Capacitive Deionization with Ion Exchange Spacer for High Purity Water Treatment

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Capacitive deionization (CDI) is one of the attention gaining technologies from researchers for water desalination/purification. It removes ions from water by applying an electric field between two porous electrodes, in which the cations are stored in the negatively charged electrode and the anions are stored in the positively charged electrode. After the ion adsorption capacity of the electrodes has been reached, the adsorbed ions are released back to the water by short-circuiting the electrodes or applying a voltage in a reverse direction. Because CDI is generally operated in a low voltage, where the water discharge does not occur, it is energy efficient compared with the other desalination methods like reverse osmosis (RO) requiring the use of high pressure pump.

In CDI, the spacer is placed in between the two electrodes to prevent a short-circuiting the electrodes and to provide the pathway for water flowing. In this manner, the concentration profile of ions has a shape decreasing from the inlet to the outlet along the spacer. So the water in between the electrode adjacent to the outlet has much lower ion concentration, which results in the higher solution resistance causing the larger voltage drop. When producing high purity water with CDI, it is important to minimize the solution resistance in between electrodes to get high efficiency of system. However until now, there has been little or no research dealing with the issue of the solution resistance increase during CDI deionization under the field as far as the authors know.

In this study, to decrease the solution resistance we adopted a spacer functionalized with ion exchange group. The spacer was coated with ion exchange polymer, Nafion and then its equivalent series resistance (ESR) was measured by EIS (Electrochemical Impedance Spectroscopy). Nafion coated spacer has a decreased ESR over than uncoated one in two spacer materials tested in this study (polyamide and PET). The coated spacers were introduced to the three CDI cells of a conventional CDI, MCDI [1] where ion exchange membranes are incorporated, and the CDI that the case of ion exchange binder was used in the electrode composition [2] and their schematic diagrams are shown in Figure 1. The performance of the three types of CDI cells were tested with NaCl solution of the concentration of 100 ppm flowing at 50 ml/min. 1.2V was applied to the electrodes for deionization and then the cells were short circuited for the regeneration of electrodes. The ion conductivity of the solution flowing out of the cell was measured by ion conductivity meter with flow-type ion conductivity cell (Horiba, 3561-10D, Japan).

The CDI cells employing Nafion coated spacer showed higher desalination efficiency than those employing uncoated one in all three types of cells tested here. It is noteworthy that MCDI cell showed much improved deionization efficiency over the conventional CDI cell did when Nafion coated spacers were incorporated in, which can be seen in figure 2. It may be caused by the lower ion concentration or higher solution resistance of the solution flowing between the electrodes of the MCDI cell than CDI cell during deionization. And it can be inferred that the lowering of solution resistance of the CDI cell using ion exchange spacer is more effective when the treating solution has lower ion contents.

The details of the experiments and results will be presented in the meeting.

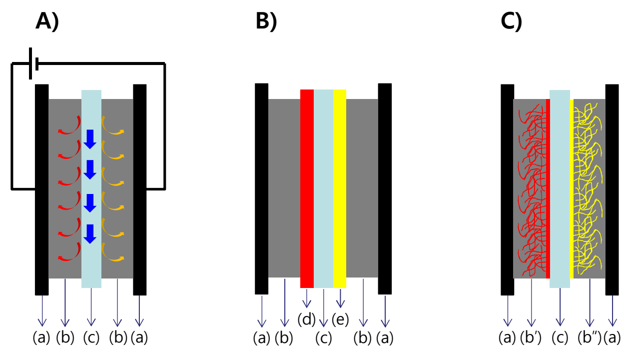

Figure 1. A) Conventional CDI, B) MCDI, C) CDI with the composite electrodes of carbon and ion exchange binder [2] where a) is graphite current collector, b) is carbon electrode, c) is spacer, d) is anion exchange membrane, e) is cation exchange membrane, b'), d') are composite electrodes of carbon and ion exchange binder.

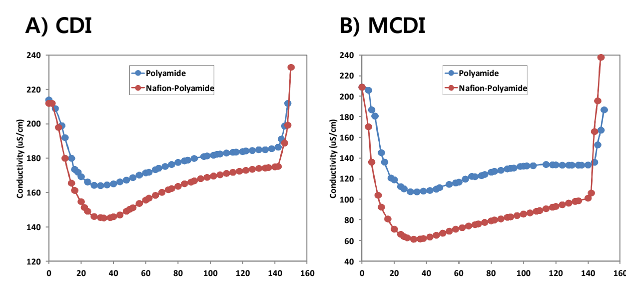

Figure 2. Ion conductivity profiles of the solution from the A) CDI cell and B) MCDI cell during deionization.

References
[1] M.D. Andelman, Charge barrier flow-through capacitor, Can Patent, CA 2,444,390 (2002).
[2] Son et al., Korea Patent, KR 10-1063913.