New solar cell production process may improve efficiency and reduce cost

Mustapha Lemiti, Anne Kaminski, Alain Fave, and Erwann Fourmond

Solar cells can be made better and less expensively by creating them on a sacrificial silicon layer and then transferring them to a low-cost substrate.

Photovoltaics is a renewable energy that can reduce pollution and climate change effects. A serious alternative to fossil energy, the solar industry is showing exponential growth in production. Currently about 90% of fabricated solar modules are made of crystalline silicon. Materials costs represent about 45% of the total module price. One way to make the photovoltaic industry more competitive is to reduce the consumption of silicon and increase the efficiency of solar cells.

Approaches to trimming materials costs include replacing crystalline silicon with silicon thin films deposited on cheap substrates at low temperatures. However, the efficiency of solar cells made using this technique is limited by the low quality of the material. Cutting thinner wafers of crystalline silicon from the ingot can also decrease costs, but mechanical problems limit this method. We are developing silicon thin films that are epitaxially grown on a sacrificial layer and transferred to a cheap foreign substrate. To maximize the potential of this material, we combine it with rear contact solar cell technology.

Figure 1 illustrates the process we use to create these solar cells. First, we create a sacrificial porous silicon layer on top of a monocrystalline silicon substrate. A high-quality single-crystal silicon film is then grown by epitaxy on this surface. The rear contact solar cell is created on this film. All metallic contacts are deposited on the rear side of the cell to avoid shadowing effects and to allow high efficiencies. A low-cost substrate (glass or ceramic) is then stuck on the back side of the cell. Using the sacrificial layer, the cell is separated from the initial wafer, which can be recycled several times.

The porous sacrificial layer, made by the electrochemical anodization of silicon, actually contains two layers: one with low porosity to facilitate growth of a high-quality epitaxial layer and one with high porosity to permit separation at the end of the process (see Figure 2). The epitaxy of the 50µm-thick silicon layer is performed by either liquid or vapor phase epitaxy (1µm/min). The usual growth temperature is 1000°C, but we are also studying the possibility of low-temperature liquid-phase epitaxy (< 900°C).

Continued on next page
At first we optimized the rear contact solar cell by 2D simulation and manufactured it using photolithography. To simplify this process, we developed a new self-aligning process (see Figure 3) based on anisotropic etching of silicon after metallization of the emitter. During creation of the solar cell, the front surface is carefully passivated by silicon nitride. We have optimized the stoichiometry of the silicon nitride to obtain the best compromise between the passivation and antireflection properties of the layer. We are also studying the possibility of enhancing the efficiency of the solar cell using the luminescence effect of silicon nanocrystals embedded in the silicon nitride layer. Finally, the solar cell is attached to a cheap substrate and separated mechanically from its original silicon substrate. This can be reused in a new cycle. The process has been tested several times on the same initial substrate.

The main limitations on photovoltaic energy development are material cost and efficiency. We can overcome these problems by creating high-efficiency solar cells on epitaxially grown single-crystal silicon on a sacrificial porous silicon layer. We have demonstrated the feasibility of this process on 2in. wafers and are now transferring it to 4in. wafers. This will permit the process to be studied on large-area solar cells and potentially to be transferred to industry.

Author Information

Mustapha Lemiti, Anne Kaminski, Alain Fave, and Erwann Fourmond
Laboratoire de Physique de la Matière
National Institute of Applied Sciences, Lyon (INSA-Lyon)
Villeurbanne, France

Mustapha Lemiti is a professor at the Laboratoire de Physique de la Matière. His group’s research focuses mainly on the production and characterization of crystalline silicon solar cells.

Anne Kaminski is an assistant professor at INSA-Lyon. She specializes in solar cell design, technology, and characterization.

Alain Fave is an assistant professor at INSA-Lyon. He is involved in silicon epitaxy and solar cell technology.

Erwann Fourmond is an assistant professor at INSA-Lyon. He works on plasma deposition systems as well as solar cell technology and characterization.

References