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Meyer Burger‘s heterojunction cell technology

Article PV Production Annual 2013

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Heterojunction cell technology of Meyer Burger: Production processes and measuring methods

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ABSTRACT

The price of crystalline silicon feedstock has fallen significantly, which means thin-film PV must struggle even harder to increase its market share. Since all the other costs of a PV installation, such as the material for module production and system mounting and the installation expense, are constant or rising, energy harvest per area must be increased through the introduction of affordable, high-efficiency solar cell technology. Conventional PV solar cells using p-type multicrystalline or monocrystalline silicon wafers have already reached efficiency limits which cannot be exceeded by cheap improvements in production: a technology shift is therefore necessary. In view of the high-efficiency PV solar cells that have already been commercialized, the most promising technology for mass production with a minimum number of process steps is the p-type a Si:H/n-type c-Si heterojunction cell pioneered by Sanyo's heterojunction with intrinsic thin layer (HIT) technology. Testing of these cells requires longer pulse durations combined with uniformity and pulse stability. As throughput rates on cell lines continue to grow, a demand for measurement methods to support the higher speeds is created.

Introduction

In the first part of this paper, the production processes of a heterojunction cell using equipment from Roth & Rau [1] are covered in detail. In the second part, the cell measuring methodology conceived by Pasan SA [2] for high-capacitive cells (e.g. heterojunction technology – HJT) is presented.

The heterojunction cell: A breakthrough in performance and cost of ownership (COO)

Heterojunction solar cells can be fabricated using the same tools and processes, and at the same cost, using either p-type or n-type silicon wafers. Because of the electrical properties of heterojunction cells, n-type wafers with a p-type amorphous emitter are more suitable and deliver higher efficiencies. From the material point of view, n-type silicon crystals grown with the usual processes in the PV industry (solar-grade multi and Cz mono) are of much higher quality than p-type crystals, exhibiting a minority carrier lifetime of up to ten times longer. For this reason, n-type silicon has become established as the material of choice for high-efficiency cells. However, despite demonstrating good industrial feasibility and achieving high efficiencies, solar cells made with thermal diffusion of boron on n-type wafers involve much more complicated and expensive thermal processes than a simple phosphor diffusion, which reduces the advantage of the high efficiency.

A standard heterojunction solar cell is created using a few simple process steps. The initial process steps are saw damage removal and surface texturing followed by surface cleaning and an HF dip (Fig. 1). Saw damage removal and texturing make use of standard technology, while chemical cleaning must be optimized for HJT. This cleaning, however, is neither complicated nor expensive; it is integrated with the HF dip in the initial wet chemical bank at the front end of the line, replacing the conventional cleaning prior to emitter diffusion in the production of standard solar cells. Wet chemistry will no longer be used in the middle part of the line, as is the case for standard technology after the thermal diffusion, because of advantages related to production complexity and costs.

Following wet chemical preconditioning, the wafer is processed in a plasma-enhanced chemical vapour deposition (PECVD) tool for coating with ultrathin a-Si layers. Two intrinsic a-Si layers directly cover the front and rear sides of the wafer, providing excellent surface passivation; two doped a-Si layers are deposited on the intrinsic ones in order to create an emitter on the front side of the cell and a back-surface field (BSF) on the rear side. These process steps are performed in a single PECVD tool with four chambers. As the a-Si layers are very thin, the deposition process is very fast and the gas consumption very limited. The PECVD tool is capable of an industrial throughput of 2400 wafers per hour with moderate costs.

Fig. 2 shows a schematic of one of the chambers of the industrial PECVD tool, comprising a parallel-plate PECVD reactor with local plasma at RF frequency. This reactor supports the same plasma process that has been used for many decades for producing heterojunction solar cells with laboratory tools and has proved to be the process that delivers the highest quality of solar cell. These chambers are included in the HELiA$_{PECVD}$ tool from Roth & Rau. Highly advanced engineering has made it possible to achieve large-

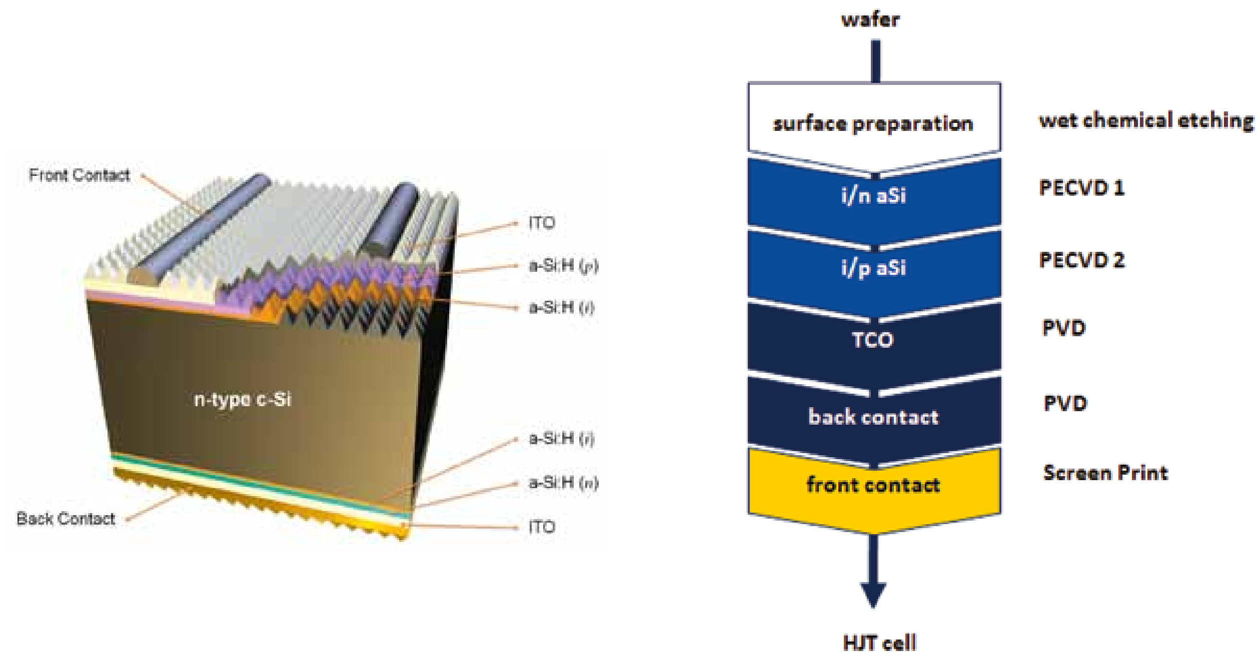

Figure 1. Schematic of the HJT cell and the process steps required to produce it [1].

scale extension of a process that until now was only possible in small laboratory reactors, while achieving comparable layer quality in terms of the uniformity and electrical properties for all wafers processed on one carrier.

After PECVD deposition using a single tool, only the deposition of the electrical contacts to extract the current remains to be performed. The contacts are deposited using a physical vapour deposition (PVD) method, and a sputtering tool is particularly well suited to this operation. A single multi-chamber sputtering tool sputters a very thin transparent conducting oxide (TCO) on both the front and rear sides of the cell at the same time; indium tin oxide (ITO) layers are very advantageous in this application, because of the good transparency and conductivity, accompanied simultaneously by good contact formation with the doped a-Si layers on the front and rear sides of the cell. A metal layer is sputtered on top of the TCO as the rear-side metallization in a subsequent chamber of the same PVD tool. Different metals are possible for this layer: silver directly on TCO together with nickel on top of silver as the rear-side metallization is the favoured combination, not only from the electrical point of view, but also in view of the solderability of the cell to ribbons for subsequent module encapsulation.

Fig. 3 shows the HELiA$_{PVD}$ tool. The two sputter chambers allow, using a single tool, the sputtering of two TCO layers at once in one chamber (on the front and back sides of the cell, with TCO targets from above and below the carrier with wafers) and two metal layers in the second chamber (on the back side of the cell, with two targets from the same side of the carrier). The process involves reactive sputtering in the case of the ITO layer. ITO and metallic targets are mounted on a rotating magnetron in the implementation of this sputtering process; it is very fast and robust and allows a very high usage of the targets. The quality of the deposited layers is excellent, with very high uniformity over the whole deposited surface in terms of not only the thickness but also the optical and electrical parameters of the layers.

Figure 2. Schematic of a PECVD chamber of the HELiA$_{PECVD}$ tool, illustrating the patented box-in-the-box concept [1]. An external chamber is pumped to a vacuum while the process takes place in the internal chamber, thus preventing contaminants from entering the process chamber from outside if leakage were to occur.

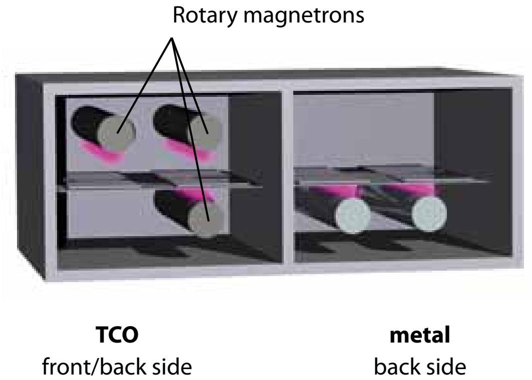

Figure 3. The Roth & Rau HELiA$_{PVD}$ tool is made up of two sputtering chambers – one for the TCO, with targets on the front and back sides, and the other for the metal, with targets only on the back side. The targets are mounted on rotating magnetrons [1].

At this stage only a single screen-printing and curing stage is required to complete the cell, which involves screen printing a conventional front-side metallization made up of fingers and busbars. An industrial screen printer is used to print an epoxy-based silver paste specifically for heterojunction cells, which is then cured using a simple thermal process at temperatures as low as the typical PECVD deposition temperature. After this has been done, the cell is ready for stringing and module encapsulation.

A production line for HJT is even less complex than that for standard technology. At the front end of the line there is a wet chemical process that is roughly similar to the one used in standard technology. After that, one PECVD tool, one PVD tool and a single screen-printing unit with a curing oven are needed for production of the whole solar cell.

The HJT process takes place at a low temperature, which prevents diffusion of contamination inside the silicon wafer; such contamination would otherwise be possible at every stage in production if high-temperature thermal processes were involved. Furthermore, the cells are mechanically very stable and not affected by bow, which means that very thin wafers can be processed without mechanical issues.

Because of the excellent surface passivation provided by the a-Si layers, very thin solar cells are particularly well suited to this technology: open-circuit voltages (V_{oc}) as high as 748mV have been published for heterojunction cells with a thickness of 100µm. Only negligible efficiency losses occur with this technology when the wafer thickness is dramatically reduced because the improvement in V_{oc} as a result of the reduced wafer thickness and excellent surface passivation almost completely compensates for the optical losses due to the thin wafer. By using appropriate light-trapping engineering, it may even be possible to reduce the optical losses and obtain a net increase in efficiency with thin wafers.

Given that the roadmap for cost reduction in crystalline silicon PV forecasts, with a very high probability, a drastic reduction in wafer thickness, a solar cell concept that facilitates high efficiency and excellent mechanical stability even with ultrathin wafers is of fundamental importance. From this point of view, the heterojunction cell is at the forefront of all technologies.

Heterojunction solar cells on 6″ pseudo-square wafers have so far yielded an efficiency of 21.3% at the Roth & Rau research facility in Neuchâtel, Switzerland, and 21.0% at the Roth & Rau pilot line in Hohenstein-Ernstthal, Germany.

A unique method for testing high capacitance crystalline silicon solar cells

Today's measuring methods for c-Si cell testing

The majority of cells used today are those with medium capacitances, e.g. thin films, cells based on n-type wafers and the like. For such cells, a measuring pulse length of 20 to 50ms is required. A xenon lamp which provides an AM 1.5 spectrum and irradiances between 500 and 1000W/m^2 is normally used. The pulse length attained is enough to test cells with low and medium capacitances.

Advantages

- Mature, proven measuring method
- Pulse length is adequate for testing cells with low to medium capacitances

Disadvantages

- Measurement of cells with high capacitances is not possible, since the pulse length is too short
- Too slow for new-generation cell lines requiring a measuring speed of up to 3600 cells/hour

For solar cells with higher electrical capacitances, three measurement methods are currently used: steady-state,

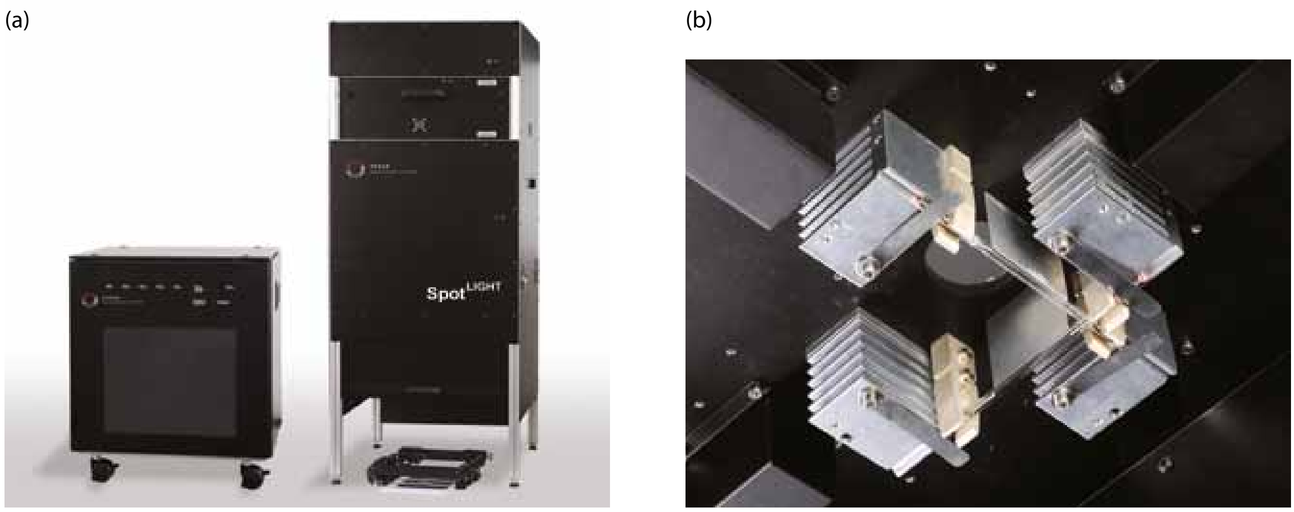

Figure 4. (a) Pasan SpotLIGHT cell tester; (b) xenon lamp source in the new SpotLIGHT series [2].

multi-flash and forward-reverse characteristic test. However, all of these methodologies exhibit high test costs and low levels of dependability and accuracy, as well as long measurement durations.

Unique measuring method from Pasan SA

Higher capacitance cells require a measurement time of 400 to 600ms. Moreover, newer generations of cell-printing lines have been developed, and the throughput will ultimately evolve from today's 1200 cells/hour to 2400 cells/hour, and then to 3600 cells/hour. Accordingly, there appear to be two major challenges for new cell-testing equipment: longer pulse lengths and higher throughputs.

Pasan SA [2], a member of the Meyer Burger Group, in cooperation with the Institute of Micro Technology (IMT) at the University of Neuchâtel in Switzerland [3], has developed a new *I-V* curve cell tester series known as SpotLIGHT, which is available in two variants: SpotLIGHT 1sec and SpotLIGHT HighCap, both rated ‘A^+’ for spectral match to the AM 1.5 spectrum, ‘A^+’ for uniformity and ‘A^+’ for pulse stability. A rating of A^+ for spectral match is currently awaiting external approval. SpotLIGHT 1sec is dedicated to high-speed measurements that are required for in-line applications, such as end-of-line quality control in solar cell production lines or beginning-of-line quality control in module production lines. SpotLIGHT HighCap is dedicated to testing solar cells with high capacitances such as heterojunction (HJT) and all back-contact cells.

SpotLIGHT 1sec

The SpotLIGHT 1sec design is based on xenon lamps (Fig. 4). As the name suggests, the cycle time is 1 second for low- to medium-capacitance cells. In order to achieve the A^+ rating

Figure 5. New unibody design for cell contacting in the Pasan SpotLIGHT series [2].

Figure 6. Tray drawer for lamp replacement in the Pasan Spot^{LIGHT} series [2].

for spectral match, custom-designed interferential filters are used. The unibody design of the contacting unit has multiple current-measuring points and minimizes the mechanical stress to the solar cell (Fig. 5).

Lower total COO has been made possible by reducing the use of consumables as well as by increasing both uptime and throughput.

1. The contacting system has a longer lifetime by a factor of ten than that of systems currently available on the market. This leads to substantially reduced costs for consumables and costs associated with downtime. The measurement reliability is not affected at all.

2. The lifetime of the lamps has been extended to reach a guaranteed lifetime of one million flashes.

3. Planned maintenance has been simplified by designing a tray drawer for lamp replacement (Fig. 6). The duration of this procedure is reduced to less than two minutes. This is a huge advantage, especially in the case of in-line measurements with cycle times approaching 1 second/cell.

Figure 7. Measuring methodology of the new Pasan Spot^{LIGHT} HighCap [2].

Spot^{LIGHT} HighCap

The Spot^{LIGHT} HighCap combines the design of the Spot^{LIGHT} 1sec with additional light-emitting diodes (LEDs) to increase the pulse length to 600ms (Fig. 7). The cycle time of this machine is about 2.7 seconds for the complete measurement process, a value which has not been matched by competitors. The accuracy of the overall measurement is determined by the A$^+$A$^+$A$^+$ rated xenon light source, whereas the pulse length is determined by the LEDs. The result is a system which provides dependable measurements for users while maintaining the total COO of the system at the same level as for the Spot^{LIGHT} 1sec. This is a unique characteristic among long-pulse solar simulators.

Advantages

- Improved performance
  - Rated A$^+$A$^+$A$^+$ (spectral match AM 1.5, uniformity, pulse stability)
  - Fewer false rejects during cell testing/sorting
  - Patent-pending unibody contacts, shadowing reduced to < 1%
  - Unique lens-less optical design
  - High repeatability of measurements, < 0.25%

- Reduced cost of cell testing
  - Guaranteed 1,000,000 flashes per lamp
  - Guaranteed 7,000,000 contact cycles with one unibody contacting unit
  - Shortest cycle time on the market, down to 1 second/cell

- Increased uptime
  - New tray drawer design reduces time for lamp replacement to < 2 minutes

- Higher yield

- Flexibility
  - 5", 6", 8" cells catered for
  - 2–5 busbars possible
  - Back contacting possible
  - Can measure high-efficiency cells (Spot^{LIGHT} HighCap)

References

[1] Roth & Rau AG [http://www.roth-rau.de].

[2] Pasan SA [http://www.pasan.ch].

[3] IMT, Photovoltaics and Thin Film Electronics Laboratory (PV-Lab), EPFL, University of Neuchâtel, Switzerland [http://pvlab.epfl.ch].

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