Polymer-based batteries:
Thin-film printable batteries and scalable redox-flow batteries

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To enable the integration of renewable energies into the energy mix, new types of electricity storage systems are needed, which have to rapidly store and release large amounts of electrical energy in order to compensate supply peaks as well as bottlenecks. Similarly, the number of mobile devices that rely on mechanically stable, space-efficient and safe batteries is steadily increasing. The active materials used so far are based mainly on metals, which can hardly meet the requirements for safety and sustainability. Therefore, polymeric compounds are developed as active materials, which offer a benign raw material base and disposal, superior charging times and performance, and improved safety and toxicity. They are mainly based on established redox-active moieties, such as quinone and anthraquinone derivatives, stable organic radicals (e.g. TEMPO) or viologen compounds, which are incorporated into suitable (co)polymer structures.
In comparison to small-molecule organic active materials, polymers allow for a more facile thin-film processing via casting and printing techniques (e.g. inkjet printing, screen printing), while cross linking leads to highly insoluble compounds. Both enables the utilization in solid-state thin-film batteries suitable for application in small, flexible mobile devices ("Internet of Things", smart clothes, intelligent packaging). On the other hand, solubilizing comonomers enable the preparation of highly soluble active compounds. These are suited as charge-storage materials in solution-based redox-flow batteries, which are mainly used for storing large amounts of electricity (e.g. in wind and solar parks). Here, the large molar masses of the polymers allow for the usage of cost-efficient dialysis instead of more expensive ion-selective membranes, which have to be used for small-molecule- and metal-based redox-flow batteries.

<u>Recent publications:</u>
ACS Appl. Energy Mater. **2025**, doi: 10.1021/acsaem.4c03127; *Energy Storage Materials* **2024**, *65*, 103063; *ChemSusChem* **2024**, *17*, e202400626; *J. Phys. Chem.* **2024**, *128*, 11465; *Chem. Eur. J.* **2024**, *302*, e202302979; *J. Mater. Chem. A* **2024**, *12*, 4806; *ChemSusChem* **2023**, *16,* e202300296; *J. Computational Chem.* **2024**, *45*, 1112; *Sensors and Actuators B: Chemical* **2024**, *403,* 135101; *J. Phys. Chem. C* **2023**, *127,* 1333; *J. Power Sources* **2023**, *556*, 232293; *ACS Appl. Energy Mater.* **2023**, *6*, 302; *ACS Appl. Energy Mater.* **2022**, *5*, 15019; *J. Power Sources* **2022**, *525*, 231061; *ChemSusChem* **2022**, *15*, e202200830; *Material Advances* **2022**, *3*, 4278; *Adv. Science* **2022**, *9*, 2200535; *Macromolecules* **2022**, *55*, 1576; *ACS Appl. Mater. Interfaces* **2022**, *14*, 6638; *Energy Conversion Management: X* **2022**, *14*, 100188; *Macromol. Chem. Phys.* **2022**, *223*, 2100373; *J. Power Sources* **2022**, *525*, 230996; *Progr. Polym. Sci.* **2022**, *125*, 101474.

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Ulrich S. Schubert performed his Ph.D. studies at the Universities of Bayreuth/Germany and South Florida/USA. After a postdoctoral training position with Prof. Lehn at the University of Strasbourg/France, he moved to the TU Munich/Germany and obtained his Habilitation in 1999. In 1999–2000 he was professor at the University of Munich/Germany, and during 2000 and 2007 full professor at the TU Eindhoven/The Netherlands. Since 2007, he has been a full professor for organic and macromolecular chemistry at the Friedrich Schiller University Jena/Germany. He is the founding director of the Center for Energy and Environmental Chemistry Jena (CEEC Jena) and the Jena Center for Soft Matter (JCSM) as well as the coordinator of the EU ETN POLYSTORAGE, of the DFG priority program “Polymer-Based Batteries” (SPP 2248), of the DFG reseach unit “FuncHeal” (FOR 5301) and spokesman of the DFG collaborative research center SFB1278 “PolyTarget”. In 2022 he received an ERC Advanced Grant on his proposal FutureBAT (next generation polymer-based redox-flow batteries; 2.5 MEURO).

Ulrich S. Schubert is co-author of 1.300 scientific publications. They received 74.000 citations (Google Scholar 100.000); his h-index is 119 (Google Scholar 140). He is author of five textbooks. Ulrich S. Schubert was listed as "highly cited researcher" 2014 to 2022. In addition, he is an external scientific member of the Max Planck Society (MPG/Germany), elected member of acatech (National Academy of Science and Engineering/Germany), elected fellow of the National Academy of Inventors/USA and fellow of the Royal Society of Chemistry/UK. U.S. Schubert was awarded with the Federal Cross of Merit/Germany and named University Professor of the Year 2019/Germany. Since July 2023 he is founding director of the new Helmholtz Institute HIPOLE Jena (as part of the Helmholtz Center Berlin, HZB).

In 2019 U.S. Schubert was elected as member of the city council (“Stadtrat”) of Jena and since 2024 he is member and chairman of the city council. He established the foundation “Kultur- und Sozialstiftung Internationale Junge Orchesterakademie” and organized 700 benefit concerts for children with cancer.