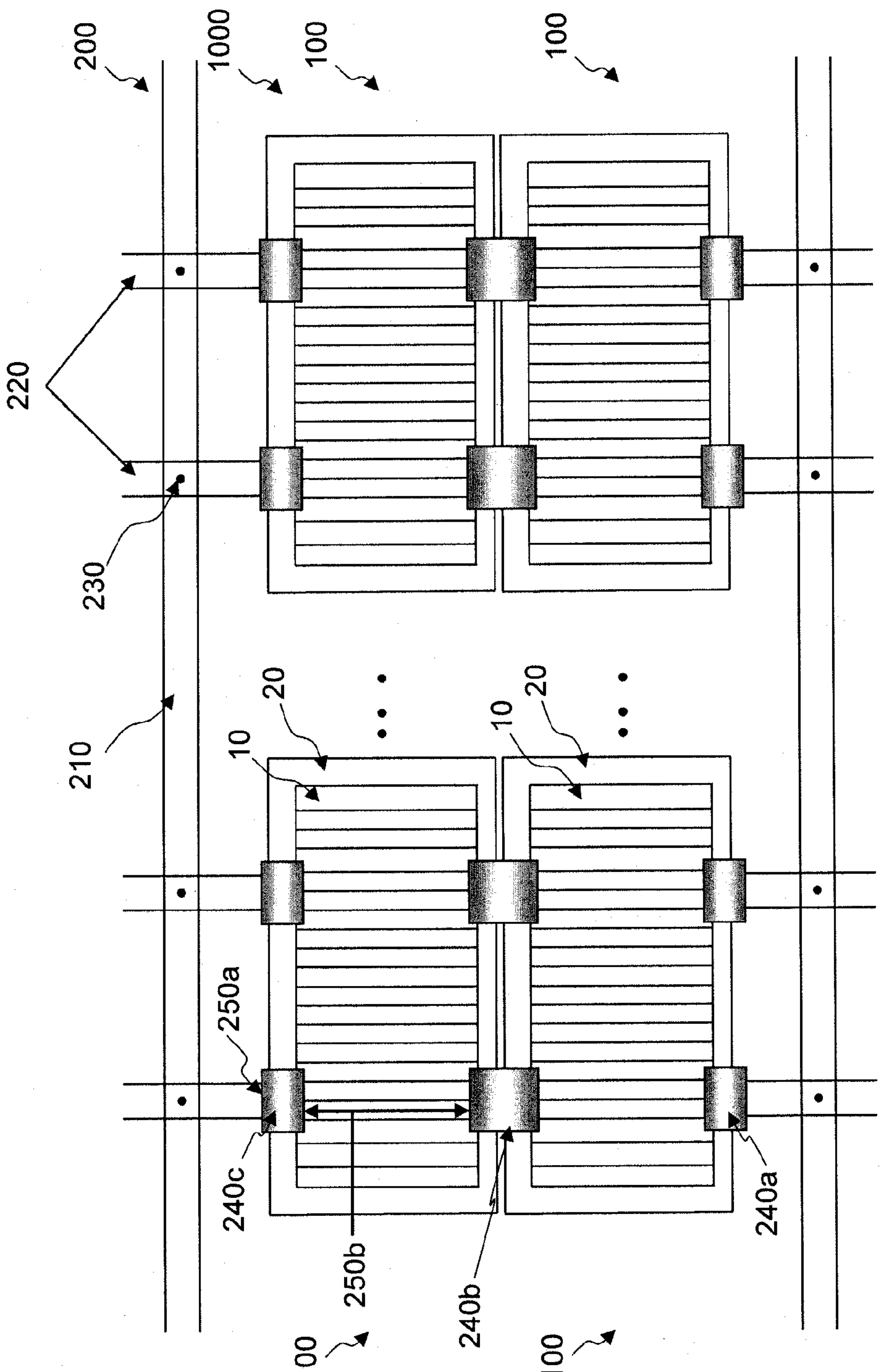

200
1000
100
100
220
230
210
20
10
10
20
250a
240c
250b
240b
240a
100
100

Figure 2

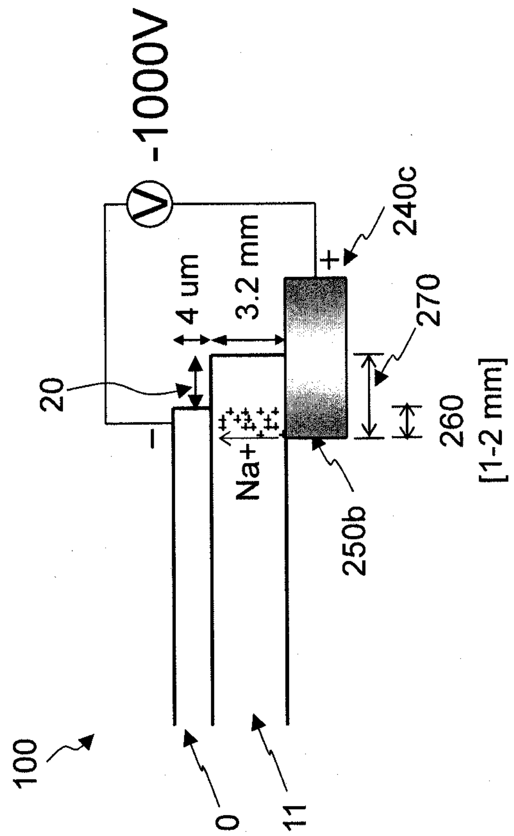


Figure 3

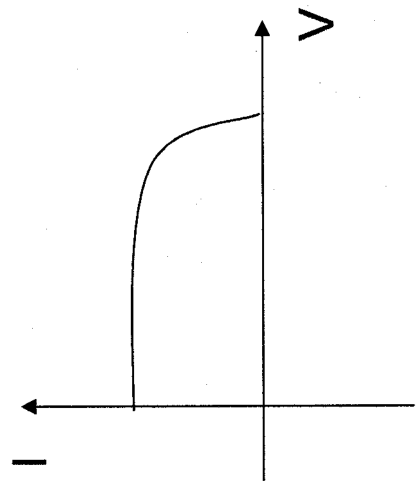


Figure 4A

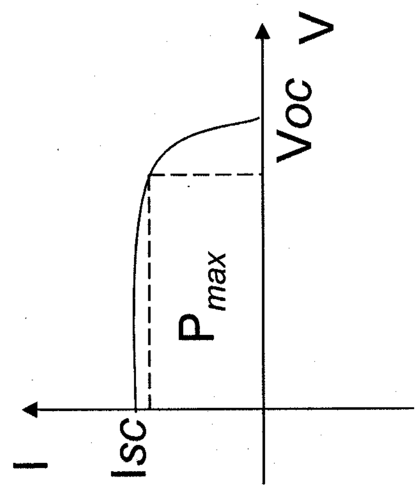


Figure 4B

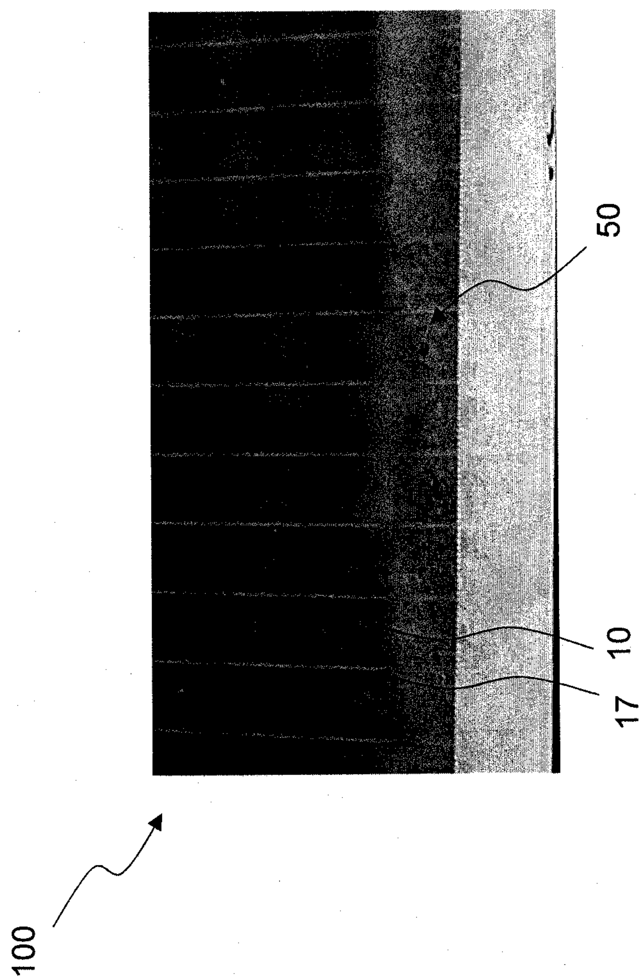


Figure 5

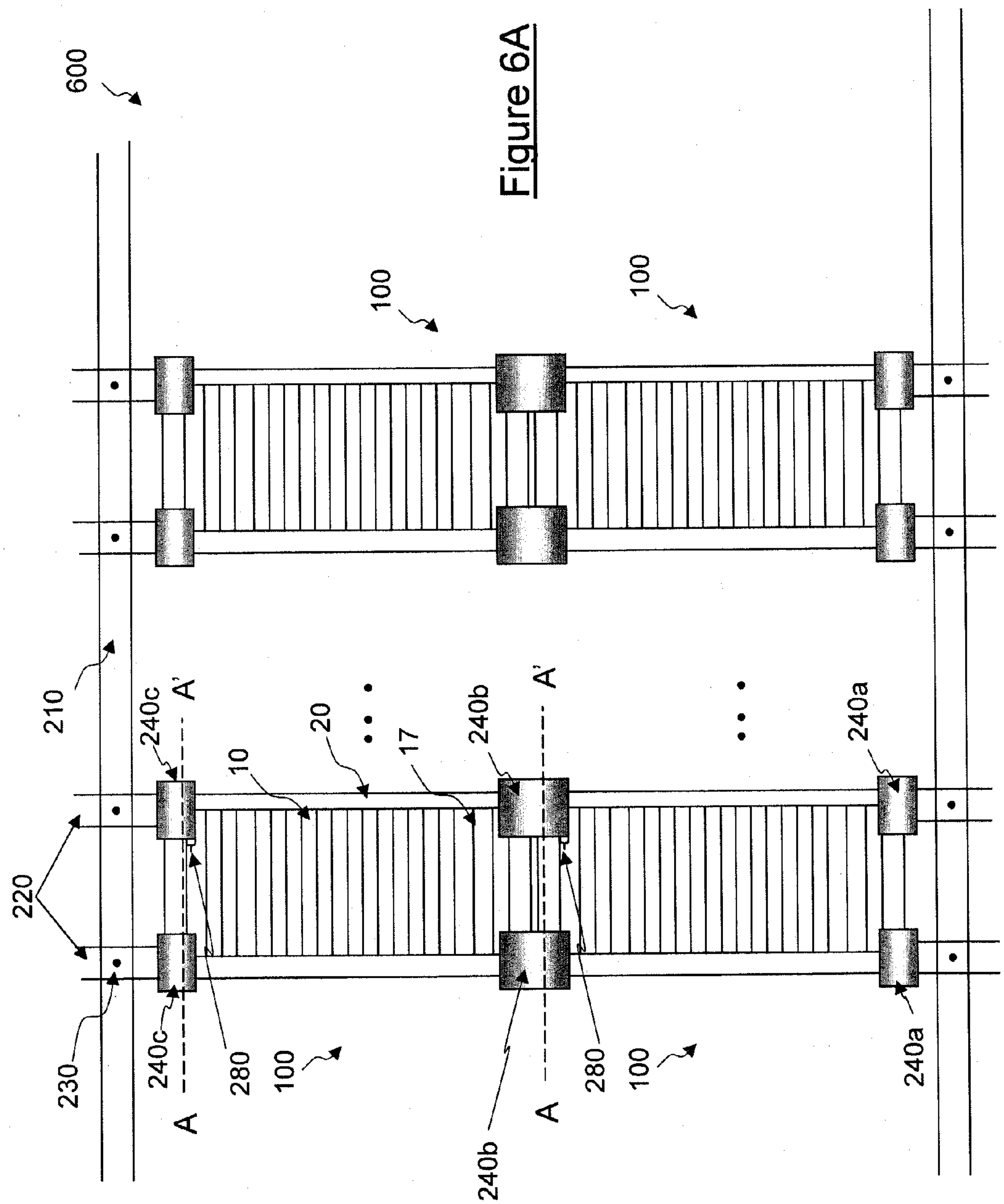


Figure 6A

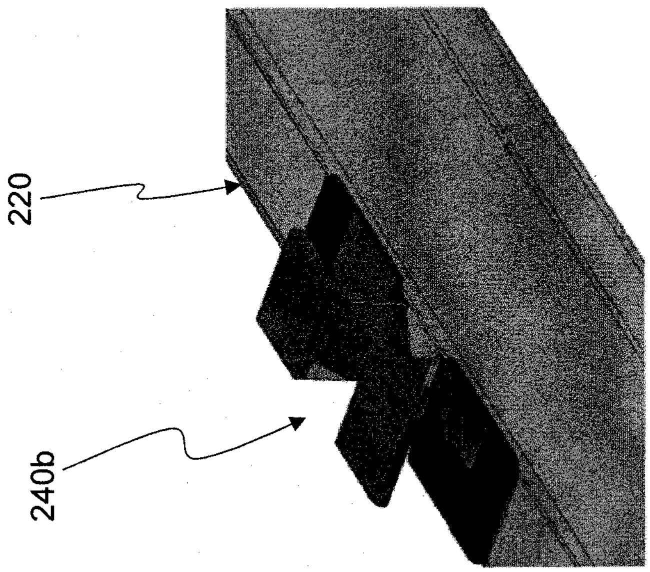


Figure 6C

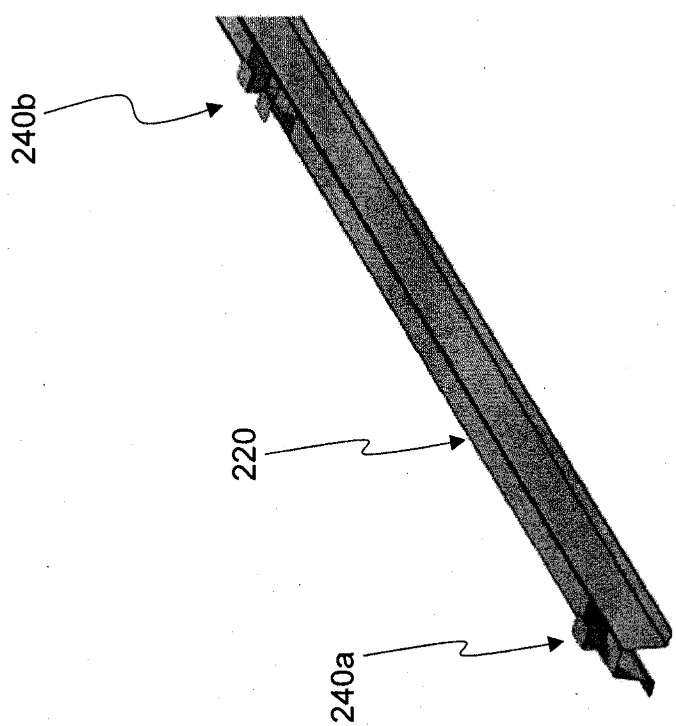


Figure 6B

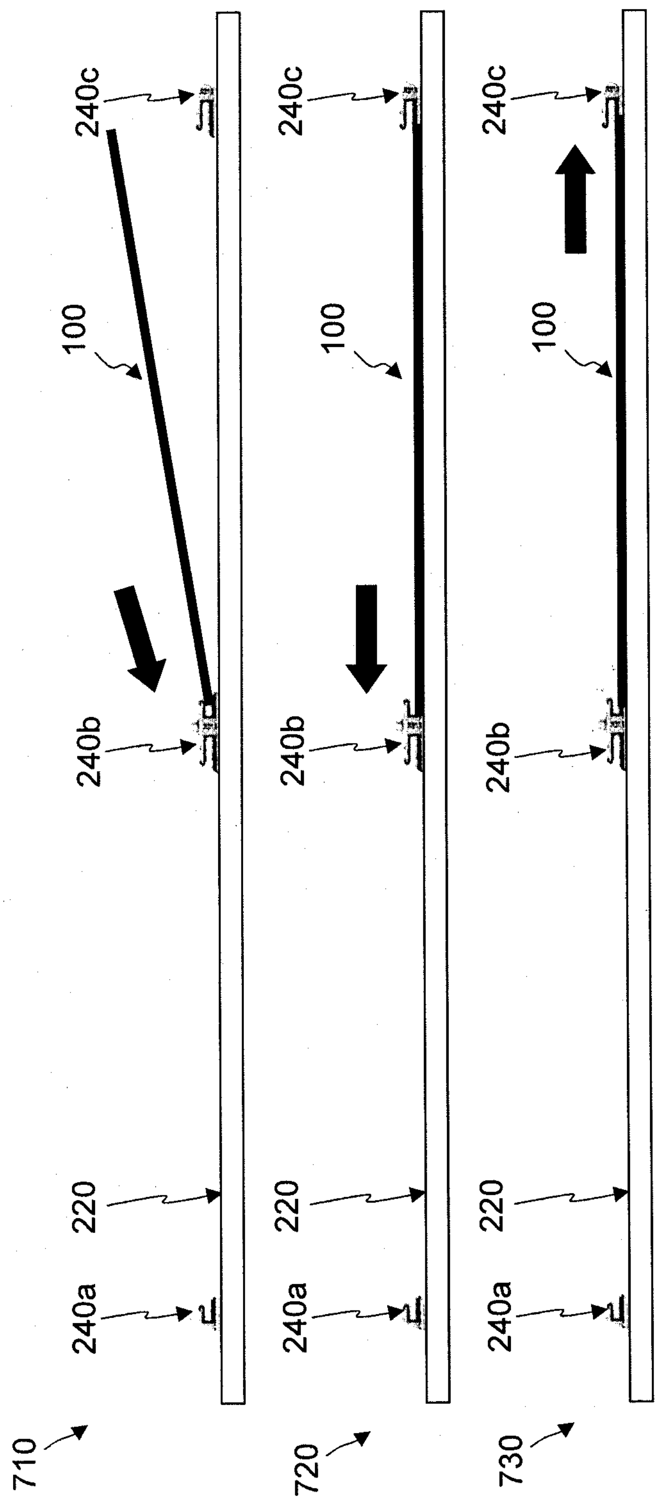


Figure 7

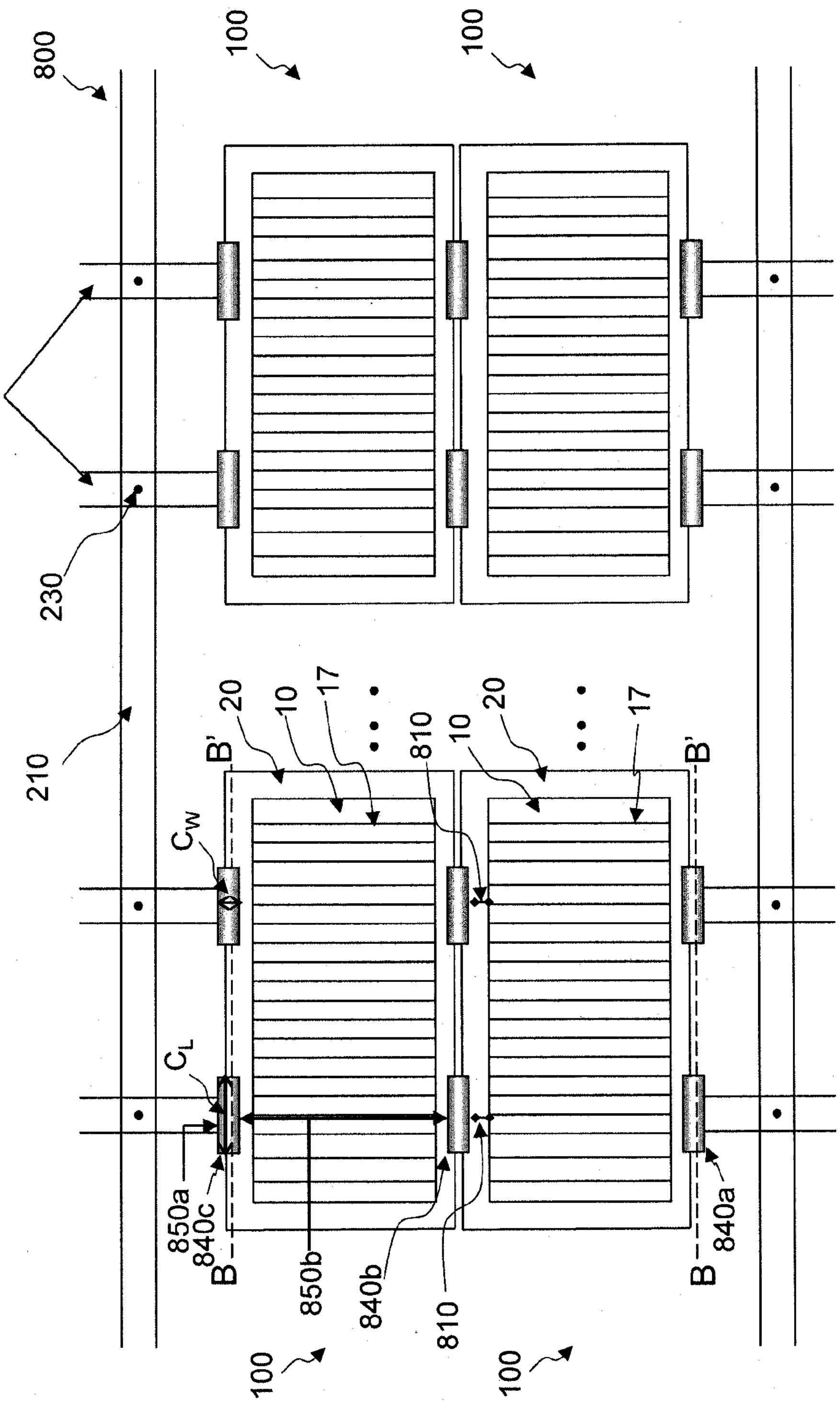

800
100
100
220
230
210
B'
20
10
17
810
10
20
17
B'
C_W
C_L
850a
840c
B
850b
840b
810
B
840a
100
100

Figure 8

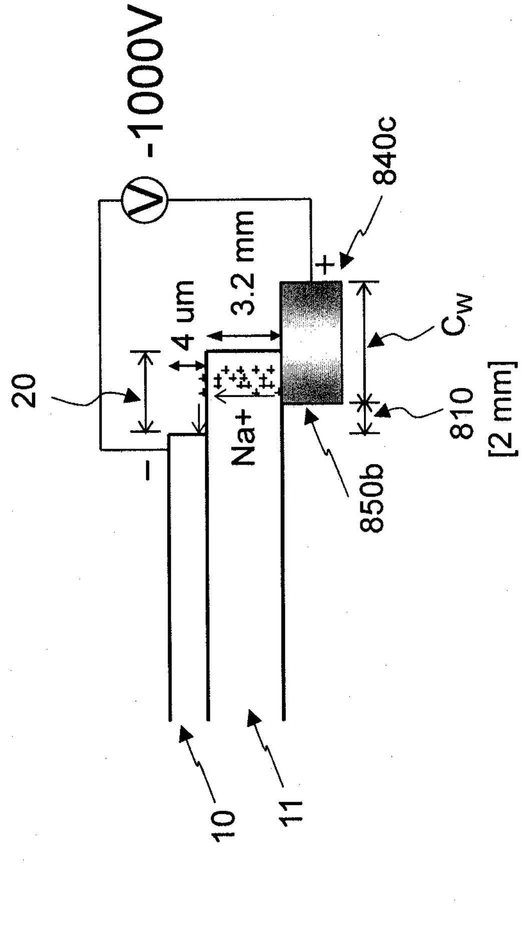


Figure 9

MOUNTING CLAMP AND MOUNTING CLAMP CONFIGURATION FOR PHOTOVOLTAIC MODULE INSTALLATION

[0001] This application claims priority to provisional application No. 61/595,370, filed on Feb. 6, 2012, which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] Disclosed embodiments relate to the field of photovoltaic (PV) power generation systems, and more particularly to photovoltaic module installation using mounting clamps.

BACKGROUND OF THE INVENTION

[0003] A photovoltaic module or solar module, also known as a solar panel, is a device that converts the energy of sunlight directly into electricity by the photovoltaic effect. Referring to FIGS. **1**A and **1**B, a photovoltaic module **100** includes a plurality of photovoltaic cells **10**, also known as solar cells, for example, crystalline silicon cells or thin-film cells. In thin-film photovoltaic modules, the photovoltaic cell **10** can include various materials formed between a front support **11** and a back support **15**. The various materials can include, for example, a first conductive material **12**, e.g., a transparent conducting oxide (TCO) material, an active material **13** and a second conductive material **14**, e.g., a back contact material. The front **11** and back **15** supports are made of a transparent material, such as, glass, so that the front support **11** allows light to pass through to the active material **13**. The active material **13** is formed of semiconductor materials, for example, a cadmium sulfide (CdS) window layer and a cadmium telluride (CdTe) absorber layer adjacent the cadmium sulfide (CdS) window layer, although other semiconductor materials can be used. The first **12** and second **14** conductive materials act as electrodes. An electrical insulator **16** edge seal encapsulates and seals the peripheral edge **20** of the module **100** to create a suitable tracking distance from the active material **13** to the exterior of module **100** for reducing the risk of electrical shock.

[0004] In the exemplary thin-film cell **10** shown in FIG. **1**B, portions of the material layers are removed to form electrical connections to the first conductive material **12** and the second conductive material **14** and define individual photovoltaic cells. The cells may be connected in series, in parallel or in a combination thereof. This is typically accomplished via a scribing process that uses pulsed lasers to form laser scribes **17***a*, **17***b* and **17***c*. Multiple photovoltaic cells **10** are formed and electrically connected by the laser scribes **17***a-c* to form a photovoltaic module **100**. The exemplary photovoltaic module **100** has a longer length (L) than width (W). For example, module **100** may have a length (L) of four (4) feet and a width (W) of two (2) feet, although any module size can be fabricated using the methods discussed herein. In the conventional photovoltaic module **100**, the laser scribes **17***a-c* are formed perpendicular to the longer length (L) of the module **100** as shown in FIG. **1** A. An edge delete area **20** of a photovoltaic module **100** is typically formed at the edge which defines a perimeter around the photovoltaic cell **10** areas and which does not participate in the conversion of solar photons to electrical power.

[0005] Referring to FIG. **2**, photovoltaic modules fabricated using the methods discussed herein may be incorporated into one or more photovoltaic arrays **1000** that are mounted on a photovoltaic module mounting assembly **200**. The arrays **200** may be incorporated into various systems for generating electricity. Electricity is produced as photons in sunlight pass through the front support **11** and are absorbed by the active material **13** (FIG. **1**B). When a photon is absorbed, its energy generates electron-hole pairs that create an electric field at the p-n junction of the photovoltaic cell **10** formed by the window and absorber layers. The p-n junction acts as a diode permitting photocurrent to flow in one direction. The photocurrent may be collected and converted from direct current (DC) to alternating current (AC) and distributed to a power grid. Light of any suitable wavelength may be directed at the module to produce the photocurrent, including, for example, light of wavelengths between 400 nm and 700 nm. Photocurrent generated from one photovoltaic module **100** may be combined with photocurrent generated from other photovoltaic modules **100**. For example, the photovoltaic modules **100** may be part of a large photovoltaic array **200**, from which the aggregate current may be harnessed and distributed.

[0006] As shown in FIG. **2**, one example of the mounting assembly **200** can include a plurality of supporting beams **210** and a plurality of supporting rails **220**. The supporting beams **210** are substantially parallel to each other. The supporting rails **220** are substantially parallel to each other and are fastened substantially perpendicular to the supporting beams **210** using connectors **230**. A plurality of clamps **240** (**240***a*, **240***b* and **240***c*) are attached to each supporting rail **220**. A pair of clamps **240** are spaced apart on rails **220** to hold edge portions of the longer length (L) side of a photovoltaic module **100**. Each clamp **240** has a back edge **250***a* that is closer to the beam **210** and a front edge **250***b* that overlaps the module **100** and extends over the edge delete area **20** and which is closer to the center of the photovoltaic module **100**. As shown in FIG. **2**, the clamps **240** extend over the modules **100** a certain distance beyond the edge delete area **20** of the module **100** thereby covering at least a portion of a plurality of photovoltaic cells **10**.

[0007] In field operation, arrays **1000** can be subject to high voltage biasing at the clamp **240** areas under certain electrical connection and grounding conditions. At the clamp **240** areas, the front support **11** can have a positive electrical potential up to several hundred volts relative to the first conductive material **12** and other materials of the photovoltaic cell **10**. It has been found that the high voltage biasing effect at the clamp **240** areas can significantly reduce the maximum power and efficiency of the module **100**. Accordingly, there is a need for a mounting clamp and mounting clamp configuration for installing photovoltaic module arrays, which mitigates the reduction in power and efficiency of the module **100**.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIGS. **1**A and **1**B respectively show a top view and a side view of a photovoltaic module;

[0009] FIG. **2** is a schematic of a photovoltaic array installed on a photovoltaic module mounting assembly;

[0010] FIG. **3** is a schematic of a mounting clamp holding a portion of a photovoltaic module;

[0011] FIGS. **4**A and **4**B show voltage-current curves for a typical photovoltaic cell;

[0012] FIG. **5** shows a portion of a photovoltaic module after high voltage biasing at a mounting clamp area;

[0013] FIG. **6**A is a top view of a photovoltaic module mounting assembly in accordance with a disclosed embodiment;

[0014] FIGS. **6**B and **6**C show a supporting element having a prefabricated clamp in accordance with a disclosed embodiment;

[0015] FIG. **7** depicts steps for installing a photovoltaic module on a photovoltaic module mounting assembly in accordance with a disclosed embodiment;

[0016] FIG. **8** is a top view of a photovoltaic module mounting assembly in accordance with a disclosed embodiment; and

[0017] FIG. **9** is a schematic of a mounting clamp holding a portion of a photovoltaic module in accordance with a disclosed embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0018] In the following detailed description, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration specific embodiments that may be practiced. It should be understood that like reference numbers represent like elements throughout the drawings. These embodiments are described in sufficient detail to enable those skilled in the art to make and use them, and it is to be understood that structural, material, electrical, and procedural changes may be made to the specific embodiments disclosed, only some of which are discussed in detail below.

[0019] Described herein are embodiments of a photovoltaic module mounting assembly having mounting clamps for connecting multiple photovoltaic modules to support rails. One embodiment of the mounting assembly includes mounting clamps arranged such that a plurality of clamps on the same side edge of a module are positioned on the mounting assembly parallel to the scribe lines of the module. Another embodiment of the mounting assembly uses mounting clamps that are configured to hold a portion of the module at a predetermined distance away from the photovoltaic cells of the module.

[0020] FIG. **3** shows in greater detail the top part of a mounting clamp **240** which holds an edge portion of the longer length (L) side of the photovoltaic module **100**, in accordance with the conventional mounting assembly **200** shown in FIG. **2**. The module **100** has a plurality of photovoltaic cells **10** formed on a front support **11**. The clamp **240** has a length of about 250 mm and a width of about 25 mm. Looking at the module **100** from the top down, i.e., from the front support **11** to the cells **10**, the clamp **240** extends a certain distance **270** over the front support **11** such as, for example, a distance **260** of 1 mm to 2 mm, beyond the edge delete area **20** on the longer length (L) side of the module **100**, thereby overlying portions of a plurality of cells **10** of the module **100**. By way of example, the front support **11** of the module **100** is about 3.2 mm thick and the photovoltaic cell is about 4 μm thick.

[0021] The front support **11** is typically made of soda lime glass, which is comprised of mostly silicon oxide (or silica), an alkali such as sodium bicarbonate (or soda) and lime Soda-lime glass has a substantial percentage of sodium ions, which can migrate across silicon oxide through Coulomb's law of attraction. That is, the force of attraction between two oppositely charged particles is directly proportional to the charges of the particles and inversely proportional to the square of the distance between them. Sodium ion (Na+) is the most mobile alkali charge carrier and can easily break away from the Coulomb bond and migrate through random diffusion or be driven to a cathode under an electric field. Assuming the photovoltaic module **100** can generate about 100 V, then ten series connected modules **100** in an array **1000** can generate 1000 V. In field operation, such arrays **1000** can be subject to high voltage biasing at the clamp **240** areas. At the clamp **240** areas, the front support **11** has a positive electrical potential up to several hundred volts relative to the first conductive material **12** (FIG. **1**B) and other materials in the photovoltaic cell **10**. The electric field generated at the front support **11** to the photovoltaic cells **10** can drive sodium ions (Na+) to migrate from the front support **11** to the cells **10**, as shown in FIG. **3**. Because the cell **10** is only about 4 μm thick, mobile ions can easily migrate vertically through the cell **10**.

[0022] The migration of mobile ions can cause leakage of current through the photovoltaic cells **10** and around the edges **20** of the cells **10** leading to module performance degradation on voltage-current characteristics (i.e., IV curve). Typical voltage-current characteristics of a photovoltaic cell can be approximated using the exemplary IV curve shown in FIG. **4**A. The power delivered to a load is zero at the open circuit voltage (Voc) and the short circuit current (Isc) and reaches a maximum (P_{max}) at a finite load resistance value as shown in FIG. **4**B. The efficiency of a cell is defined as:

$$\eta_{max} = \frac{P_{max}}{P_{in}}$$

which is the ratio of the electrical power delivered to the load (P_{max}) to the power incident on the cell (P_{in}). The maximum efficiency is when power delivered to the load is P_{max}.

[0023] Photovoltaic module performance degradations at and near the clamp **240** areas can be measured using an accelerated damp heat with voltage bias test called the Damp Heat With Bias (DHWB) test. This test is used to primarily assess the resistance of modules to the electric field generated from the front support **11** to the photovoltaic cells **10** (FIG. **1**B) that can drive sodium to migrate and cause module performance degradations. The DHWB test is run in an environmental chamber typically set for an ambient temperature of 85° Celsius and a relative humidity of 85%. A −1000V biasing voltage (FIG. **3**) is applied to the front support **11** at the clamps **240** areas to simulate the biasing. During the testing period, it is estimated that sodium ions equivalent of more than 2000 milli-Coulomb/cm^2 can be driven from the front support **11** to the photovoltaic cells **10**. Laboratory DHWB testing of the module **100** under the above-described conditions for approximately 330 hours at the clamp **240** areas indicate performance degradations of up to a 20% drop in maximum power and about 15-30% drop in efficiency. The migration of mobile ions can also cause visual defects **50** to be formed on the module **100** at and near the clamp **240** areas, as shown in FIG. **5**.

[0024] FIG. **6**A is a top view of a photovoltaic module mounting assembly **600** having mounting clamps **240** (**240***a*, **240***b* and **240***c*) in accordance with an embodiment of the invention. The mounting assembly **600** includes a plurality of supporting beams **210** and a plurality of supporting rails **220**. The supporting beams **210** are substantially parallel to each other. The supporting rails **220** are substantially parallel to each other and are fastened substantially perpendicular to the supporting beams **210** using connectors **230**, such as a rivet or any other suitable fastener. A plurality of clamps **240** are attached to each supporting rail **220**. In this embodiment, the module **100** is rotated 90 degrees from the orientation of the module **100** in FIG. **2** such that the mounting clamps **240** hold edge portions of the shorter width (W) side of the module **100**. Each pair of mounting clamps **240** on a side of a module **100** is positioned on the mounting assembly **600** parallel to the scribe lines **17** of the module **100** as shown by the lines A-A' in FIG. **6**A. The beams **210**, rails **220** and clamps **240** can be made of a metal material, such as, aluminum or steel. Although FIG. **6**A shows two pairs of clamps **240** holding the shorter edge of module **100**, it shall be appreciated that any number of clamps may be used.

[0025] When looking at the module **100** from the top down in FIG. **6**A, the clamps **240** extend a certain distance over the module **100** edge beyond the edge delete area **20** such as, for example, a distance **280** of 1 mm to 2 mm, beyond the edge delete area **20** on the longer length (L) side of the module **100**. Unlike the mounting assembly **200** shown in FIG. **2**, the mounting clamps **240** cover a portion of at most one photovoltaic cell **10** when the clamps **240** are positioned along line A-A' in parallel to the scribe lines **17** of the module **100**. The mounting clamps **240** can hold a corner portion of the photovoltaic module **100** as shown in FIG. **6**A or any edge portion of the shorter width (W) side of the module **100**. Although the mounting assembly **600** is shown in FIG. **6**A holding four photovoltaic modules **100**, it should be appreciated that the assembly **600** may hold any number of photovoltaic modules **100** in any row and column configuration.

[0026] Laboratory DHWB testing of the biasing induced effects of the mounting clamps **240** placed at the shorter width (W) side of the module **100** showed significantly less performance degradation on the module **100** compared to placing the clamps **240** at the longer length (L) side of the module **100**. For example, there is about a 2% drop in efficiency when the clamps **240** hold only edge portions of the shorter width (W) side of the module **100** compared to about a 15% to 30% drop in efficiency when the clamps **240** hold edge portions of the longer length (L) side of the module **100**.

[0027] It shall be appreciated that the clamps **240** may be mounted on the rail **220** after the module **100** are placed thereon or the rails **220** may be prefabricated with clamps **240** into which the modules **100** may slide in the manner described in application Ser. No. 12/846,365, the entirety of which is incorporated herein by reference. FIG. **6**B shows a partial portion of a rail **220** having a prefabricated clamp **240***a* and a prefabricated clamp **240***b*. FIG. **6**C shows a detailed view of a portion of the rail **220** with a prefabricated clamp **240***b*. Clamps **240***a* and **240***c* hold the edge portion of one photovoltaic module **100** while clamps **240***b* hold the edge portions of two photovoltaic modules **100** as shown in FIG. **6**A. Other types of mounting clamps **240** can be mounted or prefabricated on the rails **220**.

[0028] FIG. **7** depicts steps for installing the photovoltaic module **100** on the photovoltaic module mounting assembly **600** using mounting clamps **240***b* and **240***c*. At step **710**, a first edge portion of the photovoltaic module **100** is inserted into the mounting clamp **240***b* such that scribe lines of the module **100** are oriented parallel to the mounting clamp **240***b* as described above. Next, at step **720**, the module **100** is laid down parallel to the rail **220**. Then at step **730**, a second edge portion opposite to the first edge portion of the photovoltaic module **100** is inserted into the mounting clamp **240***c*. It shall be appreciated that the placement location of the module clamps **240** on the mounting assembly **600** can be easily modified to accommodate photovoltaic modules **100** of any width and length.

[0029] FIG. **8** is a top view of an embodiment of a photovoltaic module mounting assembly **800** using mounting clamps **840** (**840***a*, **840***b* and **840***c*). Mounting clamps **840** are configured to hold an edge portion of the longer length (L) side of the module **100**. The top portion of clamp **840** has a back edge **850***a* that is closer to the beam **210** and a front edge **850***b* that is closer to the center of the photovoltaic module **100**. The front edge **850***b* of clamp **840** which overlaps module **100** is positioned at a predetermined distance **810** away from the edge of cell **10** of the module **100**. Similar to the mounting assembly **200** shown in FIG. **2**, the clamps **840** hold edge portions of the longer length (L) side of the module **100** such that the clamps **840** are positioned on the mounting assembly **800** perpendicular to the scribe lines **17** of the module **100** as shown by cross section B-B**1** in FIG. **8**. Unlike the mounting assemblies shown in FIGS. **2** and **6**A, the shape and dimension of the clamp **840** is modified in order to reduce the damaging effects caused by high voltage biasing at the clamp **840** area. The differences between clamp **840** and clamp **240** are explained below. Clamp **840** is narrower in width (C_W) than clamp **240**. The clamp **840** has a width (C_W) less than 25 millimeters, preferably less than 10 millimeters. The overlapping front edge **850***b* of clamp **840** is laterally positioned a distance **810** which is at least 1 mm away from the edge of cell **10** of the module **100**. For example, the distance **810** between the front edge **850***b* of the clamp **840** and the edge of cell **10** may be about 2 millimeters. Clamp **840** may also be shorter in length (C_L) than clamp **240**. As one example, the clamp **840** may have a width (C_W) of about 6 mm and a length (C_L) of about 150 mm. Although FIG. **8** shows two pairs of clamps **840** holding sides of the module **100**, it shall be appreciated that any number of clamps may be used.

[0030] FIG. **9** systematically shows a top portion of clamp **840***c* holding an edge portion of the longer length (L) side of the photovoltaic module **100** in accordance with FIG. **8**. In contrast to FIG. **3**, clamp **840***c* has a width (C_W) sufficiently narrow such that the front edge **850***b* of clamp **840***c* is a predetermined distance **810** of least 1 mm away from the edge of cell **10** of the module **100**. The front edges **850***b* of the clamps **840** shown in FIGS. **8** and **9** are each laterally positioned **2** mm away from the edge of cell **10**. By positioning the clamps **840** a predetermined distance **810** away from the edge of cell **10**, the sodium ions and other mobile ions must migrate an additional minimum distance **810** laterally along the front support **11** to reach a photovoltaic cell **10**. Electroluminescence imaging and optical micrographs of the mounting clamp **840** areas in the mounting assembly **800** showed almost no damage (e.g., visual defects or shunting) on the module **100**. In addition, laboratory DHWB testing of the biasing induced effects of using the mounting clamps **840** showed significantly less performance degradation on the module **1.00** compared to using the clamps **240** that covered portions of multiple cells **10**. For example, the use of mounting clamps **840** in the manner described above with respect to FIG. **8** resulted in only about a 3% drop in maximum efficiency and about a 2% drop in maximum power. By contrast, the use of mounting clamps **240** resulted in about a 15% to 30% drop in maximum efficiency and power. It shall be appreciated that the placement location of the module clamps **840** on the mounting assembly **800** can be easily modified to accommodate photovoltaic modules **100** of any width and length.

[0031] It shall be appreciated that the placement of the clamps **240** in embodiment of FIG. **6**A may be combined with the configuration of the clamps **840** in embodiment of FIG. **8** to further minimize the effects of the biasing on module performance. The embodiments described above are offered by way of illustration and example. It should be understood that the examples provided above may be altered in certain respects and still remain within the scope of the claims. It should be appreciated that, while the invention has been described with reference to the above example embodiments, other embodiments are within the scope of the claims.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. An apparatus for holding an edge portion of a photovoltaic module, comprising:

a support element; and

a mounting clamp attached to the support element, the mounting clamp being positioned parallel to scribe lines of the photovoltaic module when holding the edge portion of the photovoltaic module such that at most a single photovoltaic cell of the photovoltaic module is covered by the mounting clamp.

2. The apparatus of claim **1**, wherein the mounting clamp extends beyond an edge delete area of the photovoltaic module.

3. The apparatus of claim **1**, wherein a front edge of the mounting clamp is laterally positioned at least 1 millimeter away from a photovoltaic cell of the photovoltaic module when viewing the module top down such that no photovoltaic cell is covered by the mounting clamp.

4. The apparatus of claim **3**, wherein the mounting clamp is positioned perpendicular to scribe lines of the photovoltaic module when holding the edge portion of the photovoltaic module.

5. The apparatus of claim **3**, wherein the front edge of the mounting clamp is laterally positioned about 2 millimeters away from any photovoltaic cell of the photovoltaic module.

6. The apparatus of claim **3**, wherein the mounting clamp has a width of less than 25 millimeters.

7. The apparatus of claim **6**, wherein the mounting clamp has a width of approximately 6 millimeters.

8. The apparatus of claim **3**, wherein the mounting clamp has a length of approximately 150 millimeters.

9. The apparatus of claim **1**, wherein the mounting clamp has a width of less than 10 millimeters.

10. The apparatus of claim **1**, wherein the mounting clamp holds edge portions of two adjacent photovoltaic modules.

11. The apparatus of claim **1**, further comprising:

a plurality of rails spaced apart; and

at least one pair of mounting clamps for holding edge portions of a photovoltaic module, the pair of mounting clamps being positioned parallel to scribe lines of the photovoltaic module when holding the edge portions of the photovoltaic module such that at most a single photovoltaic cell of the photovoltaic module is covered by the pair of mounting clamps.

12. The photovoltaic module mounting assembly of claim **11**, wherein each mounting clamp holds a corner edge portion of the photovoltaic module.

13. The photovoltaic module mounting assembly of claim **11**, wherein the photovoltaic module is installed on the photovoltaic module mounting assembly such that a front edge of a respective mounting clamp is laterally positioned at least 1 millimeter away from a photovoltaic cell of the photovoltaic module when viewing the module top down.

14. A photovoltaic module mounting assembly, comprising:

a plurality of rails spaced apart; and

at least one pair of mounting clamps for holding edge portions of a photovoltaic module, a top portion of each mounting clamp is located above an edge delete area of the photovoltaic module and has a front edge that is laterally positioned at least 1 millimeter away from a photovoltaic cell of the photovoltaic module.

15. The photovoltaic module mounting assembly of claim **14**, wherein each mounting clamp of the pair is positioned parallel to scribe lines of the photovoltaic module when holding the edge portion of the photovoltaic module such that at most a single photovoltaic cell of the photovoltaic module is covered by the pair of mounting clamps.

16. The photovoltaic module mounting assembly of claim **14**, wherein the front edge of each mounting clamp of the pair is laterally positioned about 2 millimeters away from any photovoltaic cell of the photovoltaic module.

17. The photovoltaic module mounting assembly of claim **14** wherein each mounting clamp of the pair has a width of less than 10 millimeters.

18. The photovoltaic module mounting assembly of claim **14**, wherein each mounting clamp of the pair holds a corner edge portion of the photovoltaic module.

19. A method of installing a photovoltaic module on a support element having preassembled mounting clamps, the method comprising:

inserting a first edge portion of the photovoltaic module into a first mounting clamp such that scribe lines of the photovoltaic module are positioned parallel to the first mounting clamp and at most a single photovoltaic cell of the photovoltaic module is covered by the first mounting clamp when holding the first edge portion;

laying the photovoltaic module parallel to the support element; and

inserting a second edge portion opposite to the first edge portion of the photovoltaic module into a second mounting clamp on the support element opposite to the first mounting clamp.

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