Launch of a Photothermal Absorption Spectrometer for Cost Reduction in Photovoltaic Materials

Project results and lessons learned

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Executive Summary

In 2019, Open Instruments undertook the challenge to build and produce an ultra-sensitive Photothermal Deflection Spectrometer (PDS) prototype suitable for commercialisation. The AURA PDS, as the product was named, allows users to measure optical absorption with 100x to 1000x higher sensitivity than other commercially available systems. This high sensitivity enables photovoltaic labs and manufacturers to identify and address efficiency-limiting defects in solar cell materials. By producing this instrument, Dr Kampwerth and his team have enabled any research laboratory and R&D group around the world to access this unique measurement capability. The appeal of this highly sensitive instrument and the success of the project is evidenced by its commercial sale to a leading Australian university in the first quarter of 2022.

Project Overview

Project summary

Eliminating defects in photovoltaic (PV) materials is critical for high-efficiency devices that will deliver a low cost per watt. Existing techniques to detect non-radiative defects either have very specific sample requirements or suffer from poor sensitivity. There is therefore a critical need to develop new characterisation techniques for the PV industry.

Our aim was to produce a PDS system that is more sensitive than any other commercial instrument for measuring optical absorption, thereby enabling researchers to rapidly improve PV materials. To this end, the AURA PDS was brought to market in late 2021 and has already found success, with both a commercial sale and continued interest from the PV industry.

The AURA PDS is the first commercially available and fully integrated PDS system that is specifically targeted at R&D in the field of thin films and devices such as solar cells, optical coatings, LEDs, and novel materials. It measures optical absorption spectra with unparalleled dynamic range and ultra-high sensitivity down to 0.001%, complete with surface selectivity that reduces interference from the substrate. By comparison, conventional spectrophotometers can only reliably measure down to approximately 0.5%.

Open Instruments currently offers thin film substrate measurements for manufacturers and research labs to demonstrate our capabilities, which we anticipate will lead to further interest and sales.

Project scope

With the aim of revolutionizing the PV industry, new materials are being developed at UNSW and other Australian universities, supported by funding from ARENA. Many of these materials have the potential to result in the cheapest and most efficient solar cells ever produced. This project aimed to accelerate this material development, by creating a production-ready prototype of a PDS instrument and making this uniquely sensitive measurement technique available worldwide.

PDS is very well suited to the characterisation of photovoltaic materials, particularly those for next generation devices such as perovskites, CZTS, quantum dot layers, CIGS, III-V alloys, or organic materials. Massive global investment has been made in optimizing the material properties and bringing them to commercial readiness. However, determining efficiency-limiting defects in these materials often requires the time-consuming process of making a complete solar cell device.

The high sensitivity and contactless nature of our PDS instrument enables researchers to measure material samples immediately after creation, thereby allowing them to rapidly identify materials with the potential to make a global impact on the PV market.

The next steps toward full commercialisation of the AURA were to develop the production-ready prototype for launch at an international conference to demonstrate the technical advantages of PDS. By doing so, we would be targeting early adopters and early sales within the PV market.

It was also identified before the ARENA application that PDS has a broad range of applications outside the PV market, including in medical diagnostics, environmental monitoring, and analytical chemistry. We also aimed to investigate these additional potential revenue streams.

Outcomes

We developed AURA, the first ever PV-specific and commercially-viable photothermal deflection spectrometer, (see Figure 1.) Technical aspects of the design, including optics, mechanics, electronics and software, went through numerous iterations to optimize the performance and user experience. The core system design, assembly, and testing was performed locally in Sydney, Australia. We partnered with an external Japanese design house for the external aesthetics, while some small mechanical parts were manufactured by various overseas CNC and 3D printing companies.

Figure 1 *PDS system*

We are pleased to say that AURA is now commercially available from the industrial project partner, Open Instruments, a Sydney-based startup company.

The system was officially launched at the 31st International PV Science and Engineering Conference (PVSEC-31) on the 15th December 2021, where Dr Kampwerth presented the unique advantages of PDS for PV material development. The sensitivity advantage is immediately apparent in Figure 2, where it is clear that AURA reveals additional information about a perovskite flake, which remains hidden by existing systems.

The response from the PVSEC conference was extremely positive, with at least 44 individuals from 26 institutes registering interest. Open Instruments subsequently received a Purchase Order for AURA from Macquarie University, thus further validating the potential market for this instrument.

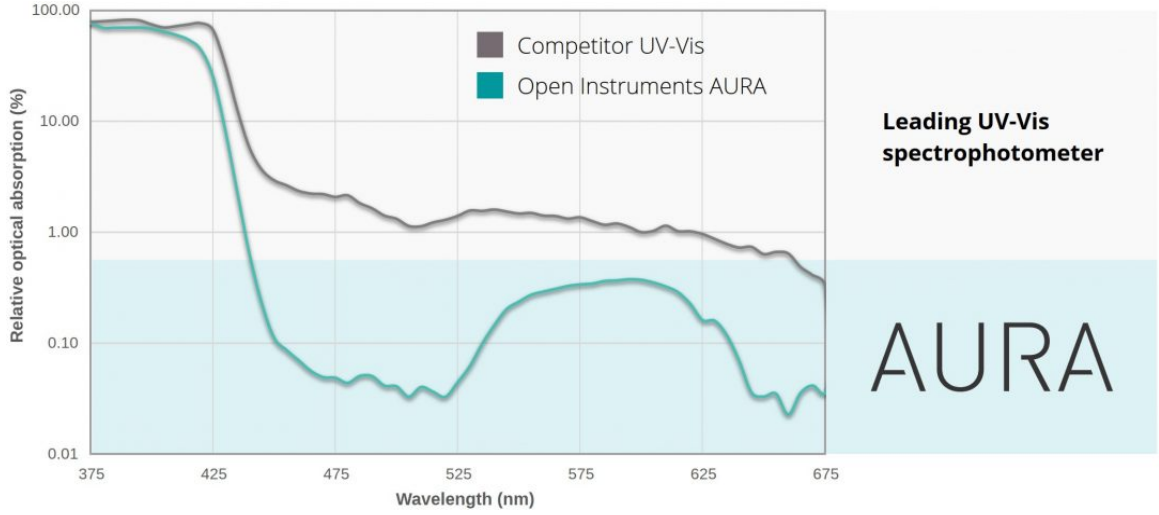

Figure 2 *Comparison between an absorption spectrum measured with AURA PDS and that of one of the closest competitive measurement techniques. The competitive technique reached its sensitivity limit, where the AURA PDS tool still reveals spectral features.*

Multiple Australian and international researchers have submitted their samples to Open Instruments for test measurements. To date, we have received samples with 7 unique materials from Australian partners to perform case studies, and many more from within the University of New South Wales.

To assure potential customers that the AURA PDS instrument is suitable for their material samples, Open Instruments is also now offering a fee-based measurement service through its website.

There remains vast future potential for the AURA PDS, both within the PV market space and further afield. Our market analysis determined that capturing just 1% of the PV industry use case will generate USD $10 million in revenue, while the more general Research Institute market represents an additional USD $24 million.

Publications

Listen to the conference presentation: https://youtu.be/EaNyib3nlec
Read more about the AURA PDS: www.openinstruments.com/aura

Conclusion, next steps and transferability

The development of AURA provides the photovoltaic industry with a much needed capability. As a result of the instrument's high sensitivity, PV researchers are now better equipped to rapidly iterate through new PV material compositions and identify those most likely to make a global impact.

Our successful commercialisation of AURA, contributes to PV applications such as:

- Semiconductor defect detection
- Production line quality control
- Novel absorber materials
- Absorption dynamics of planar and textured surfaces
- Contaminant tracing and identification of non-radiative defects

Open Instruments aims to capitalize on the success of the product launch, by promoting the AURA instrument and the PDS technique, both online and at international conferences. The company is currently in talks with distributors in several countries. Concepts for even further increasing the sensitivity will be tested, and methods for liquid measurements developed.

The future application space for the AURA PDS is vast. In addition to revolutionising the way new photovoltaic materials are studied, Dr Henner Kampwerth and Dr Michael Pollard are currently investigating applications in a broad range of fields including, but not limited to, medical diagnostics, environmental monitoring, physical optics, and analytical chemistry.

Lessons Learned

1. Take advantage of start up incubator programs to leverage networking and upskill with like-minded individuals

Knowledge Category:	Social / technical
Description of issue	Mentoring and growth support is available in person and online via programs designed to help start-ups 'get off the ground'. These programs and the individuals you connect with provide useful networking links and open possibilities for new technologies and applications that were previously not explored. If we were to begin this project again, we would leverage off the knowledge we now have about start-up incubator programs and the value of meeting and working with people in this space.
Key learning	There are various in-person and online programs supporting innovators. One that we have recently engaged with is the Founders Program at UNSW which is Australia's most comprehensive university entrepreneurship program. We are in the process of registering for this program and look forward to engaging with entrepreneurs and growing Open Instruments alongside like-minded individuals in this space. In mid 2021 we investigated Cicada Innovations and had many interesting discussions with medtech Leader, Dr Dharmica Mistry. Dr Mistry was able to provide mentorship and specialises in coaching founding teams looking to commercialise their impactful innovations. We have also been proactive in engaging with MTP Connect which is an independent, not-for-profit organisation. MTPConnect develops stronger connections between research and industry to help maximise opportunities to make scientific and technological breakthroughs and to see them developed and commercialised. We have met extremely helpful contacts via this connection and as a result intend to develop a diagnostic medical application for the AURA PDS.
Implications for future projects	For future projects, research into the entrepreneurial start up space would be of value both from a social and technical point of view.

2. Thorough and extensive research into available programs to help develop our project should be prioritised

Knowledge Category:	Social / financial
Description of issue	There are various applications that stem from AURA PDS. One is a medical/diagnostic application that we are currently exploring. During the process of engaging with various industry programs we have discovered the Australian Postgraduate Research Intern (APR.Intern). This is Australia's only national PhD and Masters by Research internship program spanning all sectors and disciplines. It is possible through this program to recruit a PhD student to explore this new possible application of the AURA PDS.
Key learning	Our key learning from this would be to discover it sooner. Had we known about this program earlier we could have two streams of potential applications running alongside one another.
Implications for future projects	For future projects, exploring and researching opportunities will be regarded as paramount so as to take advantage of all available to us and position ourselves in the best possible way to take AURA PDS to market.