Open Science Hardware Setup for investigating the Stability of Organic Solar Cells - Interim Report

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1 Introduction

Solar cells are becoming increasingly prevalent in the fight against climate change[1, p. XV], leading demand to increase worldwide. This project aims to contribute to the designing of the next generation of solar cells to be manufactured out of organic material (rather than the current industry standard of Silicon). Currently, controlled lifetime testing of organic solar cells is difficult due to the multitude of failure mechanisms. These are caused by chemical degradation via Oxygen and water[2, p. 689]. To combat this problem, this project will design, manufacture and test a programmable lifetime solar testing container. This project is being run in conjunction with Oxford University Physics departments Advanced Functional Materials and Devices group (AFMD), headed by Professor Moritz Riede, therefore I am, and will be collaborating closely with the members of AFMD to ensure the device meets the specification they require. A key tenet of the project is ensuring the accessibility of the research through the use of open hardware in order for the potential acceleration of the development of organic solar cells.

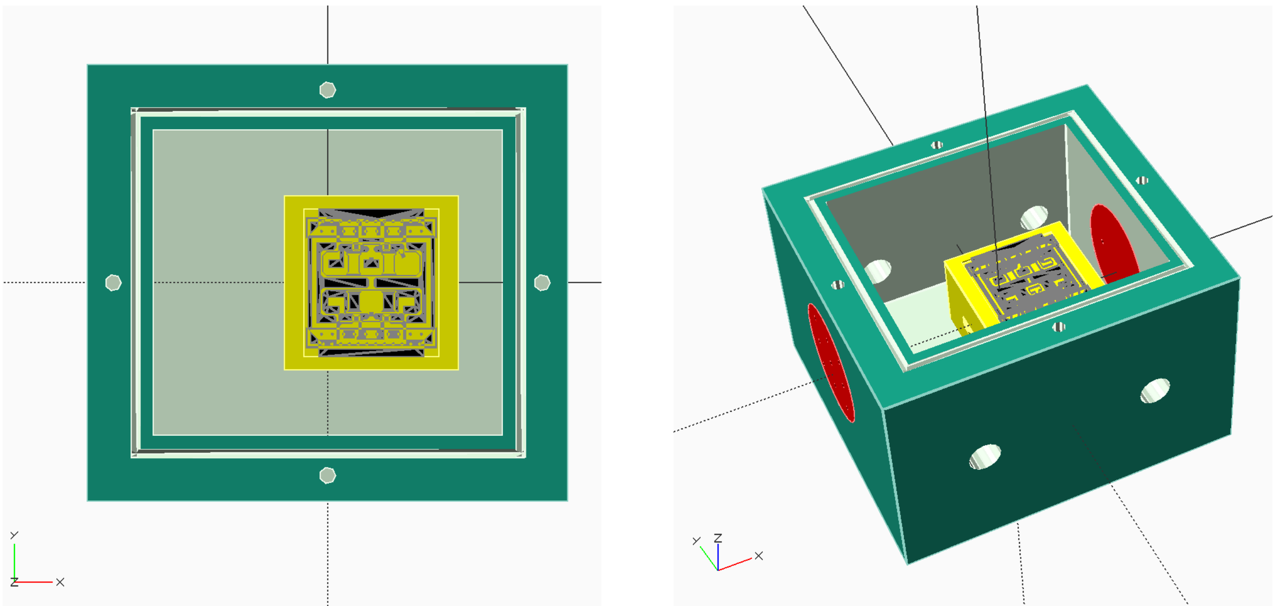
2 Aims and Objectives

The aim of the container is to simulate a lifetime (for example: 20 years) of real world degradation in a *reasonable* timeframe. Reasonable means that ideally the testing container should be able to test the solar cell in a short cycle test (15 minutes) or a long multiple cycle test (a period of days). To ensure accurate testing of the cells, the container needs to be airtight. This is to prevent any atmospheric Oxygen and water vapour getting into the container and causing unwanted degradation of the cell. Furthermore, the container should have to have gas inlets and outlets so that the conditions that the solar cell is tested under can be varied. This will be in conjunction with a temperature controller capable of varying the temperature of the solar cell up to 120°C. These objectives were guided by the paper *Consensus stability testing protocols for organic photovoltaic materials and devices* [3, p. 1255-1261] which cites multiple different testing criteria for an organic solar cell. Additional aims that would enhance the scope of the project is a graphical user interface (GUI) developed to control the conditions within the testing container. To ensure the project is completed, not all the components will be manufactured from scratch, some will be purchased while others are provided by the AFMD research group. Some of the components include: the push-fit valves, a safety relief valve, o-rings and the mass flow controller.

3 Progress

At this stage in the year, the container is past the design stage and is onto manufacturing, with the outer shell being manufactured within the Engineering Science Workshop from AL-xxxx. A full design was completed using the open source software OpenSCAD. Using inspiration from Karl-Augustin Zaininger (an AMFD researcher who has developed a similar type of device, without the functionality) a CAD model of the testing container was built and is shown in Figure 1.The outer shell (coloured in blue) is the component currently bring manufactured. The parts in red will be 3D printed using acrylic and will be used to hold metal pins to connect a controller to conduct measurements within the container.

The three important factors that the container had to accommodate were: the substrate (coloured black in Figure 1), any electronic devices (e.g. a temperature controller) and gas inlet ports. The substrate



(a) Plan View of Model　　(b) Isometric View of Model

Figure 1: Showing plan and isometric view of the full OpenSCAD model

used carries 8 solar cells with dimensions of 30 mm x 30 mm and a thickness of 1 mm, the model in Figure 1 was provided to me by Dr Grey Christophoro - AFMD researcher [4]. In order to carry the substrate in the testing container, a substrate holder (coloured yellow in Figure 1) was designed to fit within the outer shell of the box. This modular design is desirable as it allows the ability to modify which cells and substrate layouts that are being tested without the redesign of the entire container, just the substrate holder and associated electronics; thereby saving those who may need to use it in the future valuable time and money.

4 Future Work

During the manufacturing of the box, there is an opportunity to start on simulations of the heat and mass flow within the container. These simulations will be conducted using SOLDIDWORKS flow and heat simulations features to provide a more accurate picture of the environmental variation around the substrate. Once the outer shell has been manufactured, following steps are to pressure test the vessel, implement the control electronics and calibrate the temperature and environmental sensors. Once the calibration is complete the container will be assessed in known control environments to check whether the solar cells output as predicted. The Gantt chart (shown in the Appendix) shows the full outline of the future plans including contingency time at the end of Hillary term.

References

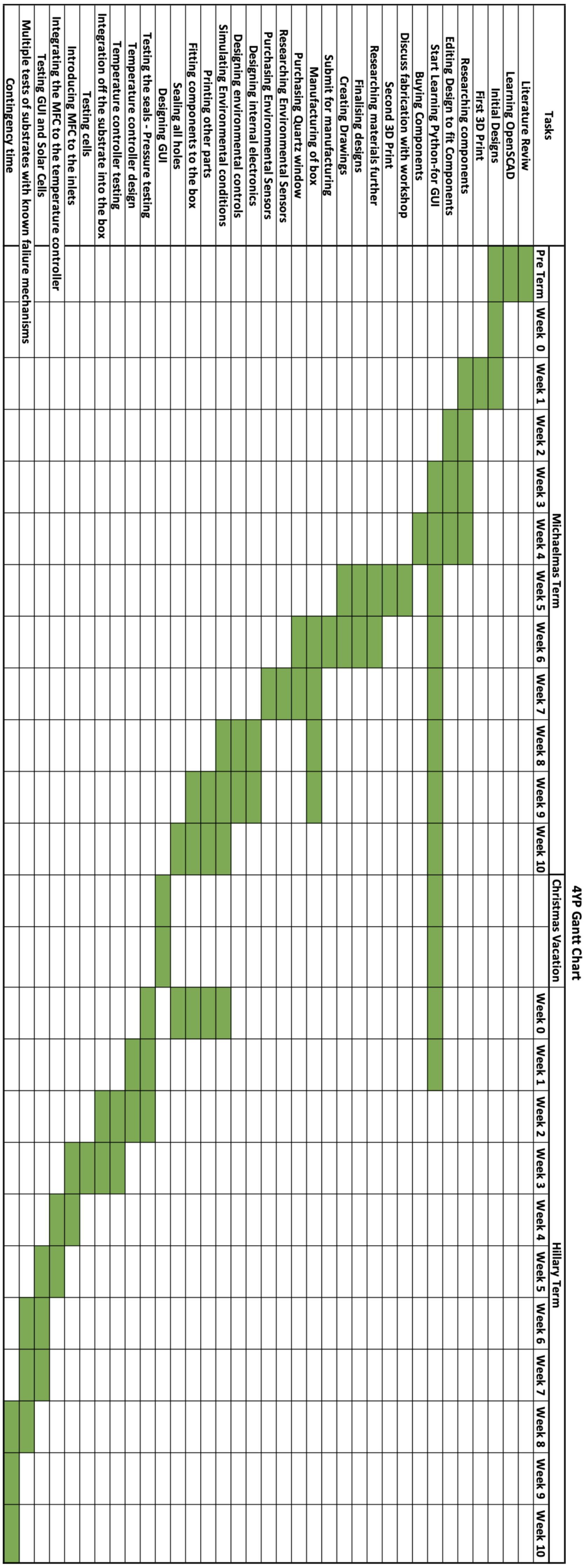
[1] Greg P Smestad. *Optoelectronics of solar cells*, volume 115. SPIE press, 2002. ISBN 0819444405.

[2] Mikkel Jørgensen, Kion Norrman, and Frederik C Krebs. Stability/degradation of polymer solar cells. *Solar energy materials and solar cells*, 92(7):686–714, 2008. ISSN 0927-0248.

[3] Matthew O Reese, Suren A Gevorgyan, Mikkel Jørgensen, Eva Bundgaard, Sarah R Kurtz, David S Ginley, Dana C Olson, Matthew T Lloyd, Pasquale Morvillo, and Eugene A Katz. Consensus stability testing protocols for organic photovoltaic materials and devices. *Solar Energy Materials and Solar Cells*, 95(5):1253–1267, 2011. ISSN 0927-0248.

[4] AFMD Layout Github Repository, Accessed 30/09/2020. URL `https://github.com/AFMD/layouts`.

Appendices


4YP Gantt Chart
Tasks
Michaelmas Term
Christmas Vacation
Hillary Term
Pre Term
Week 0
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Literature Reviw
Learning OpenSCAD
Initial Designs
First 3D Print
Researching components
Editing Design to fit Components
Start Learning Python-for GUI
Buying Components
Discuss fabrication with workshop
Second 3D Print
Researching materials further
Finalising designs
Creating Drawings
Submit for manufacturing
Manufacturing of box
Purchasing Quartz window
Researching Environmental Sensors
Purchasing Environmental Sensors
Designing internal electronics
Designing environmental controls
Simulating Environmental conditions
Printing other parts
Fitting components to the box
Sealing all holes
Designing GUI
Testing the seals - Pressure testing
Temperature controller design
Temperature controller testing
Integration off the substrate into the box
Testing cells
Introducing MFC to the inlets
Integrating the MFC to the temperature controller
Testing GUI and Solar Cells
Multiple tests of substrates with known faliure mechanisms
Contingency time