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Performance and Analysis of Recent Thin film Solar Cells Status and Perspectives

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Abstract : The present article gives a summary of recent technology and scientific developments in the field of thin film solar cells in various substrates layers method. Cost effective fabrication methods and cheap substrate materials make poly-silicon thin film solar cells promising candidates for photovoltaic cells applications. However, it is still the challenge for research and development to achieve the necessary high electrical material quality known from crystalline silicon wafers on glass as a prerequisite to harvest the advantages of thin film technologies. Phase crystallization methods by laser or electron beam. The status of four different thin film solar cells concepts is summarized, by comparing the technological methods, as well as the structural and electrical properties and solar cell performance of the respective materials were discussed. In the second part, highly auspicious properties regarding material quality and throughout aspects were discussed during fabrication.
Index terms : Thin film solar cell, Photovoltaic cells, Silicon wafers, Polysilicon wafers.

I. Introduction

The photovoltaic system is dominated by wafer-based crystalline silicon solar cells with a market share of almost 90%.Thin film solar cell technologies which only represent the residual part employ large-area and cost-effective manufacturing processes at significantly reduced material costs are therefore a promising alternative considering a massive global deployment of photovoltaic in the coming decades[1].However, poly silicon layers exhibit distinct advantages since they could benefit from the advantages of thin film solar cells wafer approach while maintaining the advantages of thin-film technologies[1-6].Fabricated as thin layers, polycrystalline, silicon also features all advantages of thin film technologies, namely low costs due to low material wastage with up to factor 100 less than material compared to wafer based solar cells can principally reach single junction efficiencies of more than 15% close to that of silicon wafer-based solar cells[3]. The only company that produced poly-silicon thin film solar cells on glass on industrial scale, fell victim to the crisis in the photovoltaic sector in the year 2012[9].In, the past years research in thin film solar cells with dip coating considerably moved toward, providing a roadmap to higher efficiencies at which thin film compete with incumbent technologies.

This paper reviews four technological methods for the fabrication of thin film solar cells with dip coating foreign substrates that subjects to intensive research activities in the past years. Silicon solar cell materials consisting of nanocrystallites embedded in an amorphous materials consisting of nanocrystallites embedded in an amorphous matrix and silicon wafer techniques from wafers therefore excluded from this review [3]. The second part of the paper covers three technologies in poly-silicon thin film photovoltaic's which are explored at emerging trends that have the potential to boost solar cell performance and throughout towards cost-effective and high efficiency devices, electron beam evaporation of silicon as an alternative high rate deposition techniques and then highly absorbing coefficient of thin film crystalline silicon films.Polysilicon microstructures by combining electron beam evaporation of silicon with nanoimprint lithographically structures substrates.

2. Status of Poly-Silicon Thin-Film Solar Cells

In all poly silicon fabrication approaches described here, silicon films are grown by vacuum deposition techniques onto a foreign substrate, such as a glass, and are aiming at an electrical material quality as close as possible to crystalline silicon wafer material[4]. We do not give a complete overview of the entire literature, but highlight fundamental technological aspects, chararacteristic structural and electrical material properties as well as current record solar cell results in terms of efficiency and open circuit voltage.

2.1 Solid phase crystallization

2.1.1 Technological aspects

Solid phase crystallization of amorphous silicon thin films by thermal annealing is a popular technique for the fabrication of poly silicon layers due to its technological simplicity. As only moderate temperatures around 600°C are required for the crystallization process in a time span of several hours, it has to be stable up-on poly silicon processing temperatures [2]. Diffusion of impurities into the silicon bulk has to be prohibited either by the inclusion of barriers layers are by the use of high-quality substrates. Usually this requirement results in the integration of barrier layers as pure substrates are often very expensive.

2.1.2 Structural and electrical material quality

The typical microstructure of thin films solar cells prepared by solid phase crystallization, exhibiting randomly oriented grains with a size of 1-3µm if an amorphous substrate like glass is used. The inset shows the respective Raman spectra for directly grown poly silicon and electron beam crystallized material [4]. The full width at half maximum of the transverse optical phonon mode of solid phase crystallized silicon at measure for structural order is about in the crystallized state of about 48cm.which is considerable larger than the respective value of a hydrogen passivation dopants activation and to heal out extended defects and hydrogen passivation in order to saturate silicon dangling bonds[2].The open circuit voltage increases from about 150mv up to about 500mv and accordingly the density of paramagnetic defects which can be attributed to silicon dangling bonds decreases from about under lining their clear impact of the micro structural properties of the poly silicon thin film material.

2.1.3 Solar cells

Impressive solar cells results by using solid phase crystallized thin silicon films on metal substrates[3].with an efficiency of 9.5% and an open circuit voltage of 553mv they could set a remarkable benchmark, was not possible to reproduce such high open circuit voltages in SPC grown by silicon thin-film solar cells down to the present day chemical vapor deposition they were able to grow 5 micro meter long columnar grains inside a thick crystal growth layer by using a thin film so called nucleation layer.

The record solid phase crystallization poly silicon thin film solar cell device has been developed by CSG solar with an efficiency of 10.4% demonstrated in the year 2006.Here,a textured borosilicate glass with a thermal expansion coefficient very close to that of silicon is used as a substrate, on which a silicon barrier 0-2µm thickness stack are grown by PECVD. This layer stack is subsequently exposed to SPC at around 600°C and the above mentioned defect-healing process and sophisticated contacting scheme allows for carrier collection without transparent conductive oxide layers. The light trapping concept including an advanced textured glass substrate and an optimized back reflector leads to a striking short circuit current density of almost annealing passivation process.

2.2 Epitaxial thickening of large-grained seed layers

2.2.1 Technological aspects

The idea of so called seed layer approach is the growth of a very thin silicon seed layer with excellent crystallographic properties as a template, and the transfer of the structural information into the solar cell absorber material by epitaxial thickening. Whereas SPC grown poly silicon thin films are restricted rather small grain sizes of several micrometers, poly silicon layers with substantially larger grains and a crystalline quality can be achieved by laser crystallization or aluminum induced crystallization forming the seed layer epitaxy. The crystallization of silicon and a simultaneous layer exchange process of the silicon and aluminimum film. For epitaxial thickening many different techniques have been developed, using various deposition methods at different temperatures.

2.2.2 Structural and electrical material quality

An electron backscatter diffraction image of a typical AIC seed layer grown on silicon nitride coated glass at a temperature of 425°C,the size of the grains is ranging from 10-20μm and is thus clearly larger than those of solid phase crystallization material.

However, often the full potential of such seed layers with large grains cannot be fully exploited for poly-silicon thin film solar cell applications, as the structural characteristics and electrical performance of this material are limited by intragrain defects.

2.2.3 Solar Cells

The best thin film solar cells produced by the layer approach have been developed crystallization of amorphous silicon in combination with thermal chemical vapor deposition at elevated temperatures beyond 1100°C.These very high temperatures disallow the use of common glass types. Other technological characteristics of this concept are the implementation of poly-silicon/heterojunction emitters, enabling much higher conventional diffused homo junction emitters[7].The layer approach has not been scaled up to industrial scale due to the rather complex fabrication procedure and very high process temperatures that have to be applied.

3. Prospective poly-Si thin-film solar cell technologies

In this section, the technologies which are under investigation at energise and which are example for three emerging trends in poly-si thin-film solar cells. The high rate deposition of silicon by electron beam evaporation as a high throughout and low cost alternative to conventional chemical vapor deposition [10].Poly-silicon structuring technique based on nano-imprint lithography is discussed at aiming an efficient light trapping in poly-silicon thin film absorbers. Solid phase crystallization technique for silicon thin-film solar cells using a focused line-shaped electron-beam for the high throughout fabrication of large grained poly-si material with high electrical material quality. [8]

3.1 Liquid phase crystallization of silicon by electron-beam

Poly-silicon thin films fabricated by liquid phase crystallization exhibit the largest grains and the best electrical material quality in terms of Voc. The best LPC poly-si thin-film solar cells were prepared by laser crystallization and exhibit an efficiency of 9.5%.

We describe the electron beam crystallization method in more detail as one representative method for liquid phase crystallization, electron beam crystallization setup employed at constant current heated electrons are focused electrostatically onto the substrate.[9]

Further, improvement of solar cells electrical performance is expected to achieved by optimized post crystallization treatments such as hydrogen passivation as well as embedding a defined p+ doped region at the glass/silicon interface to act as a back surface field. By an implementation of periodic light trapping structures.

4. Conclusion

The paper summarizes status and emerging trends in the field of poly-silicon thin film solar cells on foreign substrates. Four technological methods for the fabrication of poly-Si thin film solar cells are reviews that have been intensively investigated in the past years:

Solid phase crystallization, the seed layer approach, directs crystalline growth and liquid phase crystallization. The current thin-film solar cells efficiency record is held by a device fabricated by solid phase crystallization. However, limited to a solid material in terms of open circuit voltage and increasing the efficiency of voltage, the largest crystal grains with a size up to centimeters, and furthermore addresses the strict throughput constraints in industrial production with the crystallization process lasting just a few seconds. Three prospective technologies have been identified to likely further boost poly-silicon thin film solar cell towards competitive photovoltaic devices combining the advantages known from crystalline silicon wafers and thin film technology. The use of periodically textured substrates patterned by nano-imprint lithography allows for a large absorption enhancement by a factor up to 452mv. A homogeneous process of the layers is possible even if strongly textured substrate are used allowing for the implementation of advanced light trapping systems. By bringing together these three technologies which complement one another high rate deposition of silicon, light trapping and liquid phase crystallization of a high efficient poly silicon thin film solar cell device at low costs is possible.

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