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Capacitive electrodes for energy generation by reverse electrodialysis

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Reverse electrodialysis (RED) is a technology to generate electrical power from mixing salt water and fresh water. The salinity difference between these waters can act as a power source by using ion selective membranes. Because the ion selective membranes allow either cations or anions to migrate, a potential difference is created when water with a different salinity is at either side of this membrane. Multiple cells comprised of an anion and a cation exchange membrane, with alternately salt water and fresh water in between, can be stacked to accumulate the voltage. At the end of such a stack, the ionic current is converted into an electrical current by using electrodes.

Traditionally, a redox reaction at the electrodes converts the transport of ions into the transport of electrons (i.e. electrical current). For example, $Fe(CN)_6^{4-}$ can be oxidized to $Fe(CN)_6^{3-}$ at the anode and reversely at the cathode [1]. Water splitting at the electrodes, using NaCl or $NaSO_4$, is also an option. However, all electrode reactions that are presented in previous research have a large overpotential (using NaCl and $NaSO_4$), are associated with potentially toxic substances (Cl_2 and $Fe(CN)_6^{3-/4-}$ in extreme conditions) or are unstable ($Fe(CN)_6$ can precipitate as a complex or can be diluted by diffusion through the non-perfect membranes) [2].

Here we introduce a new, sustainable approach, using electrodes with active carbon that absorb charged ions and consequently drives an electrical current. These capacitive electrodes make the use of redox reaction obsolete. A periodic switch of the current direction, by switched the feed waters, is applied to prevent saturation of the capacitive electrodes. The RED system with capacitive electrodes is named capacitive reverse electrodialysis (CRED).

As shown in figure 1, the maximum power density obtained experimentally from a CRED-stack is only slightly lower than for a conventional electrode system using $Fe(CN)_6^{3-/4-}$ as an electrode rinse solution. It is however approximately 4 times higher than when using a conventional electrode system using NaCl as an electrode rinse solution. Several strategies are available to improve the power density of CRED even more. The capacitive electrodes are considered as a clean, safe and high performing system for application in RED.

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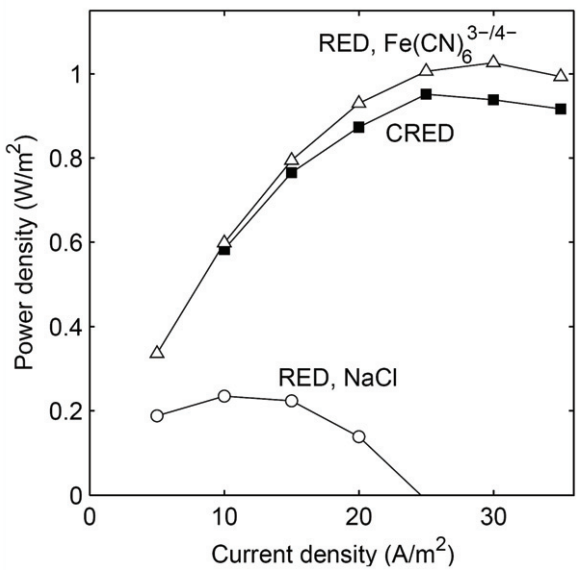

Figure 1: Power density (in Watt per m^2 of membrane area) obtained from RED and CRED, as function of the current density (in Amperes per m^2 of electrode area). All stacks had 30 cells. The RED-stacks used either NaCl (0.25 M) or $Fe(CN)_6^{3-/4-}$ (0.05M) as electrode rinse to facilitate a redox reaction. The CRED-stack used an electrode rinse solution of NaCl (0.25M).

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Keywords: Reverse Electrodialysis, Electrodes, Salinity gradient energy, Ion exchange membranes