Abstracts

Metal deposition and slurry type RFBs

Metal deposition and slurry batteries have the potential to achieve higher energy densities than regular RFB due to utilization of the solid phase.

FlowCamp project – Team Zinc Nak Heon Choi – Fraunhofer ICT Diego del Olmo – UCT Prague Ricardo Paz Moldes Duarte – Johnson Matthey Misgina Tilahun Tsehaye – LEPMI Grenoble- INP Diego Josué Milián Izeppi - Laboratoire Rhéologie et Procédés	**Zinc slurry air batteries** - Zinc slurry air batteries have the potential to achieve extraordinarily high energy densities. In this demonstration the researchers of FlowCamp's zinc team present their results of zinc slurry air flow batteries.
Lukas Siefert – University Duisburg-Essen	**Unprecedented current densities for zinc/polyiodide flow batteries** - Zinc/polyiodide flow batteries exhibit the highest volumetric energy density of all redox flow batteries and are therefore considered as a promising alternative to VRFB. Here, experimental results obtained with a 100 cm² flow cell with different flow fields are presented. In experiments with highly concentrated electrolyte, the highest ever reported current densities in the range of 500 mA/cm² for zinc/polyiodide RFB could be achieved.
Alessandro Brilloni – University of Bologna	**Super-concentrated electrolytes based slurries for advanced flow batteries** - A solution proposed to increase the energy density of Redox Flow Batteries (RFBs) is the use of semi-solid slurries. The electrical percolating network and electrochemical stability of the flowable electrodes are key features can be enhanced by tailored electrolyte formulations. In this, Super-concentrated electrolytes represent an emerging alternative to conventional solutions. Here we report about the effect of the ion concentration of super-concentrated electrolytes (3 mol/kg and 5 mol/kg) on the electronic percolating network of carbonaceous slurries, investigated at different carbon content percentage(from 2% up to 12 % wt.) . We demonstrated that super-concentrated electrolytes stabilize the electrical percolating network over time and reduce the electrical resistance of the slurries.
Giampaolo Lacarbonara – University of Bologna	**Aqueous copper-based flow batteries for renewables integration and sustainable energy storage** - The H2020 CuBER Project, coordinated by Aarhus University, proposes the validation of an all-copper redox flow battery (CuRFB) based on the three oxidation states of copper. CuRFB exhibits a modular design, scalability, non-toxic, and earth-abundant materials [1]. In this system, the redox couples are Cu^{2+}/Cu^{+} in the positive half-cell and $Cu^{+}/Cu(0)$ in the negative one and the highly concentrated chloride medium brings to the formation of chloro-complexes that stabilize the redox species [2]. In order to improve the cell performance, it is crucial to balance the concentration of the copper species, the electrode surface area, the operating temperature, and the presence of different complexing agents and additives [3].
Premysl Richtr – UCT Prague	**Development of oxygen evolution electrode for alkaline zinc-air flow battery** - The aim of this work is to develop stable and efficient electrodes for oxygen evolution reaction (OER) for application in alkaline zinc-air flow battery. In case of OER we tested, several 3D electrodes based on nickel foam and expanded nickel catalytically activated by $NiCo_2O_4$. The performance and mid-term stability of OER electrodes under current load was studied by combination of galvanostatic load, electrochemical impedance spectroscopy and load curve measurements.
Dr David Trudgeon – University of Exeter	**Zinc-Nickel Membrane-Free Redox Flow Battery System** - This talk will provide an overview of membrane-free redox flow battery (RFB) technologies with a focus on the alkaline zinc-nickel membrane-free system, which shows potential as a cost-effective alternative to currently available RFB systems. Our work has been directed at improving the performance of zinc-nickel flow cells through investigation of the effects of zinc electrode substrate material, electrolyte concentration, additives to the electrolyte and management of electrolyte flow regime. Combining our findings, round trip energy efficiencies approaching 90 % have been achieved in a laboratory scale flow cell over hundreds of charge / discharge cycles.

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Organic RFBs and membrane technology

Organic chemistry can offer new possibilities for energy storage materials like membranes or new redox couples for energy storage. For these materials often with no mining is required resulting in a better environmental impact and lower costs.

FlowCamp project – Team Organic XianYang – JenaBatteries GmbH Martyna Charyton - AmerSil S.A. Adriana Cappozzi – LEPMI Grenoble - INP Gaël Mourouga – ZHAW Sergio Navarro Garcia – Hungarian Academy of Science	**Aqueous organic redox flow batteries** – aqueous organic redox couples can provide flow batteries with no mining and therefore better environmental impact. In this demonstration the researchers of FlowCamp's organic team present their results of aqueous organic flow batteries.
Juan Asenjo – Universidad Autónoma de Madrid	**DFT calculation, a practical tool for predicting the electrochemical behaviour of organic electrolytes** - We have synthetized and characterized by electrochemical methods a small family of non-planar bipyridines. DFT studies have been performed in order to explain electrochemical parameters as well as k, E, or reversibility. This work provides a versatile method for the prediction of these parameters for future electrolytes.
Afaaf Rahat Alvi – University of Padua	**A detailed study on structure-properties relationship in polyketone based anion exchange membrane for Redox flow battery (RFB) applications** - The development of anion exchange membranes with both high ionic conductivities and long-term performance stability is of great significance and an attractive alternative to proton exchange membranes in electrochemical energy conversion and storage systems, such as redox flow batteries (RFBs). Herein, we report the fabrication of a polyketone-based anion exchange membrane that is carried out by converting 1,4-dicarbonyl units into N-substituted pyrrole moieties and then inducting quaternary ammonium pendant side group functionalities. Experimental results indicate a high functionalization degree of PK, i.e. 62%, which leads to high I- and OH- conductivities up to 8.6 and 10 mS/cm, respectively, as well as to a structural integrity which is retained for more than 70 hours in KOH solution.
Paula Navalpotro – IMDEA	**Membrane-Free Batteries: one idea, a multidisciplinary project** - In this talk, our innovative strategy to address the present limitations of Redox Flow Batteries will be explained. The MFreeB project focuses on the development of a new concept of a membrane-free battery based on immiscible electrolytes with organic active species. The most important results will be discussed and the multidisciplinary approach we are pursuing to face the new challenges of this technology will be shown.
Giovanni Crivellaro - University of Padua	**Hybrid inorganic-organic proton-conducting membranes based on SPEEK doped with WO_3 anoparticles for application in VRFBs** - One of the most challenging issues of vanadium redox flow batteries (VRFBs) is the poor ion selectivity of the commercially available membranes [1]. In this work, a new family of hybrid inorganic-organic membranes based on a sulfonated poly (ether ether ketone) (SPEEK) matrix hosting between 0 and 23.6 wt% of WO_3 nanoparticles (NPs) is prepared and thoroughly studied. The [SPEEK/(WO3)0.20] membrane presents the highest ion selectivity (2.1 × 104 S min cm−3), that is more than three times higher than that of recast Nafion (6.5 × 103 S min cm^{-3}). Single cell tests of the [SPEEK/(WO3)0.20] membrane show a consistent improvement in coulombic efficiency upon all current densities which renders (i) much larger cyclability and (ii) much more stable open circuit potential if compared to a VRFB incorporating a Nafion 212 membrane. Their good conductivity, outstanding [H+/VO2+] ion selectivity and the low-cost qualify this proton-conducting membrane for the application in VRFBs.
Ivan Salmeron – Universidad Autónoma de Madrid	**Impact on chemical and morphological properties of modified ion-exchange membranes** - Some Ion-Exchange Membranes were modified with pyrrole by chemical in situ polymerization for their use in RFBs to reduce the cross-mixing of the electroactive species. Most fundamental properties of modified membranes were characterised as well as their transport properties.
Duburg Jacobus Cornelis – Paul-Scherer Institute	**Preparation and performance of a polybenzimidazole based composite membrane for vanadium redox flow batteries** - Composite membranes can suffer from delamination during operation, leading to a decreased effectiveness of your membrane. During this talk, a new method of producing composite membranes, comprising a thin polybenzimidazole "skin layer" and a thicker porous polypropylene "support layer", together with the obtained microstructure and performance in a vanadium redox flow battery will be discussed.

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Bromine and vanadium redox flow batteries

Bromine and vanadium flow batteries are established redox chemistries, but can offer still some surprises. Some redox-chemistries like hydrogen bromine can offer high power densities combined with excellent energy densities.

FlowCamp – Team Bromine Brenda Berenice Martinez Cantu – Fraunhofer ICT Jakub Włodarczyk – ZHAW Sanaz Abbasi – Elestor B.V. Samuel Spencer Hardisty – Bar-Ilan University Detlef Jannes – University of Stuttgart	**Hydrogen bromine redox flow batteries** – hydrogen bromine flow batteries have an excellent redox kinetics paired with high energy density. Therefore, this chemistry offers some advantages for flow batteries with dynamic power demands. In this demonstration the researchers of FlowCamp's bromine team present their results of hydrogen-bromine flow batteries.
Nicholas Gurieff – CENELEST UNSW	**VRB and flow cell design for renewable energy ecosystems** – Established vanadium redox flow battery chemistry allows for novel multidisciplinary research including mechanical engineering for cell design. Multi-physics modelling with computer aided design and additive manufacturing was used to develop higher efficiency architectures and enable innovative battery designs to promote public engagement with the technology. This led into collaborative research to reimagine sustainable energy and resource ecosystems based around renewable poly-generation with electrolysers, flow batteries and fuel cells.
Lihi Amit – Technion	**A membraneless RFB with multiphase flow** - We present an experimental investigation of a single flow zinc-bromine RFB, operating without a membrane or separator.[1] The single flow is achieved by utilizing a flowing emulsion consisting of a continuous bromine-poor phase and a bromine-rich polybromide phase. The results are promising towards low capital cost stationary energy storage for renewable energy.
Jindrich Mrlik – UCT Prague	**Study of vanadium redox flow battery negative graphite felt electrode deactivation in single electrolyte setup** - Main reason for decrease of vanadium redox flow battery voltage efficiency is usually deactivation of negative felt electrode. To study this phenomenon, we used single electrolyte setup, which provides possibility of tests under defined conditions (SoC of electrolyte, just oxidation or reduction on one electrode), instead of standard charge-discharge cycling alterations of conditions during each cycle. We have observed that the main source of negative electrode felt deactivation is purely chemical deactivation due to negative electrolyte without current load with negligible changes due different SoC (+25 – +95 %) and that mild acceleration of deactivation takes place on reduction felt, whereas a bit stronger deceleration on oxidation felt under current density loads (150 – 500 mA cm^{-2}) compared to purely chemical conditions.
M.Bures – UCT Prague	**Mathematical modelling of redox flow batteries** - The redox flow batteries can be modelled in different ways, such as simplified 0D model or advanced multidimension models. In my contribution I will show both approaches applied to different parts of RFB. Firstly, I present the a simplified validated 0D model of VRFB and its usage to the overall battery optimization. And in the second contribution I show optimization of a carbon felt electrode using an advanced 3D model.
Jiří Charvát – UCT Prague	**Effect of membrane properties on the performance and stability of vanadium oxygen fuel cell** - An investigation showing how the thickness and ion exchange capacity of membrane affects water management in the cathode catalyst layer and the performance of a vanadium oxygen fuel cell. The fuel cell shows higher efficiency and performance stability with more conductive membranes (thinner and with higher ion-exchange capacity).
Abhiroop Bhadra – TU Delft	**Membraneless H_2/Br_2 Flow Battery Simulations** - This presentation aims to show a 2D computational model of a membraneless redox flow battery design. The effect of various geometrical and operational parameters in the new design is studied and the ultimate aim of the model is to optimize these parameters associated with such a flow battery to improve its energy efficiency.
Nicola Poli – University of Padua	**VRFB maintenance procedures: technical and economical relevance** - In this work, some major maintenance procedures and their impact of the system cost are presented, considering both technical and economical points of view. In order to evaluate how the maintenance costs impact on the VRFB economic features, specific cost indicators are proposed, in particular the levelized cost of storage (LCOS) and the net present value (NPV). • This analysis shows how the LCOS of a vanadium redox flow battery decreases as the energy stored and E/P ratio increases, in the case of 20-year daily operations. For E/P = 4h the LCOS is between 0.65 and 0.5 € kWh-1, and for E/P = 10h the LCOS is between 0.33 and 0.27 € kWh-1, depending on the maintenance procedure adopted. • Moreover, the study suggests that an industrial system is more profitable than the residential one. Indeed, a VRFB system with a power P = 1MW and E/P = 10h (industrial size) can recover the initial investment (NPV = 0) in ten years with an energy sales price of 0.38 € kWh-1, which is close to the average price of the EU market. A smaller system, instead, with a power P = 10 kW and E/P = 4h (residential size) requires a higher energy sales price: 0.83 € kWh-1. This latter can become competitive only with a longer lifetime, hence confirming that an efficient maintenance procedure plays an essential role. • Finally, a sensibility analysis on LCOS and NPV is provided.

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Cross topics – System and system analysis

System and system analysis

Lucija Babic & Morana Lončar – KONCAR	**Organic Redox Flow Battery's BMS** - Scalable and modular organic redox flow battery management system, based on standardized communication protocols and hardened in line with critical infrastructure cyber security requirements..
Carlos Blanco Rocha – Leiden University	**Sustainability assessment of flow batteries -** While many flow battery technologies are still at an early stage of technological maturity, quantitative methods like life cycle assessment (LCA) and human and ecological risk assessment (HERA) can offer important insights toward more sustainable design, implementation and operation. We review key aspects in the sustainability of these batteries and identify the main challenges and possible ways forward to obtain insightful assessments that can feed into the research & development of such batteries.