Harvesting Microbial Fuel Cell Ionic Current to Augment Power Densities from Capacitive Mixing

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With the ongoing depletion of our fossil energy sources, the global community is in search of renewable energy technologies that can aid in meeting rising energy demands. In addition, the recently identified interrelationship between energy and water has placed a greater emphasis on generating renewables which diminish this dependence between water and energy. Salinity gradient energy technologies and bioelectrochemical systems, as well as the combination of the two, represent new means to address these issues.

Power from salinity gradients can be generated from the reversible mixing of two salt solutions of different concentrations. The global potential of power recovery from mixing in estuaries has been estimated to be ~2.6 TW [1]. Three main technologies are currently under development for the conversion this free energy directly into electrical energy, Pressure Retarded Osmosis (PRO), Reverse Electrodialysis (RED) and Capacitive Mixing (CapMix). PRO has been regarded as having the greatest potential impact, because it is currently capable of generating 4-5 W m^{-2} (total membrane area, mem). RED and CapMix are currently only able to generate 1 W m^{-2} (mem) and 0.2 W m^{-2} (mem)[2].

Bioelectrochemical systems are capable of generating electricity through coupling wastewater organic matter oxidation by electrode respiring bacteria to a cathodic reaction such as oxygen reduction. Power production from bioelectrochemical systems has improved over the last decade, yet still remains on the order of 1-2 W m^{-2} (cathode). Recent studies have pointed to multi-chamber systems as a means to reduce overpotentials at the cathode [3].

To date, power densities from CapMix reactors have low (0.2 W m^{-2}), but the technology is regarded as nascent due to the low cost and potentially long materials lifetime. In this current study the insertion of capacitive mixing electrodes within bioelectrochemical systems was investigated for the first time (Fig 1a). Through unifying the two technologies in a multi-chamber system, the MFC electrodes were able to operate more optimally through a reduction in both the anode and cathode overpotentials. In addition, because the MFC electrodes drive ionic current, flux into the capacitors can was improved.

Experiments were conducted to investigate the effects of MFC operation on a capacitive mixing cell located in-between a bio-anode and an oxygen reduction cathode. The combined system was shown to increase the energy harvested from the capacitive mixing process with NaCl solutions by 60 times, from 0.04±0.003 mJ $cycle^{-1}$ to 2.64±0.240 mJ $cycle^{-1}$ with a constant MFC current of 4 mA. Power densities achieved through the capacitive mixing cell increased by 50 times from ~10 mW m^{-2} (without MFC current) to ~500 mW m^{-2} (with MFC current) (Fig 1b). These results represent a significant increase in both the energy extracted and the power densities produced by capacitive mixing technologies. Further investigations into CapMix-MFC as a means for simultaneously harvesting energy from both salinity gradients and wastewater could ultimately allow for wastewater treatment facilities to operate without the need for additional the grid energy.

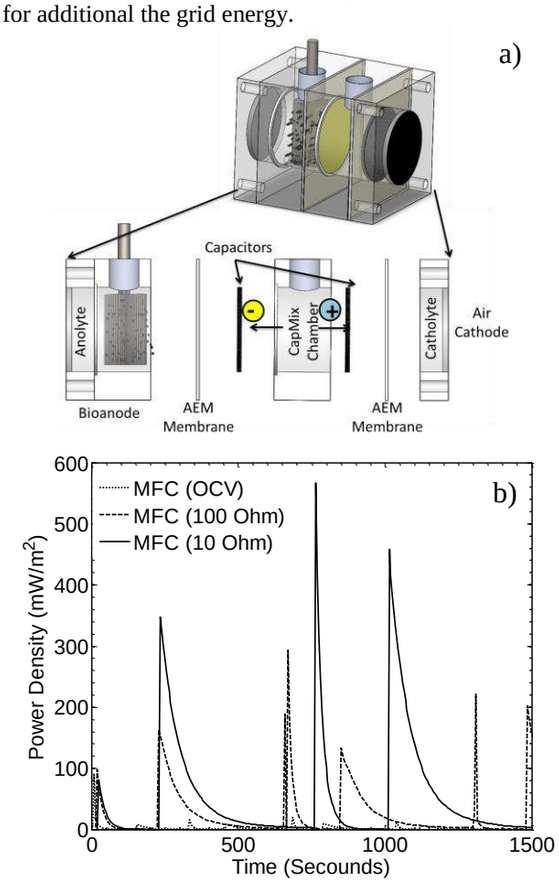

Figure 1: Schematic of Microbial Capacitive Mixing Cell (CapMix-MFC), and (b) power densities for CapMix chamber with different external resistances.

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3.R.D. Cusick, Y. Kim, B.E. Logan, Energy capture from thermolytic solutions in microbial reverse-electrodialysis cells, Science 335 (2012) 1474-1477.