CELLULOSE DERIVED GRAPHENIC FIBERS FOR CAPACITIVE DESALINATION OF BRACKISH WATER AND PREPARATION METHOD OF THE ELECTRODE THEREOF

IITM Technology Available for Licensing

Problem Statement

- The need for clean water for domestic, agricultural, and industrial processes has resulted in intense search for **alternate sources of water supply, such as brackish groundwater and seawater**.
- **Conventional methods such as Reverse Osmosis (RO)**, Ultra Filtration (UF) etc. are **energy intensive and result in rising proportion of concentrates**. **Capacitive deionization (CDI)** is increasingly being considered as a viable solution for water desalination that is **more energy efficient**..
- However, the **existing mainstream CDI materials** with their inherent limitations in **stability and resistance to biofouling limit** the application of such electrodes for larger scale operations. Carbon-based electrodes such as **mesoporous carbon have larger pore size** and can address the problem of slow diffusion. However, mesoporous carbon has **high inner resistance**.
- There is a need for a **cost-effective** mesoporous carbon based CDI electrode with **enhanced conductivity** using incorporated graphene and **higher resistance to biofouling**.

Intellectual Property

- IITM IDF Ref 1308
- **IN 335882 Patent Granted**

TRL (Technology Readiness Level)

TRL 5 Technology Validated in Relevant environment

Technology Category/ Market

Category-Micro & Nano Technologies

Industry Classification:

- **NIC (2008)- 3600-** Water collection, treatment and supply; **28195-** Manufacture of filtering and purifying machinery or apparatus for liquids and gases

Applications:

Drinking water and sanitation, Desalination of brackish water and sea water.

Market report:

The global desalination systems market was valued at USD 1.54 trillion in 2024, and is projected to reach USD 2.35 trillion by 2029, growing at a CAGR of 8.91% during the forecast period.

Research Lab

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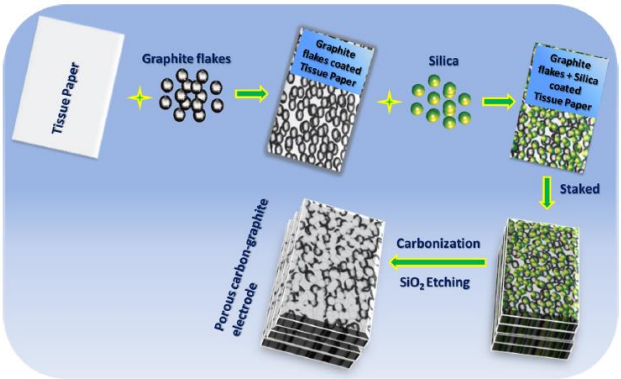

Figure: Schematic Representation of the Procedure for the Preparation of Layer-by-Layer Stacked Graphite reinforced-Carbon (GrC) Fiber Electrodes.

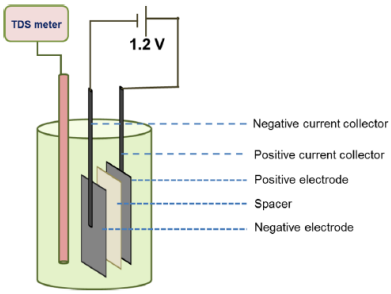

Figure: Schematic Representation of the Capacitive Deionization Setup

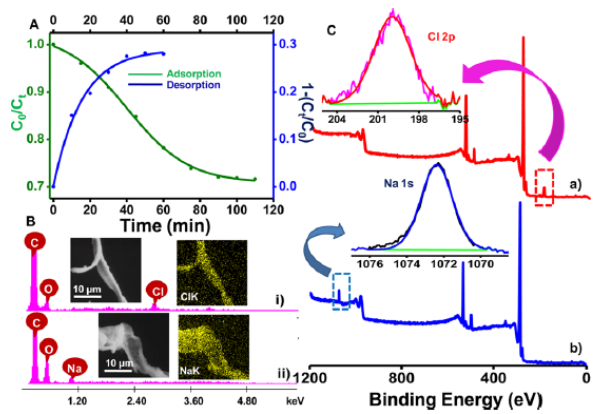

Figure: (A) Electro-adsorption/desorption curve of the graphite reinforced-carbon fiber electrode for a single cycle. The electrolyte present is NaCl measured at room temperature. **(B)** EDS spectra of (i) positive and (ii) negative terminals after single adsorption cycle. The corresponding SEM images along with the elemental maps are shown in the inset. **(C)** XPS survey spectrum of the material after single adsorption cycle, (a) positive and (b) negative terminals. The inset shows the deconvoluted XPS spectrum of Cl 2p and Na 1s

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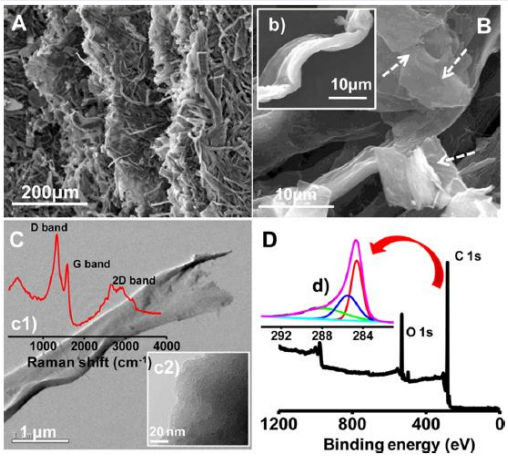

Figure: (**A** and **B**) FESEM images of layer-by layer stacked graphite reinforced carbon fiber. The white arrow in panel **B** shows the presence of graphite flakes. The inset in panel **B** represents the single layer graphenic carbon (b), **(C)** TEM image, the inset c1 represents the Raman spectrum of the material and c2 represents the HRTEM image of graphenic carbon, **(D)** XPS survey spectrum of the material and the inset shows the deconvoluted C 1s spectrum (d).

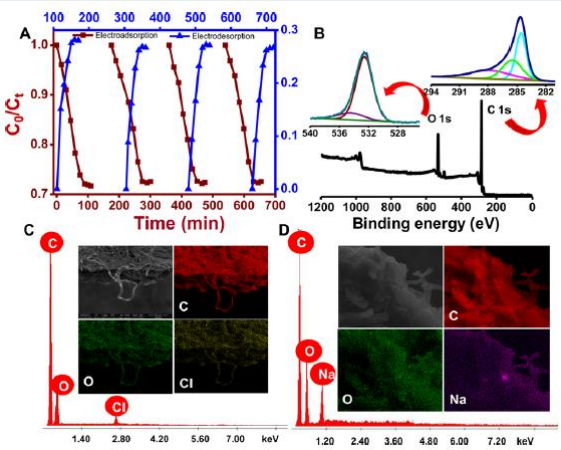

Figure: (A) Electro-adsorption/desorption cycles of the material (up to four cycles). **(B)** XPS spectrum of regenerated positive terminal after the tenth cycle showing the presence of carbon and oxygen only. The inset shows the deconvoluted C 1s and O 1s spectrum. **(C and D)** EDS spectra at the inset shows the SEM image and the corresponding elemental mapping for carbon, oxygen, and respective adsorbed ions. The electrolyte used in all cases was NaCl.

Technology

The invention describes a graphite reinforced-cellulose (GrC) derived 3D mesoporous fibrous carbon electrode for capacitive deionization and a capacitive deionization apparatus with improved desalination efficiency.

The Graphite reinforced-cellulose (GrC) derived carbon electrode was synthesized on a tissue paper using a layer-by-layer method followed by carbonization under nitrogen atmosphere at 700 °C for 3 h. After carbonization, silica was etched out from the stacked GrC electrode by aqueous NaOH (I mM) for 3h to generate pores then washed and dried.

The laboratory-scale CDI batch reactor consisted of a single pair of GrC electrodes and a pair of current collectors. The conductivity was measured at the cell exit stream by using a conductivity meter while the regeneration of the electrodes was carried out by reversing the terminal of the electrodes.

The electrode was tested for biofouling using monoculture biofilms of *pseudomonas putida* grown on the surface of the electrodes and imaged using a Scanning Electron Microscope (SEM)

The GrC electrodes are collectively intertwined in a unique fiber-like morphology with a thickness of 4-5 µm and a length of ten to several hundred micrometers. Further, the layer by layer staking enhances graphite reinforcement leading to enhanced conductivity and mechanical strength.

Key Features / Value Proposition

- The GrC electrode maintains its adsorption and desorption capacity even after ten consecutive cycles. These results exhibit high electro-adsorption capacity and a fast and reversible electro adsorption/desorption.
- The developed electrode was effective in the presence of multiple anions (SO_4^{2-}, Cl^- , NO_3^- and F^-) and the electrode successfully reduced the concentration of all the anions over time. While the fractions of Cl^- and NO_3^- are removed more than the other two anions, the recyclability of the GrC electrodes was excellent resulting in regeneration of the electrode even after 10 cycles.
- The SEM results show that in comparison to a commercially available electrode, the invented graphite reinforced-carbon fiber electrode has an enhanced resistance to biofouling.

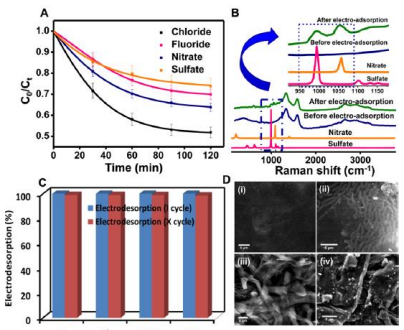

Figure: Plot of CDI performance of graphite reinforced carbon fiber electrode in the mixed negative ions (Cl−, F−, NO3−, SO42−) system **(A).** Raman spectra of graphite reinforced carbon fiber electrode before and after electro-adsorption of positive electrode **(B)**, inset shows enlarged Raman spectra of a narrower region. Plot of desorption capability of electrode in 1st and 10th cycle **(C)**. SEM images of before and after 5 days growth of biofilms of Pseudomonas putida on commercial electrode **(D(i,ii))** and graphite reinforced carbon fiber electrode **(D(iii,iv)).**

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