Investigation of HNO_3-Treated Carbon Xerogels for Capacitive Deionization Applications

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The concept of capacitive deionization (CDI) cell is straightforward – by control of electrostatic force, ions dissolved in an aqueous liquid can be trapped on a polarized surface, and regenerated back to a concentrated stream. Therefore, CDI is an alternative technology for wastewater treatment, competing with other current technologies. In contrast to the membrane and thermal treatments (*e.g.*, reverse osmosis and mechanical vapor compression), CDI offers the advantages of low-pressure operation and lower maintenance costs.[1] In addition, since a CDI cell employs chemically/physically-stable carbon materials as electrodes under the operational potential for water decomposition (*i.e.*, thermodynamically < 1.23 V), the degradation of carbons is seriously minimized, and therefore a long cycle life can be expected. In our group, the carbon xerogel (CX) synthesized via poly-condensation reactions exhibits high surface area consisting mainly of mesopores.[2] Due to the lack of wettability, ~10% of surface area is estimated for the CDI process.[2] As a consequence, the use of chemical or thermal oxidations to treat the CXs is the way to improve the wettability. This is because this oxidation allows hydrophilic functional groups (*e.g.*, carbonyl and carboxylic groups) to be formed on the carbon surface[3], reducing the barrier for aqueous ions to infiltrate the porous carbon.

The CX sheets were made of resorcinol-formaldehyde (RF) solutions and carbon cloths, and its procedure has been stated by Landon et al.[2] The procedure for the HNO_3-treatment is as follows. A graduated cylinder with a film cover was used to heat 300 cm^3 of 70% HNO_3 in a temperature-controlled water bath. When the temperature of HNO_3 was stable, a CX sheet with a geometric area of ~70 cm^2 (corresponding to ~1.4 g) was placed into the cylinder for 1 h. After treatment, to remove any residual HNO_3 on the surface of the carbon, the treated carbon was washed with a great amount of deionized water until the pH value reached neutral. Subsequently, the wet carbon was dried overnight in a vacuum oven before characterization. To facilitate analysis, we define the CX-20, -35, and -50 to represent the CX sheet treated at different temperatures, *e.g.*, the CX-20 means that a CX sheet was treated at 20°C.

The deionization performance with the treated CXs was investigated in a flow system. The flow cell was constructed of plastic plates. Each electrode had a geometric area of ~65 cm^2, and was contacted by means of a titanium current collector. The space between two electrodes was 6 mm, allowing a solution to flow. During the system operation, 1 dm^3 of ~4 mmol dm^{-3} NaCl was purged with N_2, and circulated at a flow rate of 10 cm^3 min^{-1} using a diaphragm pump at room temperature. A conductivity meter at the flow cell outlet was installed for the calculation of deionization capacity.

Fig. 1 shows the deionization capacity for the untreated and treated CXs. It is found that the deionization capacity for the CX-20 shows the highest value of ~5.46±0.47 mg (NaCl) g^{-1} (Carbon), and the deionization capacity decreases with increasing the treatment temperature. This observation illustrates that the deionization capacity cannot be improved simply by forming a large number of functional groups on the CXs. Thus, these electrodes (*i.e.*, CX-35 and -50) are not suitable for the CDI applications.

In this paper, we will report the change in chemical and physical properties for the CXs treated in 70% HNO_3 at various temperatures, show the deionization capacity for NaCl solution using these treated CXs, and discuss the possibility of HNO_3-treated CXs for CDI applications.

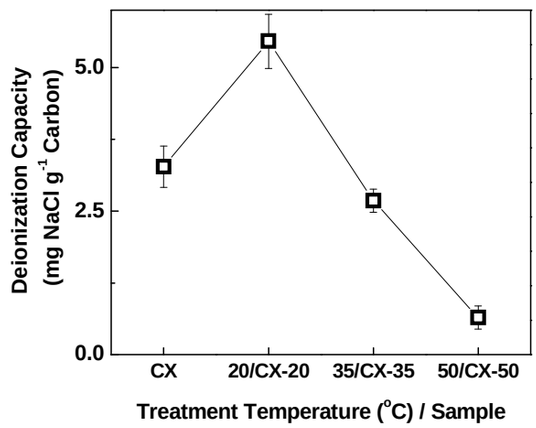

Fig. 1 Deionization capacity for the untreated and treated CXs. The CX-20 shows the highest value of ~5.46±0.47 mg (NaCl) g^{-1} (Carbon).

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References

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