FROM ILLUMINATING OUR LIVES AND SOULS TO ILLUMINATING OUR LIVING

From purely transparent material to electricity generation – glass now has this added feature with the application of solar cells. Highly efficient, photovoltaic solar cells can now be used in combination with glass or other transparent materials, with advantages such as cost effectiveness, it can be readily manufactured and its reflection and transparency can be controlled.

David Ward*

First generation of Power Glass™

Stained glass windows showed us the beauty of sunlight and how God illuminates our lives, and now we have Power Glass™ that can illuminate our living and working space too, with its very thin semi-transparent coatings and films that create see-through solar cell structures.

Ever since pane glass was invented, and dwellings could finally keep out the cold and keep in the heat, housing has gone from being a means of shelter to one of living ambient and surroundings. Now, some 400 years later, *industrialized* pane glass has been given an additional function, the generation of electricity…….while keeping all the other features that sparked its original success.

Since the inception of modern photovoltaics, the relatively young solar cell industry has made tremendous strides in improving the efficiency of solar products. However, it is fair to say that nearly all of the work to improve solar cells has been done with the goal of improving their efficiency and/or reducing cost. Much less effort has been placed in adapting solar technologies to suit applications and the environments in which they are used.

Second generation of Power Glass™

SOLAR TECHNOLOGY

Essentially, photovoltaic technology development has followed three routes:

1. crystalline silicon solar cells that are obtained by melting and drawing from an ingot of crystalline silicon or as a ribbon and then placing a conductor on either side of the resulting solar cell;
2. polycrystalline silicon solar cells that may be formed as thin layers on wafers and can thus be made much thinner than crystalline silicon solar cells. Polycrystalline silicon can be formed by heating amorphous silicon;
3. a third type of solar cell has been formed using doped layers of amorphous silicon. These are not subject to some of the problems inherent in crystalline silicon or polycrystalline solar cells. First, amorphous silicon can be formed using low temperature processes. Thus, it can be formed on plastic and other flexible substrates. They can also be formed over large surfaces. Second, the processing techniques are less expensive. Unfortunately amorphous silicon cells are opaque.

So far, and in summary, these technologies have been limited either by their properties e.g. efficiency in generating electricity or transparency, and by the manufacturing processes involved.

INNOVATIVE TECHNOLOGY

Now, *XsunX Inc.*, based in California, United States, has developed a new innovative technology that has shifted focus from the *how* to *how and where,* i.e. making sure that solar technologies are used more effectively. In other words, the company's approach has been to combine technology with application, together with a good measure of massification. In particular, XsunX has focused on integrating alternative energy technologies into some of the most commonly used building materials: architectural glass, plastics and thin-films.

To achieve this goal, XsunX has purposefully developed very thin semi-transparent coatings and films that create large area monolithic solar cell structures that you can see through. This has taken several years to achieve but, as is testified by the two pictures, giant steps have been achieved and that have effectively moved the technology forward in a very short space of time. The end product is *Power Glass™*.

POWER GLASS™

The semi-transparency of Power Glass™ makes it desirable for glazing purposes, while maintaining photovoltaic energy generation. The inherent technology makes it applicable also to other materials such as plastics and other see-through structures such as composite windows. The success of the technology is also based on patented processes, such as reel-to-reel manufacturing techniques and multi-terminal cell structure designs. Future development involves the commercialization of large area cell manufacturing processes for thin film flexible plastics.

The basic invention of Power Glass™ thus provides a solar cell and method of its manufacture. It combines the following advantages:

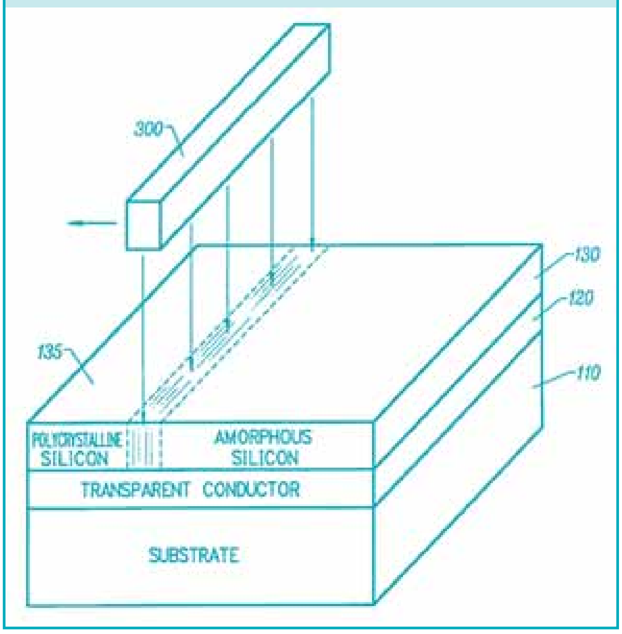
- *it is transparent and therefore can be used in places not applicable to existing solar cells e.g. buildings;*
- *it is cost effective because it uses a thin film amorphous silicon;*
- *it may be readily manufactured because the method for manufacture uses commercially available CVD and laser annealing equipment;*
- *it can be used on a wide variety of substrates including low temperature substrates such us plastics;*
- *reflection and transparency can be controlled.*

The resulting solar cell is thin, flexible, and easy to make and use with conventional semiconductor processes. The solar cells also operate effectively as optical filters.

Production method

The method includes steps of providing a substrate, of which several combinations of structure have been developed and patented. For example, in one version, the structure includes a transparent substrate, which can be selected from glass, crystal, plastic, Mylar, and other substrates, including those that have low melting points. A conductive layer is formed overlying the transparent substrate. A first polycrystalline silicon layer

Fabrication method for a transparent solar cell structure



SCIENCE & TECHNOLOGY

from a first amorphous silicon layer of a first dopant type is formed overlying the first conductive layer. The structure also includes a second polycrystalline silicon layer from a second amorphous silicon layer of a second dopant type overlying the first polycrystalline silicon layer, and a second conductive layer overlying the second polycrystalline silicon layer. The combination of these layers forms a transparent structure.

Transparent solar cell structure

A further aspect of the inventions behind Power Glass™ includes a method for fabricating a transparent solar cell structure. Numerous advantages are achieved with this technique over conventional techniques for forming solar cells. For example, the present method uses conventional equipment and processes from semiconductor operations to manufacture the solar cells.

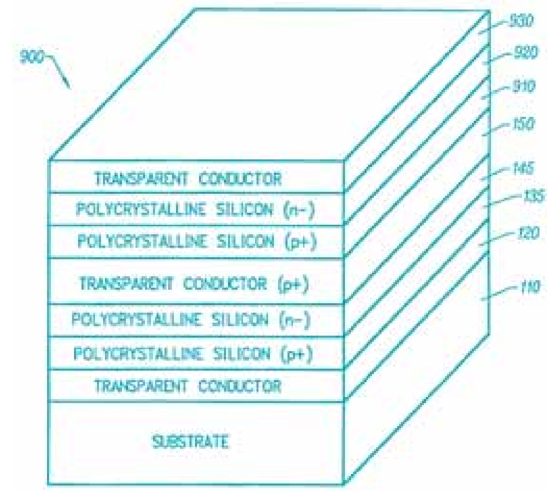
One technique involves an Excimer laser to anneal the amorphous silicon layers. Use of a laser allows the forming of polycrystalline silicon without exposing the substrate to high temperature that will distort or destroy it. Therefore, low melting point materials such as plastic may be used. A major breakthrough has therefore been the processing temperature, which allows the use of a substrate with a melting temperature of less than 450°C.

SOLAR CELL STRUCTURES

In order to protect its invention, XsunX has patented several solar cell structures.

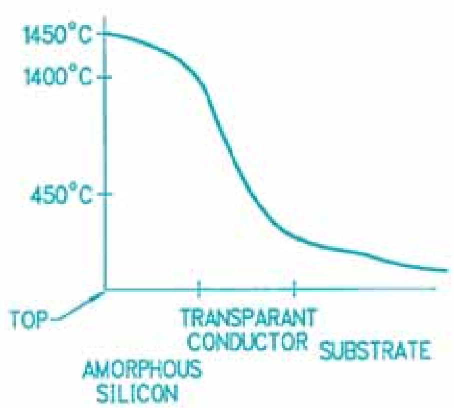
In one embodiment, the method includes forming a first conductive layer (120) overlying a transparent substrate (110), and forming a first amorphous silicon layer overlying the first conductive layer (120). Solar cell manufacturing includes converting the first amorphous silicon layer into a first polycrystalline silicon; and forming a second amorphous silicon layer overlying the first amorphous silicon layer (135). This is repeated for the second amorphous silicon layer into a second polycrystalline silicon (145). Following this, a second conductive layer (150) overlying the second amorphous silicon layer (145) is formed. The combination of these steps provides a transparent solar cell structure overlying the substrate.

Solar cell structure, possibilities of replication and stacking



The structure and process can be replicated and stacked as shown. In operation, i.e. sunlight, the P-N junction develops a typical 0.46 Volt potential at approximately 7mA/cm but higher orders of magnitude are obtainable. Even if the design efficiency is lower than opaque crystalline solar cells (2-3 per cent versus 13 per cent), this is compensated by the efficient use of surface area.

Behaviour of the structure



All of the solar cells developed can be transparent, which makes them desirable for placing over glass and other see-through structures. Also, the present cell structure is extremely thin and efficient and can be implemented on a variety of applications. For example, it can be formed on a flexible substrate while substantially maintain the flexibility of the substrate.

PATENTS

In view of these advances and applications, in September 2004, XsunX entered into a royalty-free agreement for the licensing of a portfolio of patents and technologies that cover a wide area of both solar cell structure, and design and manufacturing processes. The company is now pushing and establishing viable manufacturing techniques for increasing the active power producing ratios of the glazing to as near 100 per cent as possible (i.e. the percentage of total area coated by the glazing that converts sunlight to usable electrical energy as compared to the total size or area of glass or other transparent substrates covered by the glazing).

When this technology hits the market, it is surely going to make its mark although its dissemination will depend, as for all renewable and alternative energy sources, on several factors, ranging from cost of the technology to the price of oil. Right now this technology is certainly in a very strong position to succeed.

*Science and Technology Correspondent