New Methods for State-of-Charge Monitoring in VFB: Electrochemical Quartz Crystal Microbalance

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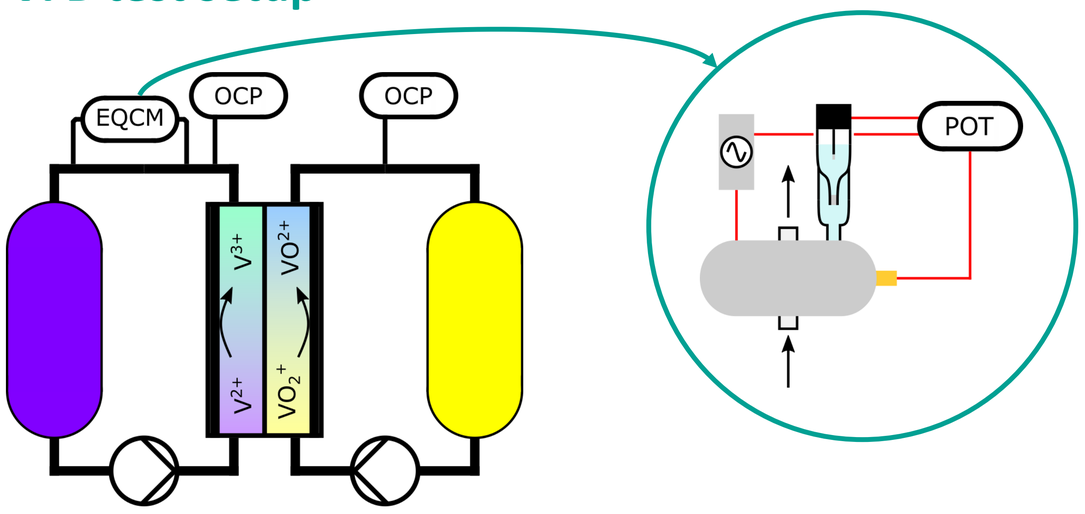
1 Introduction

- Reliable **state of charge (SOC) monitoring methods** are essential for an efficient and safe operation of all-vanadium redox flow batteries (VFB)
- In this work, an **electrochemical quartz crystal microbalance (EQCM)** is demonstrated as a novel SOC monitoring method
- Additional **half cell open circuit potential (OCP) measurements** at a glassy carbon rod using a Hg/Hg_2SO_4 reference electrode are implemented for comparison

2 VFB test setup



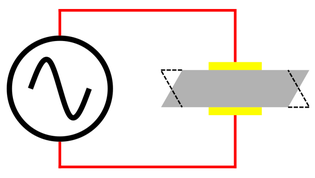
VFB schematic (left)

- Custom VFB cell with 40cm² of active area
- OCP measurements in both half cell electrolytes

EQCM schematic (right)

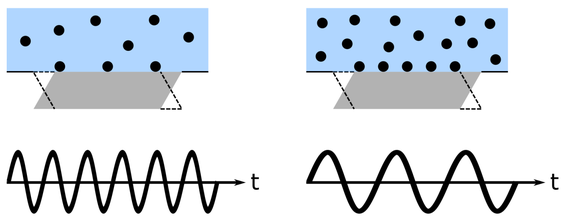
- EQCM cell with reference electrode and independent potentiostat (POT)

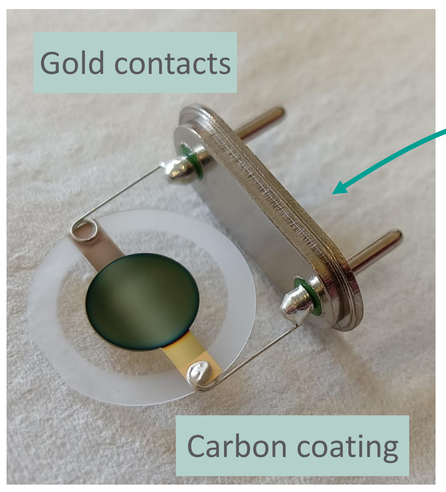
3 EQCM principle & cell design

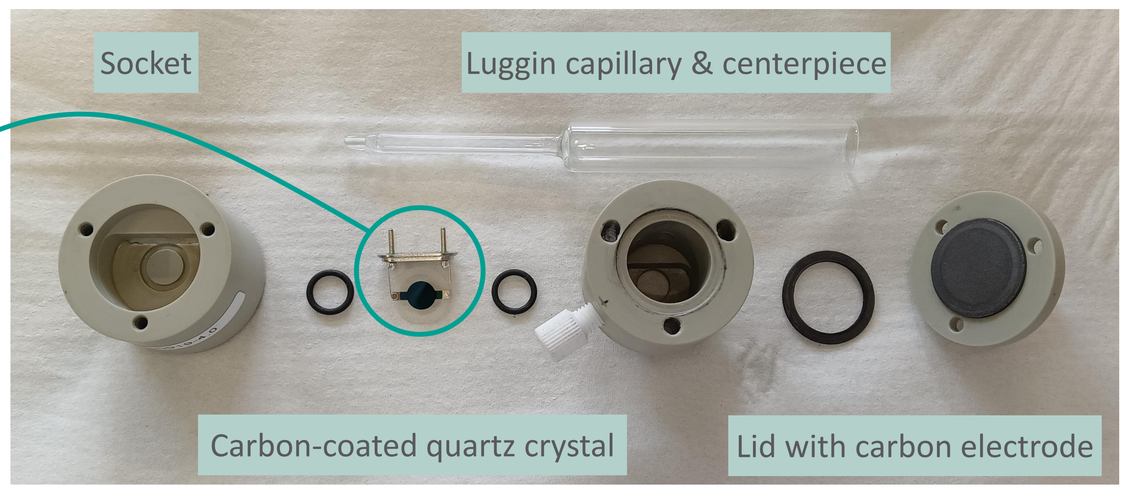


$$f = -\frac{2f_0^2}{A\sqrt{\rho_q \mu_q}}\Delta m$$

Sauerbrey equation

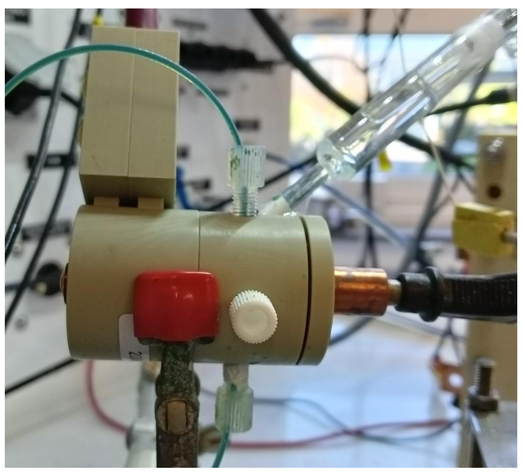




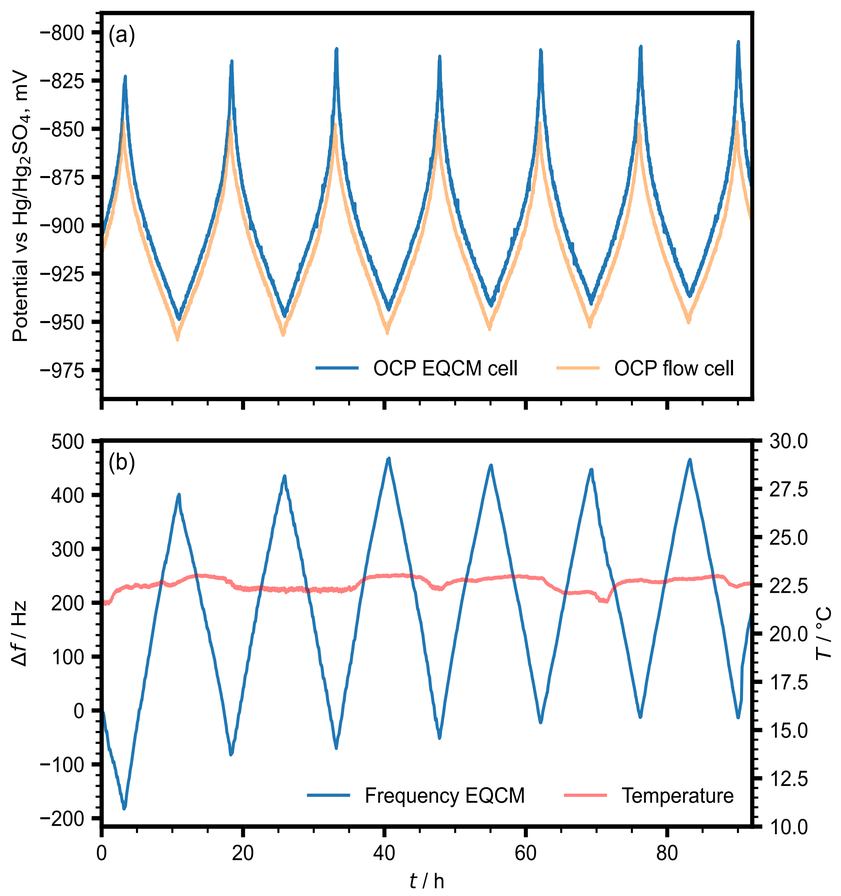


4 Results

OCP and oscillation frequency measured in EQCM cell



- VFB cycled at 50mA/cm² between 0.8V and 1.65V
- OCP measured in secondary flow cell is identical to OCP measured at EQCM working electrode
- EQCM frequency changes in correlation with changes in OCP
- Frequency changes depending on density/viscosity changes
- Since OCP and density/viscosity depend on SOC, EQCM can be used for SOC monitoring



(a) OCP of the negative electrolyte measured in the EQCM cell (blue) and in the OCP flow cell at a glassy carbon rod (orange)
(b) Frequency change of the quartz crystal and temperature measured in the EQCM cell

5 Conclusion

Summary

- Setup with an EQCM in the negative half cell of a VFB was realized
- **OCP** measured at carbon-coated quartz crystal in EQCM cell depends on SOC
- EQCM **oscillation frequency** at carbon-coated quartz crystal depends on SOC

Outlook

- EQCM tests in PHC
- Tests with different crystals/quartz coatings
- Electrochemical experiments (*e.g.* chronoamperometry) and EQCM SOC determination in the same setup

6 Literature

- Sauerbrey, G. *Z. Physik* **1959**, *155* (2), 206–222.
- Tan, F.; Qiu, D.-Y.; Guo, L.-P.; Ye, P.; Zeng, H.; Jiang, J.; Tang, Y.; Zhang, Y.-C. *AIP Advances* **2016**, *6* (9), 095313.
- Weidlich, C.; Lulay, F.; Wieland, M. *J. Electrochem. Sci. Eng.* **2023**, https://doi.org/10.5599/jese.1699