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Review

# Improved electrosorption kinetics in meso/microporous carbon composite electrode for swift salt removal

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ABSTRACT

To maximize the ion adsorption capacity with fast electrosorption, hierarchical multi-pore structures have been suggested in energy conversion and desalination technologies. However, it is hard to synthesize hierarchical structure *via* successive chemical process or template methods. In this article, we developed carbon composite electrode including mesoporous and microporous carbon *via* facile method for both high surface area and fast electrosorption. We observed that introducing mesoporous carbon to microporous carbon can improve the adsorption kinetics by enhancing wettability for water transport and simplifying ion transfer pathway. Finally, GNPAC 1:1 composite electrode showed the highest average salt adsorption rate, attributed from better adsorption kinetics and increased effective area for adsorption in fast flow rate of electrolyte compared to pristine microporous and mesoporous carbon electrode.

## 1. Introduction

Water plays a vital role in human life, but the growth of the world population and accelerated environmental pollution have caused the scarcity of fresh water. Demand for water is guarded by more than 40% by 2050 [1]. Some nations are trying to secure water resources by converting seawater or brackish water to fresh water. Through continual improvement for more than 50 years, primary desalination techniques (*e.g.*, multi-stage flash (MSF) and reverse osmosis (RO)) could have become practical and enormously efficient. However, these techniques still have issues, such as significant energy consumption and periodic membrane replacement [2]. Of late, capacitive deionization (CDI) is a re-emerging desalination and water softening technique with low energy demand and no secondary pollutants [3]. CDI is based on a capacitor, which consists of two oppositely polarized electrodes and salty electrolyte. Once the electric field is applied to the two electrodes, cations and anions in the feed water migrate to the oppositely charged electrode and are adsorbed on an electric double layer formed between electrolyte and surface of the electrode. Until charged ions saturate the electrical double layer on the surface of the electrode, fresh water is produced. Hence, for the past decade, several research groups have focused on theoretical understanding [4], cell architecture, experimental method and designing electrode materials to enhance CDI performance in terms of charge efficiency, salt adsorption capacity and so on [5].

Materials for CDI electrode should have properties such as high surface area, high electrical conductivity, and wettability [6]. Classic CDI researchers have suggested microporous materials like activated carbon and carbon aerogel for high surface area. However, all kinds of microporous activated carbon are not effective in forming an electrochemical double-layer capacitor (EDLC). Only micropore larger than 0.5 nm can electrochemically adsorb hydrated ions and contribute forming EDLC [7–9]. Furthermore, the contribution of micropore to a capacitor at fast discharge rate reduces compared to mesopore [10]. Hence, new materials have been proposed for facilitating adsorption of ions in the pore structure. (*e.g.*, graphene [11,12], metal oxide intercalated graphene [13,14], graphene/carbon composite [15–18], carbon nanofiber/nanotube [19,20], and ordered mesoporous carbon [21,22]) It was also reported that hierarchical multiporous carbon structure can enhance the kinetics of electroadsorption due to simple and regular pore structure [23]. However, the yield of graphene-based material because of complex synthesis step is insufficient to apply to mass production of CDI electrode. Faradaic reaction from oxidized carbon or metal oxide as intercalating material can trigger degradation of an anode during CDI operation.

Wettability is also one of the essential requirements in the CDI

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