ELECTROCHEMICAL REMOVAL OF SALT IONS VIA CAPACITIVE DEIONIZATION USING ELECTRODES FABRICATED FROM LOCALLY ACTIVATED CARBON

Hashila O. Weerakkody, Didula S. Alwis, Nuwan De Silva, Yasun Y. Kannangara*
Sri Lanka Institute of Nanotechnology (Pvt) Ltd, Sri Lanka

INTRODUCTION

In the present era, access to safe water sources has become a great challenge. Thus, seawater desalination has been recognized as a solution to overcome this issue by following several methods for ion removal, including ion exchange, electric dialysis, and reverse osmosis, though higher maintenance cost, high energy consumption, complex pre-treatment methods remained as major drawbacks, where alternatives electrosorption method, Capacitive deionization (CDI) emerged as a low cost, energy-efficient, and environmental-friendly technology for desalination. This process of electrosorption occurs at two electrodes for removing ions from the feed solution(Hu et al., 2021). Applying an electrical potential difference across porous carbon electrodes, charge them positively and negatively. Cations and anions move to the polarized electrodes creating electrical double layers (EDLs), while removing ions from the feed solution (Xu et al., 2014). The adsorption capacity, and electric conductivity of the electrode highly depend on the electrode material (Zhao et al., 2022).

METHODOLOGY

Surface modification of activated carbon

Surface modification of the commercially available activated carbon was done in an acidic medium, where the activated carbon sample was impregnated in 2:1 ratio in 2 M HNO_3 acid overnight. The acid-treated activated carbon sample was washed with distilled water, until pH was neutral and it was dried in the oven at 120^0℃ for 4 hours. Acid treated sample was then agated and ball milled 12 hours to obtain high porous activated carbon.

Fabrication of electrodes with surface modified activated carbon

Acid treated, surface modified activated carbon was mixed with conductive additive and the polybond binder with surfactant span-20 in 8:1:1 ratio, until a consistent slurry was formed. Then, this slurry was casted on the current collectors using the thin film applicator to form a uniform thin layer of electrode material.

RESULTS AND DISCUSSION

In the acid treatment process, HNO_3 reacts with the inorganic and organic compounds and produces pores. The surface areas of activated carbons are usually measured using the Brunauer Emmett-Teller (BET) method,(Grima-Olmedo et al., 2016) which employs nitrogen adsorption at different pressures. Furthermore, BET surface area also improved from 1289 m^2/g to 1562 m^2/g as an effect of acid treatment and ball milling, while resulting in a high degree of micro-porosity. The finer particle size of activated carbon expresses the increase of both surface area and it could increase the rate of adsorption kinetics. After carbonization of the raw material, the method of producing activated carbon is activation, and there are two main activation methods, physical and chemical activation (Salinas-Torres et al., 2015). Under the chemical activation method, acid treatment can increase porosity and surface area while attaching hydrophilic groups. After being treated with HNO_3, surface properties of activated carbon particles become uneven and develop porosity. It can be seen in figure 1.

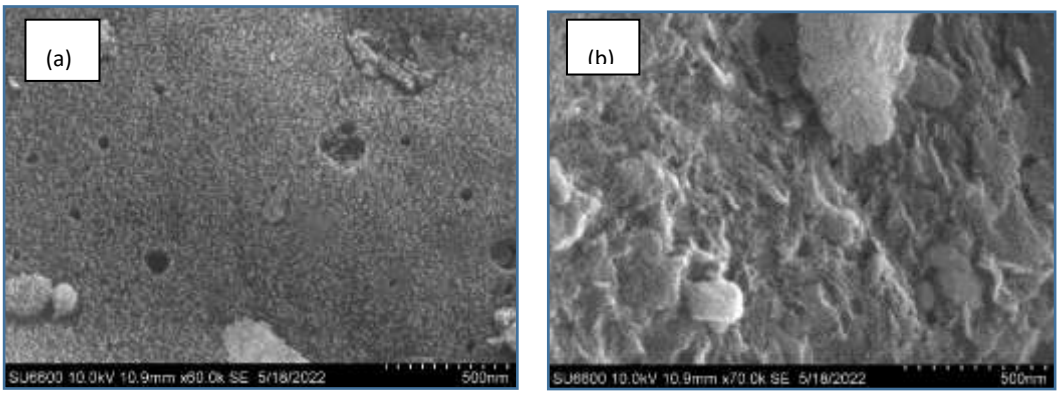

Figure 1. SEM images of activated carbon (a) before treated and (b) after treated

The electrochemical properties of the fabricated activated carbon electrodes were characterized in 1M NaCl with a typical three-electrode cell, the prepared electrode was used as the working electrode, a platinum electrode and Ag/AgCl electrode as counter and reference electrodes, respectively. (Climent & Feliu, 2018) Using thin-film applicator active material coated on stainless steel plates, the working electrode was sized 3x4 cm^2. Cyclic voltammetry (CV) measurements were taken in a potentiostat. The specific capacitance was calculated based on the following equation. (Pastushok et al., 2019) The potential window was 1.2 V. The specific capacitance (Eq.1) of the working electrode was also calculated based on the area of CV curve in fig (2). A dramatic increase of the specific capacitance from 47.08 F/g to 73.15 F/g was observed with the decrease of scan rate from 500 to 10 mV/s.

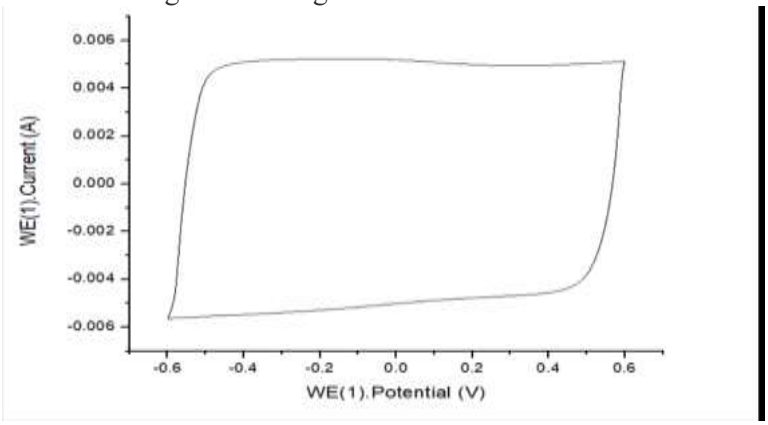

Figure 2. CV curve at 10 mV/s scan rate for treated activated carbon

The results described that the low scan rates provide more time for ion transportation and penetrating into the porous electrode surface and the high scan rates limit the time needed for ions to move to the electrode (Zi et al., 2019). The symmetrical rectangular shape of the CV curve indicates the reversible ions adsorption-desorption performance and also did not indicate the oxidation or reduction process in the EDLC (Electrical Double Layer Capacity) set up showing the absence of peaks on the CV curve (Liu et al., 2021). The enhanced CV sweep areas reflect the high specific capacitance.

$$\text{Specific Capacitance} = \int I \, dV / 2 \, \Delta V \, m \, \upsilon \qquad (1)$$

ΔV is the voltage window, m is the mass of the active material, υ is scan rate and I is the current (Sun et al., 2020)

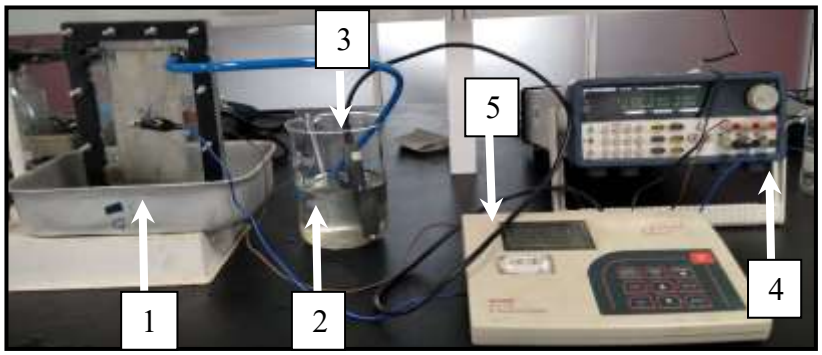

Figure 3. Setup of CDI unit

CDI electrosorption was carried out in a flow-through mode with cyclic-pass electrical conductivity measurements using 193.0 μS/cm NaCl, corresponding to 100 ppm. The symmetrical CDI cell was used to measure the ion removal capacity. The optimal ion removal capacity was 9.6 mg/g by using conductivity according to the following equation (2) and shows a symmetric assembled CDI cell. (Zou et al., 2008)

Ion adsorption capacity = $(C_i - C_f)$ V/m (2)

C_i is initial concentration of NaCl,C_f is final concentration of NaCl, V is volume of the solution and m is mass of active material. (Wu et al., 2021)

CONCLUSION

The surface area of mesoporous activated carbon was improved by HNO_3 acid treating method from 1286 m^2/g to 1562 m^2/g, which implies a specific capacity for electrode 73.5 F/g, at a scan rate 10mV/s and NaCl ion removal capacity of 9.6 mg/g. Thus, it suggests that locally available activated carbon can be used for the fabrication of electrodes in electro-sorption techniques including capacitive deionization.

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