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Advanced materials for hybrid energy storage devices

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Supercapacitors, one electrochemical energy storage device (EES), are fascinating devices due to their high power, low cost, long cycling performance and and fast charge/discharge rates. However, their energy density needs to be improved to compete with other ESS in the market, especially with batteries such as Li-ion tecnologies. The development of hybrid electrodes by means of combining different nanomaterials is one of the strategies to enhance the energy density of supercapacitors. In this sense, the properties of faradaic redox-active nanomaterials and purely double-layer capacitive nanocarbons are integrated into the same electrode. Moreover, the combination in the same device of a capacitive electrode and a faradaic one is another possible hybridization method to increase their performance, such as in the case of metal-ion supercapacitors (Li+, Na+, Zn2+). Among these, Zn-ion chemistry has a greater impact on the development of novel and greener energy storage devices due to zinc's low-cost, abundance and water compatibility. As redox-active materials, that can be used to hybridize electrodes, polyoxometalates (POMs) are well-suited nanomaterials (nanoscale metal oxide clusters from Mo, W, and V) that can perform fast reversible redox reactions without changing their structural stability, providing an increase of capacity and cyclability when they are combined with nanocarbons such as activated carbon or graphene oxide. Their combination with inorganic 2D materials MXene materials has yielded a great performance in terms of a very high volumetric capacitance, which combined also with nanocarbons (high gravimetric capacitance) allows to have a device which can have 1.5 times higher volumetric capacitance than those with Mxenes alone. Other sustainable nanomaterials that have shown promising perfomance on different energy storage devices are the Prussian Blue Analogues (nanocubes made from iron, nitrogen, and carbon). Due to their chemistry and crystalline structure, they can intercalate cations (Na+, K+ and Zn+2) in aqueous media providing many possibilities for the development of safe and green EES.

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