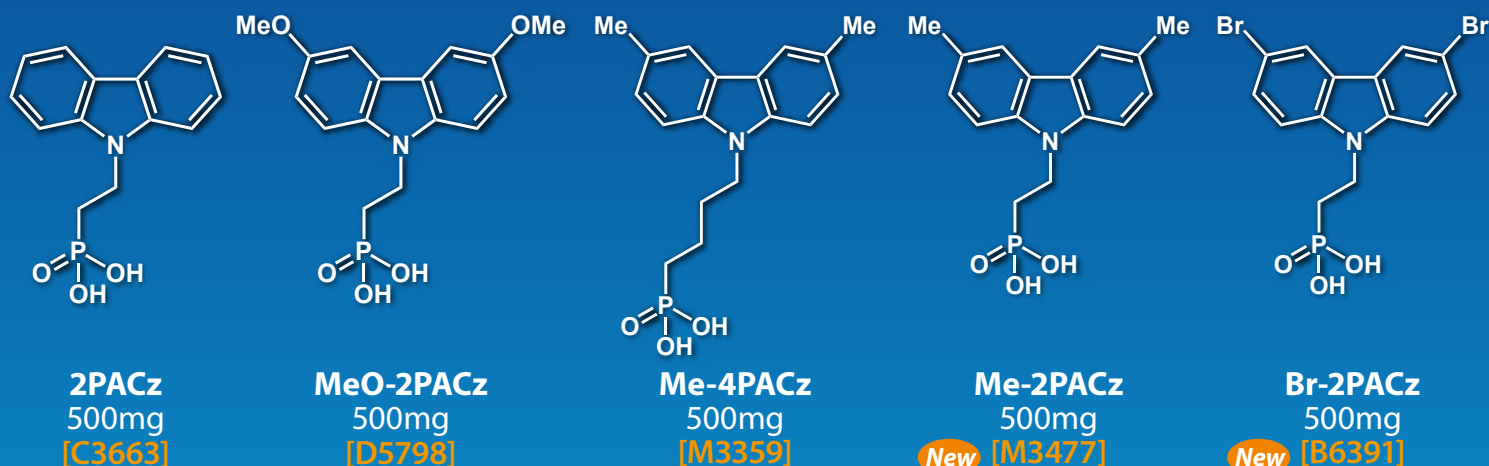


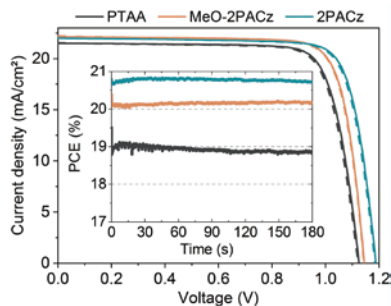
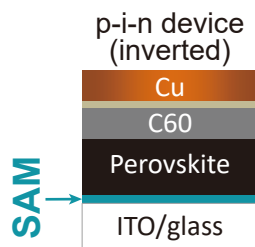
# For Highly Efficient Solar Cells, Hole-Selective, Self-Assembled Monolayer (SAM)-Forming Agents



## Advantages

- Enable efficient, versatile and stable solar cell devices without additives, interlayers or dopants
- Self-assembly leads to conformal coverage of oxide surfaces (including textured)
- Simple, scalable and extremely cost-effective processing

## Application



Efficiency on 1 cm<sup>2</sup> = **23.26%**



**SAM**  
oxide

World-record CIGSe/perovskite tandem enabled by conformal SAM

Stabilized power conversion efficiencies of PSC and OPV with self-assembled monolayer (SAM):

SAM	CsMAFA	MAFA	Co-evaporated MAPbI <sub>3</sub>	Slot-die coated MAPbI <sub>3</sub>	CIGSe/CsMAFA tandem	Silicon/CsMAFA tandem	OPV Ternary BHJ
2PACz	20.8% <sup>1)</sup>	21.1% <sup>1)</sup>	-	20.8% <sup>5)</sup>	-	27.36% <sup>3)</sup>	18.03% <sup>4)</sup>
MeO-2PACz	20.2% <sup>1)</sup>	21.1% <sup>1)</sup>	20.6% <sup>2)</sup>	-	23.26%, certified <sup>1)</sup>	28.60% <sup>3)</sup>	-
Me-4PACz	20.8% <sup>3)</sup>	-	-	-	24.16% certified <sup>6)</sup>	29.15%, certified <sup>3)</sup>	-
Br-2PACz	-	-	-	-	-	-	18.4% <sup>7)</sup>

(CsMAFA = Cs<sub>0.05</sub>(MA<sub>0.17</sub>FA<sub>0.83</sub>)<sub>0.95</sub>Pb(I<sub>0.83</sub>Br<sub>0.17</sub>)<sub>3</sub>, MAFA = MA<sub>0.05</sub>FA<sub>0.95</sub>Pb(I<sub>0.95</sub>Br<sub>0.05</sub>)<sub>3</sub>, Cs = cesium, MA = methylammonium, FA = formamidinium, CIGSe = copper indium gallium selenide)

\* These data are from References below:

- 1) A. Al-Ashouri, A. Magomedov, V. Getautis, S. Albrecht, *et al.*, *Energy Environ. Sci.* **2019**, *12*, 3356. <https://doi.org/10.1039/C9EE02268F>
- 2) M. Roß, S. Albrecht, *et al.*, *ACS Appl. Mater. Interfaces* **2020**, *12*, 39261. <https://doi.org/10.1021/acsami.0c10898>
- 3) A. Al-Ashouri, A. Magomedov, V. Getautis, S. Albrecht, *et al.*, *Science* **2020**, *370*, 1300. <https://doi.org/10.1126/science.abd4016>
- 4) Y. Firdaus, T. D. Anthopoulos, *et al.*, *ACS Energy Lett.* **2020**, *5*, 2935. <https://doi.org/10.1021/acsenerylett.0c01421>
- 5) J. Li, A. Abate, E. Unger, *et al.*, *Adv. Energy Mater.* **2021**, *11*, 2003460. <https://doi.org/10.1002/aenm.202003460>
- 6) NREL Best Research-Cell Efficiency Chart <https://www.nrel.gov/pv/cell-efficiency.html>
- 7) Y. Lin, A. Magomedov, V. Getautis, T. D. Anthopoulos, *et al.*, *ChemSusChem* **2021**, *14*, 3569. <https://doi.org/10.1002/cssc.202100707>

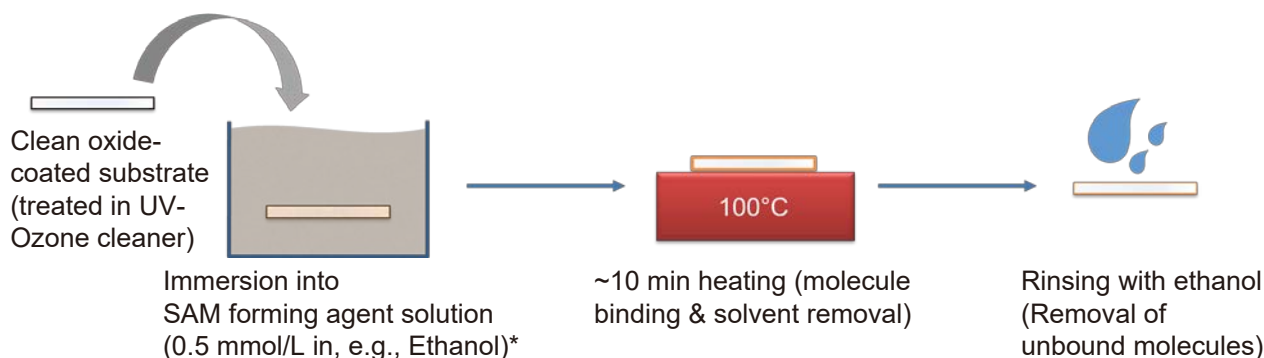
The 2PACz, MeO-2PACz and Me-4PACz materials are covered by a joint patent pending PCT/EP2019/060586) of Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Germany and Kaunas University of Technology, Lithuania. TCI has been granted the right to manufacture and sell these materials.

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## Processing

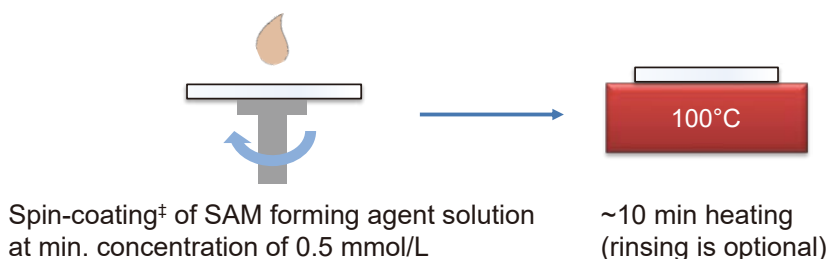
### Method 1: Dip coating

suitable for large-area coating and textured substrates



### Method 2: Spin coating

suitable for fast research & optimization



\* The minimum needed dipping time can vary from minutes to hours. After some further testing with 2PACz, researchers found more reproducible results with rather 0.5 mmol/L and 5 min dipping. Note that optimal concentration and dipping time may vary depending on the used substrate oxide and pre-treatment.

- The SAM forming agents can be processed within wide processing windows with higher reproducibility than current standard hole transport materials (like PTAA). The substrates (e.g. ITO) have to be clean and activated by, for example, UV-Ozone treatment.
- The SAM forming agent powders were usually dissolved in ethanol or isopropanol (1 mmol/L  $\approx$  0.3 mg/mL), MeO-2PACz powder was stored in air, while 2PACz and Me-4PACz were stored in a N<sub>2</sub>-filled glovebox.

<sup>‡</sup>For more details, see supplementary information of the following reference.

A. Al-Ashouri, A. Magomedov, V. Getautis, S. Albrecht, *et al.*, *Energy Environ. Sci.* **2019**, *12*, 3356. <https://doi.org/10.1039/C9EE02268F>

\*These data are provided by Prof. Steve Albrecht and Prof. Vytautas Getautis.

For further information please refer to our website at [www.TCIchemicals.com](http://www.TCIchemicals.com).

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##### TOKYO CHEMICAL INDUSTRY CO., LTD.

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