Supporting Critical Raw Material Circularity – Upcycling Graphite from Waste LIBs to Zn-air Batteries

Reio Praats[1], Alexander Chernyaev[2], Jani Sainio[3], Mari Lundström[2], Ivar Kruusenberg[1], Kerli Liivand[1*]

[1]*National Institute of Chemical Physics and Biophysics, Akadeemia tee 23, 12618, Tallinn, Estonia*
[2]*Department of Chemical and Metallurgical Engineering, School of Chemical Engineering, Aalto University, P.O. Box 16200, 00076 Aalto, Finland*
[3]*Department of Applied Physics, School of Science, Aalto University, P.O. Box 15100, 00076 Aalto, Finland*
**Kerli.liivand@kbfi.ee*

The use of Li-ion batteries (LIBs) is continuously growing, leading to a corresponding increase in the volume of end-of-life LIBs. Recycling of LIBs not only ensures the safe management of hazardous waste but also minimizes the losses of critical materials. While some battery metals, such as Co, Ni, and Cu, have already established industrial recovery processes, graphite is currently discarded as waste. This research introduces an innovative approach to create a bifunctional oxygen electrocatalyst by using graphite waste fraction from hydrometallurgical recycling. This fraction is mainly composed of graphite as well as residual transition metals (Co, Ni, Mn, and Cu) and plastic impurities (seprator and binder)[1]. Notably, we strategically utilize residual transition metals left into the graphite fraction to synthesise M-N-C based catalyst materials for both oxygen reduction reaction and oxygen evolution reaction in alkaline conditions. Our novel oxygen electrocatalyst was used as air cathode catalyst in Zn-air battery and demonstrated high-power density of 104 mW cm^{-2} with outstanding stability of 80 hours (Figure 1)[2]. This work unlocks new opportunities for repurposing overlooked graphite waste in energy conversion and storage applications.

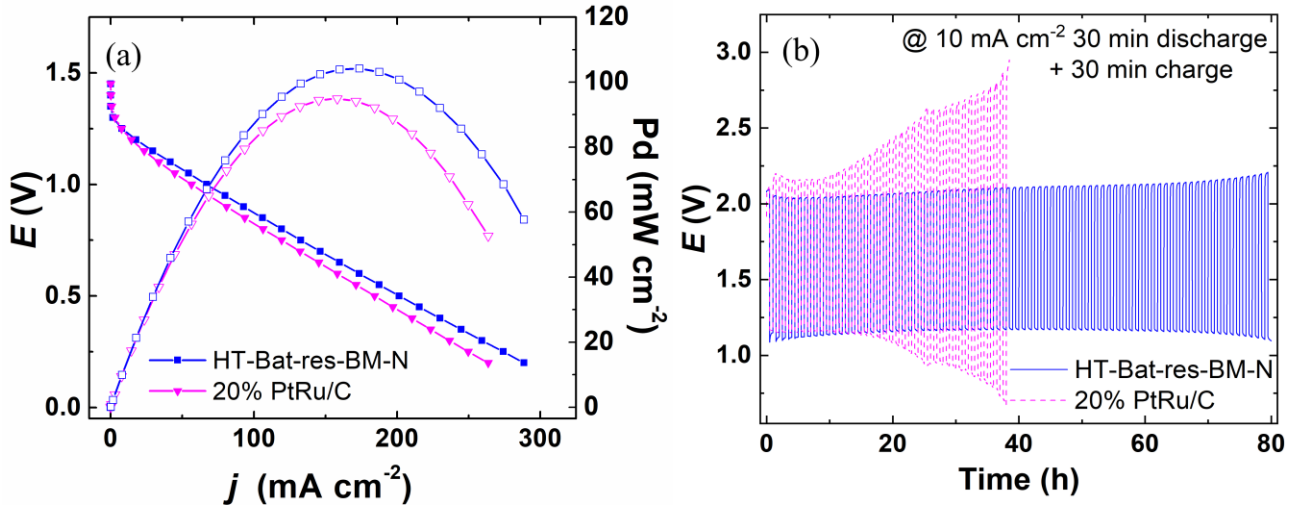

Figure 1. ZAB results of our catalyst and commercial 20% PtRu/C catalyst material (a) discharge polarization curves and power density curves and (b) galvanostatic charge/discharge cycling.

Acknowledgements
This research has been supported by the Estonian Research Council (PUTJD1029, PSG312, EAG248), the Environmental Investment Centre (KIK 17988), as well as the Business Finland BatCircle2.0 project (Grant Number 44886/31/2020). Additionally, the Academy of Finland's RawMatTERS Finland Infrastructure (RAMI) based at Aalto University and the OtaNano - Nanomicroscopy Center (Aalto-NMC) were utilized as part of this research.

References

1. Chernyaev, J. Partinen, L. Klemettinen, B. P. Wilson, A. Jokilaakso and M. Lundström, Hydrometallurgy, 2021, 203, 105608, DOI: 10.1016/j.hydromet.2021.105608.
2. R. Praats, A. Chernyaev, J. Sainio, M. Lundström, I. Kruusenberg and K. Liivand, *Green Chemistry*, 2024, DOI:10.1039/D3GC04315K.