

## Multifunctional Hybrid Materials for Energy Conversion in Photovoltaics

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Hybrid organic-inorganic materials are increasingly relevant for emerging energy technologies.<sup>1</sup> In particular, metal halide perovskites have become one of the leading semiconductors for solar-to-electric energy conversion in photovoltaics.<sup>2-3</sup> However, their operational instability hinders practical applications.<sup>3</sup> While this can, to an extent, be overcome by incorporating organic moieties within hybrid perovskite frameworks that form low-dimensional architectures with superior operational stabilities, their electronically insulating character often compromises the resulting photovoltaic performances.<sup>3-5</sup> This issue will be addressed by discussing the capacity of supramolecular engineering in the design of adaptive bio-inspired materials<sup>3</sup> and the use of (photo)electroactive organic species to enhance the functionality of hybrid perovskites by enabling control in response to external stimuli,<sup>4</sup> such as voltage bias,<sup>5</sup> light,<sup>6</sup> and pressure,<sup>7</sup> opening a path toward multifunctional materials and smart photovoltaics.



Schematic of multifunctional perovskite materials responsive to external stimuli, such as pressure.<sup>7</sup>

[1] S. Krause\* and J. V. Milić\*, Commun. Chem. 2023, accepted.

[2] J. V. Milić\*, Chimia 2022, 76, 784–791.

[3] W. Luo, G. AlSabeh, J. V. Milić\*, Photochemistry 2022, 50, 342–366.

[4] J. V. Milić\*, J. Mater. Chem. C 2021, 9, 11428–11443.

[5] Mishra, P. Ahlawat, G. Fish, F. Jahanbakshi, M. Mladenović, M. A. Preciado-Ruiz, M. Almalki, M. C. Gelvéz-Rueda, V. Dufoulon, T. Schneeberger, D. J. Kubicki, R. Poranne, F. C. Grozema, S. M. Zakeeruddin, J. E. Moser, U. Rothlisberger, L. Emsley\*, J. V. Milić\*, M. Graetzel\*. Chem. Mater. 2021, 33, 6412–6420.

[6] W. Luo, G. AlSabeh, J. V. Milić\*, et al. 2023, unpublished work.

[7] L. A. Muscarella, A. Dučinskas, M. Dankl, M. Andrzejewski, N. P. M. Casati, U. Rothlisberger, J. Maier, M. Graetzel, B. Ehrler\*, J. V. Milić\*, Adv. Mat. 2022, 202108720.

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