Interim Project Dissemination Report

(including Lessons Learnt)

Tandem Silicon - Triple Junction Silicon-Perovskite-Perovskite Tandem Photovoltaics

Lead organisation:	University of Sydney		
Project Partners:	Australian National University, Macquarie University, University of New South Wales, Shenzhen Heiking PV Technology Pty Ltd		
Project commencement date:	18 Sept 2020	**Completion date:**	10 April 2023
Date of reporting:	7 October 2021		
Contact name:	Anita Ho-Baillie		
Title:	Professor and John Hooke Chair of Nanoscience		
Email:	anita.ho-baillie@sydney.edu.au	**Phone:**	02 8627 8916
Website:	https://www.sydney.edu.au/science/about/our-people/academic-staff/anita-ho-baillie.html		

Contents

Acknowledgement: *This project received funding from the Australian Renewable Energy Agency (ARENA) as part of ARENA's R&D Renewables Program.*

Executive Summary

The Project aims to demonstrate high efficiency triple junction silicon (Si)-perovskite-perovskite solar cells.

In addition, research directions in terms of cell design and material choice will be identified based on technology-economic-analysis.

Project Overview

The work packages are:

a. develop novel bottom Si cell designs with innovative contacting and interfacing schemes with perovskite middle cell such as the use of polycrystalline-silicon in conjunction with an interfacial oxide;
b. develop low cost interfacing strategies for middle and top perovskite sub-cells such as the use of metal oxide being more stable than organic interlayers; exploration of various deposition techniques (e.g., atomic layer deposition vs solution process vs sputtering vs pulsed laser deposition) paying attention to process compatibility for monolithic tandem integration. Indium-tin-oxide-free (ITO-free) interfacing will also be explored;
c. demonstrate efficient and stable high bandgap top junction perovskite multi-crystalline thin film and perovskite quantum dot (QD) sub-cells. Strategies include composition engineering, quantum dot size engineering and layer-by-layer coating-with-ligand-exchange-process development and optimisation; and
d. carry out techno-economic analysis on various possible Si-perovskite-perovskite tandem structures to identify cost drivers and suggest low cost alternatives (e.g., new Si bottom cell designs, for perovskite absorber layers, interlayers, hole transport layers and electron transport layers) to guide future research. The impact of cell lifetime (durability) on levelized cost of electricity (LCOE) will also be analysed and reported.

Project Update in terms of progress against outcomes

Expand existing and establish new research capability and capacity for multi-junction tandems through this multi-centre research between the Recipient, ANU, MQ and UNSW generating higher quality research outcomes increase the profile of Australian researchers for:

- high efficiency high and medium bandgap perovskite multi-crystalline thin film cell demonstrations with reduced toxicity and respectable durability. **High bandgap (1.77eV) perovskite multi-crystalline thin film cell demonstrated with respectable efficiency. Medium bandgap (1.56eV) perovskite multi-crystalline thin film cell demonstrated with high efficiency of 23.6% (https://doi.org/10.1016/j.xcrp.2021.100511). Low bandgap (1.25 eV) with reduced toxicity (Pb content reduced by 50%) perovskite multi-crystalline thin film cell demonstrated. Ongoing work for improving efficiency of low bandgap perovskite cell.**
- high efficiency perovskite quantum dot cell demonstrations. **High efficiency 15.1% $CsPbI_3$ (1.77eV) perovskite quantum dot cell demonstrated (https://doi.org/10.1038/s41467-020-20749-1). Higher bandgap QD cells demonstrated as proof of concept. Ongoing work for improving efficiencies.**
- low-cost and high-performance integration approaches for monolithic tandem solar cells. **Elegant and effective interlayer stack for monolithically integrating the top and bottom perovskite multi-crystalline cells demonstrated. Next step for integrating top perovskite QD and bottom perovskite multi-crystalline.**
- expertise on cost structures of various multi-junction tandem approaches guiding development efforts on minimising cost and optimising performance for more rapid progress towards commercialisation. **Developed expertise on cost structures of two triple-junction tandem approaches identifying their cost drivers and minimum efficiencies for respectable levelised cost of energy (LCOE)**

Key highlights

- 10 domestic and international conference presentations
- 5 relevant journal publications
- At least 11 high profile outreach activities, publicity or public announcements and industry engagement. Highlights include:
    - Interview with Joe O'Brien on live TV - ABC News Mornings,
    - Solar cell lab tour for company Maoeng Group;
    - Anita Ho-Baillie named Clarivate Highly Cited Researcher and Australian Research Council Future Fellow,
    - Anita Ho-Baillie and team named Australian Museum Eureka Prize finalists
- Number of jobs created = 4.5 FTE for 2 years.
- Research training of at least 1 PhD student.

Engagement with industry partner – Heiking PV

Activities include the following

- Participation in project reporting meetings
- Technology transfer for perovskite cell fabrication baseline from USYD to Heiking
- Technology transfer for perovskite tandem cell fabrication baseline from USYD to Heiking
- Technology transfer for large cell perovskite fabrication baseline from USYD to Heiking

For their immediate needs aligning with their current business model, Heiking sees our expertise on large area perovskite cell design and fabrication as being most valuable.