

A process-line for large area organic solar cells

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Abstract

This is a simple approach for building a process-line of glove boxes for making large devices. The processes housed in the glove boxes are spin coating, evaporation, lamination/sealing and testing. The main strategy was to have multiply connected glove-boxes with one load lock. One of the glove boxes was going to house an evaporator build up from scratch.

Objectives

To build a process-line capable of making solar cells in the size 400 mm by 400 mm, in an inert atmosphere (oxygen < 1 ppm, Water < 1 ppm).

Introduction

Organic based electronics is a growing research area. In the field of solar cells the traditional inorganic Silicon cells are costly due to the demand of high purity materials and production environment. The price's have generally been the same for the last decade at 4 US dollars/Watt. The organic based solar cells could have an estimated cost of 2 us dollars/m² when optimized and produced in large scale. With a power conversion efficiency of 5 % at 1000 W m⁻² solar power, this could give a price of 4 cents/watt, which is an interesting perspective. The biggest technical problems so far are their limited lifetime and their scale up process from small cells (mm²) to modules of big cells (cm²). The goal of the process-line presented is to make big solar cells modules with a size of 400 mm x 400 mm. An overview of the process-line is presented in Fig. 1.

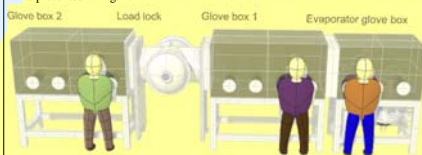


Figure 1: The final process-line design

The solar cell modules are prepared on a polyester (PET) substrate. The front electrode is made of indium tin oxide (ITO). The ITO is made on the PET in a pattern by a lithography technique. The pattern is made up by 7 rows in parallel of 13 cells connected in series. This substrate is introduced to glove box 2 by the load lock. Glove box 2 houses the screen printer, and the printing is performed here. After printing the substrate, now PET/ITO/Organic is transferred to glove box 1. This is done through the load lock. In glove box 1 the substrate is mounted on the sample holder for the evaporator. The sample holder and substrate is transferred to the evaporator glove box, and mounted in the evaporator lid. The lid is closed and the evaporator is pumped down to <10⁻⁶ bar. The sample-holder is rotated and the back metal electrode is then evaporated on top of the organic Photovoltaic compound. The final geometry of the solar cell module cell is: PET/ITO/Organic/metal. The module is transferred back to glove box 1, and the substrate is dismounted from the sample-holder. The module is then encapsulated by lamination with a barrier film. The protected solar cell module is transferred to the load lock, and ejected from the process-line.

Design and Building

A 3D drawing program is essential to carry out the design. The process line was designed using Rhinoceros 3d drawing program, which was found an powerful and intuitive tool. The basic geometric figures (squares, cylinders, balls,...) can be made and combined/alterted to the desired design. The position of the different parts can easily be changed.

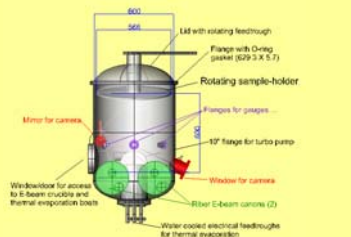


Figure 2: The Evaporator is made in the shape of a cylinder. The lid in the top is closed against a rubber O-ring. Several flanges are welded on for the different equipment. A camera system with an adjustable mirror makes up the evaporation monitor system

Optimization of the design is thereby fast and efficient. Possible/impossible solutions can be found/rejected, before costly production time is wasted. Considerations regarding how the parts could be produced and assembled have to be taken into account.

The first design was the evaporator. It is made as a cylinder because of the mechanical and production advantages over a box design. It is made with a camera system which makes it possible to monitor the e-beam crucible or the thermal sources or the substrate. Since all these things are inline, tilting an adjustable mirror easily shifts the view between them. By using a mirror the problem of metal covering on a window is eliminated. The mirror will be covered with the evaporating substance but this will just make a new mirror surface, which will still reflect the image monitored. A service port is integrated for easy access to the e-beam crucible and the thermal boats. The substrate holder is made as a disc because of the round design. The substrate is rotated during evaporation for uniformity of the electrode. This is done by setting the disc on an axle from a rotational feedthrough in the lid. The lid can be lifted by an electric actuator.

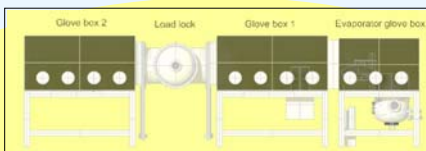


Figure 3: The process line seen from the side. The load lock connects the two glove boxes, separated by guillotine doors.

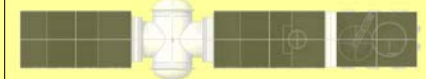


Figure 4: The process line seen from the top. The cross tube load lock has one unused door that can be used to expand the process line if wanted.

The glove box design is rectangular. This is due to arm length limits the depth of the box. So increasing the area of the glove box means making it longer, and therefore rectangular in shape. The first glove box is designed with a well for a spin-coater. The spin-coater can be elevated/lowered from the well by an actuator, if the spin-coater is not used it does not occupy space in the glove box. Glass windows are used instead of plastic for lower oxygen permeation.

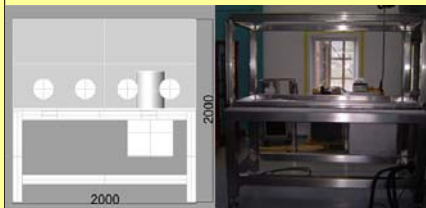


Figure 5: The first glove box as a. Almost 2 m² of surface area. The spin coater can be stowed away in a well.

The load lock was made over size so instruments etc. can be moved in and out of the glove box. The screen printer frame is 520 mm x 660 mm x 30 mm. This part has to be taken in and out of the process line every time it has been used. So this was the minimum measurement the load lock should be able to handle. The design was made as a cross tubing. The load lock connects the two glove boxes. It can be accessed from both sides. The crossing tubes are made in a slightly different dimension. This makes the construction easier to build. The tube connecting the glove boxes are made 650 mm in diameter, and the crossing tube is 700 mm in diameter. The two doors to the outside are made of two 700 mm DIN 28011 caps 5 mm thick.

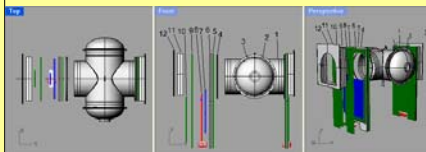


Figure 6: Left: The load lock seen from above the cross tube. Middle: Seen from the side with the access doors fronting (3). Right: Seen in perspective from the side. The left door of the load lock is taken a part so individual parts can be distinguished.

The load lock is constructed so it rests on the two door chambers for the guillotine doors. The parts for the load lock are listed below, numbers refers to Fig. 6 part number.

1. The cross tube that makes the chamber for the load lock.
2. Flanges welded to the cross tube. An O-ring is incorporated for tightening and hinges for the door effect.
3. DIN 28011 cap welded to a flange with hinges for the door (outside door).
4. Flange welded to the cross tube. 32 holes for bolts and a o-ring for a tight connection to part 5.
5. The side of the door chamber (load lock side).
6. The frame that makes the cavity where the guillotine door slides.
7. The guillotine door (glove box door).
8. The spindle and motor for the door.
9. The side of the door chamber (glove box side).
10. The service port for the spindle system.
11. The space between the load lock and glove box.
12. The flange for connection to the glove box.

The total process line is planned to consist of: The evaporator, glove box 1, the load lock and glove box 2. The strategy was to build the evaporator first.

Thereby experience from building and using the evaporator could be integrated in the other designs. The second design was glove box 1. A well for a spin coater was incorporated. The glove box was designed so a screen printer also could fit inside until glove box 2 was finished. The next part was the load lock. The doors from the load lock to the glove boxes was made as guillotine doors. This was decided from a space saving point of view. If a hinged door is used, space is wasted as the door has to swing out to open. The second glove box was next and thought to house testing and sealing facilities and the screen printer. The first step of building is to make technical drawings so an engineering shop can build the parts. The design is drawn in two dimensions seen from all the necessary angles with measurements written. This is easily done in the drawing program.

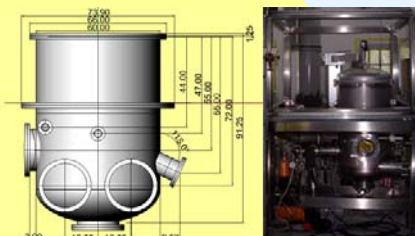


Figure 7: The Evaporator chamber as a technical drawing and the operational evaporator.

In Fig. 8 the making of the tubes for the load lock is shown. The first picture shows the starting material, a 5 mm stainless steel plate. The plate is cut to size (length and circumference). The third picture shows the press where the steel plate is pre-bend in the ends as shown in the fourth picture. In the second row the plate is in the roll and rolled to a tube. The two tubes for the load lock are shown in the last picture. The cross is made from these tubes and connected to the guillotine doors as illustrated in Fig. 6.



Figure 8: From plate to tube. The two tubes are for the load lock (cross tube).

Results

The evaporator is able to cover surfaces up to 560 mm in diameter. This can be done by E-beam evaporation or thermal evaporation. The main substance we have E-beam evaporated is Aluminum. This is for the back electrode in solar cells of the geometry PET/ITO/MEHPPV/Al or PET/ITO/MEHPPV/C60/Al. This can be done at a rate of 0.1 to 100 Å/s. The modules made are 250 mm x 400 mm. The thermal evaporation was done with aluminum and C60. The cells realized are of the geometry PET/ITO/MEHPPV/Al and PET/ITO/MEHPPV/C60/Al.

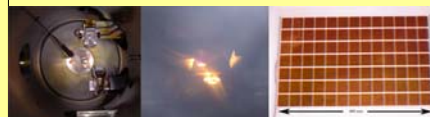


Figure 9: From left to right: The inside of the evaporator chamber, e-beam evaporation, a realized solar cell module 400 mm x 250 mm.

Conclusion

An evaporator was designed and build completely in house with Risø workshop facilities. It is operational and able to evaporate substances by e-beam (5 different materials per pump cycle) or thermal heating (2 different materials per pump cycle). Solar cells modules 250 x 400 mm with 91 cells have been made. The glove box and load lock is under construction. They are planned to be operational October 2005. The financial cost for hardware will approximately end up at 130000 Euro. The time spent on design and assembling will approximately be one man year.

ACKNOWLEDGEMENTS

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