Development of Stable Electrodes for Perovskite Solar Cells

Public dissemination report

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Executive Summary

Perovskites are an exciting new class of materials for solar cells because they are low cost and can be used to make high efficiency solar cells. Key advantages are that they can be cheaply deposited at room temperature, they have high material quality, and they can be tuned to absorb light across the solar spectrum. A limitation of perovskite cells is that so far the highest efficiency solar cells have used high cost electrodes with limited stability. This project developed novel integrated contacts that can achieve high efficiency, reduced cost, and improved stability. A variety of integrated electrode structures were developed and tested for efficiency and stability, and the cost of the developed structures has been assessed. Development of improved electrodes is expected to substantially accelerate the commercialisation of this promising technology, leading to reduction in the cost of solar energy.

Project Overview

Project summary

In this project, ANU worked with Monash University to develop new approaches for perovskite electrodes. Perovskites are a very promising class of materials for solar cells because they are low cost and can be used to make high efficiency solar cells. However, so far the highest efficiency perovskite solar cells have used high cost electrical contacts. These contacts also have limited stability. This project developed novel integrated contacts for high efficiency, low cost, and improved stability.

Project scope

Perovskites are a broad class of materials that have shown high efficiency in solar cell applications. This project addressed one of the key limitations of perovskite solar cells, which is their electrodes. Solar cells require two electrical contacts to be made to each cell; normally one on the front and one on the rear. The purpose of these electrodes is to provide a high-conductivity path between the active surface of the cell and the electrical contacts at the edges of the cell. Development of improved electrodes is expected to substantially accelerate the commercialization of this promising technology, leading to reduction in the cost of solar energy.

Gold is by far the most common rear electrode material for perovskite cells, but it is prohibitively expensive, and can also diffuse into the perovskite active layer, leading to cell degradation. High efficiencies have also been achieved with silver electrodes, but they rapidly degrade when exposed to iodide ions that are present in most perovskite photovoltaic materials. Other metals have been explored to a limited extent, but the data with regards to long term stability is scant, and in most cases they have been unable to match the performance of the best gold-based cells.

In this project a variety of integrated electrode structures has been developed and tested for efficiency and stability, and the cost of the developed structures assessed.

Outcomes

A range of material configurations were investigated in this project, and two types of gold-free electrodes were developed into full cells, one based on a metal layer stack, and one based on carbon. Both show promising efficiency and stability.

The metal layer stack consists of a thin barrier metal and a thicker high conductivity metal. With the metal layer stack we were able to demonstrate certified 19% efficiency using a combination of bismuth and silver. The corresponding gold contact solar cells had an efficiency of 21%, showing that there is only a small efficiency penalty with a gold-free contact. The metal layer stack also shows promising stability under high temperature and high humidity (85C,85%) testing. An encapsulated device retained over 90% of its initial efficiency after 1000 hours of damp-heat exposure.

The carbon electrode showed promising efficiency and stability, achieving very good stability under thermal temperature cycling. Over 90% of its initial efficiency was achieved after 200 thermal cycles (-20°C/85°C). Our cost analysis indicated that the Bi/Ag electrode would be 4-6% of the cost of a gold electrode, while a carbon electrode would be 1-2% of the cost.

Transferability

The material configurations developed in this project are suitable for industrial application, though would require further development of suitable fabrication processes. The achievements of this project can also be applied to other projects involving perovskite technology. For example, the use of barrier layers within contacts is applicable to many types of electrical contacts and will be important for a range of approaches to improve perovskite stability.

We have established a website (perovskite group.com.au) which features current projects, latest results, press releases, researchers, opportunities, publications, and other information.

All group members regularly attend conferences, visit research institutions, and give talks at a variety of fora to both specialist and lay audiences. In addition, significant results also feature in media releases.

Conclusion and next steps

This project has been successful in helping to achieve high efficiency and improved stability using commercially relevant contact materials, which is essential for the commercialisation of the technology. There are still several remaining challenges. In particular, further improvements to stability and extended stability testing will be required for the new contact structures developed in this project.

The key benefit of this project is improvement of the commercialisation prospects of perovskite solar cells, which has the potential to lead to a significant reduction in the cost of solar electricity. Solar energy is already the largest contributor to new electricity capacity globally and is likely to be the most important source of electricity generation in the Australian grid in the coming decades. Along with the expansion of the electricity grid as transport and heating become electrified, reduction in the cost of electricity will lead to a substantial economic benefit for Australia.