India's first a-Si Photovoltaic solar module production Line

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Abstract: HHV offers a complete production line of reliable equipments for the production of a-Si solar photovoltaic (PV) module with semi automatic and fully automatic options with turnkey solutions. Its state-of-the-art technology refined over several years of research, and cost effective manufacturing assures maximum value to the end user. A world class complete production line is offered at competitive prices, with a strategic advantage to exploit the opportunities in the expanding photovoltaic market. The offer includes the line of equipment and the training in both equipments and technology. The a-Si technology has developed at Indian Association for Cultivation of Science (IACS), Kolkata, and it is been transferred to HHV. The technology is developed for 1 sq. ft and it is upscaled to 1 m^2 size on glass with a power output 60 - 65 W, with stabilized efficiency 6 - 6.5 %.

I. INTRODUCTION

Among potential new sources of energy the 'Sun' is outstanding. Sunlight is abundant, widely distributed and universally appreciated. Of various energy forms, electricity is highly prized for its general utility. Thus the direct conversion of sunlight to electricity is likely to be a prime method of the future assuming that practical economic means of direct conversion can be developed. Photovoltaic conversion is a strong candidate for this. It is well known that only 0.1% of the solar energy incident on the earth's surface is enough to meet the present demand of the world, if put into usable form. The growing world demand for electrical energy will be accompanied by a geographical shift since the largest growth rate of this energy expenditure will be situated in the developing nations. Due to the prevailing rural or agro-industrial nature of these countries solar electricity seems to be a very attractive approach as it makes fuel-free highly reliable stand-alone systems possible. In the developing world the need for decentralized power stations is very large; outstanding examples are water pumping and village power. Moreover, almost all of the developing countries are situated in the sunbelt of the world.

At present SPV electricity is 4-5 times costlier than grid electricity (which is substantially subsidized). The grid electricity cost does not take into account the social cost of environmental degradations. To make SPV electricity cost competitive with grid electricity the module cost should be ~US$ 1-1.5/pW (a peak watt is a watt of SPV electricity when the cell is working at its peak load and maximum intensity of solar insolation). There is a need for a low cost method of converting sunlight into electrical energy. The need will become more pressing as the reserves of fossil fuels are gradually depleted and as the cumulative effect of conventional means energy generation on the environment becomes more onerous. Increasing costs of conventional power might obviate part of this cost reduction. But the ultimate way to reaching the cost goal is to improve the mass production technology and by using low cost production technology. The following technology options are available now for large-scale use of SPV: (1) single crystal silicon; (2) multicrystalline silicon and (3) thin film technologies. Only thin film solar cell (TSF) technologies have the potential of reaching the cost goal of $1-1.5/pW. This is due to the following factors:

(1) low cost of materials;
(2) low energy pay back period and
(3) capability of fabrication of large area module in a single step.

Amongst the TFS technologies a-Si has the following special advantages viz:

(1) no problem with availability of materials for very large scale production;
(2) proven production technology suitable for large area modules (1 sq.mt.)
(3) no environmental hazard with the process and the product
(4) low material requirement (0.5 micron compared to 400 μm for single crystal silicon).

The problem of this type of technology is significant light induced degradation before stabilization.

In this paper, we describe the various machineries and technologies involved in the manufacturing process of a-Si thin film solar modules in details. Also the economics of the modules production is discussed.

I. RESEARCH BACKGROUND.

The single junction a-Si technology has been developed at IACS, Kolkata on 300 mm x 300 mm size glass substrate. HHV has fabricated and installed a 7-chamber PECVD system for depositing silicon thin films. a-Si modules of maximum stabilized power output of 5W have been developed at IACS. The process technology is transferred to HHV and a similar system is installed at HHV campus to fine tune the technology. HHV has set up a modern R&D facility with all necessary characterization equipments required for a-Si film and device characterization.

To facilitate the upscaling of a-Si process and technology, a large area twin chamber PECVD system is fabricated and installed. The chamber is capable of depositing on substrate of size 1016 mm x 1016 mm. various process involved in the modeling technology is optimized for this size. FIG 1 shows typical I-V curve of 1 sq. meter substrate.

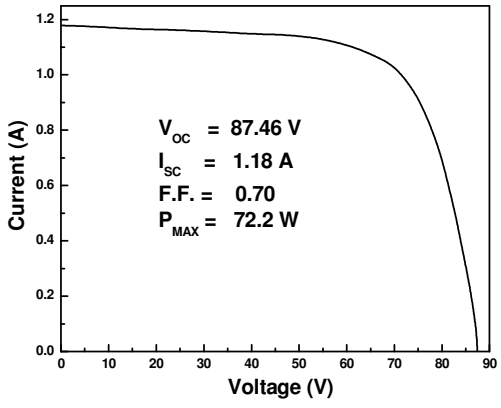

FIG 1. I-V curve of 1m x 1m a-Si module, which shows an initial module efficiency of 7.2 %.

Light induced degradation (LID) studies also been carried out in various modules. It was giving an average degradation of 18-20 % in efficiency.

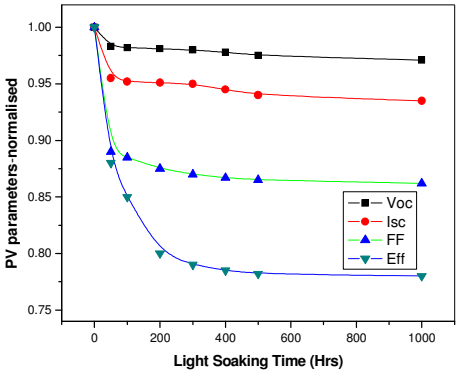

FIG 2. Results of light induced degradation studies

Modules are subjected to extreme climate conditions as per the International Electrotechnical Commissions (IEC) standards using the inhouse facilities. Various components involved in the moduling process, like EVA, tabbing strips, soldering materials, back sheets, junction boxes, have been qualified based on the different tests based on IEC standards.

II. EQUIPMENTS OFFERED

1. PECVD for a-Si Deposition

The PECVD system consists of vertical vacuum chambers connected via gate valves and the substrates to be processed is fixed on a window frame like trays and it is introduced into a preparatory chamber, which is being evacuated and then it is transferred to the process chamber through an isolation chamber, which is maintained at slightly high pressure than the process chamber. This design ensures the purity of process chamber which is essential to get high rate repeatability and precision in the mass production. An isolation chamber is provided in between two dissimilar process chambers, where different types of gases are being used.

A heater is placed at the centre of the entire chamber to heat the substrate uniformly. In the preparatory chamber, substrate will be heated to a desired temperature while evacuating and this temperature is maintained in all the chambers.

Substrate mounted on the holder is taken out from the exit chamber and substrate is then removed and the substrate holder is taken for dry cleaning.

The present system configuration ensures that the substrates are not exposed to the air in between the

process steps, avoids cross contamination of various gases used in the process chambers, which in turn guarantees high quality of films deposited
The following list summarizes the capabilities of the HHV- 14 chamber PECVD system:

- 2 substrates (1016 x 1016 mm) per chamber
- 5 minutes tact time
- < 10% deposition uniformity
- mechanical cleaning is required, resulting in 40 hours downtime
- Unique gas distribution system

2. SPUTERING for Back Contacts

The Sputtering system is an in-line system in which substrates are transferring sequentially to multiple of vacuum chambers that are arranged along the substrate transfer path. Substrates are placed horizontally and transferring form one chamber to the other by means of specially designed belt conveyors, that avoids the sagging of the substrates.
A substrate heating mechanism is provided with reflectors to effectively concentrate the heat energy to the substrate surfaces, which ensures the minimum loss of energy. The heating mechanism consists of infra red heaters with reflectors mounted in the upper portion of the entry chamber. The substrates are heated prior to the coating which ensures surface cleaning and improved adhesion of thin films.

Each vacuum chamber is provided with separate pumping mechanism to evacuate the chambers, which will also minimize the any risk of cross contaminations. Entry and exit chambers are connected with pumping system with higher capacity, which ensures the very fast rate of evacuation.

3. LASER SCRIBING SYSTEM for P1, P2, P3 and P4

The fundamental laser processes involved in thin-film module production are based on the direct laser-induced evaporation and melt-ejection of the thin-film layer materials. Currently nanosecond laser pulses of different wavelength and pulse energy are applied. Each large-area thin film layer is separated in single cells using a laser or mechanical tool in between the coating processes. Doing this a monolithic series connection of the single cells on a large module is achieved. The laser is an ideal scribing tool based on its main characteristics being a flexible, non-contact tool with smallest dimensions. It is suited to scribe the thin films and selectively remove specific layers preventing damaging the underlying ones.
Another process where the laser shows technological advantages over conventional mechanical processing like sand blasting is the removing of the complete thin-film layer build up around the edge of the thin-film module, the so-called edge deletion, to leave a clean glass substrate for further module integration steps.

HHV offers four laser machines to do the three scribing (P1- TCO, P2 – a-Si, P3- metal contacts) and edge deletion (P4).

4. TABBING STATION

HHV has developed high precision tabbing- (a process of attaching conductive strips to the solar cells) machine for thin film solar modules. This process is carried out on both sides simultaneously and the cycle time is just one minute.

5. LAMINATORS

HHV offers glass to glass laminates and designed the PV laminators to do the encapsulation of several modules at a time which substantially reduces the cycle time and increases the potential productivity.
HHV offers fully automatic and semiautomatic line configurations with conveyors, pick and place arrangements etc. The production line includes all necessary machineries like glass cleaning machine, Sun simulators, Junction Box fixing station, sun simulators etc.
HHV's turnkey lines open up a new chapter in the economics of a-Si thin film modules production. With the capital expenditure for setting up a thin film line at around $1.2 / watt , the return on investments are very attractive even at a low capacity of 10 MW , offering scope for very aggressive pricing . This can make a-Si thin film modules highly competitive vis-à-vis other technologies like c-Si etc. The benefit will be more pronounced at higher capacities as economies of scale also would add to the attractiveness of the investment.

III.CONCLUSION

HHV is in a unique position to offer world class and reliable turnkey equipments for manufacture of THIN FILM MODULES at competitive prices, providing manufacturers with a strategic advantage to exploit the opportunities in the expanding photo voltaic market. Included with the line are the required equipment and the training of operators in both equipment and technology. HHV also offers assistance in set-up and installation at the customer's facility, module design assistance, applications support, and access to HHV's advanced technology research base.
The HHV LINE is designed to produce 10 MW of a-Si PV modules annually.