Cost effective non-aqueous Zn-ion hybrid supercapacitors with high energy density and long-term durability

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The design and exploration of new-type energy storage devices with exceptional energy and power density as well as ultra-long cycling lifespan are still on highly demand. The hybrid supercapacitors (HSs) are classified as alkali metal ion (Li^+/Na^+/K^+) HSs or multivalent metal ion (Zn^{2+}/Mg^{2+}/Ca^{2+}/Al^{3+}) HSs, based on the different metal ion types. Multivalent metal ion HSs are more appealing than alkali metal ion HSs because of the natural abundance of multivalent metals in the earth's crust and their ability to provide multi-electron transfer. Zn-ion hybrid supercapacitors (ZIHSs) have been reported as emerging and promising candidates for energy storage devices in recent years, which integrate the complementary advantages of supercapacitors and batteries.

We demonstrated that a cost effective and high energy density ZIHSs, using Zn foil as the negative electrode, commercially available Spectracarb™ 2225 activated carbon fabric as the positive electrode material and Zn cation based various 1 M acetonitrile (AN) and propylene carbonate (PC) based electrolytes (zinc tetrafluoroborate, $Zn(BF_4)_2$; zinc di[bis(trifluoromethylsulfonyl)imide], $Zn(TFSI)_2$ and zinc trifluoromethanesulfonate, $Zn(OTf)_2$) are really possible. Very high energy and power densities (80 Wh kg^{-1} and 21.2 kW kg^{-1}) have been calculated for 1 M $Zn(BF_4)_2$/AN based ZIHSs. Very good stability after 3000 cycles of cells has been achieved demonstrating reasonably high energy efficiency value (66.8%) for $Zn(TFSI)_2$/AN based ZIHS cell, and decreased in the order electrolytes: $Zn(TFSI)_2$/AN > $Zn(BF_4)_2$/PC > $Zn(TFSI)_2$/PC > $Zn(OTf)_2$/AN > $Zn(BF_4)_2$/AN. The coulombic efficiency values are very high, nearly 99.8 – 99.9%. Some assembled ZIHSs tested, in particular based on $Zn(TFSI)_2$/AN (and as well $Zn(BF_4)_2$/AN) electrolytes has shown good cycling and energy stability during 20000 cycles (Fig. 1). Thus, this work provides some insight into the strategy for designing effective non-aqueous Zn-ion hybrid supercapacitors.[1]

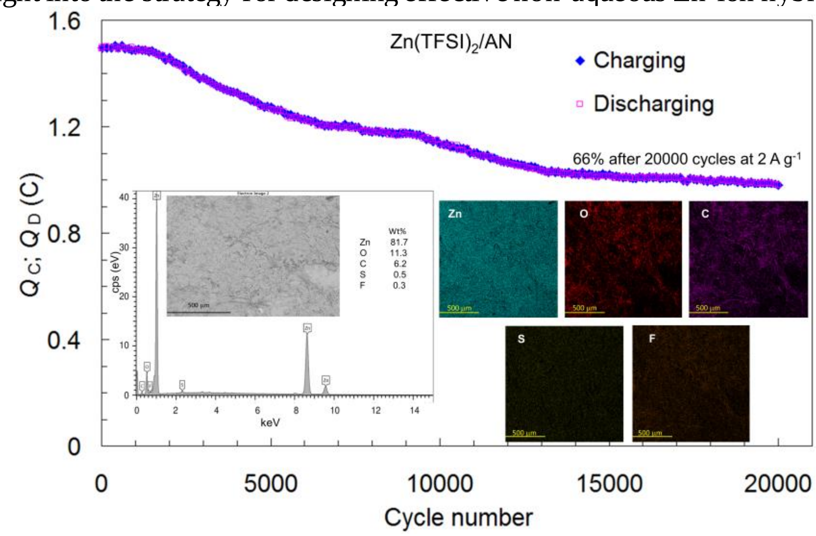

Figure 1. Calculated charge and discharge process charge density values for $Zn(TFSI)_2$/AN based ZIHS at cell voltage from 0 to 2.0 V and at current density 2 A g^{-1}. Inset: SEM-EDS analysis and elemental mapping for Zn electrode after 20 000 charge/discharge cycles. For 1 M $Zn(TFSI)_2$/AN based cell nearly 100% coulombic efficiency have been observed.

Acknowledgements

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Reference

[1] K.-S. Põder, J. Eskusson, E. Lust, A. Jänes, J. Electrochem. Soc. 170 (2023) 060501.