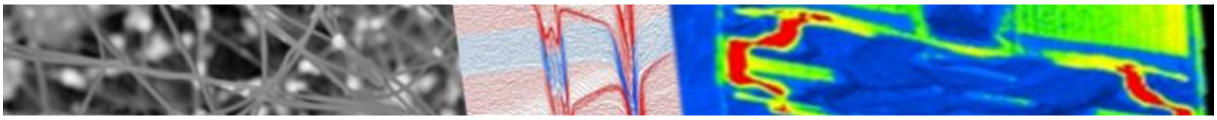

Master or Bachelor Thesis

"Investigation and study of the Aluminium anode Surface using different Treatments"

Starting date: from September 2021

The global energy consumption is multiplied by 2.3, comparing its values in 1971 to 2017 [1]. This trend indicates that finding new efficient and sustainable energy-storage technologies is crucial. Rechargeable batteries, such as Li-ion batteries (LIBs), are the established technology that dominates the market [2]. LIBs have a notable volumetric capacity and the highest gravimetric capacity (3857 mAh g^{-1}) [3]. However, the high cost and low abundance of Li (0.0065 wt% of the earth's crust) and the flammability and hazard of the state-of-the-art electrolytes push the scientists to find alternatives [3]. Al is the most plentiful element (8 wt%) comparing to Li, Mg, Na, Ca, and K [6]. Among both multivalent (MV) ions (Zn^{2+}, Ca^{2+}, and Mg^{2+}), and monovalent ions (Na^{+}, K^{+}), Al^{3+} is one of the alternatives. Aluminum batteries are sustainable, safe, and environmentally friendly due to non-flammable ionic liquid electrolytes [6,7]. The volumetric capacity of Al is 2980 mAh g^{-1}, about four times higher than that of Li (2062 mAh cm-3) [7]. This higher volumetric capacity is the result of the high density of Al and its redox reaction, which involves three electrons per exchanged ion. AlBs (with metallic Al as an anode) promise high theoretical energy density due to the smaller ionic radii of Al^{3+} (0.53 Å) compared to Li+ (0.76 Å) [8,9] and also the transport of three charges per exchanged ion.

AlBs, as a promising post-lithium batteries, have some drawbacks and unsolved issues, like:

- Slow solid diffusion and high charge transfer resistance at the cathode and the low output voltage [3].
- Strong Coulombic interaction between Al^{3+} ion and host materials due to the high charge density of Al, which results in slow kinetics, poor cycling stability, and electrolyte compatibility [7,10–12].
- The ionic-liquid-based electrolytes are corrosive and have low oxidation potential, which strongly affects Al^{3+} intercalation[13].
- The oxidation or passivation layer Al_2O_3 and dendrites formation on the Al surface hinders the Aluminum plating and stripping upon electrochemical cycling.

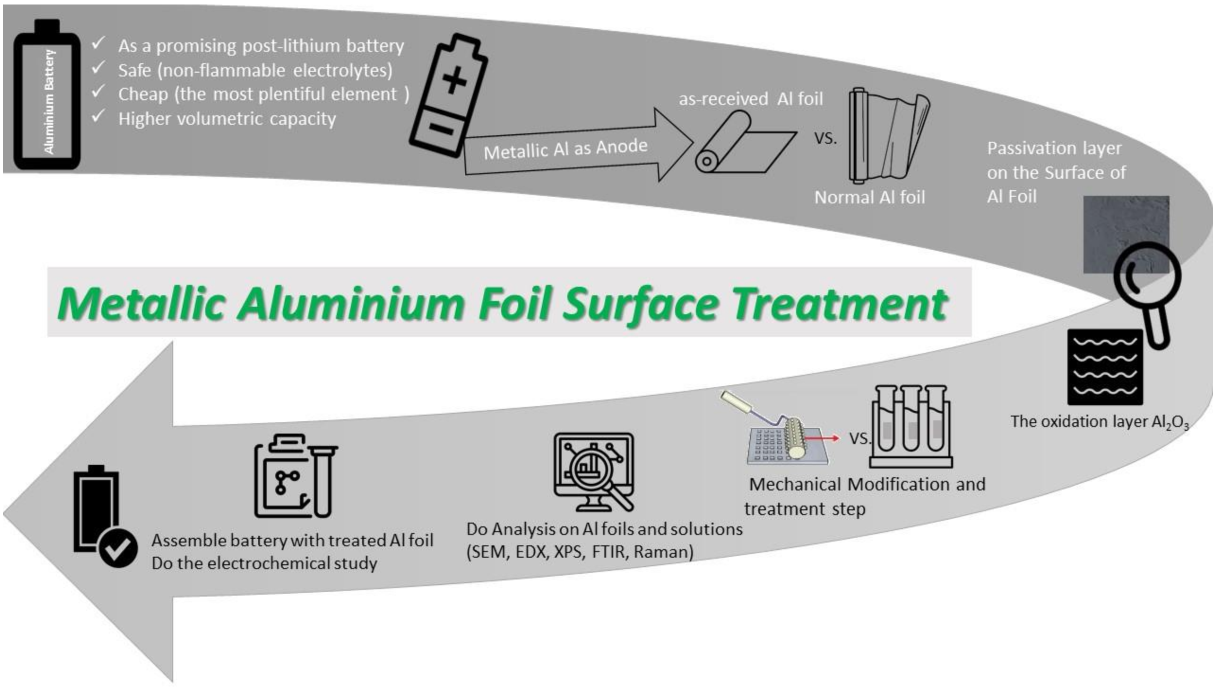

Figure 1. A general overview of the designed project [14]

This project is embedded in the cluster of excellence POLiS (https://www.postlithiumstorage.org/en/) and aims to modify the Aluminum foil surface in order to improve the Al plating/stripping. Imidazole-based ionic liquid electrolyte, $AlCl_3$-free electrolytes, and other solutions are considered as treatment agents for the Aluminum surface. Moreover, the effect of mechanical surface modification of Al Foil with the help of the microneedle treatment technique will be investigated [14].

The key-research question is if to understand the role of the combined approaches of micro-needle treatment and acidic treatment (e.g. with $AlCl_3$-based ionic liquid) on the removal of Al_2O_3 from the Al foil surface.

The objective of this project is to study the surface of as-received Al foil and the common Al foils (e.g. for kitchen use) with and without treatment and to perform electrochemical characterization (i.e. cyclic voltammetry, galvanostatic cycling, and impedance spectroscopy). In addition to electrochemical techniques, different analysis techniques will be used, such as SEM, EDX, XPS, FTIR, and Raman (Figure1).

Your profile:
You are a Master or a bachelor student in Chemistry or Materials Science at the Karlsruhe Institute of Technology, motivated to learn about materials for energy storage systems and electrochemical techniques.
The project is carried out in an international team and hence the project supervision and team meetings will be mostly held in English. Therefore, knowledge of the English language is preferred.

Contact persons: Dr. Sonia Dsoke (sonia.dsoke@kit.edu, +49 721 608 41915) and Fatemehsadat Rahide (fatemehsadat.rahide@partner.kit.edu, +49 721 608 41445)

Literature

1. IEA. World Energy Balances 2018. *Report*. Published online 2018. doi:10.1787/3a876031-en

2. Chen H, Cong TN, Yang W, Tan C, Li Y, Ding Y. Progress in electrical energy storage system: A critical review. *Prog Nat Sci*. Published online 2009. doi:10.1016/j.pnsc.2008.07.014

3. Yang H, Li H, Li J, et al. The Rechargeable Aluminum Battery: Opportunities and Challenges. *Angew Chemie - Int Ed*. Published online 2019. doi:10.1002/anie.201814031

4. Elia GA, Marquardt K, Hoeppner K, et al. An Overview and Future Perspectives of Aluminum Batteries. *Adv Mater*. Published online 2016. doi:10.1002/adma.201601357

5. Pribat D. *Rechargeable Batteries—Materials, Technologies and New Trends; Zhang, Z., Zhang, SS, Eds*.; 2015.

6. Ambroz F, Macdonald TJ, Nann T. Trends in Aluminium-Based Intercalation Batteries. *Adv Energy Mater*. Published online 2017. doi:10.1002/aenm.201602093

7. Wu F, Yang H, Bai Y, Wu C. Paving the Path toward Reliable Cathode Materials for Aluminum-Ion Batteries. *Adv Mater*. Published online 2019. doi:10.1002/adma.201806510

8. Zhang Z, Zhang X, Zhao X, Yao S, Chen A, Zhou Z. Computational Screening of Layered Materials for Multivalent Ion Batteries. *ACS Omega*. Published online 2019. doi:10.1021/acsomega.9b00482

9. Geng L, Lv G, Xing X, Guo J. Reversible Electrochemical Intercalation of Aluminum in Mo6S8. *Chem Mater*. Published online 2015. doi:10.1021/acs.chemmater.5b01918

10. Canepa P, Sai Gautam G, Hannah DC, et al. Odyssey of Multivalent Cathode Materials: Open Questions and Future Challenges. *Chem Rev*. Published online 2017. doi:10.1021/acs.chemrev.6b00614

11. Levi E, Levi MD, Chasid O, Aurbach D. A review on the problems of the solid state ions diffusion in cathodes for rechargeable Mg batteries. *J Electroceramics*. Published online 2009. doi:10.1007/s10832-007-9370-5

12. Liu M, Jain A, Rong Z, et al. Evaluation of sulfur spinel compounds for multivalent battery cathode applications. *Energy Environ Sci*. Published online 2016. doi:10.1039/c6ee01731b

13. Wang H, Gu S, Bai Y, Chen S, Wu F, Wu C. High-Voltage and Noncorrosive Ionic Liquid Electrolyte Used in Rechargeable Aluminum Battery. *ACS Appl Mater Interfaces*. Published online 2016. doi:10.1021/acsami.6b10579

14. Ryou MH, Lee YM, Lee Y, Winter M, Bieker P. Mechanical surface modification of lithium metal: Towards improved Li metal anode performance by directed Li plating. *Adv Funct Mater*. 2015;25(6):834-841. doi:10.1002/adfm.201402953