connected everything.

# Solar Skin: Additive manufacturing of customised, fully integrated, photovoltaic products


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**Industrial Partners:** NOVACENTRIX, solar capture TECHNOLOGIES, ecospheric

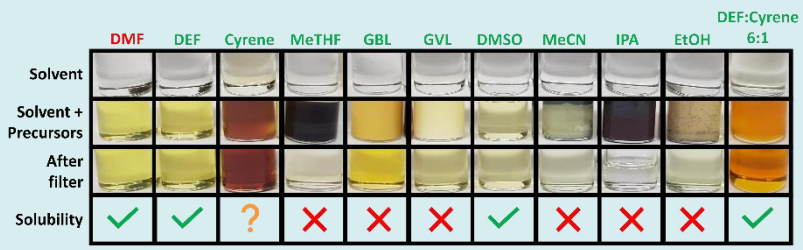

## What does the project demonstrate?

The aim of this project is to print bespoke solar cells directly onto products during manufacturing, to maximise the generation of clean electricity from all available surfaces. The project explored using low-cost additive manufacturing and low temperature photonic annealing to fabricate customized perovskite-based solar cells on flexible substrates. A tool was created to allow the cells to be optimized for the light spectrum available within their intended environment. Novel safe solar inks were developed, and these were successfully deposited onto prototype products. This project demonstrates the potential for customization of low-cost photovoltaics, while the prototypes demonstrate the wide applicability of this approach.

## Project outcomes

- **Developed safe stable perovskite solar cell inks**

The first challenge we encountered was making our absorber inks safe enough to be printed without the need for specialist safety equipment. We developed a novel solvent system and new perovskite precursor formulation to achieve this. Our non-toxic perovskite ink, $FA_{0.75}MA_{0.25}SnI_3$ in DEF:Cyrene (6:1), is safe to use without containment or prohibative safety equipment but doesn't compromise printability.





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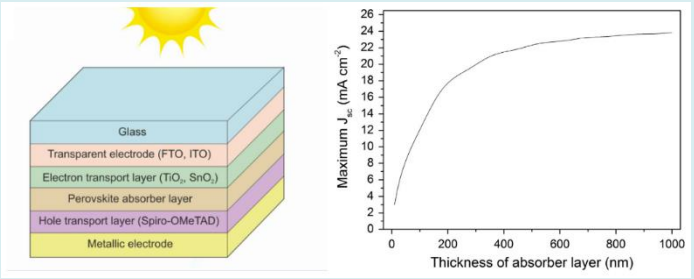
- **Creating a data driven design tool**

A new design tool was used to create bespoke solar cell configurations for specific applications, optimizing layer thickness to maximise the collected current based on the specific absorber bandgap and the incident light spectrum.




- **Fabricated printed prototype solar skin products**

Several prototype solar skin products were successfully fabricated. The image shows a non-toxic perovskite solar cell printed directly onto a Fitbit strap. The connected everything logo was chosen to demonstrate the possibilities with direct patterning afforded by inkjet printing.

## Next Steps

The early promise shown in this project has opened several exciting future avenues, including three funding applications (two successful, one waiting on an outcome) and a PhD studentship:

- **EPSRC new investigator award, Title '*Printing Perovskite Solar Cells: Reducing Toxicity and Improving Scalability*' – funding decision pending**.

This work will allow us to develop the chemistry of our safe solar cell inks further, as well as to focus on furthering the scalability of the technology.

- **Early career UoL funding, Title 'In-Situ Impedance Measurements for Defect Detection in Perovskite Solar Cells' – Successfully awarded and underway.**

In collaboration with colleagues from electrical engineering we are working to determine the feasibility of using in-situ impedance measurements, based on a DC-DC power converter, to identify mechanisms leading to performance loss in perovskite solar cells.

- **Royal Society Research Grant, title 'Scalable Slot Die Coating of Non-toxic Perovskite Solar Cells' – Successfully awarded and underway**

The aim of this project is to develop slot-die coating of non-toxic tin-based perovskite solar cell (PSC) inks that are stable in atmospheric conditions. This work aims to investigate low cost, scalable slot-die fabrication processes to create a route to market for the PSCs.

- **EPSRC PhD studentship, title 'Spray-On Solar Cells: Scalable Additive Manufacturing of Flexible Perovskite Photovoltaics' – Successfully awarded and currently in recruitment**

During the PhD, the student will work with non-toxic tin-based perovskite solar cell inks developed at the University of Liverpool. They will explore the use of spray coating to deposit perovskites onto flexible substrates. The goal is to produce working prototype PSCs that have been sprayed directly onto products such as clothing and folding smartphones.

- **'*Solvent Selection for Printable, Green, Non-toxic Perovskite Solar Inks*':** Paper in preparation

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