

Amphiphilic DNA-assembly for high-performance Li-S batteries

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Self-assembly of nucleic acids (i.e., DNA and RNA) provides an attractive ‘Bottom-up’ fabrication strategy with sub-nanometer resolution [1]. In particular, sequenced DNA has been established as versatile building blocks for sophisticated nanoscale assembly. However, due to the principle of base-directed assembly, DNA self-assembly is sensitive to surroundings (i.g., pH and ionic strength in solution), need to the additional separation process, and difficult to manufacturing micro-sized structure. Furthermore, non-remarkable physicochemical properties of DNA itself provoke integration with another functional material [2] to maximize the addressable complexity and functionality. Enormous efforts have been undertaken to design the integration with other functional components based on interactions of hydrophobic nucleobase (multiple hydrogen bonds, π - π stacking) and hydrophilic phosphate backbone (electrostatic interaction) [2-4]. Even large and exquisite architectures are possible, but asymmetric hybridization [2] and attracting scale limit [2] remain challenges.

Here, to address the above-mentioned challenges of DNA self-assembly regarding nucleobase dependency, we demonstrate a DNA-directed single-walled carbon nanotube (SWCNT)/DNA amphiphilic self-assembly (ASA) as a new class of DNA self-assembly. Aromatic nucleobase can directly disperse SWCNT in aqueous solvent via sequential π - π stacking, which form a DNA wrapped SWCNT (as called DNA/SWCNT). Anionic phosphate groups on external surface of DNA/SWCNT can be crosslinked by divalent metal ions, formed as self-assembled DNA/SWCNT hydrogel, which rarely depends on the hybridization of nucleobases and can be demonstrated as an alternative solution to macro-scale architecture. Subsequently, freeze-dried ASA aerogel exhibits unique porous framework with uniform and percolated SWCNT network, resulting in enhanced electronic conductivity and suppressed junction resistance. Furthermore, due to potential of various anchoring sites on DNA, polysulfide-DNA binding energy was theoretically calculated in previous study [5]. As a proof-of-concept of the ASA, their potential application to Li-S batteries is explored with practical attention to the polysulfide trapping in the cathode region. Benefiting from the well-developed 3D architecture of ASA significantly improve the cycling performance and areal mass loading, which is difficult to achieve with conventional sulfur cathodes.

References:

- [1] N.C. Seeman, Nature. 421 (2003) 427–431.
- [2] W.B. Rogers, W.M. Shih, V.N. Manoharan, Nat. Rev. Mater. 1 (2016) 16008.
- [3] C.X. Guo, Y.Q. Shen, Z.L. Dong, X.D. Chen, X.W. Lou, C.M. Li, Energy Environ. Sci. 5 (2012) 6919–6922.
- [4] Y.-L. Wu, N.E. Horwitz, K.-S. Chen, D.A. Gomez-Gualdrón, N.S. Luu, L. Ma, T.C. Wang, M.C. Hersam, J.T. Hupp, O.K. Farha, R.Q. Snurr, M.R. Wasielewski, Nat. Chem. 9 (2017) 466–472.
- [5] Z. Ji, B. Han, Q. Li, C. Zhou, Q. Gao, K. Xia, J. Wu, J. Phys. Chem. C. 119 (2015) 20495–20502.