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

Samuel Mendis

Department of Engineering Science, University of Oxford

Department of Physics, University of Oxford

2nd March 2021



1 Introduction

Solar cells are becoming increasingly prevalent in the fight against climate change[1, p. 34], leading demand to increase worldwide. This project aims to contribute to the development of the next generation of solar cells to be manufactured out of carbon-based materials (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 well controlled lifetime solar testing container. This project is being run in conjunction with the Advanced Functional Materials and Devices group (AFMD) in the department of Physics, 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 (up to 3 months). To ensure accurate testing of the cells, the container needs to be airtight. This is to prevent any uncontrolled variables from entering the testing container and causing degradation of the cell. Furthermore, the container should have gas inlets and outlets so that the conditions that the solar cell is tested under can be varied in a controlled manner. 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 - in the absence of a tailored ISO standard. 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 and existing open science hardware/software efforts. Some of the components include: the push-fit valves, a safety relief valve, o-rings, a mass flow controller and an illumination source.

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. A full design was completed using the open source software OpenSCAD. Using inspiration from Karl-Augustin Zaininger (a Physics 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 green) is the component currently bring manufactured. The red circular parts will be 3D printed using acrylic and will be used to hold metal pins to connect a controller on the outside to the instrumentation within. The three important

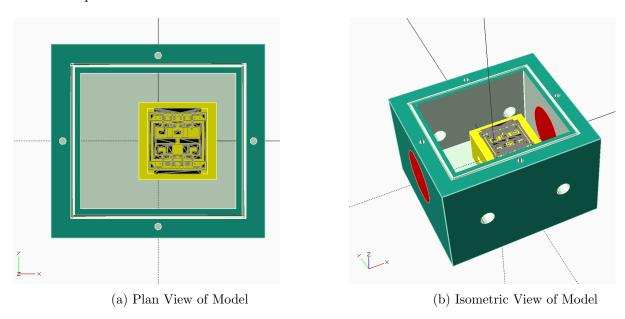


Figure 1: Showing plan and isometric view of the full OpenSCAD model

factors that the container had to accommodate were: the substrate (shown in black in Figure 1), any electronic devices (e.g. a temperature controller) and gas inlet ports. The substrate used carries 6 solar cells with dimensions of 30 mm x 30 mm and a thickness of 1.1 mm. The substrate design in Figure 1 was provided to me by Dr Grey Christophoro - Physics 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. The modular design is deliberate to allow the user to modify which cells and layouts are being tested, without the redesign of the entire container, just the substrate holder; 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 SOLIDWORKS flow and heat simulations features to provide a more accurate picture of the environmental variation around the substrate. These simulations will allow the user to control the environment with a better understanding, hence creating more consistent ageing conditions. Once the outer shell has been manufactured, following key steps are to pressure test the vessel, implement the control electronics, calibrate the temperature and environmental sensors as well as installing the container in front of a lamp. 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 Hilary term.

References

- [1] International Energy Agency. World Energy Outlook 2020. OECD Publishing, 2020. URL https://www.oecd-ilibrary.org/content/publication/557a761b-en.
- [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

Iterative Review Initial Designs Interative Review Interative Revi		Michaelmas Term Week 0 Week 1 Week 2 Week 3 Week 4 Week 5 Week 6 Week 7 Week 8 Week 9	0 Week	1 Week	2 Week	Michaelı Week 4	Michaelmas Term Week 4 Week 5	Week 6	Week 7	Week 8	—	Week 10	Christmas Vacation	\vdash	Week 0 Week 1 Week 2 Week 3 Week 4 Week 5 Week 6 Week 7	eek 1 We	ek 2 We	ek 3 Wee	Hillary Term	Term	k 6 Wee	ek 7 Week 8
Learning DesisCAD											\rightarrow											ı I
Initial busgins First 2D Print Researching components Editing Design to Edition powers Editing Design to Edition powers Editing Design to Edition powers Start Learning Python-for GUI Buying Components Second 2D Print First Start Learning Python-for GUI Design Design Edition with workshop Escand 2D Print Researching materials further First Start Learning Python-for GUI Buying Components Scaling Design Start window Purchasing Edition House Multiple Edition Start window Purchasing Edition House First Start window Purchasing Environmental Sensors Purchasing Environmental Sensors Purchasing Edition House Purchasing Edition House Sealing al hoise Fitting components to the box Sealing al hoise Fitting Components to the box Sealing al hoise Fitting Edition House Integration of the substrate into the box Testing Edit and Solar Cells Multiple test of a substrate into the box Multiple test of a substrate into the substrate into the box Multiple test of a substrate into the box	Learning OpenSCAD																					1
Interaction components Set It learning Periphon-for Gil Buying Components Discuss Birlication with workshop Interactive Components Interactive Compon	Initial Designs																				4	
Researching components Start tearning Python-for GUI Buying Components Start tearning Python-for GUI Buying Components Second 30 Print Researching materials further Finalising Designs Creating Drawnings Submit for manufacturing of box Purchasing Cutting Components Multiple Components Submit of manufacturing of box Purchasing Environmental Sensors Purchasing Environmental conditions Multiple Environmental conditions Mu	First 3D Print																					- 1
Eating Design to fit Components Second 3D Pint Researching methods with workshop Second 3D Pint Researching methods with workshop Second 3D Pint Researching methods with workshop Researching methods with workshop Subhali for manufacturing Subhali for manufac	Researching components																					
Start Learning Python-for Gull Buying Components Second 3D Print Researching materials further Researching materials further Researching materials further Researching materials further Researching invitoring Manufacturing of box Purchasing Quartz window Researching Environmental Senors Designing environmental Senors Designing environmental Senors Designing environmental Senors Simulating Components on the box Researching collect parts Firthing	Editing Design to fit Components																					
Discuss faint-callow with workshop	Start Learning Python-for GUI																					
Discuss fabrication with workshop Second De Print Researching materials further Finalizing designs Creating Davings Submit for manufacturing Manufacturing of box manufacturing Manufacturing of box manufacturing Manufacturing of box manufacturing Manufacturing of box manufacturing Designing internal electronic or manufacturing of box parts Purchasing Environmental Sensors Designing internal electronic or manufacturing of the parts Frinting onther parts Frinting onther parts Frinting onther parts Frinting the sails - Pessure testing Testing controlled testing Testing cells Integration of the substrate with known failure mechanisms Multiple tests of substrates with known failure mechanisms Multiple tests of substrates with known failure mechanisms	Buying Components																					
Second 3D Print Researching naterials futther Rinalising designs Certing Drawings Submit for manufacturing Manufacturing of box Purchasing Environmental Sensors Purchasing Environmental Sensors Purchasing Environmental Conditions Purchasing Environmental Conditions Purchasing Environmental Conditions Simulating Envir	Discuss fabrication with workshop																					
Researching materials further	Second 3D Print																					
Finalising designs Creating Drawings Submit or manufacturing Manufacturing of box Purchasing Quartz window Purchasing Environmental Sensors Purchasing Environmental Sensors Purchasing Environmental Sensors Purchasing Environmental Controlis Designing internal electronis Simulating Environmental Controlis Simulating Environ Controlis Fitting Components to the box Designing all holes Temperature Controller design Integration of the substrate in the lens the lens to the	Researching materials further																					
Creating Drawings Submit for manufacturing of box Submit for manufacturing of box Purchasing Quartz window Purchasing Quartz window Purchasing Environmental Sensors Purchasing Environmental Controls	Finalising designs																					
Submit for manufacturing of box Purchasing Quartz window Purchasing Environmental Sensors Purchasing Environmental Sensors Purchasing Environmental Sensors Purchasing Environmental Sensors Perchasing Environmental Sensors Perchasing Environmental Sensors Perchasing Environmental Sensors Purchasing Environmental Sensors Perchasing Environmental Sensors Perchasin	Creating Drawings																					
Manufacturing of box Purchasing Quartz window Researching Environmental Sensors Purchasing Environmental Sensors Purchasing Environmental Sensors Designing Environmental Controlics Designing Environmental Controlics Designing Environmental Controlics Simulating Environmental Controlics Simulating Environmental Controlics Simulating Environmental Controlics Fritting Components to the box Sealing all holes Sealing all holes Sealing all holes Sealing Tensperature Controlic design Tens	Submit for manufacturing																					
Purchasing Quartz window Researching Environmental Sensors Purchasing Environmental Sensors Designing internal electronics	Manufacturing of box																					
Researching Environmental Sensors Designing Internal electronics Designing environmental controlis Designing environmental controlis Simulating Environmental controlis Simulating Environmental controlis Simulating Environmental controlis Simulating environmental controlis Friting components to the box Fitting components to the box Testing components to the box Integration off the substrate into the box Integration off the substrate into the box Integrating the NFC to the inlets Introducing NFC to the inlets Integrating the NFC to the inlets Introducing NFC to the inlets Integrating the NFC to the inlets Introducing NFC to the inlets Integrating the NFC to the inlets Introducing NFC to the inlets Integrating the NFC to the inlets Integrating the NFC to the inlets Introducing NFC to the inlets Integrating the NFC to the inlets Integrating the NFC to the inlets Integrating the NFC to the inlets Integrating NFC to the inlets	Purchasing Quartz window																					
Purchasing Environmental Sensors Designing internal electronics Designing internal electronics Simulating Environmental controls Simulating Environmental conditions Fritting components to the box Sealing all holes Designing GUI Testing the seals - Pressure testing Integrature controller design Integrature controller testing Integrature controller testing Integrature to the box Integrating the MiFC to the inlets Introducing MFC to the inlets Introducing MFC to the inlets Integrating the MiFC to the temperature controller Integrating the MiFC to the inlets Integrating the MiFC to the	Researching Environmental Sensors																					
Designing environmental controlis Designing environmental controlis Designing environmental controlis Designing environmental conditions Designing en	Purchasing Environmental Sensors																					
Designing environmental conditions	Designing internal electronics																					
Simulating Environmental conditions	Designing environmental controls																					1
Printing onther parts	Simulating Environmental conditions																					
Fitting components to the box Fitting components to the box Image: Component to the box	Printing other parts																					
Sealing all holes Seal	Fitting components to the box																					
Testing testing Sulf Testing testing Sulf S	Sealing all holes																					
Testing the seals - Pressure testing Imperature controller design Integration off the substrate into the box Integration of the box Integration o	Designing GUI																					1
Temperature controller design Temperature controller testing Integration off the substrate into the box Integration off the substrate into the box Integration off the substrate into the box Introducing MFC to the inlets Introducing MFC to the temperature controller Integrating the MFC to the temperature controller Integrating Solar Cells Multiple tests of substrates with known failure mechanisms	Testing the seals - Pressure testing																					
Temperature controller testing	Temperature controller design																					l
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 failure mechanisms Multiple tests of substrates with known failure mechanisms	Temperature controller testing																					
Testing cells	ntegration off the substrate into the box																					'
Introducing MFC to the inlets Integrating the MFC to the temperature controller Testing GUI and Solar Cells Multiple tests of substrates with known fallure mechanisms	Testing cells																					
Integrating the MFC to the temperature controller Testing GUI and Solar Cells Multiple tests of substrates with known fallure mechanisms	Introducing MFC to the inlets																					'
Testing GUI and Solar Cells Multiple tests of substrates with known fallure mechanisms	Integrating the MFC to the temperature con	ntroller																				
Multiple tests of substrates with known fallure mechanisms	Testing GUI and Solar Cells																					
	Multiple tests of substrates with known fal	liure mechanism	s																			