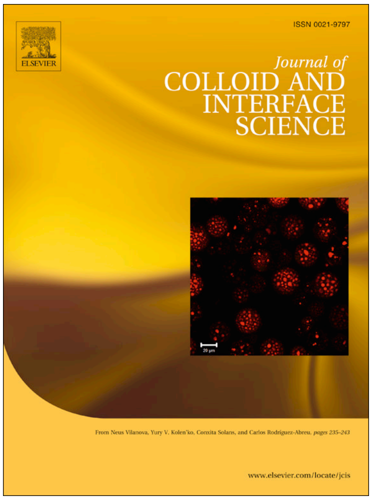

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Periodic Energy Conversion in an Electric-Double-Layer Capacitor

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Abstract

Electrostatic conversion devices operate through periodic modulation of capacitance. Such devices have a wide range of configurations, involving either changes in permittivity, electrode-plate spacing or wetting area. The presented study examines, theoretically, a potential configuration of an electric-double-layer capacitor (EDLC)-based transducer, as it converts concentration and temperature oscillations into an electric alternating current. A constant voltage applied at EDLC electrodes forms two opposite-sign EDLs, and an electric current is generated when ionic charges pass from one EDL to the other. In the examined configuration, this ionic charge transfer is induced by boundary modulation of temperature and concentration. To capture the oscillating dynamics of the ion distribution and ion flux, we solve the full set of Poisson-Nernst-Planck (PNP) equations coupled with the energy equation. We find that the transducer's optimal conditions for conversion, for which the device's frequency response is maximized, are governed by three main factors: low irreversible Joule heating, confined geometry, where the capacitor thickness is a close as possible to the EDL's characteristic screening length, and, most importantly, 'tuning' the system to a resonance frequency dictated by the interplay between geometry and characteristic time scales for mass and heat diffusion.

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1. Introduction

Capacitive or electrostatic energy conversion devices harness mechanical vibrational energy to produce electricity through a variable capacitor. These devices typically serve as energy harvesters, scavenging energy from small amplitude ambient vibrations, intended for self-powered electronic systems and remote sensors [1, 2, 3, 4]. An electrostatic parallel-plate capacitor stores electric energy by separating opposite charges with a dielectric inserted between the two conductive plates. When maintaining constant voltage V between the

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