Helmholtz - OCPC - Programme 2017-2021
for the Involvement of Postdocs in Bilateral Collaboration Projects with China

PART A

Title of the project: Liquid Metal Batteries for Energy Storage

Helmholtz Centre and institute: Karlsruhe Institute of Technology (KIT), Institute of Pulsed Power and Microwave Technology (IHM)

Project leader: Prof. Dr. Georg. Müller, Dr. Alfons Weisenburger, Dr. Adrian Jianu

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Description of the project:
Liquid metal batteries (LMB) are an intriguing energy storage technology with advantages of low-cost, large-capacity and long-lifespan. Recently, it has been gained great interest as a large scale electricity storage device able to integrate the intermittent renewable energy technologies like wind and solar into the grid. A liquid metal battery consists of a low-density liquid metal as negative electrode (e.g Li, Na, Mg), a medium-density molten salt electrolyte (a mixture of molten salts like NaCl, $MgCl_2$, LiCl, NaF, NaI) and a high-density liquid metal as positive electrode (Sb, Pb, Bi, ….). A seal (i.e. a ceramic insulator) is applied to isolate the negative current collector (NCC) from the positive current collector (PCC). Due to the density difference and the mutual immiscibility, the liquid metal electrodes and the molten salt electrolyte will be self-segregated into three layers when heated to the working temperature range of 300-700°C (depending on the electrode/electrolyte material systems). The molten salt electrolyte also serves as an isolation layer between the negative and positive electrodes to replace the battery separator existing in traditional batteries. The strong interaction between the two liquid metals acting as electrodes provides the thermodynamic driving force (cell voltage) for the liquid metal cell. The main scientific issues to be solved for LMBs are: (i) the compatibility of structural and functional materials with the positive electrode material and electrolyte materials and (ii) the electrolyte composition, stability and the solubility of negative electrode element.

The general objective of the research proposal is to develop an efficient, long-life and low-costs LMB, based on new combinations of liquid metal electrodes (e.g. Na/Li/K - Sn/Sb/Bi and salts electrolytes from halides of the alkali metals with low melting point (<450°C). To

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achieve this objective, the above identified major challenges will be addressed both theoretically and experimentally as follows: (i) evaluation of the corrosion mechanism and the development of corrosion resistant materials for the components in contact with the positive electrode, (ii) evaluation and selection of the best sealing materials/coatings required for a safe operation of the LMB, (iii) selection of the molten salt electrolyte composition with the best thermo-chemical properties and the lowest material solubility (e.g. Na). The corrosion experiments will be performed in liquid metals and molten electrolytes. The selection of the parameters (temperature, impurities) in which the corrosion experiments in stagnant liquid metal will be performed will be made based on the general objective of the project. One specific goal of the project is to define, produce or acquire and characterize the properties of materials which may sustain long-term exposure to molten metals and salts. The following material systems are in consideration: Al_2O_3 and BN for the sealing and as structural materials in contact with the molten electrodes and electrolytes the ferritic steels (T91), the new alumina-forming stainless steels and high-entropy alloys, modified surface layers and different type of coatings (e.g. Mo, C). Another goal is to identify the best suitable molten salt electrolyte for a low temperature LMBs.

Finally, in the second stage of the project the simulation, design and setup of battery stacks will be performed. On basis of the most stable electrolyte, the sealing materials and the positive current collector, two different LMBs (eg. Na||Sb-Sn and Na||Sb-Bi) will be built and tested.

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

Huazhong University of Science and Technology (HUST) - School of Electrical and Electronic Engineering

The Chinese Partner at Huazhong University of Science and Technology (HUST) has a wide expertise in the development of liquid metal batteries. The research team at Huazhong University of Science and Technology (HUST) has an advanced experimental platform, including battery processing facility, glove boxes for battery construction, battery test systems, advanced test and analysis center, simulation software and server. The team leader Prof. Kangli Wang worked in the field of LMB as a postdoctoral associate at MIT. She has done pioneering research work on LMB design, properties test and conversion materials. Dr. Wang and her team reported in 2014 for the first time a high performance Li||Sb–Pb liquid metal battery. The collaboration with the “Huazhong University of Science and Technology” is based on our common interest in developing materials and technologies for the energy production and storage. This collaboration established at the end of 2018 in the frame of a common Chinese German DFG project with mutual benefit will facilitate the transfer of know-how between the project partners regarding liquid metals technologies and corrosion mitigation strategies (from KIT side) and the design, construction, testing and qualification of the liquid metal batteries (from HUST side).

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Required qualification of the post-doc:

- PhD in Mechanical Engineering or Material Science.
- Experience with corrosion and corrosion mitigation of metals in contact with liquid metals and salts; alloy design, development and manufacturing; metallographic analysis of the microstructure properties applying SEM (Scanning Electron Microscopy) and XRD, chemical composition using energy dispersive X-ray spectroscopy (EDX) heat transport properties using flash calorimetry.
- Additional skills in writing articles and communicating the scientific results.

PART B

Documents to be provided by the post-doc, necessary for an application to OCPC via a postdoc-station in China, which is affiliated to a research institution like a university:

- Detailed description of the interest in joining the project (motivation letter)
- Curriculum vitae, copies of degrees
- List of publications
- 2 letters of recommendation
- Proof of command of English language

PART C

Additional requirements to be fulfilled by the post-doc:

- Max. age of 35 years
- PhD degree not older than 5 years
- Very good command of the English language
- Strong ability to work independently and in a team

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