Capacitive Deionization Using Porous Carbon Electrodes

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Capacitive deionization (CDI) is one of emerging approaches by using common porous carbon materials to electrostatically remove ions from a solution.(1-3) CDI may possess advantages over current desalination technologies, *e.g.*, substantial minimization of heat treatment, high-pressure pump, and chemical additive, leading to a significant reduction in capital and operating costs for desalination. (4)

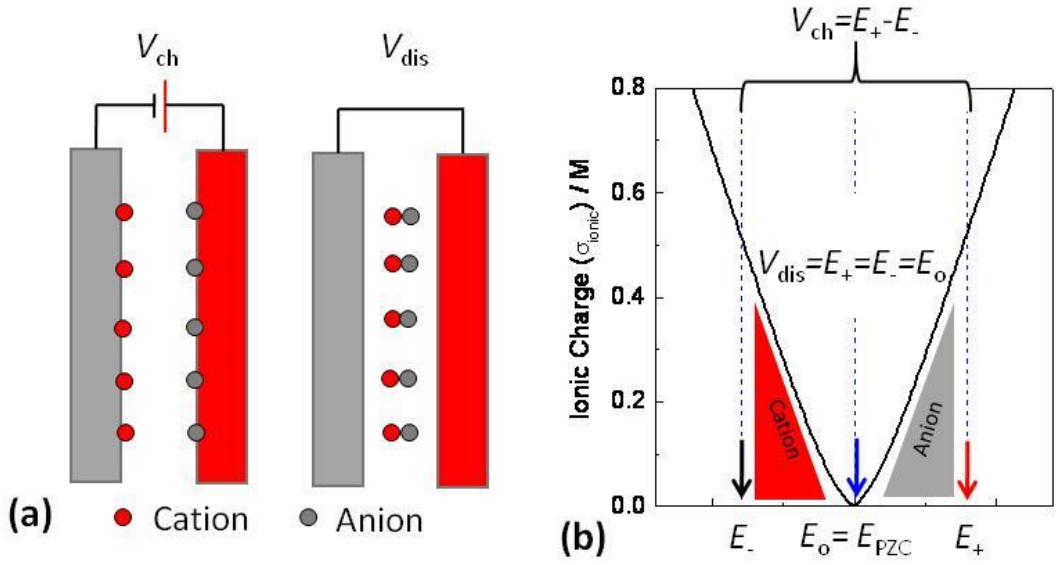

Figure 1 (a) Constant-voltage operation of a CDI cell including a charging voltage (V_{ch}) for ion adsorption and a discharge voltage (V_{dis}) for ion desorption, and its operational mechanism is presented in a potential distribution diagram in (b). In (b), E_+, E_-, E_o, and E_{PZC} denote the potentials at the anode, cathode, short circuit, and zero ionic charge, respectively.

Desalination of CDI is achieved in a flow cell with a pair of porous carbon electrodes separated by a water channel as sketched in Fig. 1(a). Often, constant-voltage operation is adopted to investigate ion transport of a CDI cell with a charging voltage (V_{ch}) for ion adsorption and a discharge voltage (V_{dis}) for ion desorption.(2) Details are illustrated in Fig. 1(b) by using an ionic charge curve plotted in a potential distribution diagram, where the ionic charge curve is defined by the modified Donnan (mD) model with chemical surface charge for a single carbon electrode according to reference (5, 6).

Ion adsorption-desorption of a CDI cell can be affected by placing the potential of zero charge (E_{PZC}) versus E_o in a potential distribution diagram,(7) where E_{PZC} commonly defines a potential when the electrode has a least ion adsorption,(8) as depicted at the lowest point on the ionic charge curves in Fig. 1(b). In this work, by modifying carbon surface chemistry, scenarios of different E_{PZC} versus E_o are created to investigate the effect of carbon surface charge on ion adsorption-desorption of a CDI cell. Results will be discussed based upon the potential distribution combined with the mD model, a similar analysis to Fig. 1(b).

References

1. J. Landon, X. Gao, B. Kulengowski, J. K. Neathery and K. Liu, *J. Electrochem. Soc.*, **159**, A1861 (2012).
2. X. Gao, J. Landon, J. K. Neathery and K. Liu, *J. Electrochem.Soc.*, **160**, E106 (2013).
3. A. Omosebi, X. Gao, J. Landon and K. Liu, *ACS Appl. Mater. Interf.*, **6**, 12640 (2014).
4. S. Porada, R. Zhao, A. van der Wal, V. Presser and P. M. Biesheuvel, *Prog. Mater. Sci.*, **58**, 1388 (2013).
5. X. Gao, A. Omosebi, J. Landon and K. Liu, *J. Phys. Chem. C*, **122**, 1158 (2018).
6. P. M. Biesheuvel, H. Hamelers and M. Suss, *Colloids Interf. Sci. Commun.*, **9**, 1 (2015).
7. E. Avraham, M. Noked, I. Cohen, A. Soffer and D. Aurbach, *J. Electrochem. Soc.*, **158**, P168 (2011).
8. A. J. Bard and L. R. Faulkner, *Electrochemical Methods - Fundamentals and Applications*, John Wiley & Sons, New York (2001).

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