

Flexible Energy Module for Low Power Internet of Things Devices by Perovskite Solar Cell and Printed Supercapacitor

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Introduction

- In this presentation we talk about a flexible energy supply unit made by printing flexible disposable aqueous supercapacitor modules onto a light harvester.
- Novel material for printable separator to make a fully printable supercapacitor.
- Printing the series connected supercapacitors monolithically on the back side of an OPV module is a fast, easy and cheap method to fabricate future energy modules for IoT.
- The device combines energy harvesting and storage module for harvesting light under normal indoor conditions.
- The flexible printed supercapacitor is charged by perovskite solar cell.

Layout pattern of the monolithic supercapacitors

Single supercapacitor (top) and two series connected supercapacitors (bottom).

Materials for supercapacitors :

Current collectors: Graphite ink

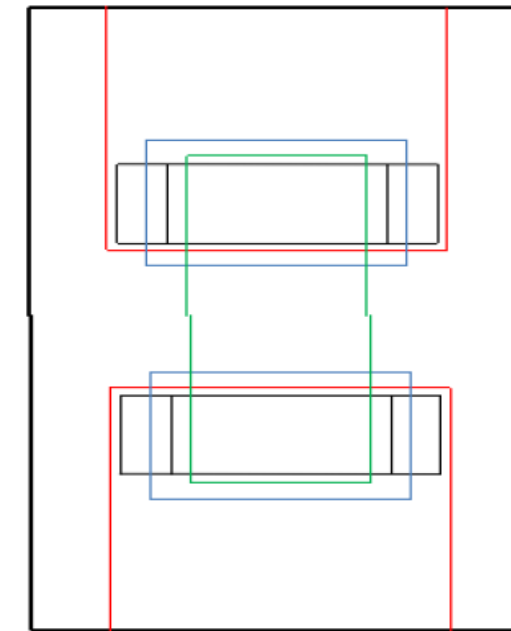
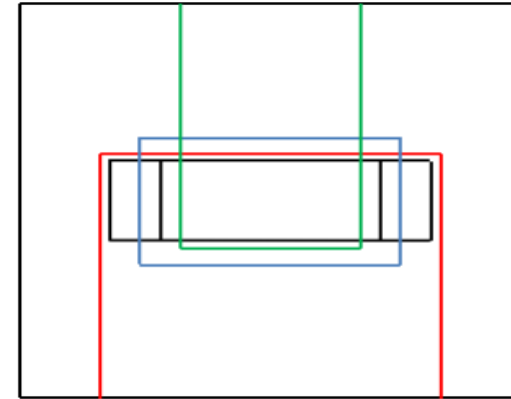
Electrodes: Activated carbon powder, chitosan, acetic acid, water

Separator: Cellulose paper (Dreamweaver Silver) or chitosan + microfibrillated cellulose

Electrolyte: NaCl + water

Sealing: Adhesive tape

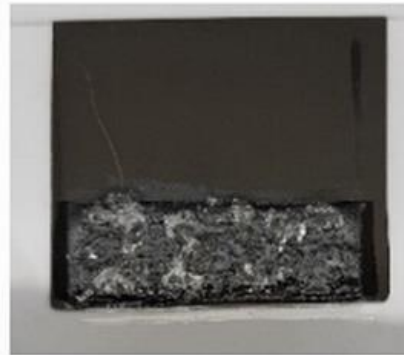
Methods: stencil printing and screen printing.



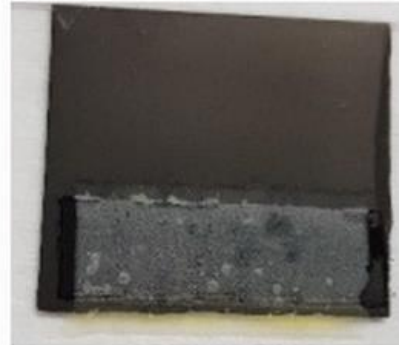
Printable separator, composite of chitosan and MFC: CM5050



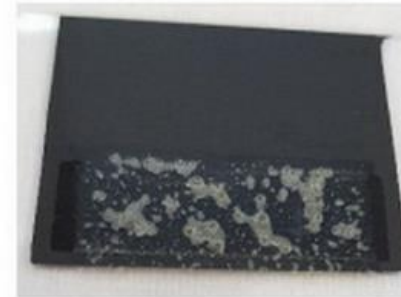
a



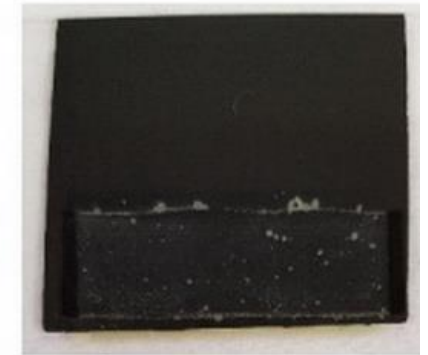
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c



d



e

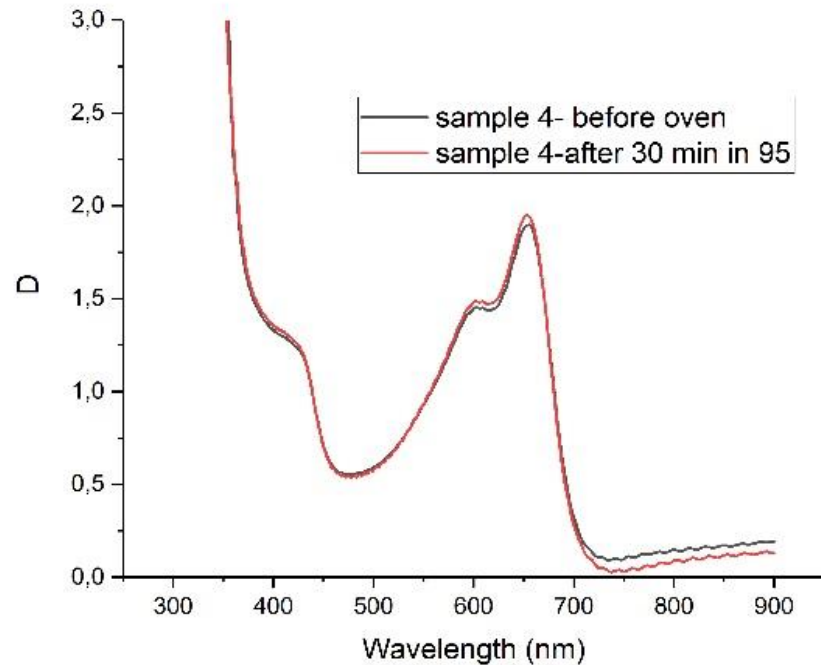
Figure 1(a) MFC, (b) Chitosan, (c) 80%MFC solution+20%chitosan solution, (d) 80%Chitosan solution+20%MFC solution, (e) 50%Chitosan solution+50% MFC solution film on glass substrate

'Additive manufacturing of monolithic supercapacitors with biopolymer separator' By M. Arvani et al., *Journal of Applied Electrochemistry*, vol. **50**, 6, p. 689-697, 2 May 2020.

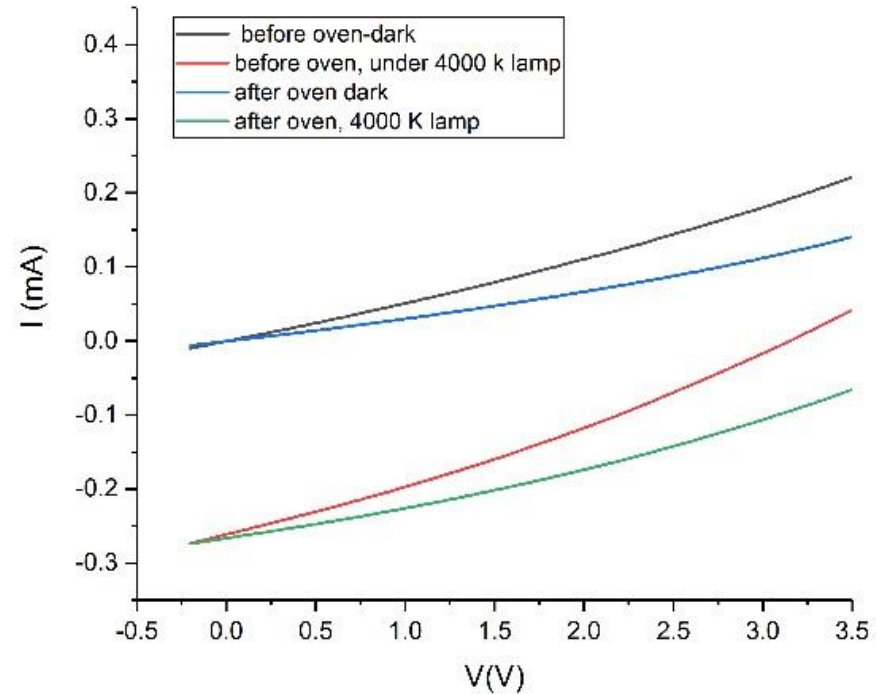
<https://doi.org/10.1007/s10800-020-01423-2>

Properties of the OPV before and after heat treatment

Absorption spectra of the OPV before and after heat treatment.



IV characterization of the OPV before and after heat treatment, in dark and under radiation of light.



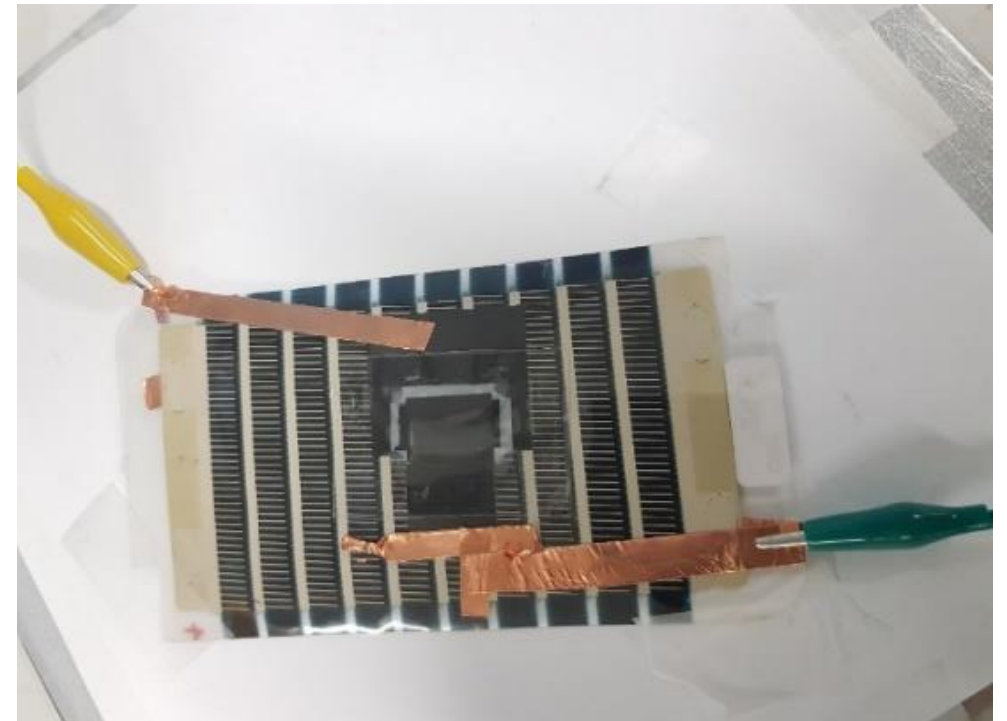
-> ink curing doesn't deteriorate OPV properties

Single supercapacitor printed on the backside of the OPV

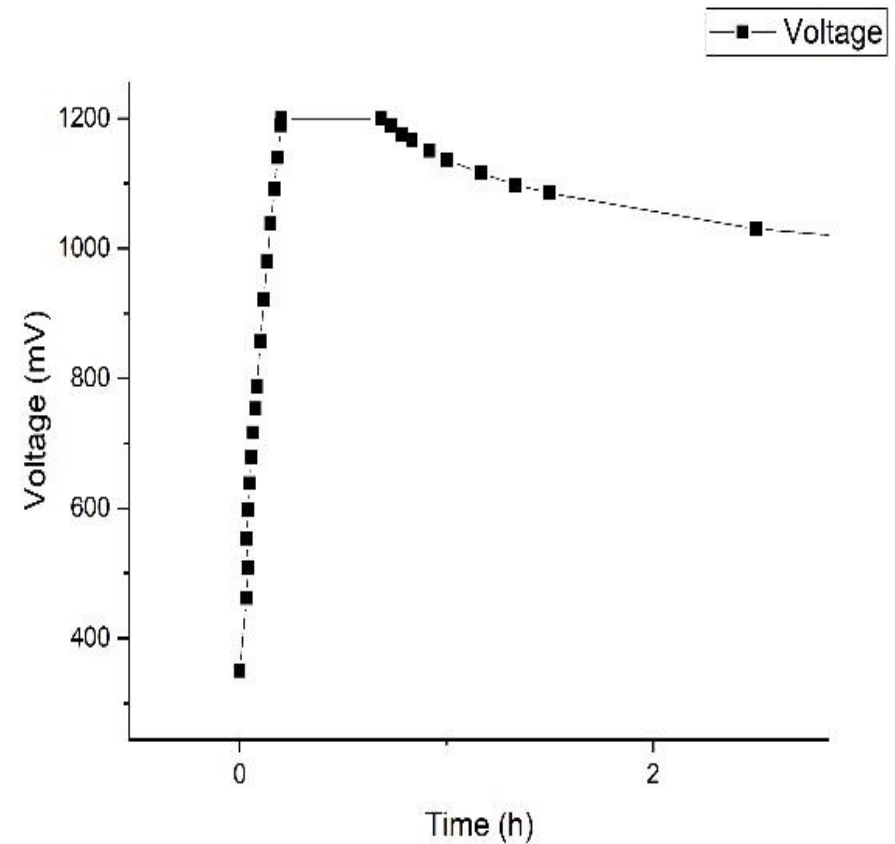
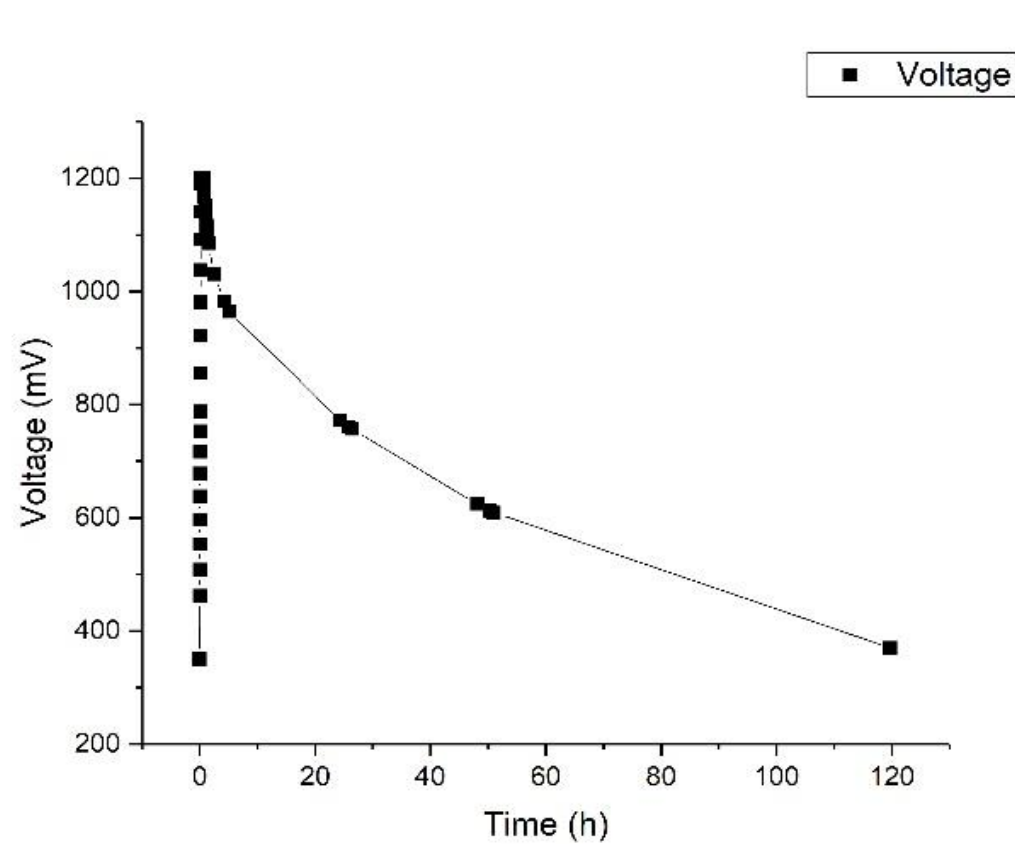
The OPV modules were from an educational solar cell kit made by infinityPV. The stated efficiency of the OPVs was 5%.

The light source was a 4000 K, 806 lm LED lamp from Airam Company. It was installed 41.5 cm above the OPV modules to simulate indoor lighting. The light intensity during measurement was 5 mW/cm².

The capacitance of the supercapacitor was 218 mF, equivalent series resistance (ESR) was 22 Ω and leakage current was 8.3 μ A.

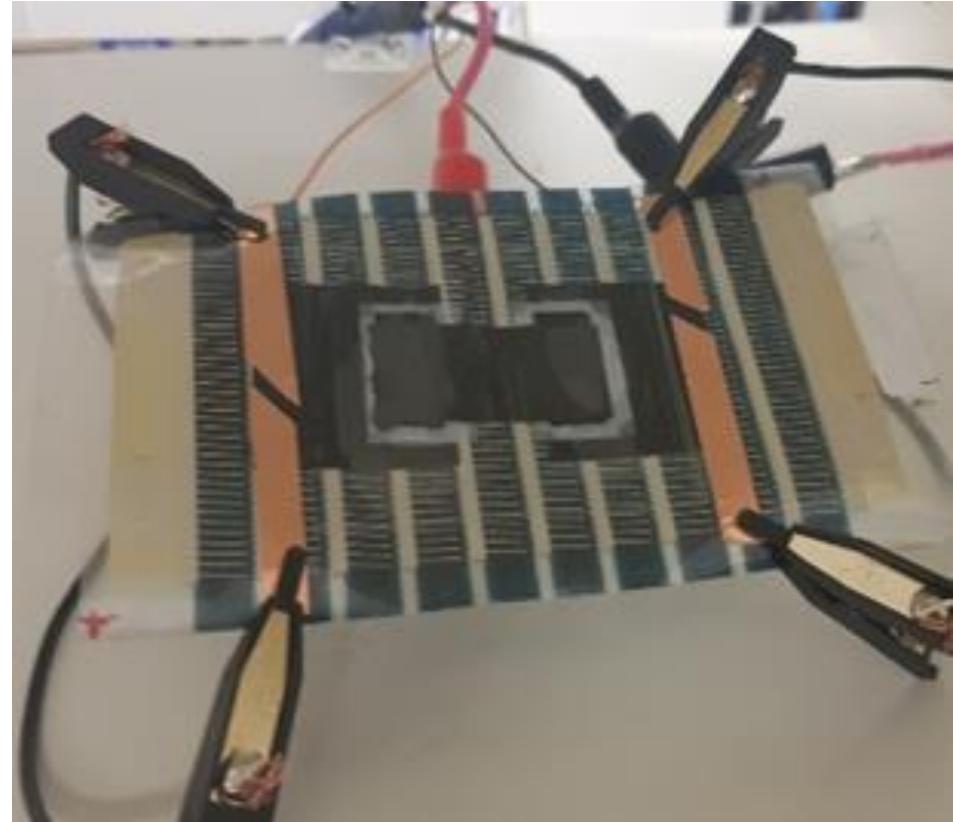


Charge and discharge curve of the single printed supercapacitor charged by OPV

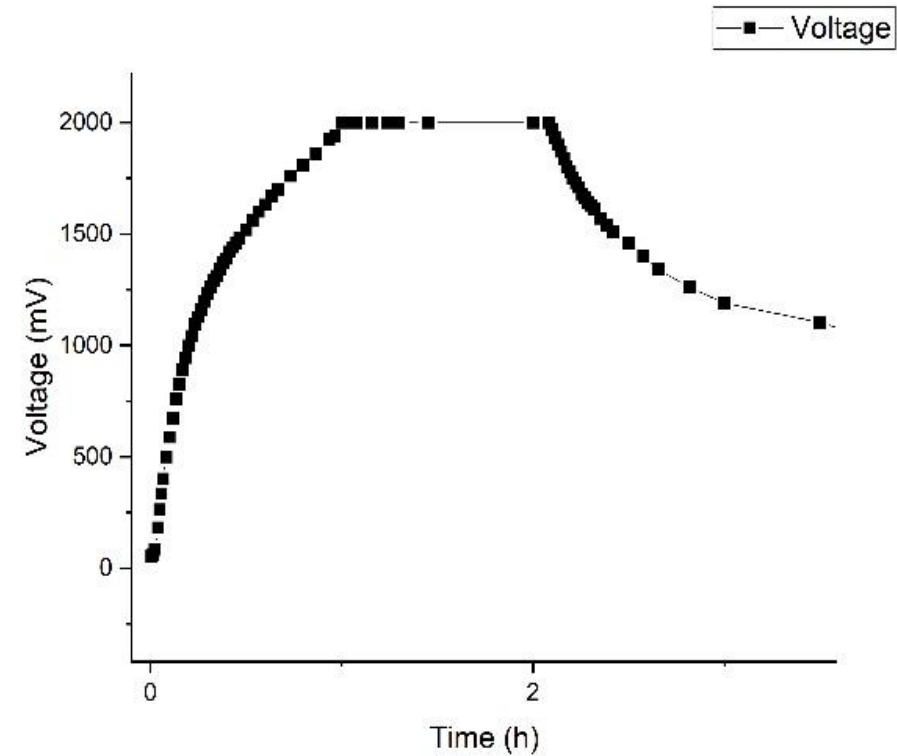
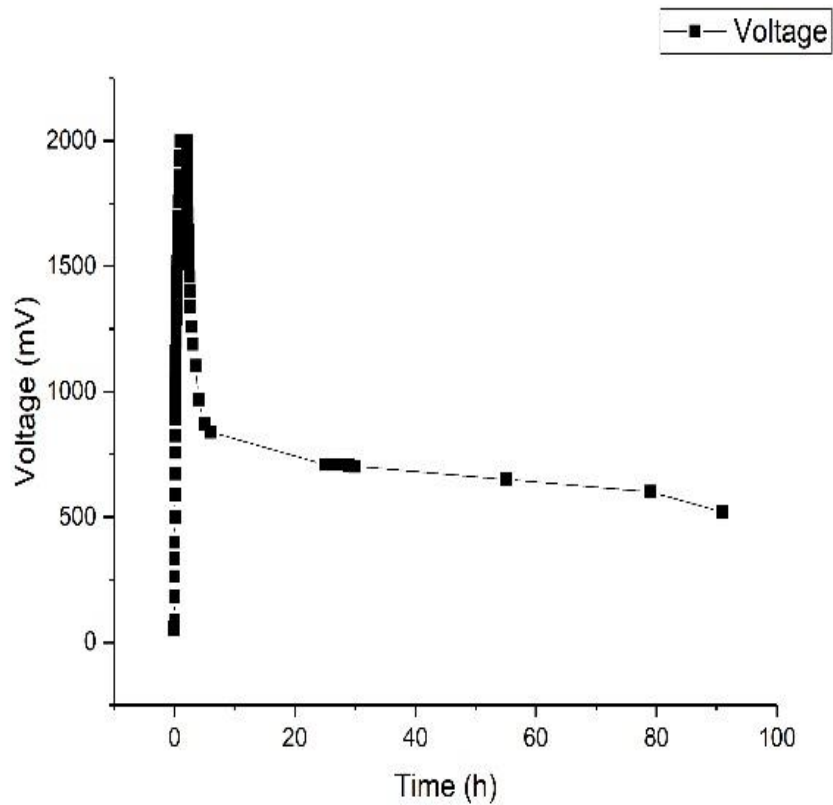


Series connected supercapacitors printed on the backside of the OPV

The performance of the module after charging to 2 V using the Maccor characterization interface shows capacitance of 93 mF, ESR of 22 Ω and leakage current of 47 μA .



Charge and discharge curve of the series connected printed supercapacitors with paper separator, charged by OPV

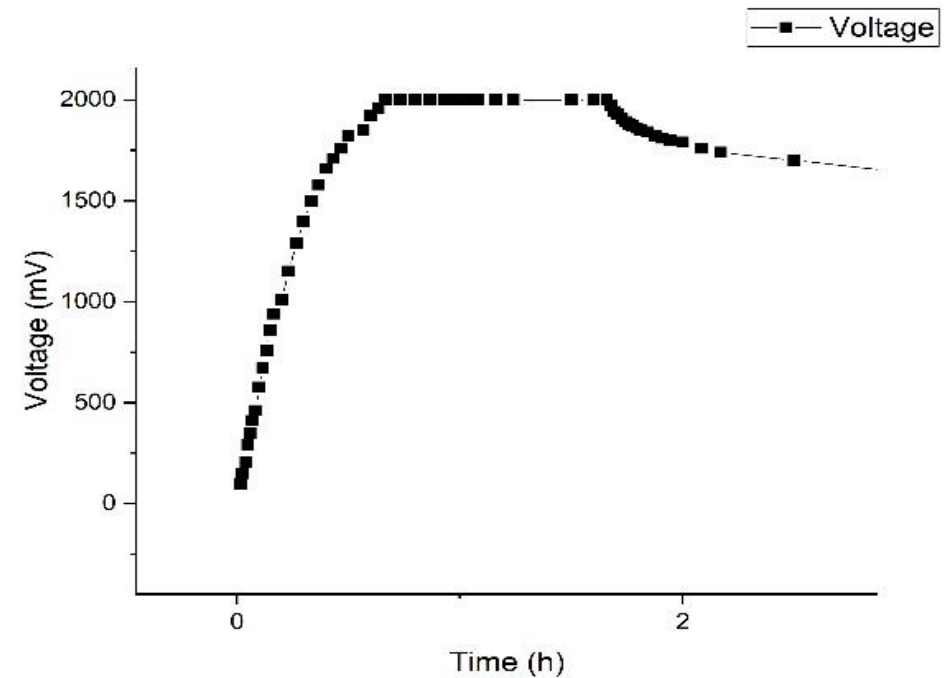
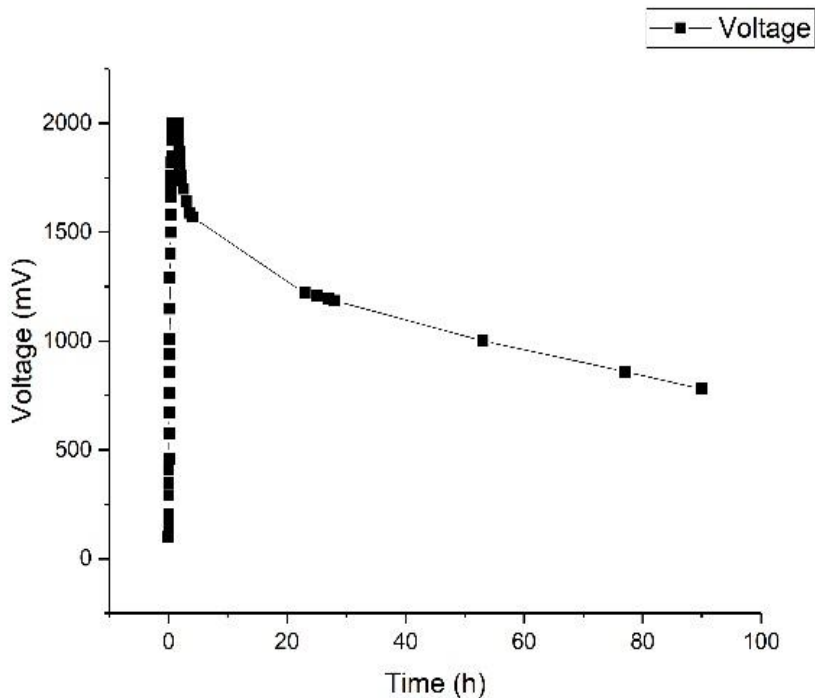


Two series connected fully printed supercapacitors printed on backside of OPV , can be charged up to 2V



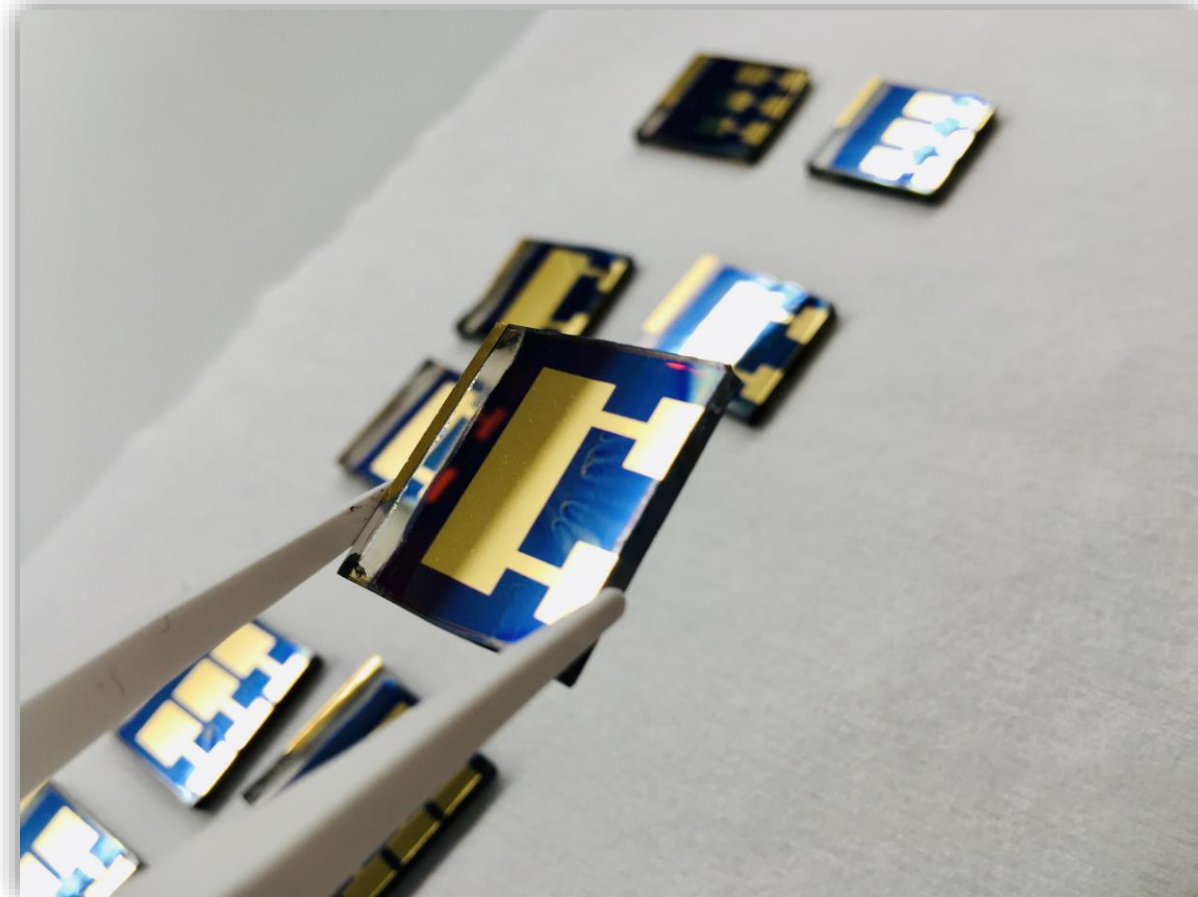
Charge and discharge curves of the series connected printed supercapacitors with CM5050 separator charged by OPV

The device was first characterized with the Maccor interface, yielding capacitance of 125 mF, ESR of 56 Ω and leakage current of 7.4 μA .

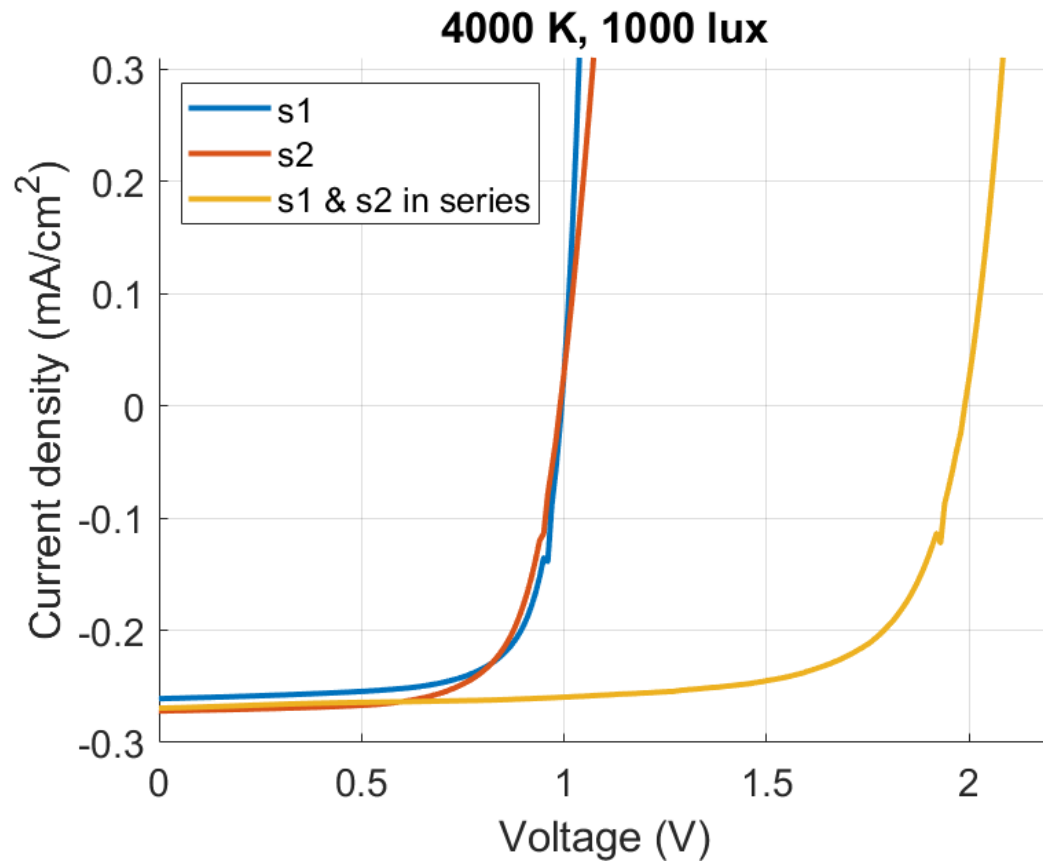


Solar cells

- FTO|c-TiO₂|m-TiO₂|Perovskite|Spiro-OMeTAD|Au
 - Area 1 cm²
 - Used for charging singly, or connecting two in series
 - Measured under LED light bulb 4000 K, 1000 lux



Solar cell performance

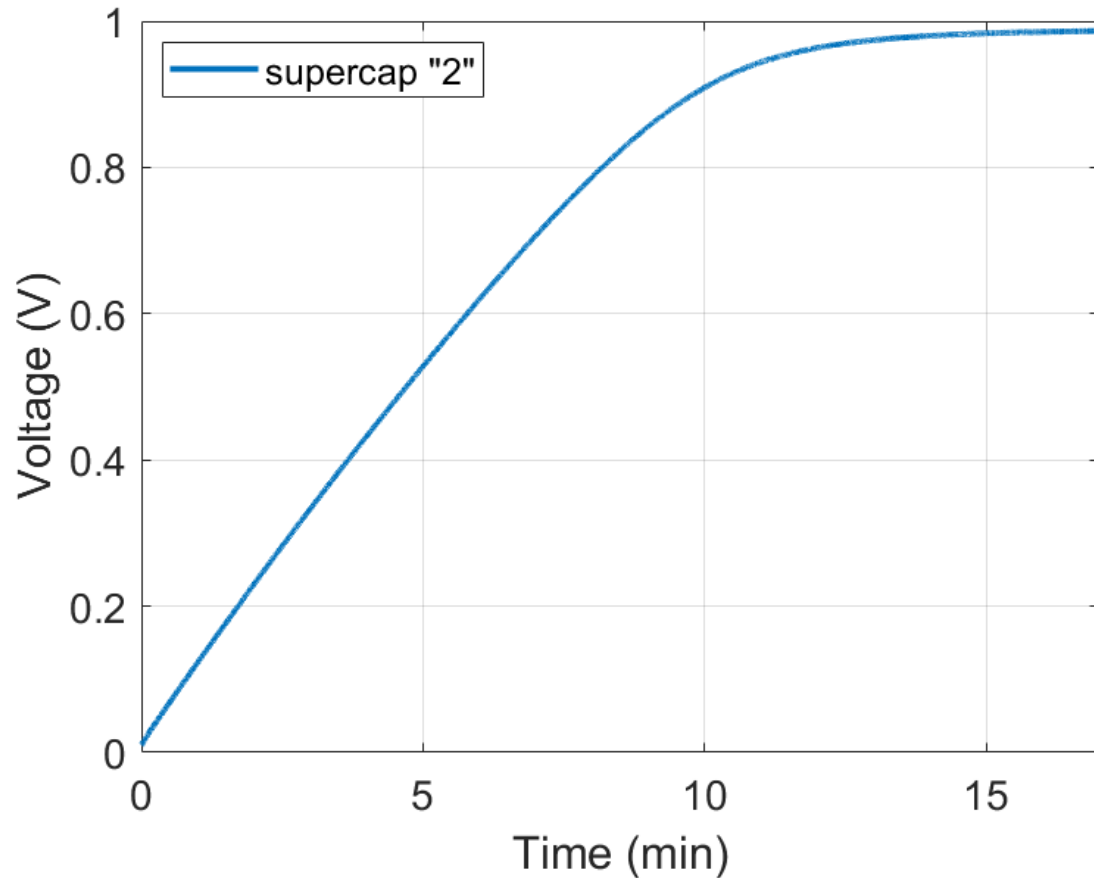


	Efficiency (%)	FF (%)	I_{sc} (mA/cm ²)	V_{oc} (V)	Area (cm ²)
s1	28,3	73,0	0,26	0,99	1,1
s2	28,4	70,3	0,27	0,99	1,1
s1 & s2 in series	28,6	71,4	0,13	1,98	2,2

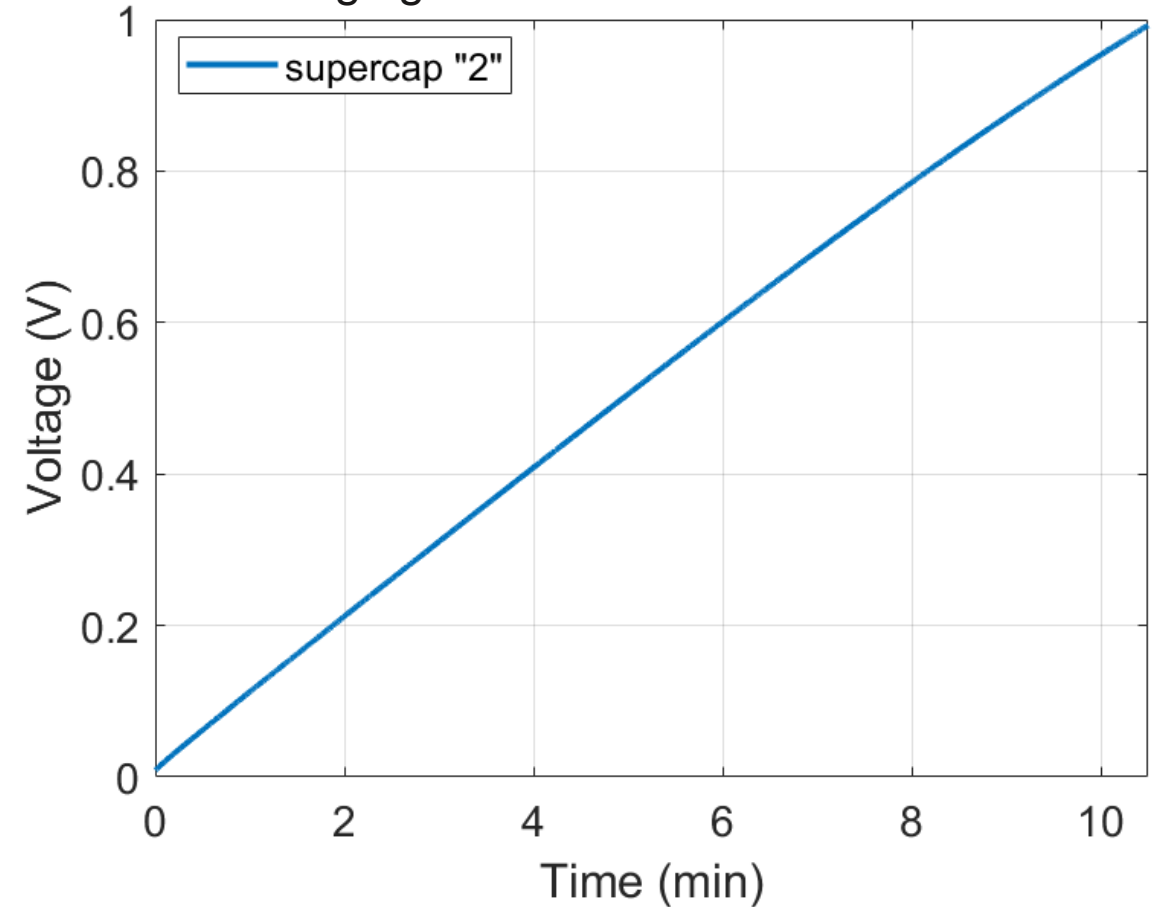
Lamp power measured with Coherent PM3 thermopile sensor; 0.67 mW/cm²

Supercap charging (184 mF)

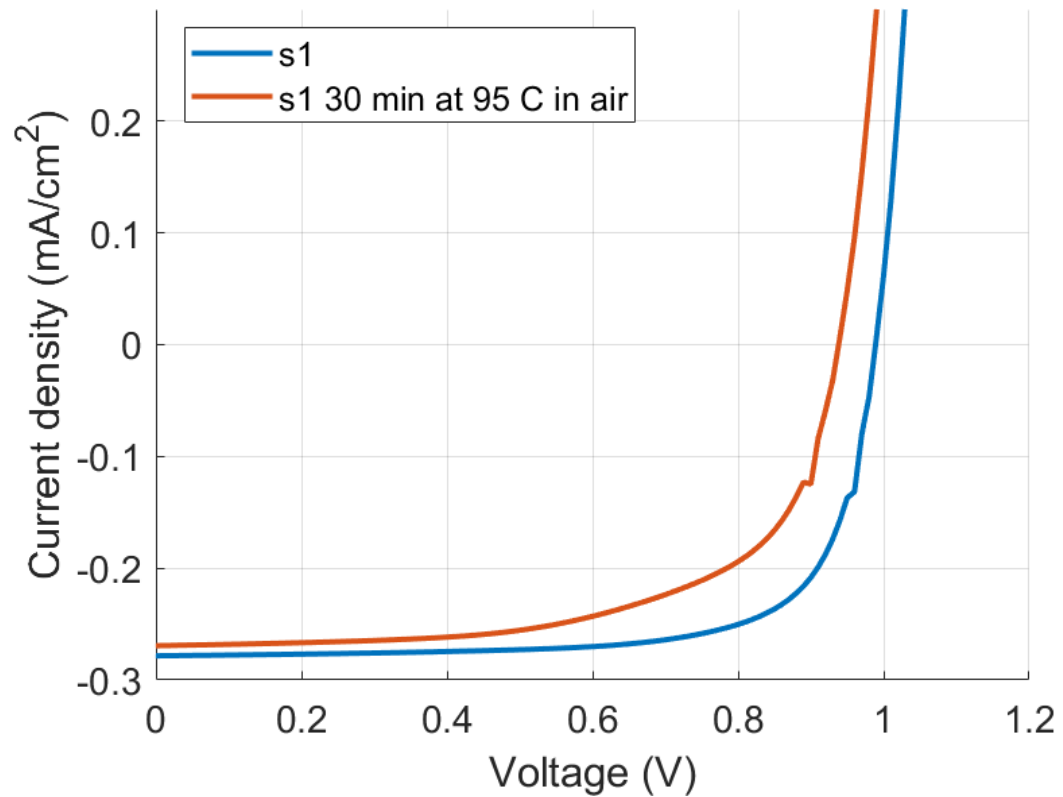
Charging with one cell (1 cm²)



Charging with two 1 cm² cells in series



Stability under heating stress



	Efficiency (%)	FF (%)	Isc (mA/cm ²)	Voc (V)	Area (mm ²)
Initial	28,6	73,9	0,28	1,0	110
30 min at 95 C in air	22,4	63,2	0,27	0,9	110

CONCLUSION

- We have demonstrated an architecture for the integration of monolithic supercapacitor modules and flexible PV modules onto a single substrate
- The energy module can provide sufficient energy from indoor light to charge the energy storage, which can maintain a large fraction of the energy for several days
- The printed energy module can provide an environmentally and economically sustainable source of energy to autonomous wireless sensor nodes for the IoT

Thanks for your attention!