Ionogel-based electrodes for non-flammable high-temperature operating electrochemical double layer capacitors

Valentina Mastronardi[1]
Agnese Gamberini[1], Tobias Burton[2], Alix Ladam[2], Anais Falgayrat[2], Ahmad Bagheri[1], Matteo Abruzzese[1], Hossein Beydaghi[1], Elena Calcagno[1], Samaneh Vaez[1,3], Francesco Bonaccorso[1,4], Sebastien Fantini[1], Sebastiano Bellani[1]
[1] Bedimensional S.p.A., Lungotorrente secca 30R, Genova, Italy.
[2] Solvionic, 11 Chemin des Silos, Toulouse, 31100 France.
[3] Department of Applied Science and Technology, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy.
4 Istituto Italiano di Tecnologia, Graphene Labs, Via Morego 30, 16163 Genova, Italy.

v.mastronardi@bedimensional.it

Electrochemical double-layer capacitors (EDLCs) have garnered significant attention as suitable energy storage solution for a wide range of applications ranging from automotive, to smart grids, wind turbines, and power electronics[1]. However, their limited energy density and narrow operating temperature range pose challenges for wider adoption, especially in harsh environments [2, 3]. This study introduces a novel approach based on ionogels-type electrodes to enhance the energy density of EDLCs, while enlarging their operating temperature window. Ionogel-type electrodes were fabricated by depositing electrode material slurries based on ionic liquid as the liquid media, eliminating the use of organic solvents and costly drying processes [4]. The designed ionogel-type electrodes demonstrate exceptional electrolyte accessibility demonstrated by high energy density (up to more than 40 Wh kg^{-1}) and simplifying assembly processes in industrial manufacturing lines, while improving device performance compared to conventional EDLC. Electrochemical characterization of ionogel-type EDLCs exhibit a maximum power density of 479.6 kW/kg at a rated voltage of 2.7 V, remarking the superior rate capability of the ionogel-type EDLCs compared to that of conventional EDLCs (139.3 kW/kg maximum power density) [5]. At the power density of 12.96 kW kg^{-1}, the ionogel-type EDLC retains ~83% of energy density measured at the low power of 0.14 kW kg^{-1}. Contrarily, the energy density of conventional EDLCs drops by 65.4% with increasing power density from 0.14 kW kg^{-1} (29.2 Wh kg^{-1}) to 8.67 kW kg^{-1} (10.1 Wh kg^{-1}). Moreover, ionogel-type EDLCs demonstrate electrochemical stability and performance even up to 180°C, surpassing the limitations of traditional EDLCs based on organic electrolytes. Overall, this research presents a promising pathway for advancing EDLC technology through innovative electrode fabrication methods and IL-based electrolytes.

References

[1] F. Bonaccorso et al., Science, 347.6217 (2015) 1246501
[2] M. Eredia, et al., APL Mater., 10.10 (2022) 101102.
[3] A. Bagheri, et al., ACS Nano, 16.10 (2022) 16426–16442.
[4] R. Lin, et al., Patent WO 2020/260444 A1 (2022).
[5] T. Van, et al., ChemSusChem 16.20 (2023) e202300756.

Figures

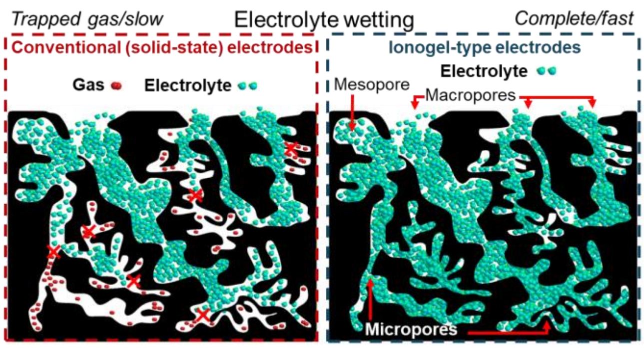

Figure 1. Sketch of the electrolyte wetting processes for conventional (solid-state) and ionogel-type electrodes.

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