PERDRY
Dry production routes for large-area benign metal halide perovskite solar cells

Project duration: from 11.2019 to 03.2023
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Publishable Summary

Solar cells, employing metal halide perovskite, HaP, light absorbers have developed tremendously over the past years. So far, best efficiencies (>26%) were all obtained with lead-based HaPs, prepared by non-scalable spin-coating using often toxic solvents. Hence, to reach a TRL > 5 it is essential to develop scalable processes without toxic solvents and either replace the lead or ensure safe “end-of-life” protocols.

We used dry processing to prepare uniform large-area and benign HaP thin films and integrate them into efficient photovoltaic devices. Physical vapour-based processes such as co-evaporation, flash evaporation of the binary constituents and pulsed laser deposition of pre-formed bulk material were used.

During the PERDRY project a large number of Sn based HaP and Ag-Bi based double HaPs were evaluated as absorbers in thin film solar cells but, unfortunately, these did not lead to efficiencies above 1 %. We did observe promising ZT factors for the Sn-based HaPs which may make these suitable for thermo-electric devices. We found addition of Ge to Sn based HaP to significantly decrease their negative tendency to oxidize. This result shows a possible way to minimize the defects formed by Sn oxidation, defects that are thought to limit Sn-HaP – based PV cell performance.

The environmental and health issues of lead in PV modules, as well as the present regulations were studied and summarized by Sticky Solar Power in a technical report. We did develop a very efficient and cost-effective lead chelating encapsulant capable to retaining > 90 % of lead in purposely broken cells when exposed to excess rain water exposure. We also investigated adsorption of Pb2+ from a mixed-cation organic-inorganic mixed HaP onto several types of soils to quantify the Pb2+ depth distribution profile. We found that the top 1st cm of soil columns retains most of the irrigated Pb2+. Though the Pb2+ concentration in the top 1 cm of the soil was higher than the hazard waste limit of 5 mg/L, it dropped to below that limit already in the 2nd cm of the soil columns.

We advanced the dry deposition of HaPs by implementing a low-cost CW laser deposition method and by developing a continuous flash evaporation tool. The lifetime of the evaporated HaPs solar cells is over 5000 hours at 85 °C, which is expected to translate to a room temperature lifetime well over 10,000 hours. Large Pb-based HaP cells with PIN architecture were tested outdoors. Their performance was tracked and correlated with weather station data from the Glava Energy Center measurement site.

The interaction between the partners on the characterization has been particularly successful. Fundamental aspects such as frontier orbital/ band extrema energy levels were determined by KAU on perovskites prepared by UVEG and BIU. In an effort to speed up material development, UVEG and BIU have developed a combinatorial approach using vacuum deposition methods.

We will continue with the implementation of the dry-processing methods for the deposition of HaPs and focus in particular on the film quality, reproducibility and throughput to facilitate their uptake in industrial production facility.

Project consortium

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Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Spain	1	183 700	173 397
Israel	2	496 885	387 129
The Netherlands	1	48 000	0
Sweden	*3*	*325 552*	*146 498*
Total	*7*	*1 054 137*	*707 024*

Funding agencies involved and contracts

Funding Agency	**Contract N° and Title**
Ministerio de ciencia e innovación- Agencia Estatal de Investigación	PCI2019-111829-2 Producción en seco para celdas solares basadas en perovskitas usando haluros metálicos benignos
Israel Min. of Energy & Infrastructure	219-11-119 Exploring Ways to Large-Area Halide Perovskite-Based Photovoltaics 219-11-081
Energimyndigheten (StEM)	P48381-1 Torra produktionsvägar för storskaliga perovskitsolceller av ofarliga metalhalider 2019-004603