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The application of functionalized 2D materials in solid-state electrolyte for flexible supercapacitors

Ahmad Bagheri, Sebastiano Bellani, Hossein Beydaghi, Matilde Eredia, and Francesco Bonaccorso
Graphene Labs, Istituto Italiano di Tecnologia, via Morego 30, 16163 Genoa, Italy
Ahmad.bagheri@iit.it

Solid-state flexible supercapacitors (SSFSs) have drawn an increasingly attention due to their special mechanical properties (*e.g.*, foldability) and high power density (*i.e.*, fast charge-discharge rate) [1]. Owing these properties, SSFSs represent appropriate candidates for powering portable electronic devices, including wearable power-supply units [2]. The SSFSs intrinsically overcome the electrolyte leakage of traditional supercapacitors, eliminating safety and environmental concerns without requiring rigid and robust packaging strategies[3]. However, solid-state electrolytes still suffer from poor ion mobility and reactivity that undermine the distinctive high power density of supercapacitors[4]. To address these issues, incorporation of transition metal dichalcogenides (TMDCs), *i.e.*, sulfonated 2D niobium disulphide (S-NbS_2), in proton-conducting sulfonated poly(ether ether ketone) (SPEEK) was investigated as solid-state electrolyte for high-power SSFSs. Single-/few-layer NbS_2 flakes were produced through ultrasonication-assisted liquid-phase exfoliation of their bulk counterpart[5]. The as-produced material was subsequently functionalized with sodium 3-mercapto-1-propane sulfonate to promote its interaction with the polymeric matrix through the formation of hydrogen bonding between functionalized groups of S-NbS_2 and sulfonated groups of SPPEK [6]. The incorporation of S-NbS_2 into the SPEEK matrix increases the proton conductivity and dimensional stability of the pristine polymer. By optimizing the weight of S-NbS_2 into the nanocomposite electrolytes, a maximum proton conductivity of 94.35 mS cm^{-2} was achieved at room temperature, coupled with an improvement of 18% of the mechanical strength compared to pristine SPEEK (up to 38.3 MPa). To design advanced SSFSs, either SPEEK or polyvinylidene fluoride was used as different binding agents for the electrodes. The aim is to elucidate the importance of the interaction between the solid electrolyte and the binder to maximize the electrostatic charging of electrode active materials. The use of optimized solid-state electrolyte in SSFSs, based on proton-conducting SPEEK binder, allowed us to achieve a specific capacitance of 115.724 F g^{-1} at 0.02 A g^{-1}, showing optimal rate capability (75.94 F g^{-1} at 10 A g^{-1}) and electrochemical stability over galvanostatic charge/discharge cycling tests. Overall, our results rationalize the use of S-NbS_2 as additive for solid-state electrolytes, promoting the development of high power SSFSs.

References

[1] X. Hou, Q. Zhang, L. Wang, G. Gao, W. Lü, ACS Appl. Mater. Interfaces. 13 (2021) 12432–12441.
[2] Y.R. Jeong, G. Lee, H. Park, J.S. Ha, Acc. Chem. Res. 52 (2019) 91–99.
[3] C. Zhong, Y. Deng, W. Hu, J. Qiao, L. Zhang, J. Zhang , Chem. Soc. Rev. 44 (2015) 7484–7539.
[4] H. Beydaghi, L. Najafi, S. Bellani, A. Bagheri, B. Martín-García, P. Salarizadeh, K. Hooshyari, S. Naderizadeh, M. Serri, L. Pasquale, B. Wu, R. Oropesa-Nuñez, Z. Sofer, V. Pellegrini, F. Bonaccorso, J. Mater. Chem. A. 9 (2021) 6368–6381.
[5] L. Najafi, S. Bellani, R. Oropesa-Nuñez, B. Martín-García, M. Prato, V. Mazánek, D. Debellis, S. Lauciello, R. Brescia, Z. Sofer, F. Bonaccorso, J. Mater. Chem. A. 7 (2019) 25593–25608.
[6] L. Najafi, S. Bellani, R. Oropesa-Nuñez, B. Martín-García, M. Prato, L. Pasquale, J.K. Panda, P. Marvan, Z. Sofer, F. Bonaccorso, ACS Catal. 10 (2020) 3313–3325.