2020 HGF – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

Title of the project:

Polymer-based Electrolyte for High-Performance Lithium Batteries

Helmholtz Centre and institute:

Helmholtz-Zentrum Berlin für Materialien und Energie (HZB)

Project leader:

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Description of the project (max. 1 page)**:**

Li-ion batteries (LIBs) currently dominate the battery market, but face tremendous challenges for their future use due to their limited energy density. Advanced LIBs using Li metal anodes and Li-S batteries exhibit capacities several times higher than commercial LIBs. However, their stable cycling is challenged by problematic Li dendrite formation on the Li metal anode and polysulfide shuttle on the cathode side. Meanwhile, critical safety concerns are present due to the poor thermal stability and high flammability of organic liquid electrolytes.

Polymer electrolyte is a promising solution to solve or mitigate the abovementioned issues. First of all, they exhibit attractive properties for the safe battery operation, e.g., non-volatility, low flammability and high thermal stability. Moreover, polymer electrolytes have a high mechanical strength and elasticity, suppressing the Li dendrite penetration. They are also free of the undesired dissolution and crossover of polysulfides, improving the cycling stability of Li-S batteries.

Intensive efforts have been devoted to the development of polymer electrolytes for LIBs, however, significant challenges remain for their implementation in advanced LIBs. Research in Polymer electrolyte-based Li-S batteries is still in its early stage.

The most significant limitation of polymer electrolytes is their low intrinsic ionic conductivity and mechanical strength. To address this problem, polymer composite electrolytes (PCEs), with enhanced ionic conductivity and/or mechanical strength, will be developed in this project. For instance, the Li-ion conduction and mechanical strength can be improved through hybridizing a polymer (e.g. polyethylene oxide (PEO)) with a Li-salt and inorganic filler, respectively. Moreover, both anions and cations are mobile in conventional PCEs, resulting in a concentration gradient and cell polarization. To solve this issue, this project proposes to further engineer the PCEs and to develop single Li-ion conducting poly(ionic liquid) (PIL)-based PCEs (PIL-PCEs). The selectivity of single Li-ion transport is achieved by immobilization of the anions of the Li-salt, e.g., through covalent interactions with the polymer backbone. Note that the inorganic filler remains to maintain their mechanical strength in PIL-PCEs.

Overall, the aim of this project is to develop high energy-density, stable and safe Li batteries, particularly advanced LIBs and Li-S batteries based on novel PCEs/PIL-PEs, for future energy storage. The main research topics of this project include the stepwise development of:

- Novel PCEs with high ionic conductivity and mechanical strength;
- PIL-PCEs with selectively facilitated Li-ion transport and high mechanical strength;
- Advanced LIBs and Li-S batteries based on the developed PCEs/PIL-PEs.

Description of existing or sought Chinese collaboration partner institute (max. half page)**:**

The project leader has already established collaboration with multiple research institutions in China. The project leader has close collaboration with Prof. Guosong Chen and Prof. Ming Jiang at Department of Macromolecular Science, Fudan University, a world-leading research group on self-assembly of functional macromolecules. We have been successfully granted a joint DFG-NSFC project (2019-2022) and a Sino-German Joint Research Project (2015-2017) on exploring the mechanism of morphological transitions of macromolecular self-assemblies. In the last five years, we have published more than 10 papers in leading journals, including *J. Am. Chem. Soc., Angew Chem. Int. Ed.* and *ACS Nano*. The project leader has also good collaboration with Prof. Meifang Zhu from College of Material Science and Engineering, Donghua University, on hybrid carbon fiber-based electrode materials.

The project leader has successfully hosted one postdoc within the framework of the HGF-OCPC Programme (2017-2019), titled "*Colloidal route-based nanostructure synthesis for energy storage applications*". The program has achieved fruitful outcome (2 published papers and 2 more in preparation) and established close collaboration with Prof. Hong Meng from Peking University (Shenzhen College).

Required qualification of the post-doc:

- PhD in polymer chemistry / electrochemistry / material science;
- Experience with polymer synthesis and battery research, preferably Li batteries;
- Additional skills in materials characterization methods and electrochemical testing;
- A good command of English (spoken and written) is required.