ADVANCED HIGH EFFICIENTCY CRYSTALLINE SOLAR CELL FABRICATION METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to co-pending U.S. Provisional Application Ser. No. 61/210,545, filed Mar. 20, 2009, entitled "ADVANCED HIGH EFFICIENCY CRYSTALLINE SOLAR CELL FABRICATION METHOD," which is hereby incorporated by reference as if set forth herein.

FIELD OF THE INVENTION

[0002] The present invention relates generally to the field of solar cells. More particularly, the present invention relates to solar cell devices and methods of their formation.

BACKGROUND OF THE INVENTION

[0003] The present invention addresses advanced methods for the fabrication of high efficiency crystalline solar cells that are enabled by the use of unique implant and annealing methodology, in contrast to the older methods of diffusion doping and metallization by screen printing.

[0004] Use of diffusion of dopant from the surface in to the substrate is plagued by problems. One of the main issues is the snow plowing of the dopants near the surface as the dopants are driven in to the bulk of the material, which can vary the resistivity in different regions of the substrate and thus lead to varying light absorption and electron hole formation performance that can result in excess surface recombination (i.e., a "dead layer"). In particular, one problem encountered is the lack of utilization of the blue light as the result of formation of such "dead layer."

[0005] Additionally, lateral positioning of the dopants across the substrate is becoming difficult as the line widths and wafer thicknesses are getting smaller. The solar cell industry is expected to require dopant lateral placements, for selective emitter and interdigitated back contact applications for example, to be from 200 microns down to less than 50 microns, which is extremely difficult for the present methodology of diffusion and screen printing. Moreover, as the wafers get thinner from 150-200 microns of today to 50 microns and below, vertical and batch diffusion and contact screen printing becomes extremely difficult or even impossible.

SUMMARY OF THE INVENTION

[0006] The present invention provides alternative fabrications methods, that in part or as a whole can provide higher efficiency solar cells. It utilizes directed implant techniques to form various emitter regions and doped back surface field (BSF), both homogeneous and selective emitter regions in an interdigitated back surface contact (IBC) cell, as well as formation of mesotaxial layers (seed implants). The BSF can comprise homogeneous or selective emitter regions for interdigitated formation of alternative doping regions in order to eliminate front surface shading. The present invention also addresses the formation of contacts to emitters and BSF regions through selective metallization, either by implantation, laser, plating, or ink jet printing. The essence of the first discovery is the use of a very cost effective self-aligned selective implant method that simplifies the cell processing.

[0007] Some of the advantages of this methodology are to minimize the resistance of contact, busbar, fingers, contact resistance of metal-silicon interface, resistance of backside metallization, and achieving the desired resistivity under the grid contact and in between the fingers. Moreover, the advantageous formation of selective emitter and BSF and its ability to improve performance is made possible by the present invention. It can be applied to as-grown single or mono-crystalline, poly or multi-crystalline silicon, as well as very thin film deposited silicon, or other materials used for solar cell formation and other applications. It can also be extended to atomic species placement for any other material used in fabrication of junctions or contacts.

[0008] Application specific ion implantation and annealing systems and methods are adopted to provide the appropriate placement of dopant both within the bulk of the material and laterally positioned across the substrate. Accordingly, the present invention can employ the fabrication methods and systems discussed in U.S. patent application Ser. No. 12/483,017, entitled "FORMATION OF SOLAR CELL-SELECTIVE EMITTER USING IMPLANT AND ANNEAL METHOD," filed Jun. 11, 2009, and in U.S. Provisional Application No. 61/131,698, entitled "FORMATION OF SOLAR CELL-SELECTIVE EMITTER USING IMPLANT AND ANNEAL METHOD," filed Jun. 11, 2008, which are both hereby incorporated by reference as if set forth herein. These patent applications disclose the ability to independently control any species and dopant positioning and provide the necessary surface concentration, junction depth, and shape of the dopant profile. In these patent applications, an Application Specific Implanter is described that can provide a plurality of dopants, selectively and otherwise. The present invention can also include the impact of surface conditionings and variability of texturing discussed in U.S. patent application Ser. No. 12/482,947, entitled "APPLICATION SPECIFIC IMPLANT SYSTEM AND METHOD FOR USE IN SOLAR CELL FABRICATIONS," filed Jun. 11, 2009, and in U.S. Provisional Application No. 61/131,688, entitled "APPLICATIONS SPECIFIC IMPLANT SYSTEM AND METHOD FOR USE IN SOLAR CELL FABRICATIONS," filed Jun. 11, 2008, which are both hereby incorporated by reference as if set forth herein. In present invention, the use of accurate and highly placed dopant and tailoring of dopant atomic profile methods are employed in order to provide heavily doped selective emitter regions (e.g., 10-40 Ohms/square) placed under the grid line, as well as methods to achieve lightly doped homogeneous emitter regions (e.g., 80-160 Ohms/square) in between grid fingers. Additionally, through the use of tailored parameters, the atomic dopant profile is simultaneously matched to provide the electrical junctions at the appropriate depth against the substrate doping levels and provide the resistivity required for the formation of the contacts on the surface. In some embodiments, use of retrograde doping and flat atomic profile (box junctions) are also employed. Furthermore, such capability will allow for independent doping of surfaces, such as emitter and BSF. Again, selective dopant capability can allow for an interdigitated doping profile on the back surface that eliminates the front surface shadowing. It is proposed that such capability alone can provide efficiency gains in advance of 1 to 2 absolute percentage points.

[0009] Furthermore, since the positioning of the dopant placement through ion implantation is highly controlled, side and back side doping can be controlled or minimized to avoid