Towards Understanding the Fundamentals of the Membrane Interfaces for Water Purification

P. Aydogan Gokturk^{1,2}, E. J. Crumlin^{2,3}

¹Department of Chemistry, Koc University, 34450, Istanbul, Turkey

² Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, United States ³ Chemical Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, United States

paydogan@ku.edu.tr

With a climate change beginning to affect temperature patterns across the world and current water/energy systems requiring increased efficiency, selectivity and lifetime, there is a significant necessity to understand the needs of current technology used in areas including electrochemical energy, separation and desalination/water purification systems. It is particularly important to understand the solid/liquid interfaces because it is where many crucial processes, facilitating the electrochemistry, permeability, selectivity and transport phenomena, occur. Yet the precise understanding of such interfaces at a molecular level is still incomplete due to difficulty of visualizing them with spectroscopy or imaging methods. To fill this gap, we use ambient pressure tender X-ray Photoelectron Spectroscopy (tender-APXPS).[1] In this talk, I will first introduce a use of XPS to understand the interaction of water with various membrane surfaces.[2] I will then present the first direct measurement of the Donnan potential of an IEM equilibrated with aqueous salt solutions.[3] The Donnan potential, an electrical potential drop formed at the membrane/solution interface, provides the basis of permselectivity in charged membranes. Despite a rich literature of charged membranes across various fields, many fundamental molecular interactions underpinning ion selectivity in IEMs are poorly understood. In addition, the direct measurement of Donnan potential has been thought to be unmeasurable and has never been accomplished in the over 100 years since the original Donnan theory was proposed.[4,5] Our results directly reveal the dependence of the membrane's Donnan potential on external salt concentration and counter-ion valence, as suggested by Donnan himself. In addition, by comparing our experimental results with well-known thermodynamic models, improved models incorporating thermodynamic non-idealities shows reasonable correlation. We anticipate that our methodology will be an important step toward better understanding water- and ion- membrane interactions that are so important in cellular processes as well as in energy storage and conversion and water purification applications.

This work was supported as part of the Center for Materials for Water and Energy Systems (M-WET), an Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Science, Basic Energy Sciences under Award #DE-SC0019272. This research used resources of the Advanced Light Source, which is a DOE Office of Science User Facility, under contract no. DE-AC02-05CH11231.



Fig. 1. Pictorial illustration of tender-APXPS for the molecular level understanding of electrochemistry, permeability, selectivity and transport phenomena at membrane/solution interface

- [1] Axnanda, S. et al. Scientific Reports 5, 9788, (2015).
- [2] Gokturk, P. A. et al. ACS Applied Polymer Materials, (2020).
- [3] Aydogan Gokturk, P. et al. Nature Communications 13, 5880, (2022).
- [4] Strathmann, H. in Encyclopedia of Separation Science (ed Ian D. Wilson) 1707-1717 (Academic Press, 2000).
- [5] Strathmann, H. in *Membrane Science and Technology* Vol. 9 (ed Heiner Strathmann) Ch. 3-Preparation and Characterization of Ion-Exchange Membranes, 89-146 (Elsevier, 2004).