METHOD FOR MANUFACTURING THIN CRYSTALLINE SOLAR CELLS PRE-ASSEMBLED ON A PANEL

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates generally to methods and systems for fabricating photovoltaic (PV) solar cells. More particularly, it relates to fabricating arrays of solar cells by partially fabricating PV cell structures on donor wafers having a separation layer, laminating multiple donor wafers to a substrate and exfoliating the thin PV cell structures from the donor wafers, and then simultaneously completing the PV cell structures.

[0003] 2. Description of the Related Art

[0004] Silicon is the basic ingredient of many solar cell technologies ranging from thin-film amorphous silicon solar cells to single-crystal silicon wafer-based solar cells. High efficiency solar cells start with electronic or solar grade polysilicon grown by chemical vapor deposition. The polysilicon is melted and ingots are pulled from the melt in the Czochralski process. The silicon ingot is then sliced into thin wafers by sawing, and solar cells are formed on the wafers by traditional semiconductor techniques and interconnected and packaged to last at least 25 years. Such silicon wafers are relatively expensive and thus severely impact the costs of solar cells in formed and packaged in the standard wafers.

[0005] Throughout the past quarter century, significant innovations in all aspects of solar cell manufacture has allowed significant reduction in cost. For example, from 1990 to 2006, wafers have decreased in thickness from 400 μm to 200 μm. However, the cost of crystalline silicon still constitutes a significant part of the overall cost, as measured by many of the metrics used to characterize the cost of crystalline solar technology.

[0006] A flow chart of a conventional process for manufacturing solar panels is illustrated in FIG. **1**. Stock blank monocrystalline wafers cut from an ingot are supplied in block **102**. Saws shape ingots into a quasi-square cross section having rounded corners, and the squared ingot is cut or wafered into individual wafers. The silicon wafers are used in step **104** as substrates for fabricating the structure of the photovoltaic (PV) cell structure, which is fundamentally a vertically oriented photodiode on the top surface of the wafers. The fabrication process uses epitaxial or diffusion furnace methods to form the required thin silicon layers doped n-type and p-type. After the PV cells have been fabricated, the wafer tiles are then assembled in step **108** onto a panel substrate in an X-Y array, and contacts to the n-type and p-type layers are added, often by screen printing or sputter deposition of metals onto the PV wafers followed by soldering tinned copper ribbons to bus bars of the deposited metal.

[0007] Further reductions in silicon thickness, and thereby the cost of monocrystalline silicon solar cells, is expected to be best offered by techniques in which a monocrystalline silicon substrate, often referred to as a "donor wafer" or sometimes "donor wafer" or "substrate wafer", is first treated to form a separation layer. Then a thin epitaxial silicon layer is deposited on the treated surface, and finally the deposited epitaxial layer is separated from the donor wafer to be used as thin (2-100 μm) single crystal silicon solar cells. The donor wafer is thereafter sequentially re-used to form several additional such epitaxial layers, each producing its own solar cell. There are several known standard techniques for growing the separation layer, such as forming a composite porous silicon layer by anodically etching a discontinuous oxide masking layer, or by high energy implantation of oxygen or hydrogen to form the separation layer within the donor wafer.

[0008] The epitaxial silicon layer that is formed needs to be separated intact from the donor wafer with little damage in order to thereafter fabricate the eventual solar cell module. We believe that this separation process is preferably done by 'peeling' in the case where the separation layer is highly porous silicon. Peeling implies parting of an interface starting from one edge and continuing until complete separation occurs.

[0009] It has been difficult or impossible to handle very thin solar cells using the prior art process in which individual PC cells are formed prior to assembly into the final X-Y array needed for a completed solar panel.

[0010] One basic process in the prior art for manufacturing epitaxial single crystal silicon solar modules includes the following steps: (1) forming a separation layer on a relatively thick, single crystal silicon substrate; (2) growing a single crystal epitaxial layer and fabricating the solar cells on the epitaxial layer and the basic cell interconnections on the solar cells; (3) separating the epitaxial layer at the cell level; and (4) assembling and packaging several such cells to form a solar panel. Despite the great potential of this prior art method for producing relatively inexpensive, highly efficient solar cells, the method has eluded commercial success for at least three main reasons: (1) some of the unit processes are deficient and difficult to reproduce; (2) manufacturing strategy generally starts and ends with making individual wafer-size solar cells and, thereafter, assembling them into solar panels; and (3) thin cells separated from their donor wafers and prior to bonding to foreign substrates easily break and often warp because of layers of different materials deposited on them. The last two problems arise in part from handling the thin epitaxial photovoltaic layer between its separation from the donor wafer and its assembly on the panel along with other such epitaxial photovoltaic layers. As a result, economical processing awaits the development of new tools and equipment.

SUMMARY OF THE INVENTION

[0011] A general aspect of the invention involves forming a photovoltaic junction as a solar cell in an epitaxial layer grown on a donor wafer or by diffusion of the appropriate dopant (boron or phosphous) into the epitaxial layer, depositing anti-reflection layers on the junctions, making metal contacts in the form of a grid, and attaching plural such donor wafers to a mounting substrate with the epitaxial layer adjacent the mounting substrate, and separating the donor wafers from the epitaxial layers still attached to the mounting substrate. In different embodiments, the mounting substrate may be a transparent glass adhered to the front side of solar cells or adhered to the back side of the solar cells so that a non-transparent mounting substrate may be used.

[0012] Some inter-cell interconnections may be included in the adhesive laminating the epitaxial layers of the solar cells with the mounting substrate.

[0013] One aspect of the invention includes forming interdigitated backside contact photovoltaic (PV) cells on a multiplicity of donor wafers, followed by tabbing and stringing of the PV cell contacts and lamination of the multiplicity of donor wafers to a substrate using a first adhesion layer. The backsides of the donor wafers are then clamped to a chuck