METHOD OF MANUFACTURING CRYSTALLINE SILICON SOLAR CELLS WITH IMPROVED SURFACE PASSIVATION

[0001] This application is a national stage application that claims priority under 35 U.S.C. 371 to Patent Cooperation Treaty Application No. PCT/NL2007/050459, entitled "Method of Manufacturing Crystalline Silicon Solar Cells With Improved Surface Passivation," inventors Komatsu, Yuji et al., filed Sep. 20, 2007, and which has been published as Publication No. WO2008/039067, which claims priority of The Netherlands patent application No. 2000248 filed Sep. 25, 2006, both of which applications are herein incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to the manufacture of solar cells. It more particularly relates to a method of manufacturing crystalline silicon solar cells comprising a silicon oxide passivation layer and a dielectric coating.

BACKGROUND OF THE INVENTION

[0003] Solar cells made of single- or multi-crystalline silicon are usually provided with a dielectric coating on a front side (i.e. the light incident side) in order to lead the incident light effectively to the semiconductor layer. Such a dielectric coating is often referred to as anti-reflection coating (ARC) film.

[0004] The performance of a solar cell is largely influenced by the degree of suppression of recombination of the photo-generated carriers at the interface between the semiconductor layer and the ARC film. Suppression of recombination of the photo-generated carriers is normally realized using what is called surface passivation.

[0005] As an ARC film for multi-crystalline silicon solar cell, a silicon nitride film is often used because it has a good anti-reflecting effect and a sufficient surface passivation effect can be expected. It is also used for single crystalline silicon solar cells for the same reason. Alternatively, a thermal oxide film is used in which case more effective surface passivation can be expected than by silicon nitride.

[0006] Normally, a thermal oxide film with sufficient surface passivation requires a high temperature process (approximately 1000° C.), which will deteriorate the efficiency of the solar cells. Additionally, the refraction index of thermal oxide film (1.45) is too low for the proper ARC for silicon solar cells.

[0007] In crystalline silicon solar cells, a back surface field (BSF) layer is usually formed by coating and alloying by heat treatment of an aluminium paste on the back side. The thickness of the crystalline silicon solar cell will most certainly decrease in the future because of a shortage of the silicon feedstock. This will lead to a worse effectiveness of the BSF layer since it will bend the thin substrate and will also lower the internal reflection at the back side. Nowadays, in order to replace the BSF layer, a dielectric film, such as a silicon nitride film, or a thermal silicon oxide film is adopted with a partly removed area for back side electrodes. As mentioned above, a silicon nitride film can provide a good passivation effect and a thermal oxide film can be even better. Additionally, these dielectric films can enhance the internal reflection at the back side of the solar cells as compared to aluminium BSF.

[0008] Requirements for a dielectric film deposited on a semiconductor substrate for a crystalline silicon solar cell are:

- **[0009]** formable at relatively low temperature
- **[0010]** high passivation effect
- **[0011]** anti-reflection effect when formed at the front side
- **[0012]** anti-reflection effect or enhancement of the internal reflection when formed at the back side.

[0013] For such a dielectric film, when used for optimal anti-reflection effect, the refractive index should be lower than that of silicon (3.3) and higher than that of packaging resin or cover glass (1.4~1.6). Silicon nitride film can satisfy most of the conditions above, but its passivation effect is inferior to that of a thermal oxide film. A thin thermal oxide may be inserted between the silicon and the silicon nitride, to satisfy the conditions described above, without reducing either optical effect of anti-reflecting at the front or enhancing internal reflection at the back in spite of low refractive index (1.45) of thermal oxide. A thermal oxide film with sufficient surface passivation requires a high temperature process (approximately 1000° C.), which will deteriorate the efficiency of the solar cells. However, forming a sufficiently thin (<70 nm) thermal oxide with a good surface passivation and under good control is very difficult. One possibility is to provide a thermal oxide film on the silicon substrate and then to thin the thermal oxide film by way of etching, but in that case it is impossible to create a thermal oxide film with a uniform thickness. Even though thermal oxidation at lower temperatures (around 800° C.) can form a thin oxide film to some extent, its surface passivation effect is normally low and sometimes even inferior to that of a silicon nitride film.

SUMMARY OF THE INVENTION

[0014] It is an object of the present invention to provide a method of manufacturing a crystalline silicon solar cell having a silicon substrate and a two layered structure for the surface passivation, wherein the solar cell efficiency is improved.

[0015] The object is achieved by providing a method of manufacturing a crystalline silicon solar cell, comprising:

- **[0016]** providing a crystalline silicon substrate having a front side and a back side;
- **[0017]** forming a thin silicon oxide film on at least one of the front and the back side by soaking the crystalline silicon substrate in a chemical solution;
- **[0018]** forming a dielectric coating film on the thin silicon oxide film on at least one of the front and the back side.

[0019] In the method according to an embodiment, a dielectric coating film and a thin silicon oxide film is manufactured at the front and/or at the back side of the substrate. The thin silicon oxide film is formed by soaking the crystalline silicon substrate in a chemical solution. The soaking process is well-controllable and is performed at a relative low temperature (<150° C.). So the forming of this layer will not affect the semiconductor properties of the (already doped) substrate. Furthermore, the passivation effect is comparable or even better than that of a thermal oxide. Also, by using a chemical solution for oxidation, a very thin uniform silicon oxide layer can be formed.