Low-power, ground water desalination system adaptable for Indian households

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सत्यमेव जयते

Department of Sciences
& Technology
Government of India

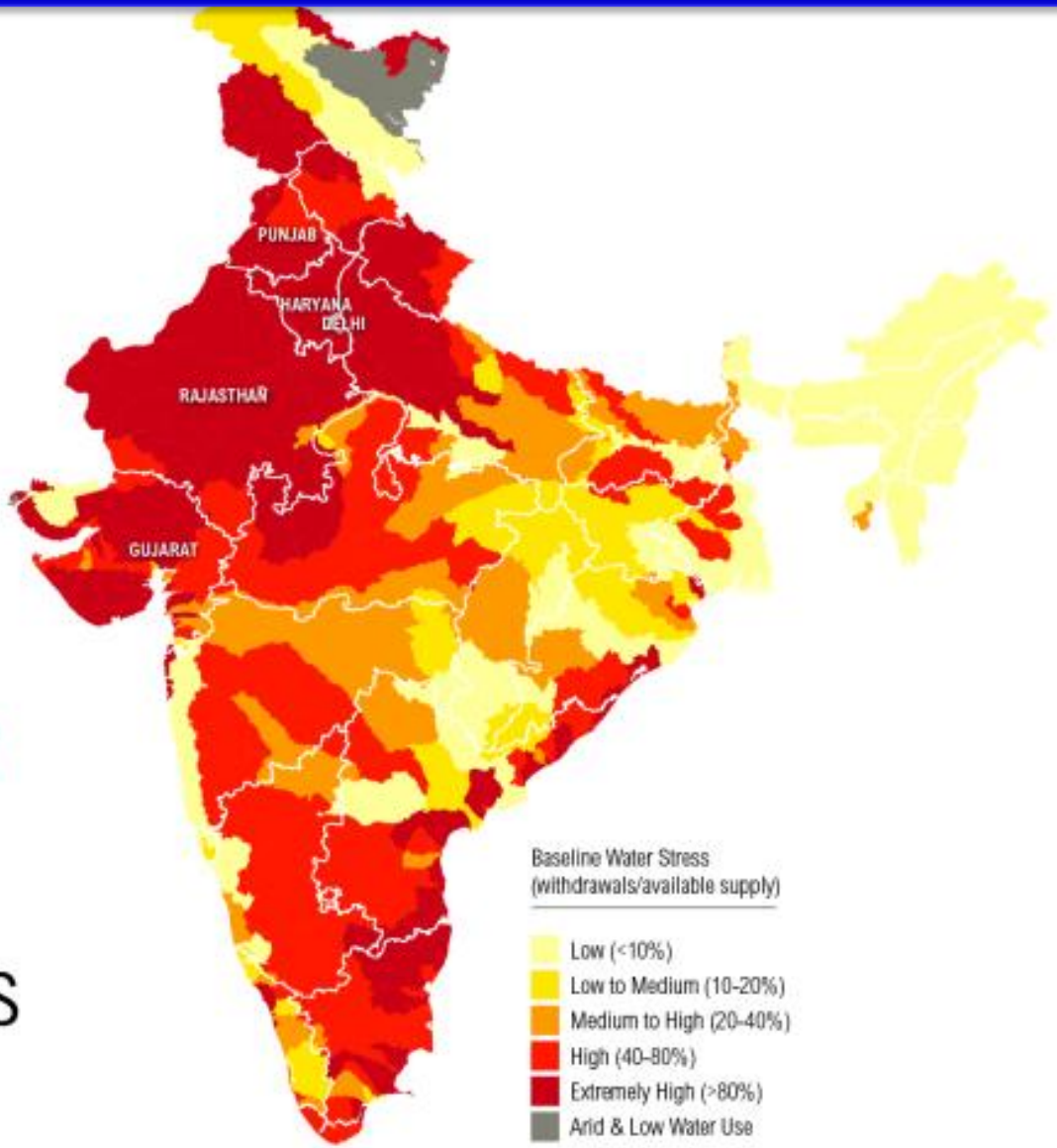
IIT Bombay Heritage Foundation

FOUNDATION

Environmental remediation

54%

of India Faces **High** to **Extremely High** Water Stress



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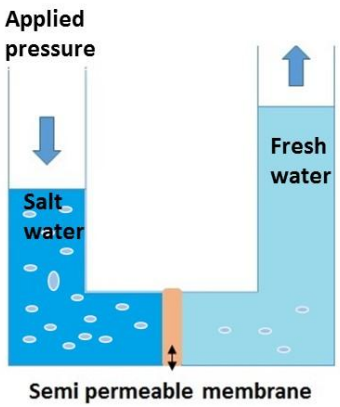
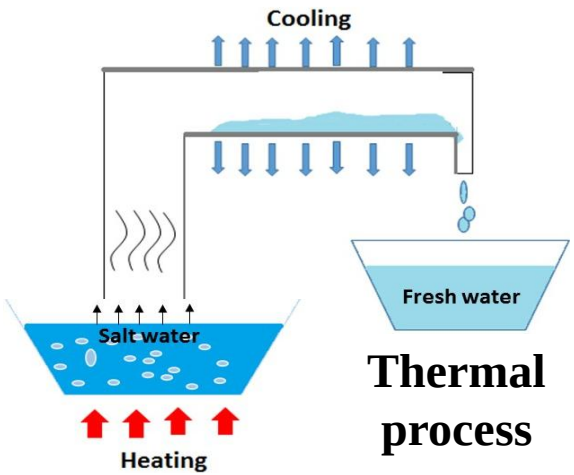
WORLD RESOURCES INSTITUTE

Motivation of the Work

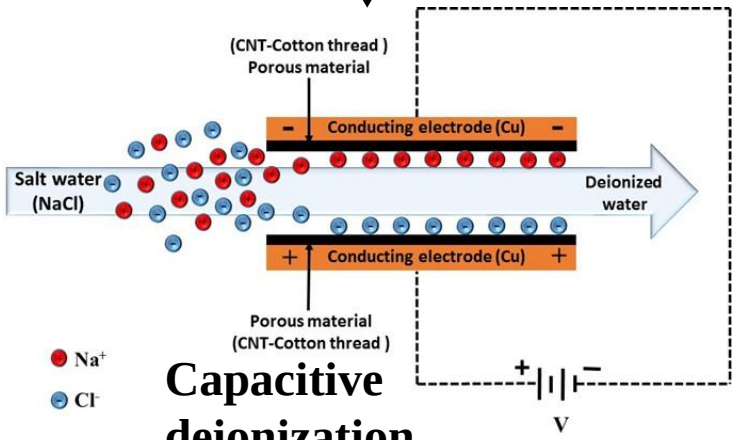
10^{21} litre



Reverse osmosis



Thermal process



Capacitive deionization

Expensive and energy intensive, non-portable

Not effective < 1000 ppm salt concentration

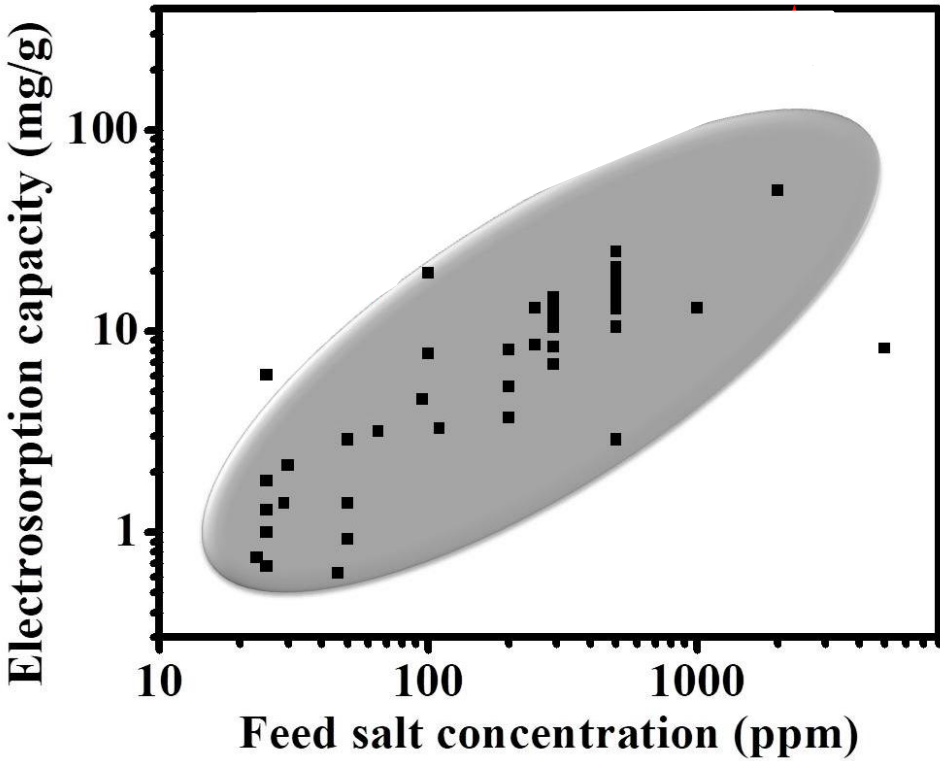
Can we develop a rapid, efficient route to desalinate water?

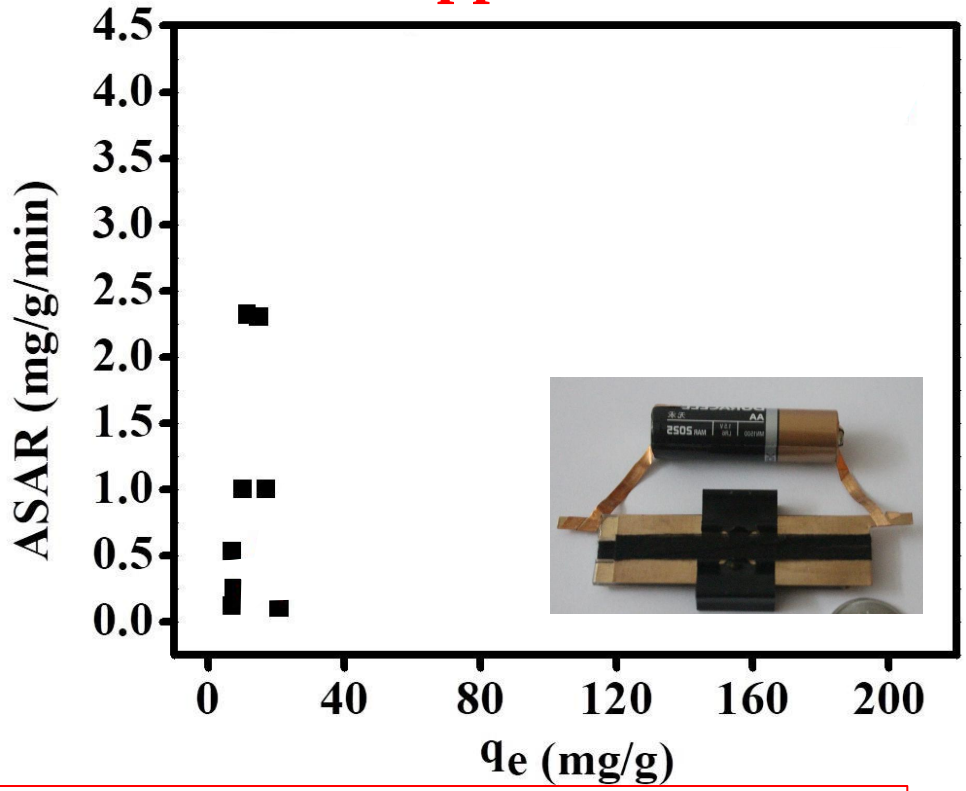
What have we achieved?

Electrosorption capacity, $q_e = \frac{\text{Concentration decrease} * \text{Volume}}{\text{Weight of electrode}}$

Average salt adsorption rate = Rate of q_e

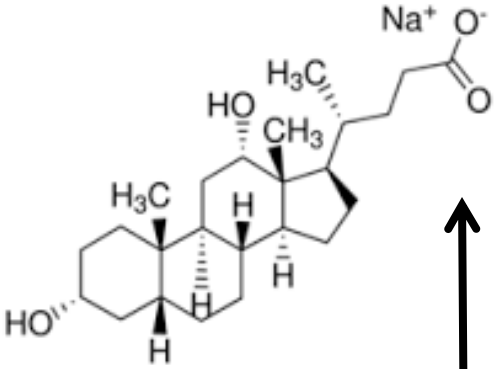
High qe and high ASAR for < 1000 ppm



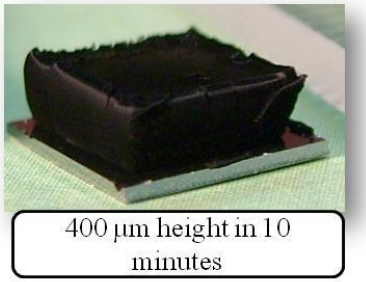


3 times higher q_e and 1.5 times higher ASAR than any known material.

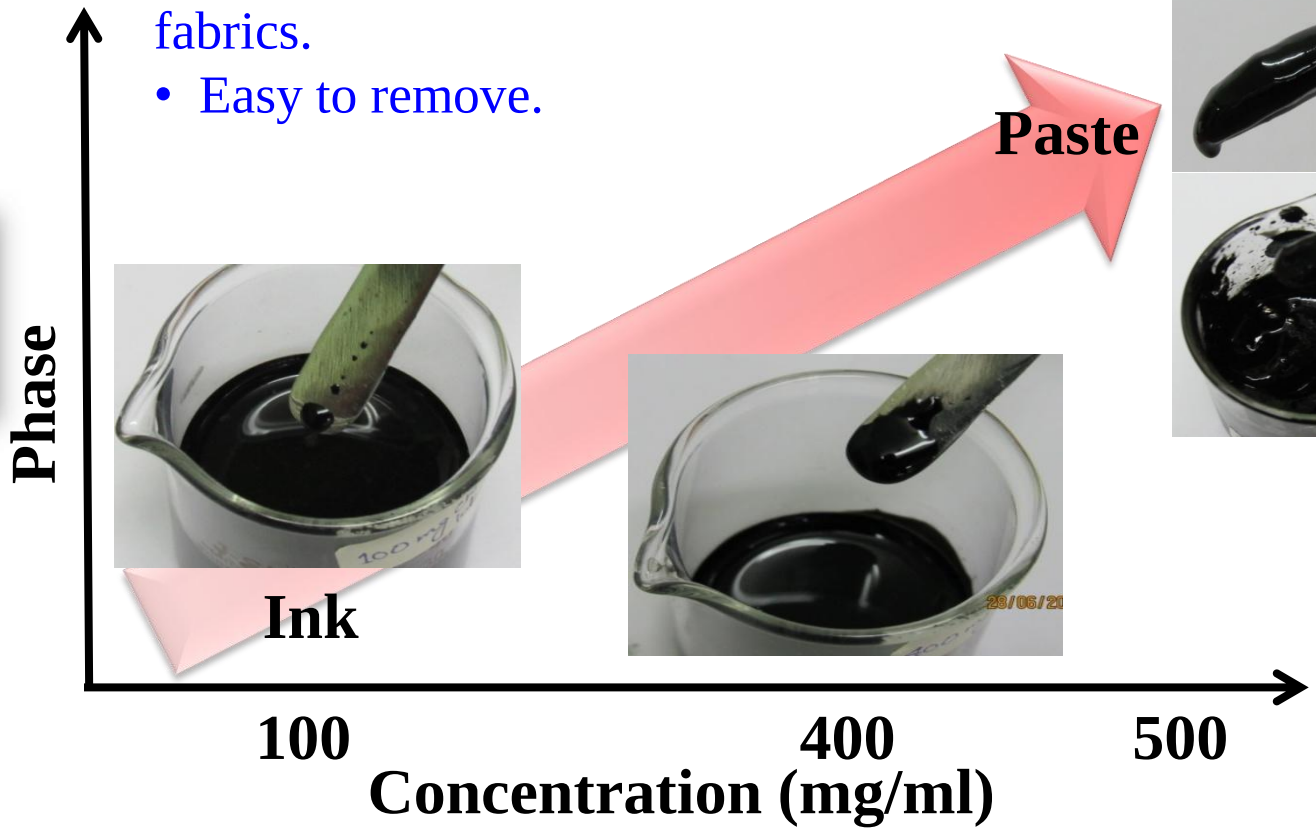
How did we achieve this? Carbon nanotubes



- Bio-compatible
- Forms supra-molecular gel-like assemblies
- Crucial for integrating onto clothing and fabrics.
- Easy to remove.

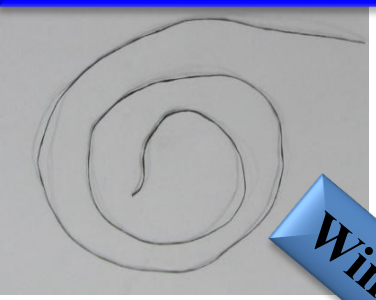


25 times around the earth



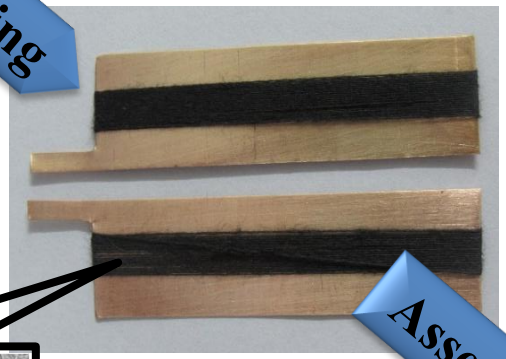
CNT conductive ink/paste stabilized by NaDoC is highly stable. No aggregation observed after 30 days.

Scaling up

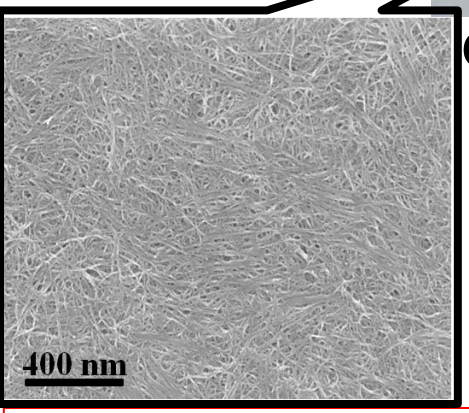


CNT-thread

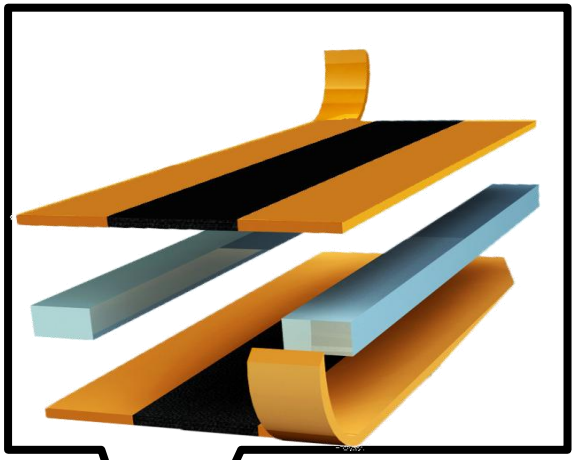
Winding



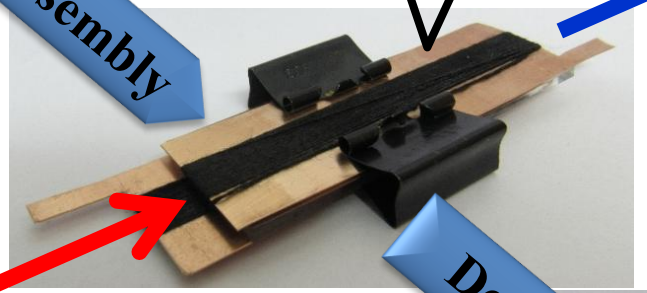
CDI electrodes



Assembly



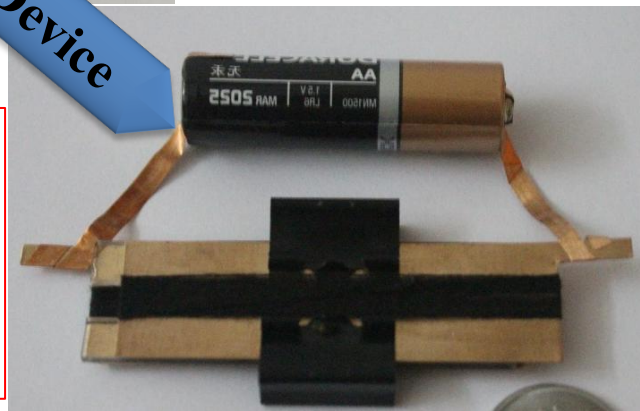
Pure water OUT



Saline water IN

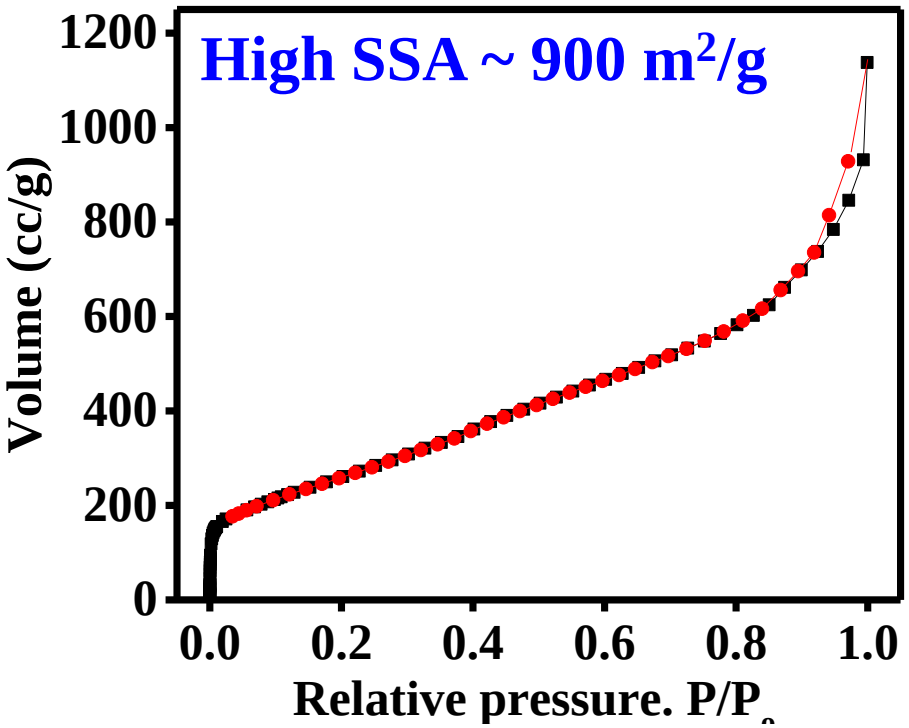
Proof-of-concept

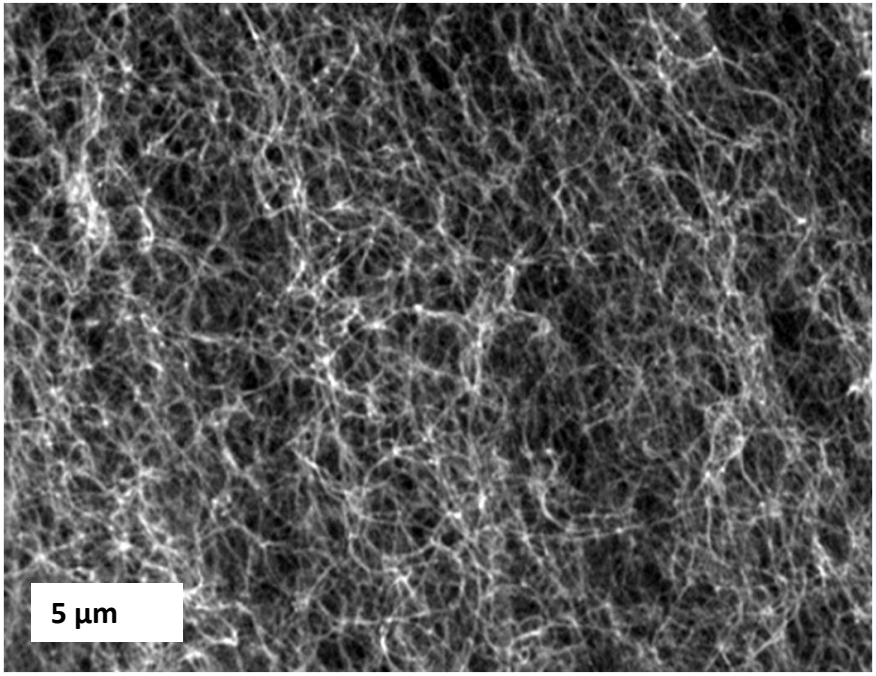
Device



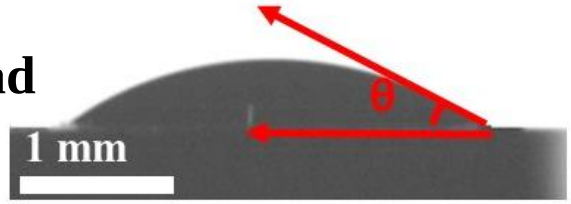
- **Facile, scalable device assembly.**
- **Miniaturized and portable.**
- **Low energy consumption (0.15 mW)**

What is important?

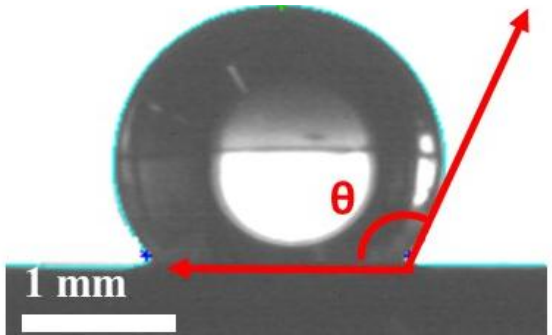




CNT-thread
t = 20 s

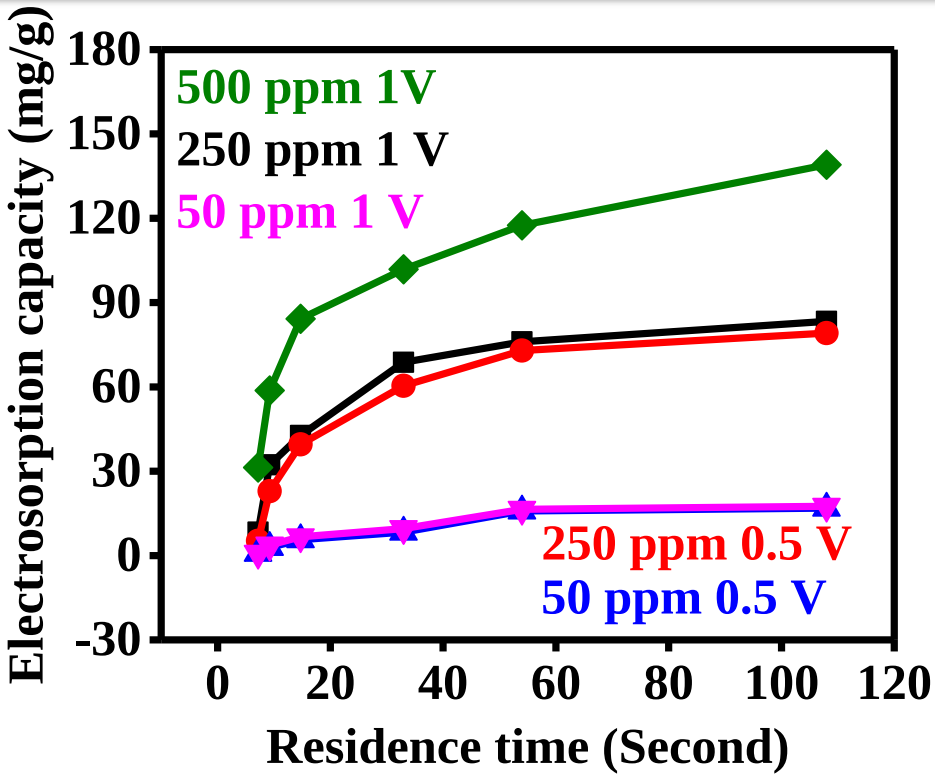


CNTs
t = 80 s

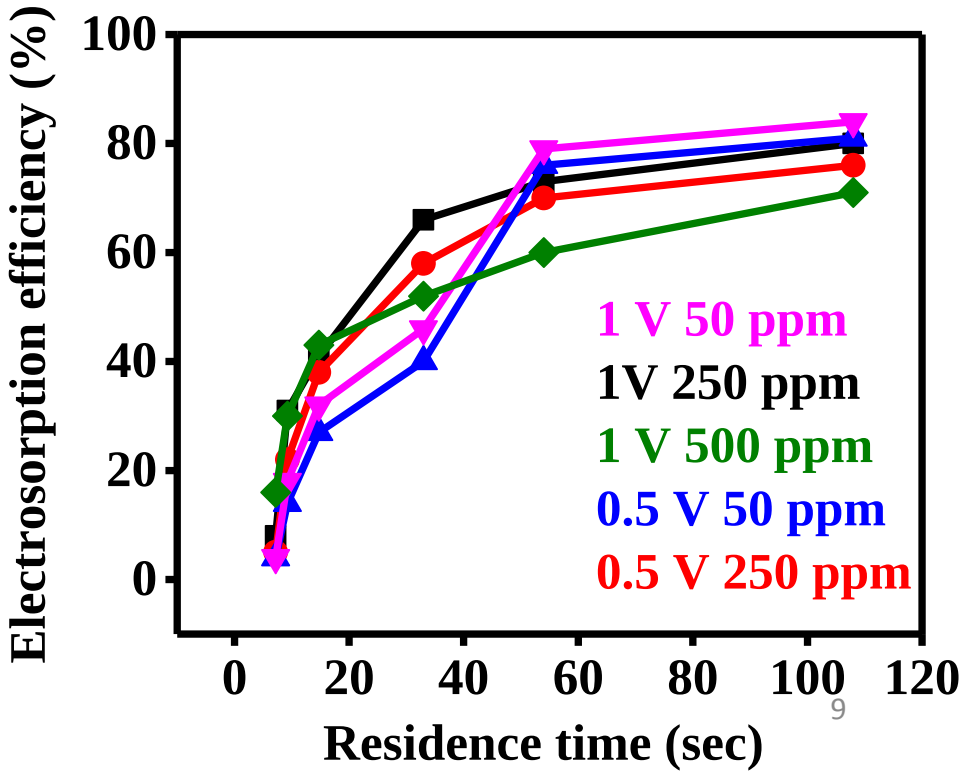


- ✓ **Sub-nanometer pores enhances electrical double layer for CDI.**
- ✓ **High SSA leads to increased deionization.**
- ✓ **Hydrophilicity is critical for fast deionization.**

Performance evaluation

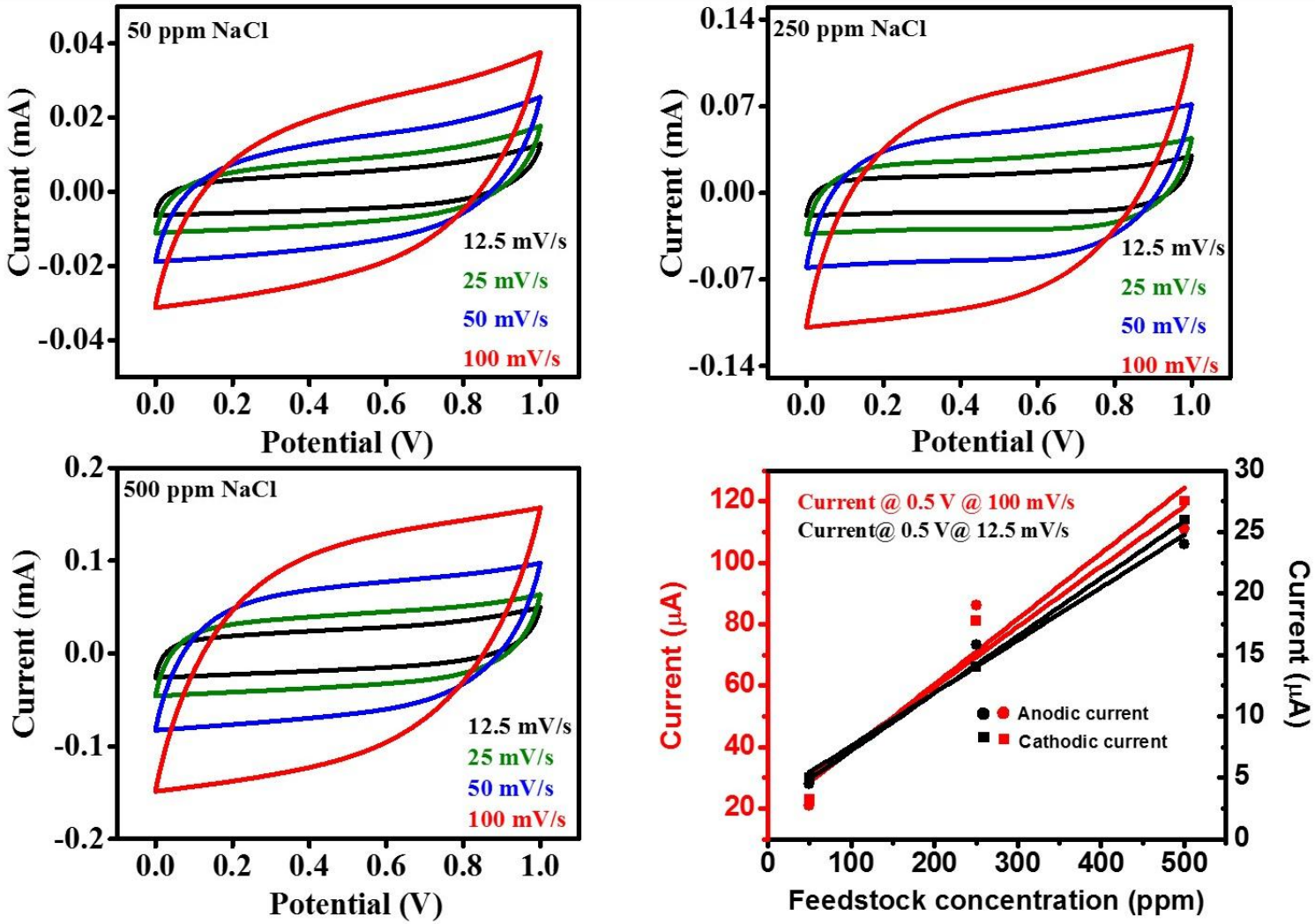


Residence time = Time of contact between water and electrode



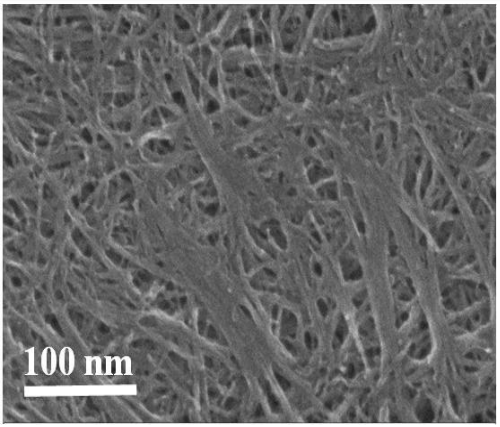
- **Electric field > 2.5 V/cm leads to saturation in performance.**
- **Qe increases with salt concentration.**
- **Saturation of q_e and EE relates to wetting of water by electrodes (hydrophilicity)**

Electrochemical studies of the CNT-thread

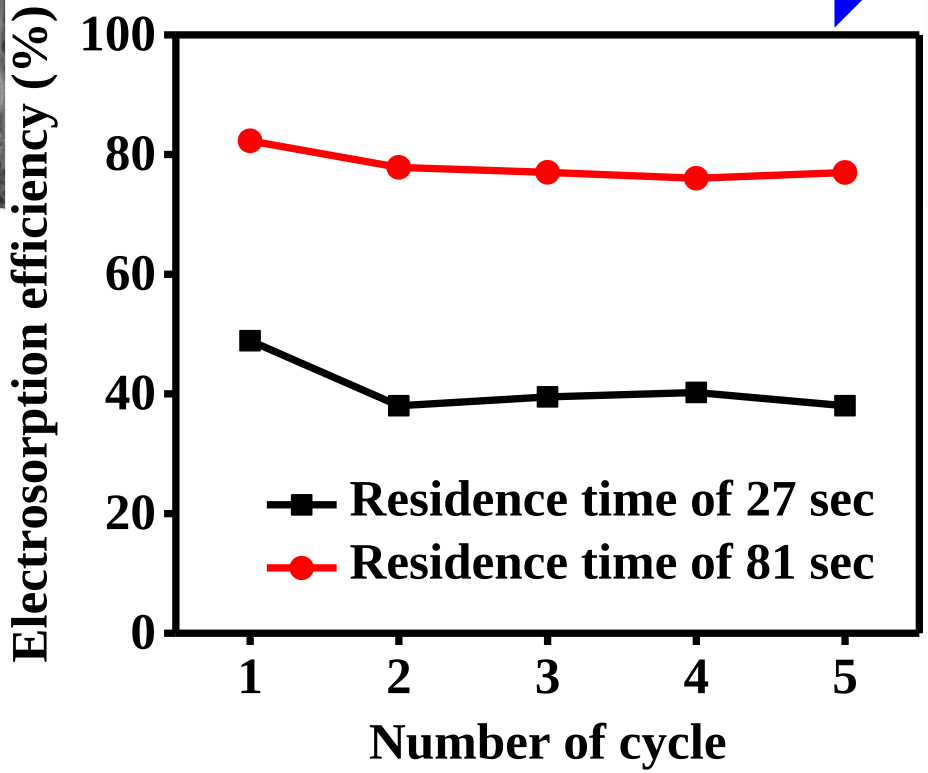


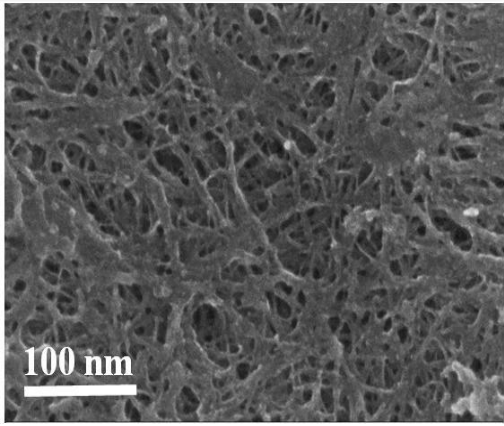
- Electrical double layer without any faradic reactions.
- Symmetric nature of electrical double layer at both the electrodes.
- Signifies the simialiar rate of diffusion for both the cations and anions.

Reusability of device



Reverse bias/ Zero bias
Washed with water and EtOH

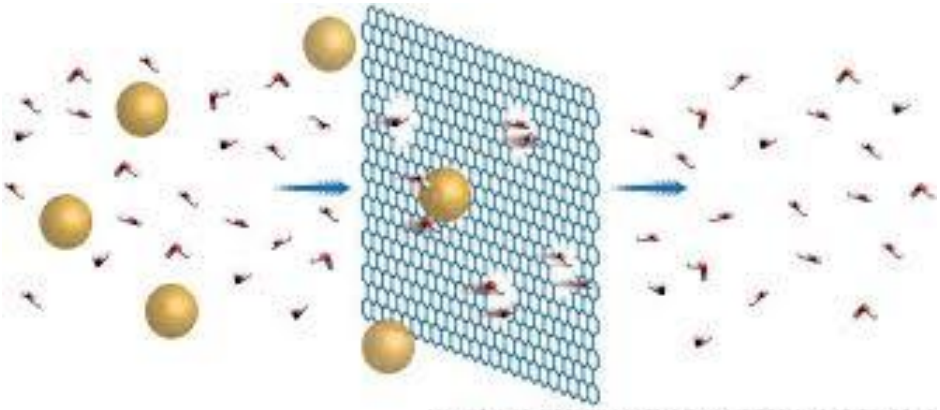




- **Initial decrease (< 10%) in activity is due to pore-blocking.**
- **Subsequent cycles exhibit stable performance to desalination.**

Indian Patent Application No 201721028189. *ACS Appl. Mater. Interf.* 2017, *9*, 39907

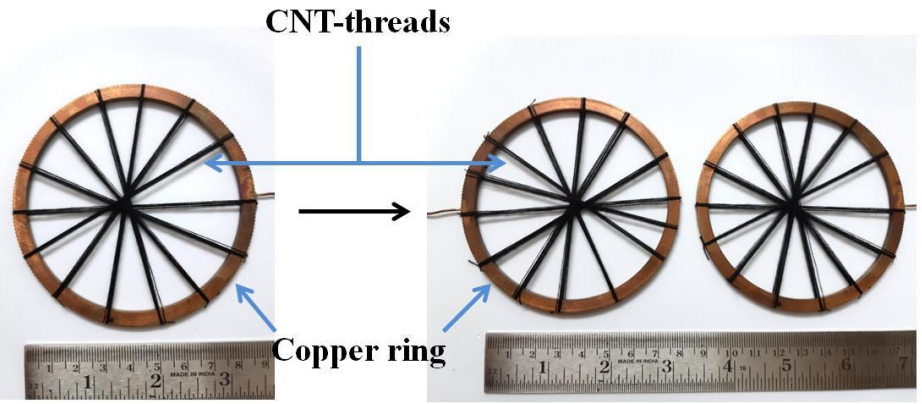
Translating from PoC to Prototype



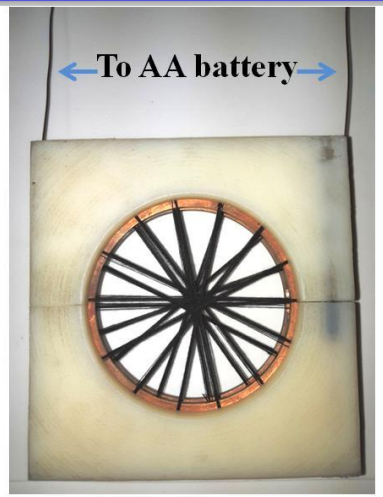
WANG AND KARNIK. NATURE NANOTECHNOLOGY. 2012

Water flows through the active material

Inverting the concept : Prototype design



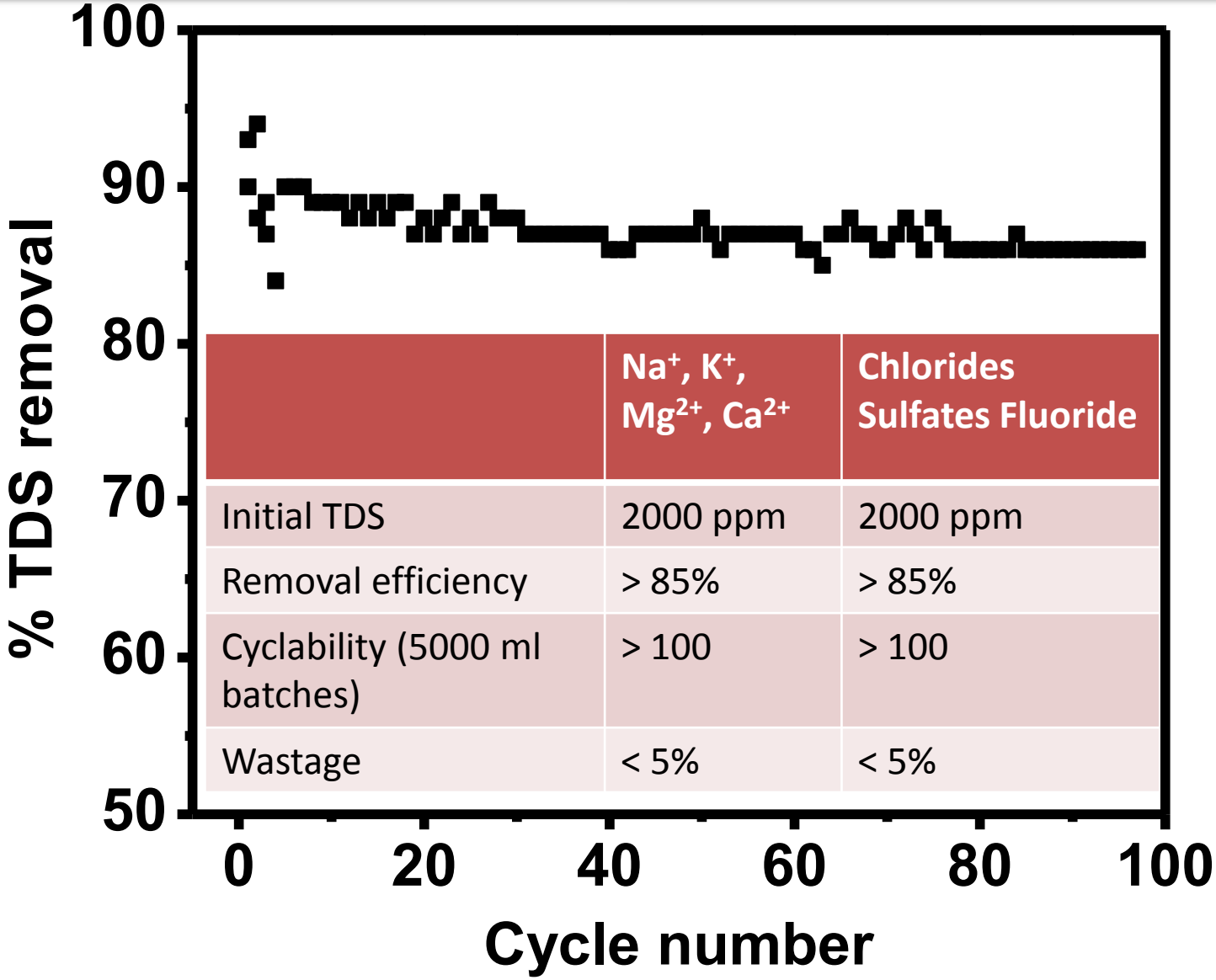
Winding of CNT-thread as electrodes for capacitive deionization



Assembling the portable CDI system for household desalination of water

Advantage of electrode flexibility and tenacity

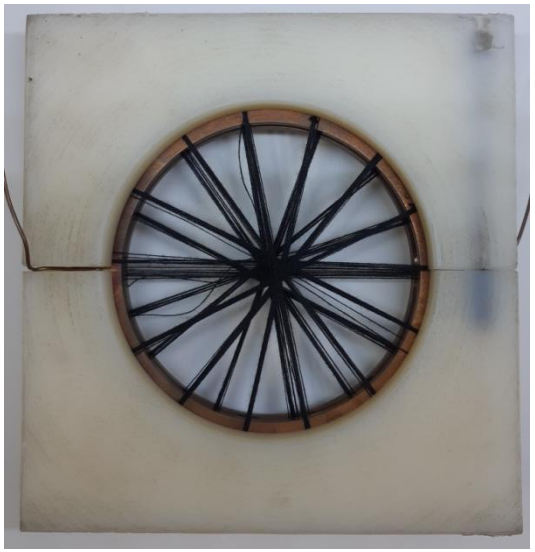
Inverting the concept : Prototyping



	Na^+, K^+, Mg^{2+}, Ca^{2+}	Chlorides Sulfates Fluoride
Initial TDS	2000 ppm	2000 ppm
Removal efficiency	> 85%	> 85%
Cyclability (5000 ml batches)	> 100	> 100
Wastage	< 5%	< 5%

Highly efficiency desalination of water at low power-cost.
Extremely low wastage of water.

Way forward

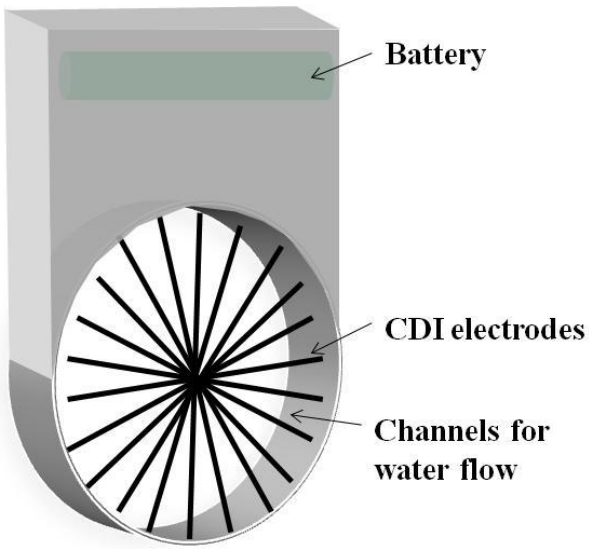


Field trials

Nov, 2018

INR 0.50/liter

INR 0.10/liter



Thank you

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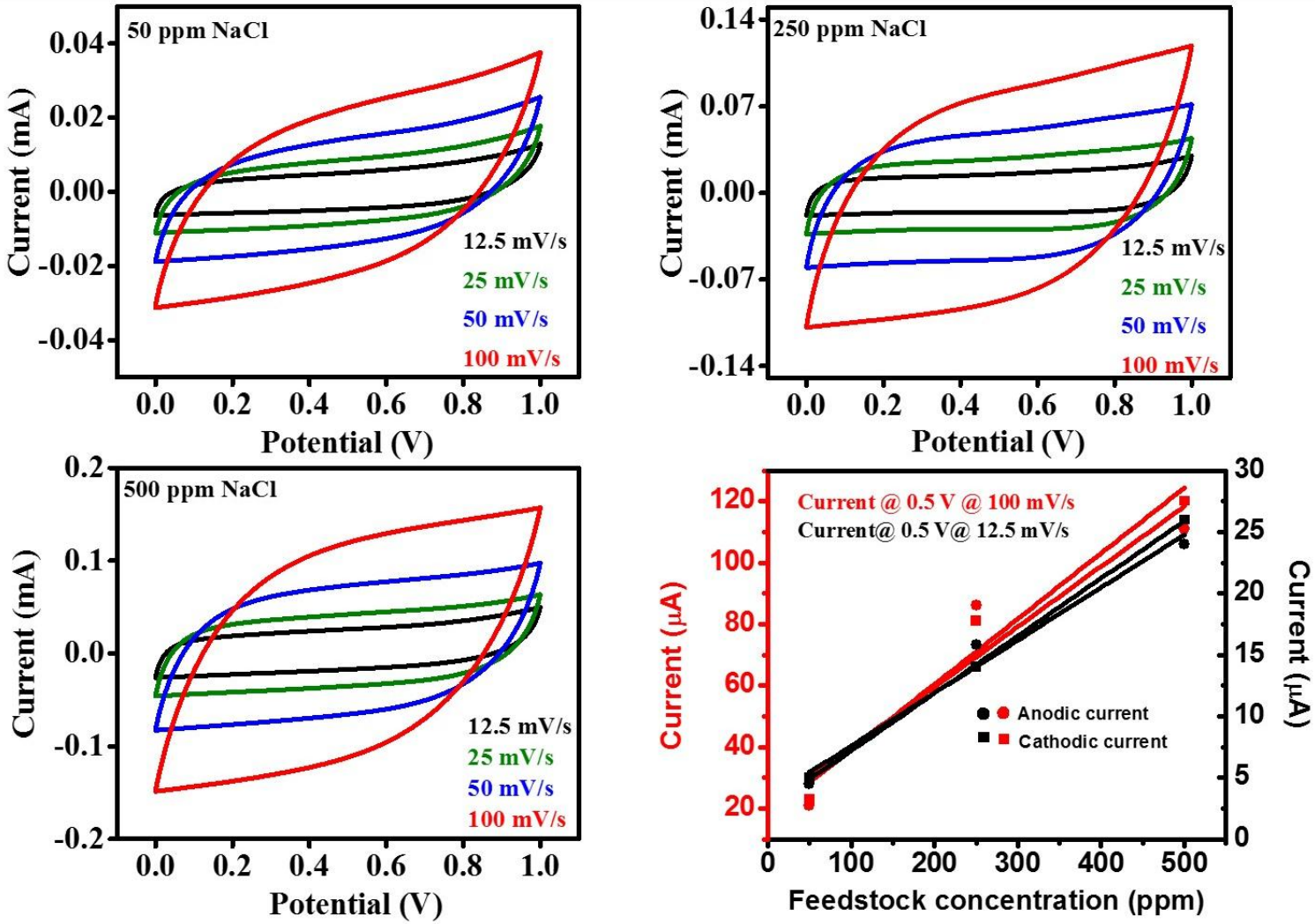

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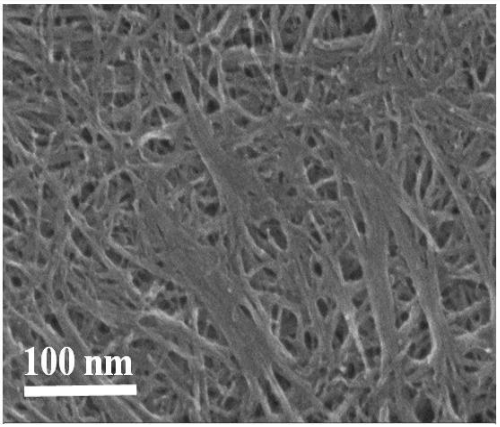

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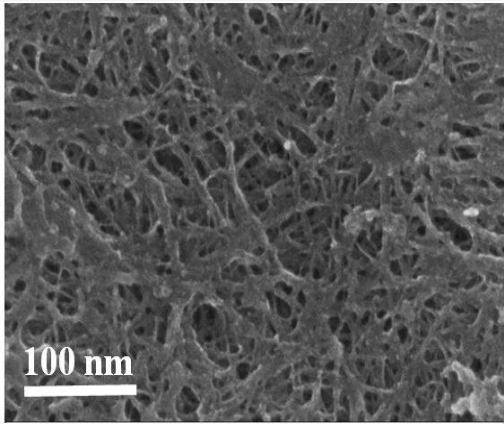

THE HINDU

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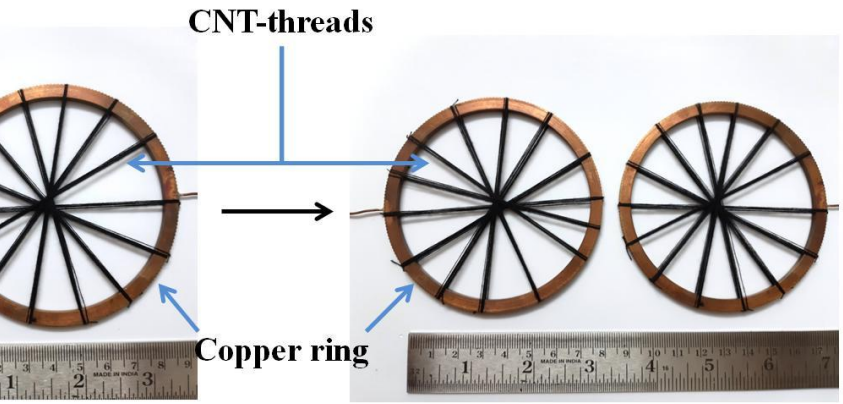

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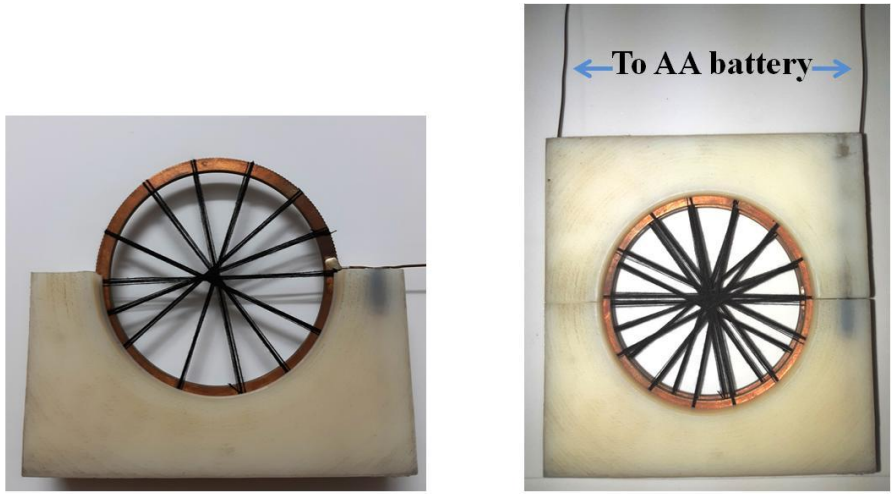

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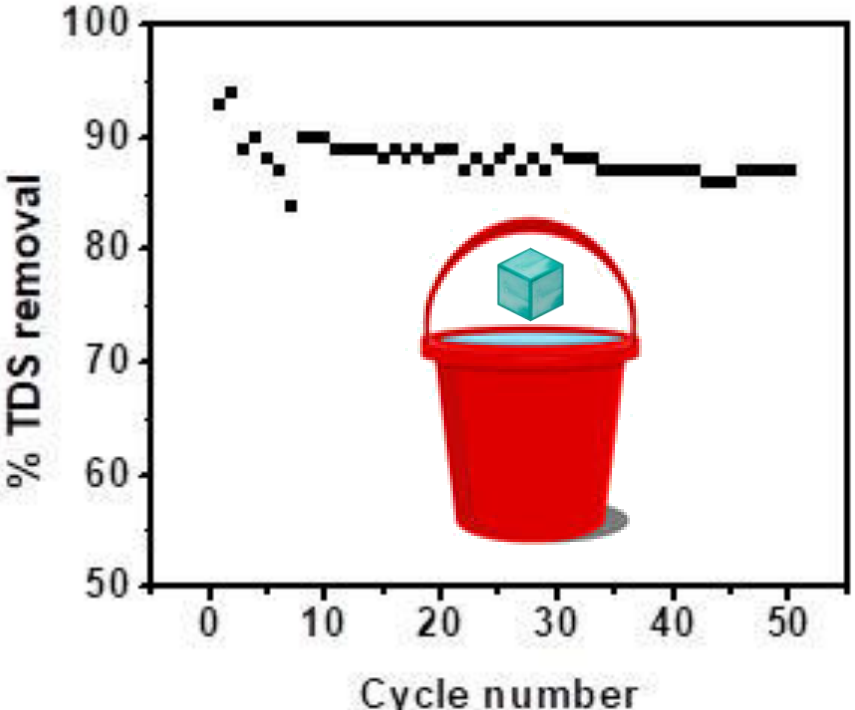

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Removal efficiency	> 85%	> 85%	> 65%
Cyclability (5000 ml batches)	> 100	> 100	Currently at 50
Wastage	< 5%	< 5%	< 10%

Next work plan

- To have electrodes and sensing system to indicate the TDS of water (green/red) for end-user.

- To develop pilot plant for making the nanomaterial.