Developing a New Type of High Efficiency Building Integrated PV Cell.

Project results and lessons learnt

Lead organisation:	Monash University		
ARENA ID:	2017/RND013		
Project commencement date:	11/12/2017	**Completion date:**	30/04/2021
Date published:	28/06/19		
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This project received funding under the Australian Renewable Energy Agency (ARENA) Solar Research & Development Program (Round 3).

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Executive Summary

Building integrated photovoltaics (BIPV) can take the form of semi-transparent solar cells integrated into a framing system – essentially a tinted window that can generate electricity with the light that it absorbs. To date, there has not been a solar cell technology that combines suitable levels of efficiency and light transmission at an adequate price point to allow for broad adoption. The objective of this project is to demonstrate that perovskites, a rapidly emerging class of photoabsorber material, can be incorporated into semi-transparent solar cells at a scale, efficiency and lifetime that make them suitable for building integrated applications.

The first phase of this project demonstrated the fabrication of semi-transparent perovskite solar cells that had an efficiency comparable to commercially available silicon solar cells, while still allowing for the transmission of 10% of light over the visible range. This level of light transmission can already be found in some non-automotive tinted window products. The materials that comprise the key components of the solar cell were selected to give a high efficiency and good long-term stability, while not compromising the level of light transmission. This solar cell can be fabricated using deposition techniques that can be translated to larger scales using commercially available manufacturing technologies.

The next phase of this project is to use the computation models that were previously developed to simulate the efficiency and optical properties of these solar cells on a large scale, and to then work in conjunction with our commercial partners to incorporate them into their integrated window frameworks. By the conclusion of this project, we will have fabricated a demonstrator module that demonstrates to the marketplace the viability of using this technology in building integrated applications.

Project Overview

Project summary

The ultimate objective of this project is to create a semi-transparent perovskite solar cell that has an efficiency, lifetime and transparency that are suitable for a building integrated application. This semi-transparent solar cell will be scaled beyond the sizes typical of a laboratory research
environment, and incorporated into our commercial partner's integrated window framing to demonstrate how it can be deployed in the real word.

Project scope

Conventional solar cells are opaque, limiting their installation to surfaces where light transmission is not required, such as rooftops. This prohibits the application of this technology to areas where the end user would be willing to accept a decrease in light transmission in order to generate electricity.
This is best illustrated by the tinted windows of a skyscraper, where the light absorbed over this large area could be used to generate electricity, with the remaining light used to illuminate the interior.
To date there is not a solar cell technology that combines suitable levels of efficiency and light transmission at an adequate price point. The objective of this project is to demonstrate that perovskites, a rapidly emerging class of photoabsorber material, can be incorporated into semi-transparent solar cells at a scale, efficiency and lifetime that make them suitable for building integrated applications.
This will necessitate the optimisation of deposition conditions for ultra-thin perovskite layers and the application of novel electrode and charge transport materials to impart a degree of transparency while maintaining efficiency and stability, all with deposition techniques that are amenable to commercial manufacturing. This project will also work with commercial partner CSR Viridian to integrate an operating solar cell device into one of their window framing systems to illustrate how it could be utilised in a real-world environment.

Outcomes

The first stage of this project laid the foundation for full module development by (i) identifying the electrode structures and alternative charge transport materials that are compatible with semi- transparent architectures and processing methods, (ii) fabricating small scale laboratory devices that have a competitive efficiency (15%) while maintaining a minimum level of transparency (10% across the visible spectrum), and (iii) developing computational models that can simulate the efficiency and optical properties of full modules (10 × 10 cm2). The project met all the milestones associated with fulfilling these outcomes.
Although proof of concept already existed for semi-transparent solar cells, this stage of the project further increased the efficiency of small-scale devices at a given level of transparency. Also, the lifetime of the devices was greatly extended, making the technology more suitable for long term deployment. The combination of these improvements substantially advances the technology towards the marketplace.

Although we do not have any media to release at this stage, the next phase of the project, to be performed with our commercialisation partner CSR Viridian, will involve module development, resulting in a full demonstrator for public display.

Transferability

While this project is focussed on semi-transparent perovskite solar cells for building integrated applications, the findings of the project to date may be of interest to others researching semi-transparent solar cells that incorporate different organic or inorganic photoabsorbers. Also, the results will be of interest to the broader perovskite solar cell community that are making conventional opaque devices; given the ubiquity of Spiro-OMeTAD as a hole transport layer, a report of an alternative that offers a longer lifetime under more robust processing conditions will receive a considerable audience.

This project is performed within Monash University New Horizons Renewable Energy Laboratory and CSIRO's Flexible Electronics Laboratory, both of which are undertaking numerous projects on perovskite solar cells.

Conclusion and next steps

The first stage of this project has resulted in the fabrication of semi-transparent perovskite solar cells with efficiencies and levels of transparency that make them amendable to building integrated applications. The next stage of the project will take these small-scale laboratory devices and increase their sizes to demonstrate to commercial partners that the technology can be deployed at an industrially relevant scale. This activity will be augmented by the development of modules that will be contained within conventional window frames to illustrate how this technology will be used in a real-world environment. By creating building integrated solar cells, this project will significantly increase the range of applications for perovskite photoabsorbers and increase the base of renewable energy sources in the Australian energy system.

Lessons Learnt

Lessons Learnt Report: Alternative Hole Transport Layers for Semi-Transparent Perovskite Solar Cells

Project Name: *Developing a New Type of High Efficiency Building Integrated PV Cell*

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Solar PV
State/Territory:	Victoria

Key learning

A new hole transport layer is required to incorporate perovskite photoabsorbers into building integrated photovoltaics, as the conventionally used Spiro-OMeTAD does not provide suitable lifetimes for long term applications. A number of alternatives previously used in OLED (organic light emitting diode) development were screened, with the use of N4,N4'-di(naphthalen-1-yl)-N4,N4'-bis(4-vinylphenyl)biphenyl-4,4'- diamine (VNPB) yielding devices with efficiencies comparable to those using Spiro-OMeTAD, but also demonstrated better stability under extended testing.

Implications for future projects

The screening of HLTs was an objective of this project, and this undertaking yielded a suitable alternative to Spiro-OMeTAD. This result demonstrates the viability of examining semiconductors that have been used for other applications, namely OLEDs, for application in perovskite solar cells.

Knowledge gap

The long term stability of perovskite solar cells incorporating VNPB over even greater testing durations remains unknown. This will be explored in the later stages of this project with further accelerated testing. Although it is not anticipated to be a problem, it is also unknown if VNPB is compatible with new perovskite compositions. This will be also examined through the remainder of the project if we test alternative perovskite compositions.

Background

Objectives or project requirements

The primary objective of this project is to develop a semi-transparent perovskite solar cell that can be incorporated into a module for building integrated application. In order for the building industry to adopt BIPV, it must be confident that the solar cell has a suitably long lifetime, as BIPV is more expensive and difficult to replace than conventional roof-top panels.

Although Spiro-OMeTAD is used widely in the field of perovskite solar cells as a hole transport layer, its shortcomings have been well documented, the most critical being it needs to be processed in an inert environment as water deteriorates the material. Even if it is deposited in a carefully controlled environment, it may still impart a degree of instability on the devices, which limits their use in BIPV applications. Therefore, this component of the project set out to identify alternative hole transport materials that could replace Spiro-OMeTAD and were compatible with the deposition processes used in the fabrication of semi-transparent solar cells.

Process undertaken

A literature search was performed to identify an alternative hole transport material. Candidates must have had a suitable band energy structure and be chemically compatible with the underlying perovskite layer. Once a list of candidate materials was finalised, a series of devices using a standard structure, in which the only variation was the hole transport material, were fabricated. The efficiencies of these devices were measured, and devices that gave reasonable efficiencies there underwent lifetime stability measurements.

Supporting information

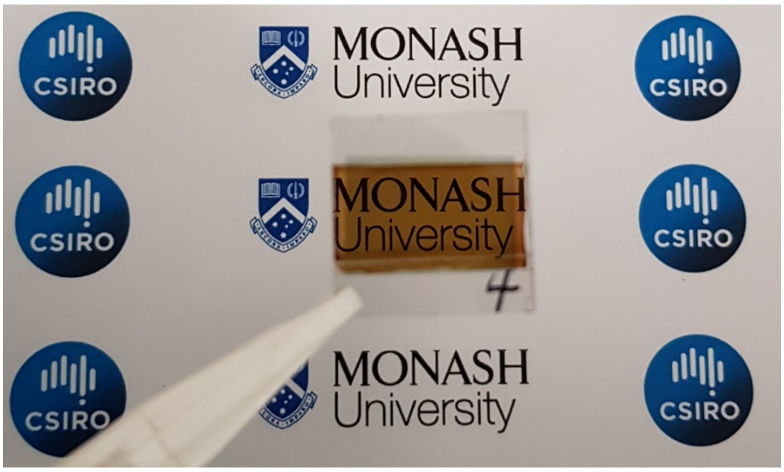

Figure 1. Semi-transparent perovskite solar cell with a Monash University and CSIRO backdrop. (Source: Jae Choul Yu)

Figure 2. Semi-transparent perovskite solar cell with natural landscape background. (Source: Jae Choul Yu)

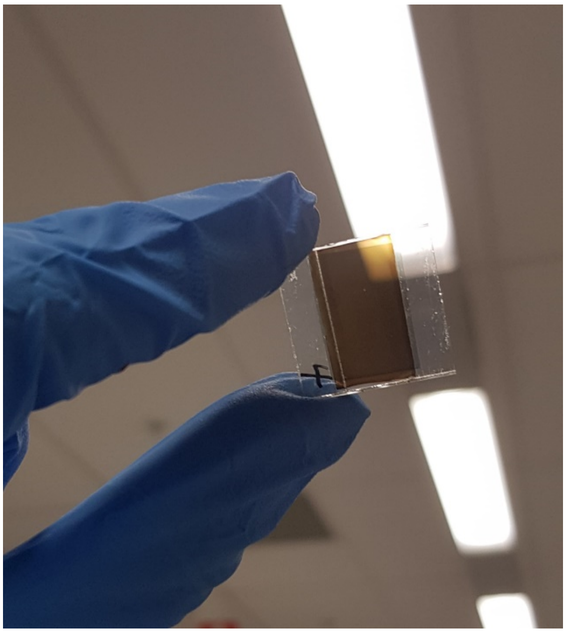
Figure 3. Semi-transparent perovskite solar cell prototype being held up by researcher. (Source: Jae Choul Yu)