

Chemically modified carbon electrodes for electrochemical separation processes



Antony Cyril Arulrajan

antony.arulrajan@wetsus.nl

Motivation

Water, being the most essential need for all living creatures, becomes scarce as consumption rapidly increases every year. To overcome the scarcity of potable water, technologies to desalinate and to purify ground water, surface water and sea water can be developed and employed. Electrochemical methods can be used to remove ions and charged molecules from water.

Capacitive Deionization (CDI)

CDI is an electrochemical method for ion removal using porous electrodes. These electrodes adsorb ions from water, resulting in a desalinated stream. Later, the electrodes are regenerated, and the ions are released, resulting in a concentrated stream. Traditionally, CDI uses a cell design with one porous carbon electrode that adsorbs and releases the cations (cathode), and another electrode that adsorbs and releases the anions (anode).

Technological challenge

Since carbons do not have a natural preference for the adsorption of either anions or cations, the ion adsorption is solely based on the potential applied. This results in a reduced ion removal efficiency due to phenomena such as co-ion adsorption.

To overcome this, following strategies can be employed.

- *Selective ion adsorption* by the electrodes can be increased.
- *Selective ion transport* across the electrodes can be achieved through *ion-selective membranes*.
- The effect of faradaic and non-faradaic processes on (selective) ion adsorption, and on potential pH changes during operation, should be understood to increase the performance and stability of the electrodes and membranes.

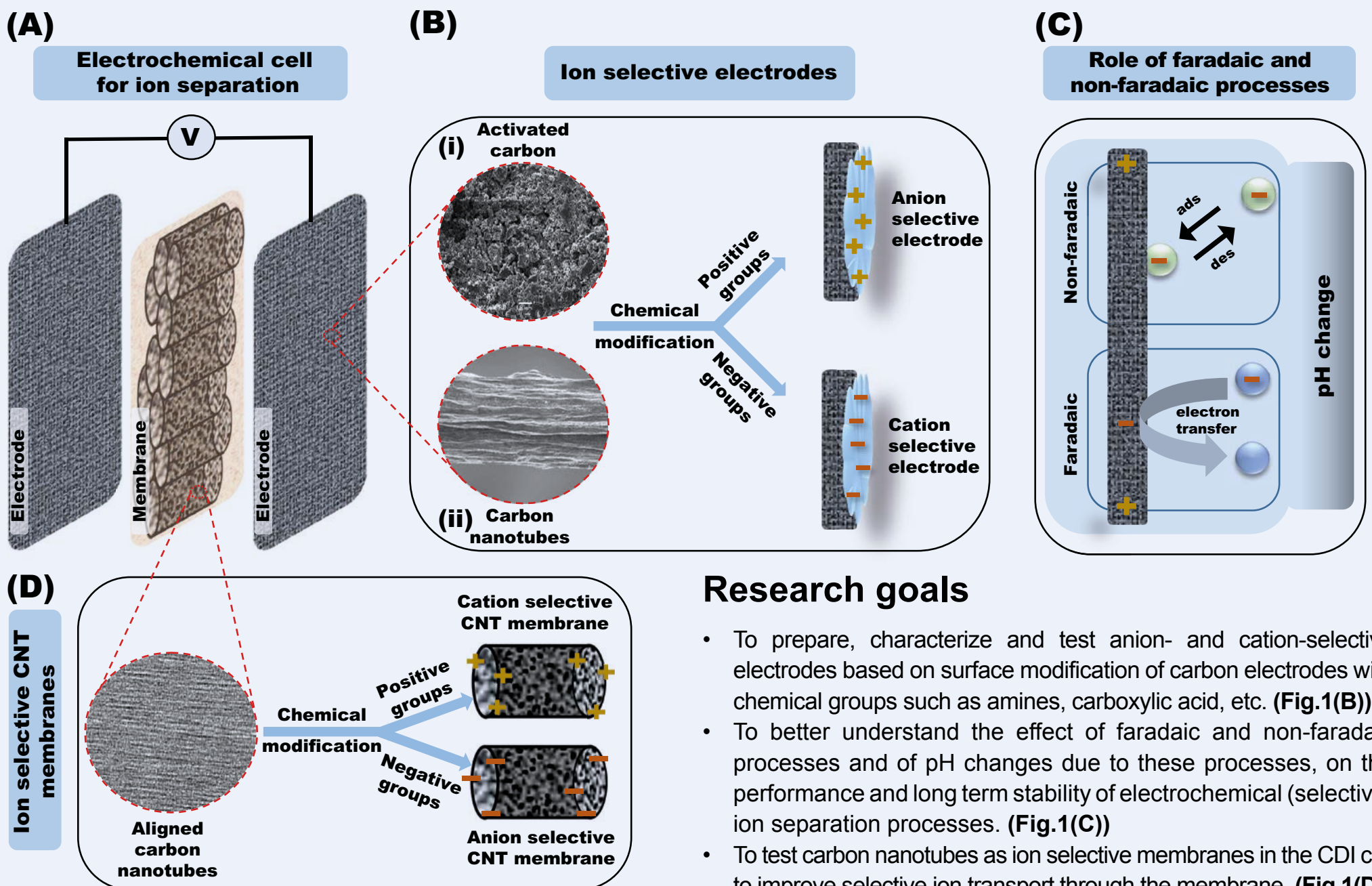


Fig.1: (A) General configuration of an electrochemical cell for ion separation. (B) Preparation of ion selective carbon electrodes from (i) activated carbon (AC) and (ii) carbon nanotubes (CNTs). (C) Effect of faradaic and non-faradaic processes on the performance and stability of the electrodes and membranes. (D) Chemical modification of aligned carbon nanotubes (CNTs) to prepare an ion-selective membrane.

Research goals

- To prepare, characterize and test anion- and cation-selective electrodes based on surface modification of carbon electrodes with chemical groups such as amines, carboxylic acid, etc. (Fig.1(B))
- To better understand the effect of faradaic and non-faradaic processes and of pH changes due to these processes, on the performance and long term stability of electrochemical (selective) ion separation processes. (Fig.1(C))
- To test carbon nanotubes as ion selective membranes in the CDI cell to improve selective ion transport through the membrane. (Fig.1(D))

References

- [1] Arulrajan, A. C.; Ramasamy, D. L.; Sillanpää, M.; van der Wal, A.; Biesheuvel, P. M.; Porada, S.; Dykstra, J. E. *Adv. Mater.* 2019, 1806937.
- [2] Smith, K. C.; Dmello, R. J. *Electrochem. Soc.* 2016, 163 (3), A530–A539.
- [3] Gao, X.; Porada, S.; Omosebi, A.; Liu, K.-L.; Biesheuvel, P. M.; Landon, J. *Water Res.* 2016, 92, 275–282.
- [4] Dykstra, J. E.; Keesman, K. J.; Biesheuvel, P. M.; van der Wal, A. *Water Res.* 2017, 119, 178–186.