**Latest trends of different polymers used in batteries**

**Challenge and Design Strategies of Polymer Organic Electrodes for Li/Na/K-Ion Batteries**

Various polymers like ionic, biobased, self-healing, mixed-ionic electronic conducting, inorganic-polymer composites, and redox polymers are utilized in batteries for electrodes, separators, electrolytes, and electrode materials.

Common polymer electrolyte materials: polyethylene oxide (PEO), polyacrylonitrile (PAN), and poly(vinylidene fluoride) (PVDF).

**Different types of Conductive polymers**

Polythiophene

Polyaniline

Polypyrrole

Polyacetylene

Poly(vinylidene fluoride-co-hexafluoropropylene) (P(VDF-HFP))

**Hexaazatriphenylene-based polymer cathode for fast and stable lithium-, sodium- and potassium-ion batteries**

In a typical synthesis, 3,3′-diaminobenzidine tetrahydrochloride (1.5 mmol, 540 mg) and triquinoyl (hexaketocyclohexane octahydrate, 1 mmol, 312 mg) were mixed in 25 mL of *N*-methylpyrrolidone. Concentrated sulfuric acid (10 μL) was then added. The mixture was evacuated and refilled with Ar three times and refluxed for 8 h. After cooling, the precipitate was filtered and washed consequently with *N*,*N*-dimethylacetamide and acetone using a Soxhlet extractor. The product was vacuum-dried at 150 °C overnight.

**Nanostructured Conductive Polymer Gels as a General Framework Material To Improve Electrochemical Performance of Cathode Materials in Li-Ion Batteries**

**Gel polymers**

Copper(II) phthalocyanine tetrasulfonate salts (CuPcTs) cross-linked polypyrrole (C-PPy) as a multifunctional framework and commercial lithium iron phosphate (C-LFP) particles as model cathode materials. [(26)](javascript:void(0);) PPy gel framework shows high electronic conductivity and decent mechanical strength when compared to other conductive polymer gels, such as polyaniline and poly(3,4-ethylenedioxythiophene)–poly(styrenesulfonate) (PEDOT:PSS).

**Synthesis procedure**

Synthesis of hybrid gel framework materials: In a typical synthesis of hybrid gel framework, 80 mg C-LFP were dispersed in 0.8 mL DI water and ultrasonicated for 5 min. Then 15 µL of pyrrole monomers and 0.3 mg of CuPcTs were added stepwise into the dispersion of C-LFP particles. After ultrasonicating the mixture for 5 min, 15 mg of APS was added into the solution and the gelation occurred within 1 min. The products were coated onto carbon coated Al foils and left overnight for complete polymerization.

A close-up of a bottle

Description automatically generated

**Synergistically modified Ti3C2Tx MXene conducting polymer nanocomposites as efficient electrode materials for supercapacitors**

**Material preparation**

**Preparation of Ti3C2Tx MXene**

2D Ti3C2Tx MXene nanosheets were synthesized by selectively etching Al from Ti3AlC2 (MAX phase) using LiF and HCl. 3.2 g of LiF is dissolved in 9 M HCl and stirred for 30 min. Subsequently, add 2 g Ti3AlC2 into the mixture and kept this for 24 h at 35 ± 1 ºC. After 24 h, the etched product was washed by centrifuging in deionized water multiple times until the pH of the supernatant solutions reaches neutral. The resulting precipitate is then ultrasonicated in water for 1 h under Argon atmosphere to exfoliate the Ti3C2Tx MXene multilayers to single-layer MXene nanosheets. The precipitate is then filtered and vacuum dried at 70 °C for 12 h.

**Preparation of MXene-PPy nanocomposite**

MXene-PPy nanocomposite was synthesized through in-situ oxidative polymerization at a controlled temperature. The required amount of exfoliated MXene nanosheets was dissolved in 1 M HCl and ultrasonicated for 1 h. Following that, 0.15 mL of pyrrole monomer was introduced into the mixture, and vigorous stirring was maintained for a duration of 2 h. To initiate the reaction, an aqueous solution containing 400 mg of ammonium persulfate (APS) was added dropwise into the mixture. The mixture was stirred for 8 h under a temperature of 1 °C. Once the polymerization process was completed, the resulting composite was subjected to multiple washes with deionized water. Subsequently, it was dried under vacuum at 70 °C for 12 h to obtain the Ti3C2Tx-PPy nanocomposite.

**Preparation of MXene-PANI composite**

MXene-PANI composite was synthesized through in-situ polymerization reaction, utilizing Ti3C2Tx MXene and aniline monomers. Initially, 120 mg of Ti3C2Tx was dispersed in 40 mL of 1 M HCl, followed by sonication for 10 min to achieve uniform dispersion. Subsequently, 10 mM aniline monomer was added to the solution and stirred in an ice water bath for 30 min. Simultaneously, another solution containing 100 mg of APS in 40 mL of HCl was gradually introduced. The resulting dispersion was subjected to continuous magnetic stirring at 0 °C for 12 h to facilitate the polymerization reaction. The resulting product was then centrifuged, washed, and finally vacuum dried at 80 °C for 24 h.

**A Review on Graphitic Carbon Nitride and Conducting Polymer Nanocomposite Electrodes for Supercapacitors**

**g-CN/Conducting Polymer Electrodes**

Conducting polymers like PEDOT:PSS, polyaniline (PANI), polypyrrole (PPy), and polyindole (PIn) have been reported for supercapacitor application. PEDOT was the first among the conducting polymers to combine with g-CN in 2015 [[**55**](https://www.mdpi.com/2673-4591/59/1/154#B55-engproc-59-00154)], Chen et al. synthesized a PEDOT/g-CN composite on a glassy carbon electrode using a simple direct mixing technique. The PEDOT/g-CN composite demonstrated an estimated capacitance of 53.89 Fg−1 in 1M H2SO4 and 31.39 Fg−1 in 1M Na2SO4 electrolytes when scanned at a rate of 1 mV/s. In 2018, Zhou et al. synthesized an electrode by compositing g-CN with PANI (PANI/g-C3N4) using an in situ oxidative polymerization method. The obtained PANI/g-CN composite exhibited a flower-like morphology and exhibited an impressive capacitance of 584.3 Fg−1 at 1 Ag−1 in 1 M H2SO4.

Synergistically modified Ti3C2Tx MXene conducting polymer nanocomposites as efficient electrode materials for supercapacitors

Table 1. Theoretical Capacitance values for different conducting polymers [[39]](https://www.sciencedirect.com/science/article/pii/S0925838823042263?casa_token=mpV2OSqG7bwAAAAA:Eh2JYEOQ9UshYIZqMsTPImZ8OMIdZJ-Pfpgw6xk5kv6thBmNVyngh7hcAWrY1nqXkzacBzo3yIte" \l "bib39).

| **Conducting Polymers** | **Theoretical Capacitance Cth (Fg−1)** |
| --- | --- |
| **PANI** | 750 |
| **PPy** | 620 |
| **PT** | 485 |
| **PEDOT** | 210 |

**Current Trends and Perspectives of Polymers in Batteries**

Inorganic−Polymer Composite Electrolytes or Hybrid Solid Electrolytes. Inorganic conductors such as oxide-based solid electrolytes (garnet-type LLZTO (Li7La3Zr1.4Ta0.6O12), perovskite-type LLTO (Li3xLa2/3−xTiO3), etc.), sulfide-based solid electrolytes (Li2S−P2S5, Li6PS5Cl, etc.),