Development of novel Li ion BATtery solid electrolyte separators based on Metal orgANic frameworks

Youven Benseghir[1], Manoj Karakoti[2], Selma Yilmaz Baylan[3], Markus Ungerank[3], Patrycja Bober[2], Kevin Wu[4], Jia Min Chin[1] and Christoph Gammer[5]

[1] Department of Functional Materials and Catalysis, University of Vienna, Währingerstrasse 42, 1090 Wien, Österreich

[2] Institute of Macromolecular Chemistry, Czech Academy of Science, Heyrovského nám. 2, 162 00 Prague 6, Czech Republic

[3] Creonia Cells GmbH, Mainstraße 12, 4470 Enns, Austria

[4] National Taiwan University, No. 1, Section 4, Roosevelt Rd, Da'an District, Taipei City, Taiwan 10617

[5] Erich Schmid Institute of Materials Science of the Austrian Academy of Sciences Jahnstrasse 12, 8700 Leoben Austria

The transition to a sustainable energy future requires advanced battery technologies that enable faster charging, higher efficiency, and improved safety. Lithium-ion batteries (LIBs), particularly $LiFePO_4$ (LFP) batteries, offer a promising solution for electric vehicles (EVs) due to their cost-effectiveness and intrinsic safety. However, their lower energy density and performance limitations must be addressed to meet growing energy demands. BATMAN proposes an innovative approach to enhancing ion conductivity and optimizing battery components through green solid electrolyte separators and surface-functionalized battery assemblies.

This project leverages interdisciplinary expertise to implement several key innovations to develop battery cells capable of higher current densities and faster charging/discharging without increasing energy loss or- excessive heat generation. Our aim is the incorporation of anisometric metal-organic framework (MOF) particles (rod-, needle-, and sheet-like structures) in conductive polymers to enhance ion transport pathways, particularly at the particle-polymer interface. An environmentally friendly non-solvent induced phase separation (NIPS) will be employed to create freestanding thin separators made of MOF@polymer via the CREOCell extrusion process.

Through the joint efforts of international partners (University of Vienna, Austrian Academy of Sciences, Czech Academy of Sciences, and National Taiwan University), several milestones toward BATMAN's objective have been achieved. Various polymer matrices have been evaluated and multiple MOFs synthesized for their incorporation into polymer composites, with successful MOF integration into P84 polyimide separators. We demonstrated that the use of external electric field during the MOF integration in polymer leads to aligned MOF particles increasing their conductivity and stability. In parallel, conducting polypyrrole colloids and electrode coatings have been developed, demonstrating long-term stability (>12 months) and successful casting and electropolymerization onto anode surfaces. High-resolution imaging has been used to analyze composite separators through in situ biasing and focused ion beam lift-out techniques, leading to detailed material characterization.

References

[1] Glycerol-tailored asymmetric polyethersulfone membranes with uniform ion transport for stable lithium metal batteries. M. Lo, K. C.-W. Wu, J. M. Chin, L.-P. Cheng, W.-F. Kuan, Giant, 2024, 17, 100227

[2] Electric-field assisted spatioselective deposition of MIL-101(Cr)$_{PEDOT}$ to enhance electrical conductivity and humidity sensing performance. Y. Benseghir, M. Y. Tsang, F. Schöfbeck, D. Hetey, T. Kitao, T. Uemura, H. Shiozawa, M. R. Reithofer, J. M. Chin, Journal of Colloid and Interface Science, 2025, 979-986

[3] Effect of Acid Blue dyes on the electrochemical capacitance of polypyrrole. D. Von Tumacder, Z. Morávková, M. Konefał, H. S. Salapare, F. Guittard, P. Bober, Materials Research Bulletin, 2023, 112455