



Dual-Functional PANI/CNF/Chitosan modified Hydrogel Composite for Electrochemical Detection and Adsorptive Removal of Heavy Metals

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Abstract

Heavy metal pollution from industrial effluents poses severe risks to health and ecosystems, particularly in Bangladesh. This work proposes a dual-functional hydrogel composite electrode of polyaniline (PANI), cellulose nanofibers (CNF), and chitosan for simultaneous detection and removal of Cr^{6+} and Pb^{2+} . The composite serves as (i) a thin-film on glassy carbon electrode for electrochemical detection (SWASV, CV, EIS), and (ii) a free-standing hydrogel for adsorption-based removal. This multifunctional system offers a low-cost, sustainable technique for wastewater monitoring and remediation.

Introduction

Heavy metal pollution is a serious issue in Bangladesh, where industrial effluents discharge toxic Cr^{6+} and Pb^{2+} into rivers, causing severe health risks. Conventional detection methods (AAS, ICP-OES) are precise but costly and unsuitable for on-site use, while electrochemical sensors offer faster, cheaper detection but suffer from low sensitivity. Conventional treatments also fail to achieve both detection and removal. Conductive polymer-based hydrogels, particularly PANI integrated with chitosan and cellulose nanofibers (CNF), provide high conductivity, porosity, and abundant binding groups, making them promising for simultaneous detection and removal of heavy metals in water.

Objectives

- Develop a PANI/CNF/Chitosan hydrogel composite electrode.
- Use the material in two modes
- 1. Thin film on GCE → electrochemical detection (SWASV, CV, EIS).
- 2. Free-standing hydrogel composite → adsorption & removal studies.
- Align research with :

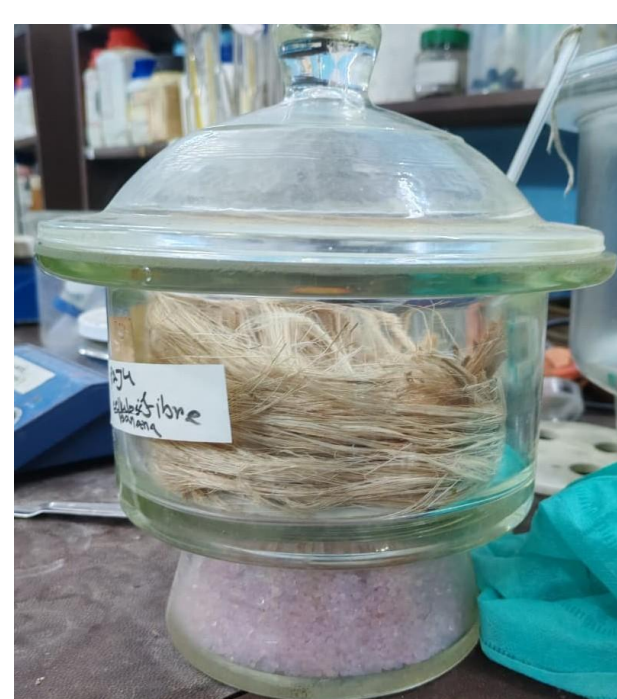
SDG-6

SDG-14

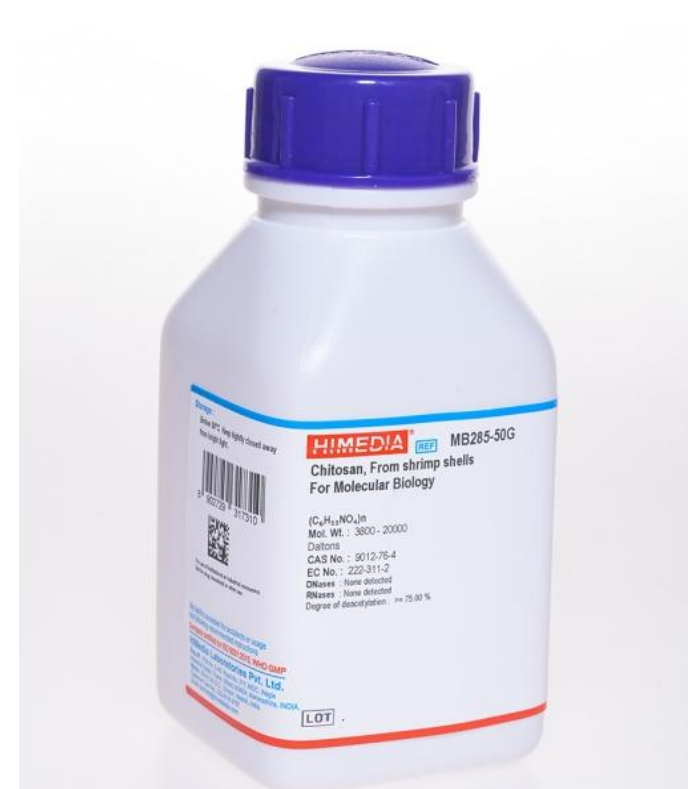
Materials



Aniline Monomer



Raw Banana Fiber for CNF



Chitosan



Glassy Carbon Electrode

Methodology

1. Synthesis of CNF from banana fiber

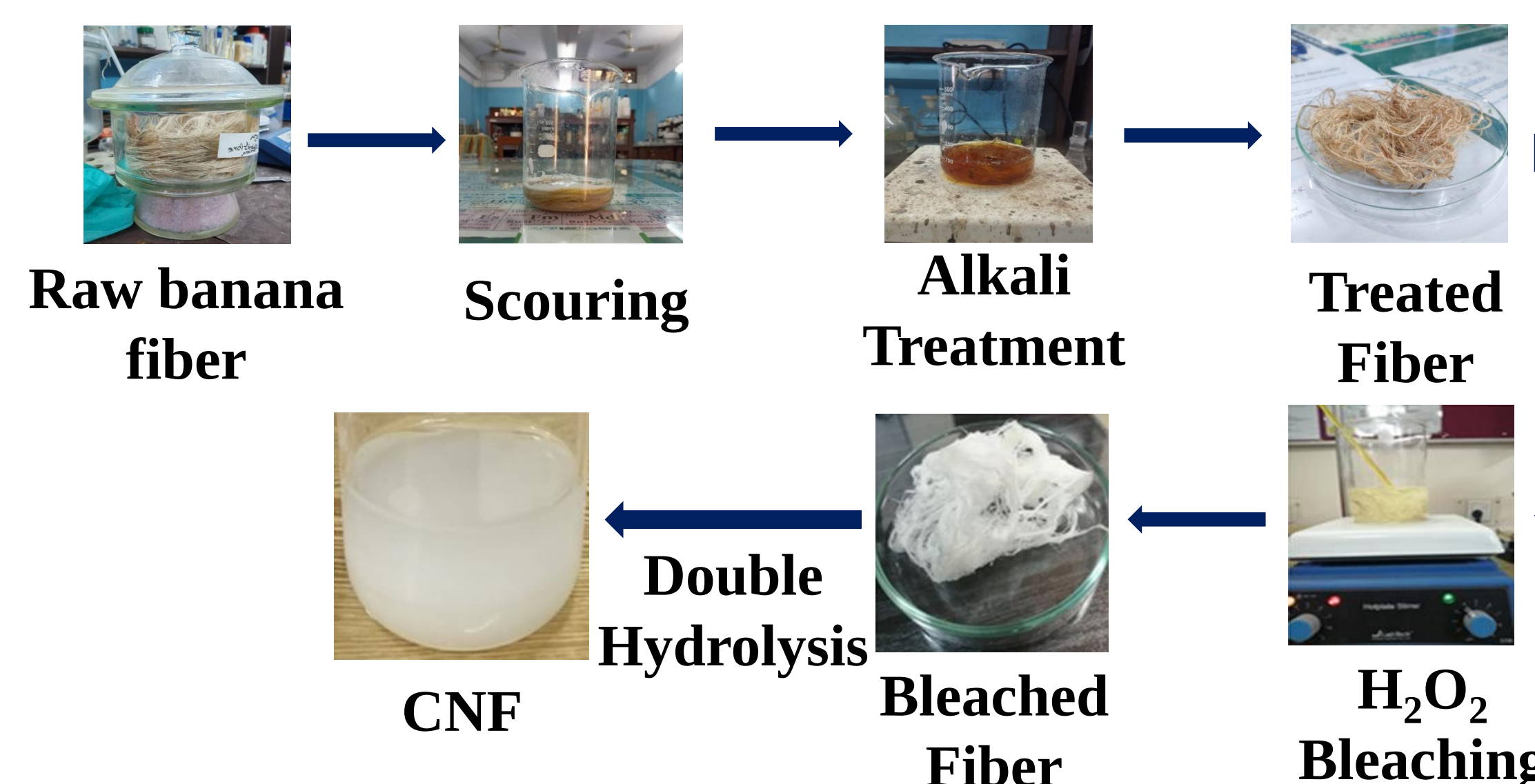
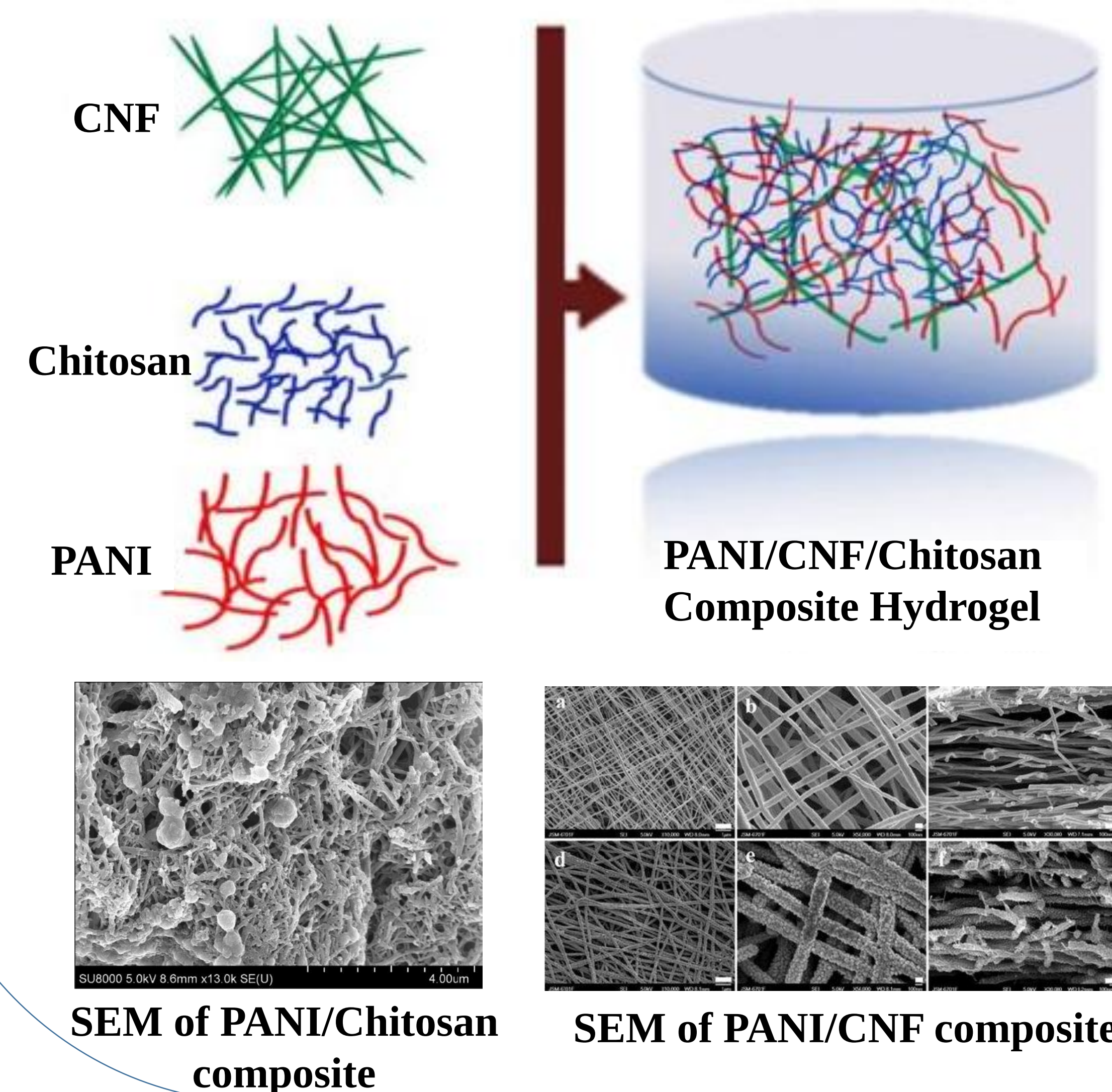


Fig.1: : Systematic diagram for preparation of CNF via double hydrolysis method .

2. Hydrogel Composite Fabrication



3. Electrode Modification (Detection Mode)

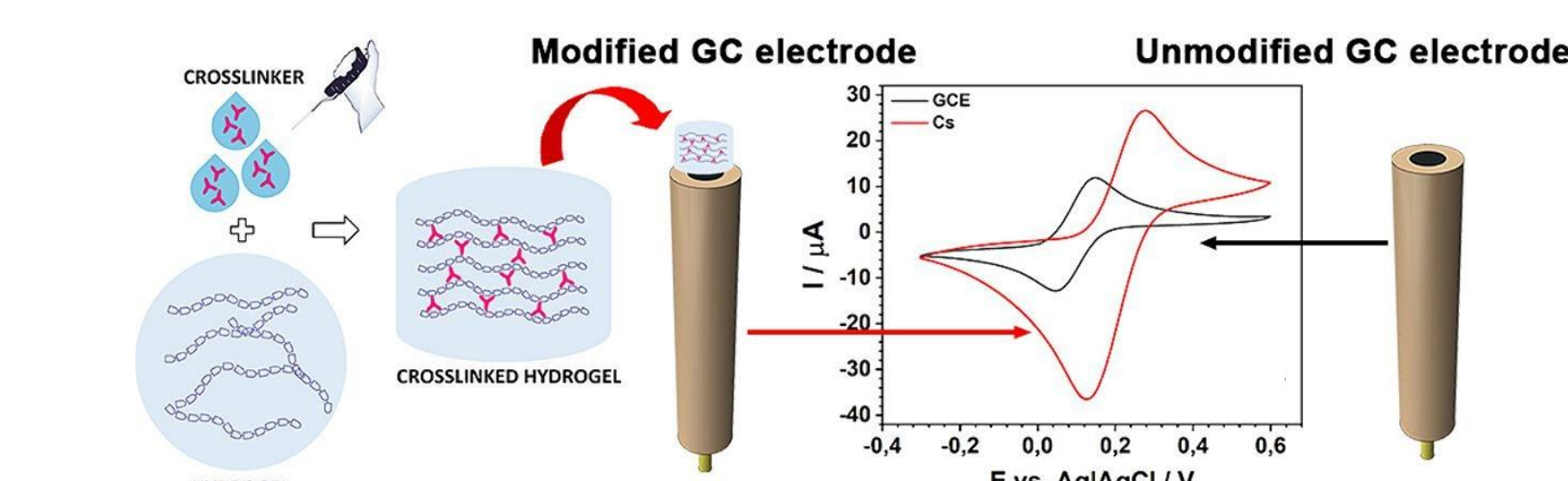


Fig.2: GCE electrode modified by the prepared hydrogel composite by the freeze-thaw method

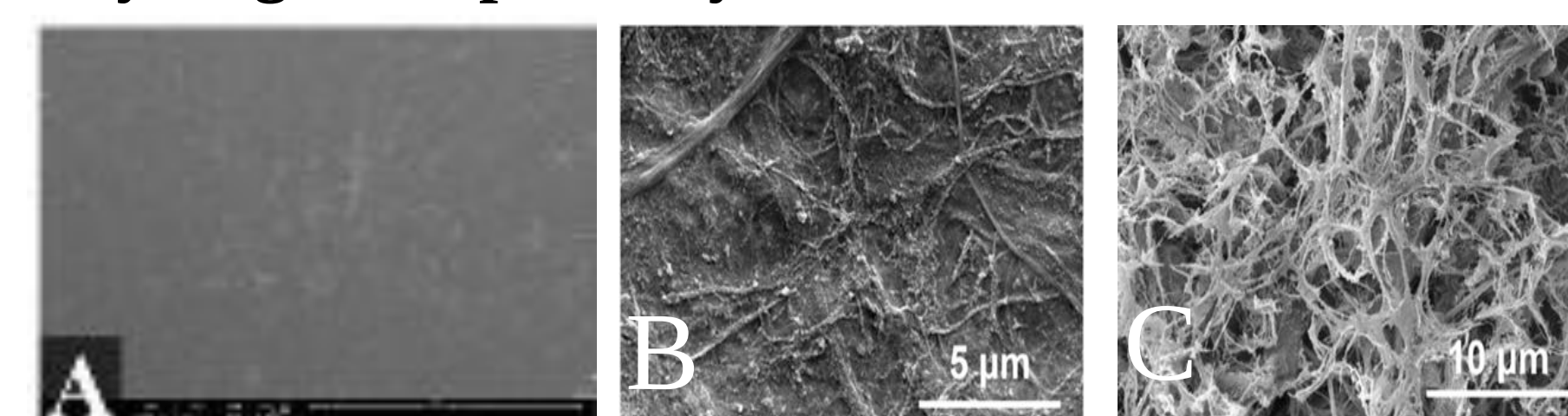
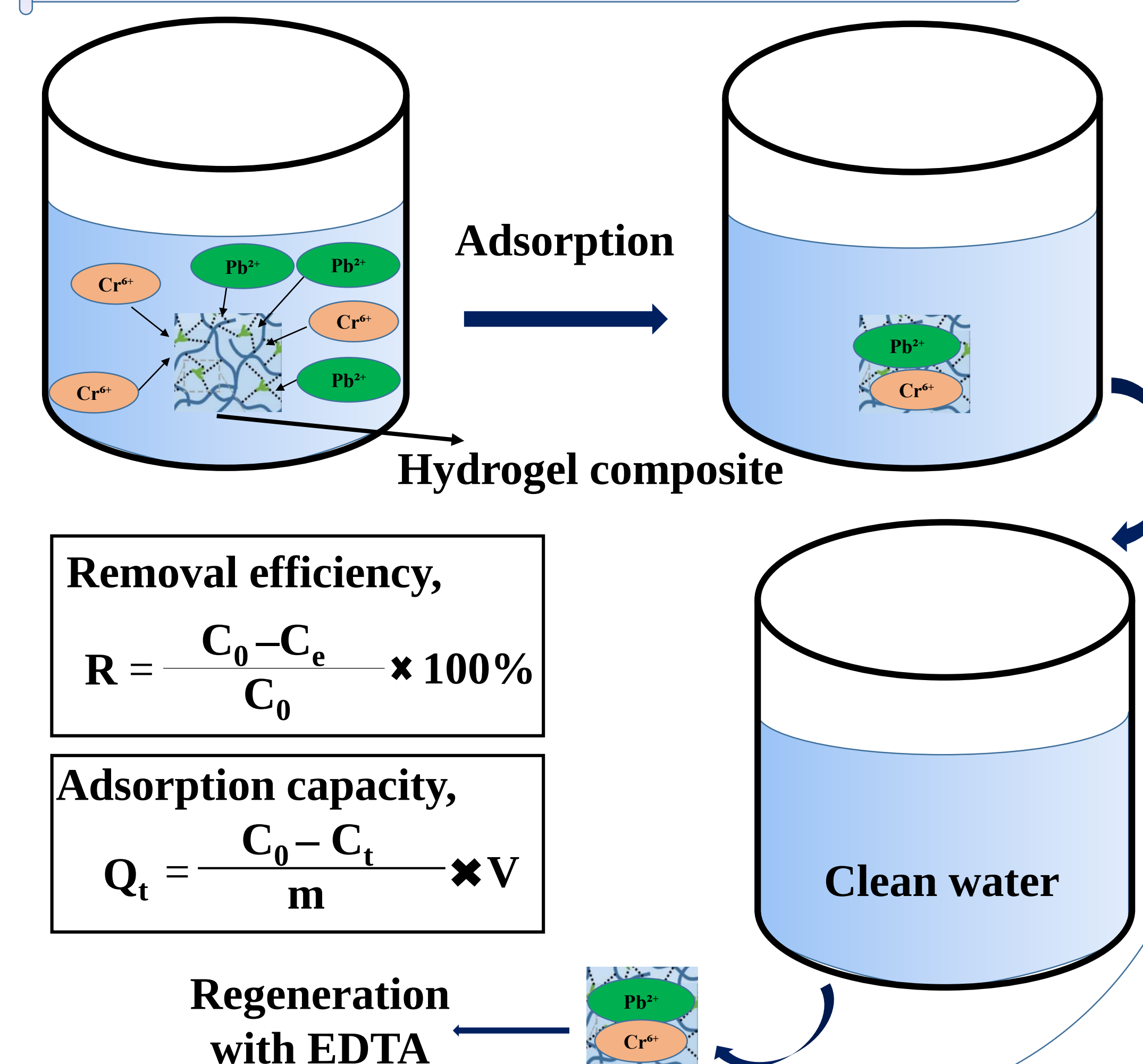


Fig.3: A) SEM of pure GCE, B) & C) SEM of modified GCE with hydrogel composite

4. Batch Adsorption(Removal Mode)



Removal efficiency,

$$R = \frac{C_0 - C_e}{C_0} \times 100\%$$

Adsorption capacity,

$$Q_t = \frac{C_0 - C_t}{m} \times V$$

Regeneration with EDTA

Expected Results

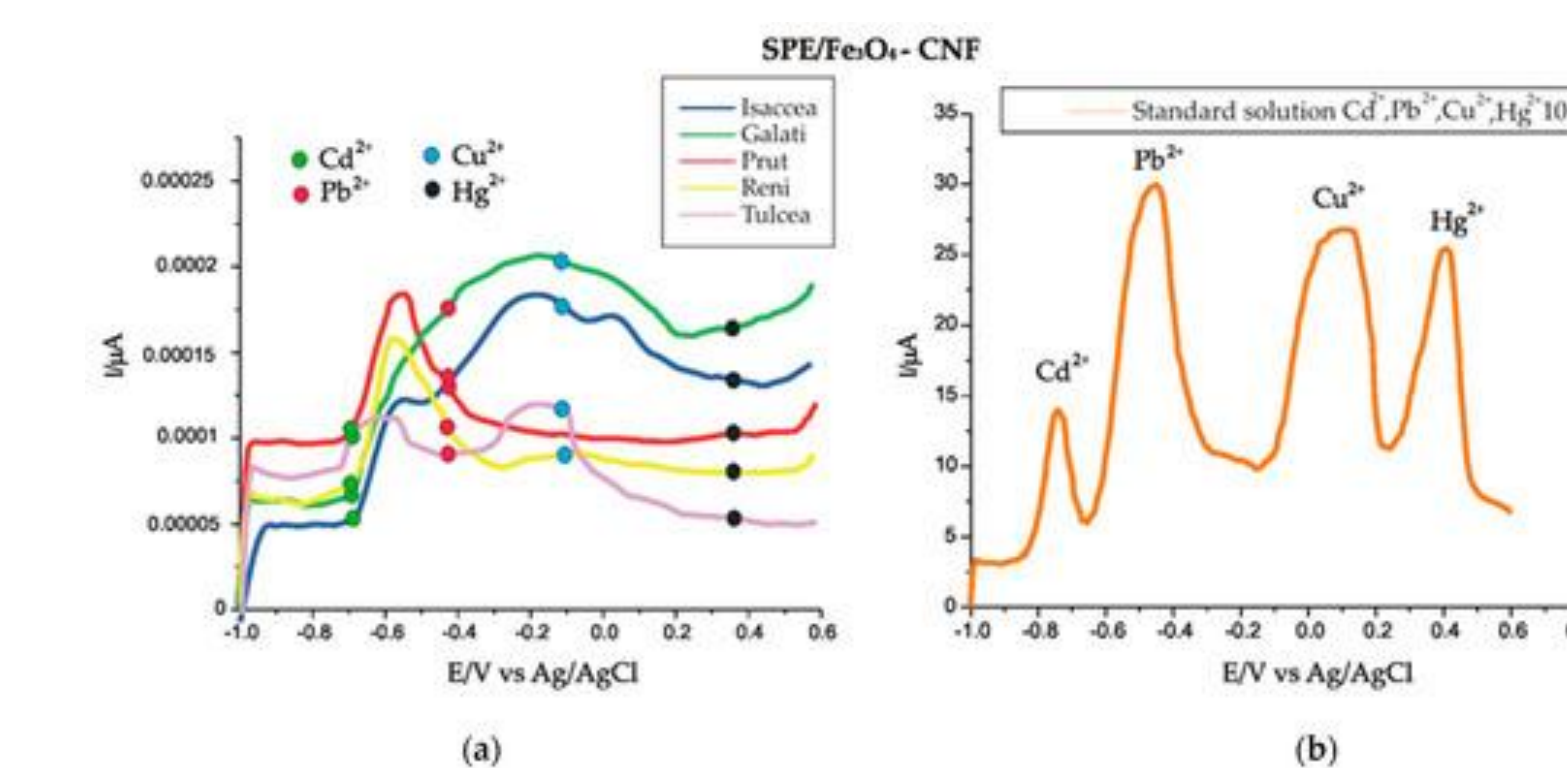
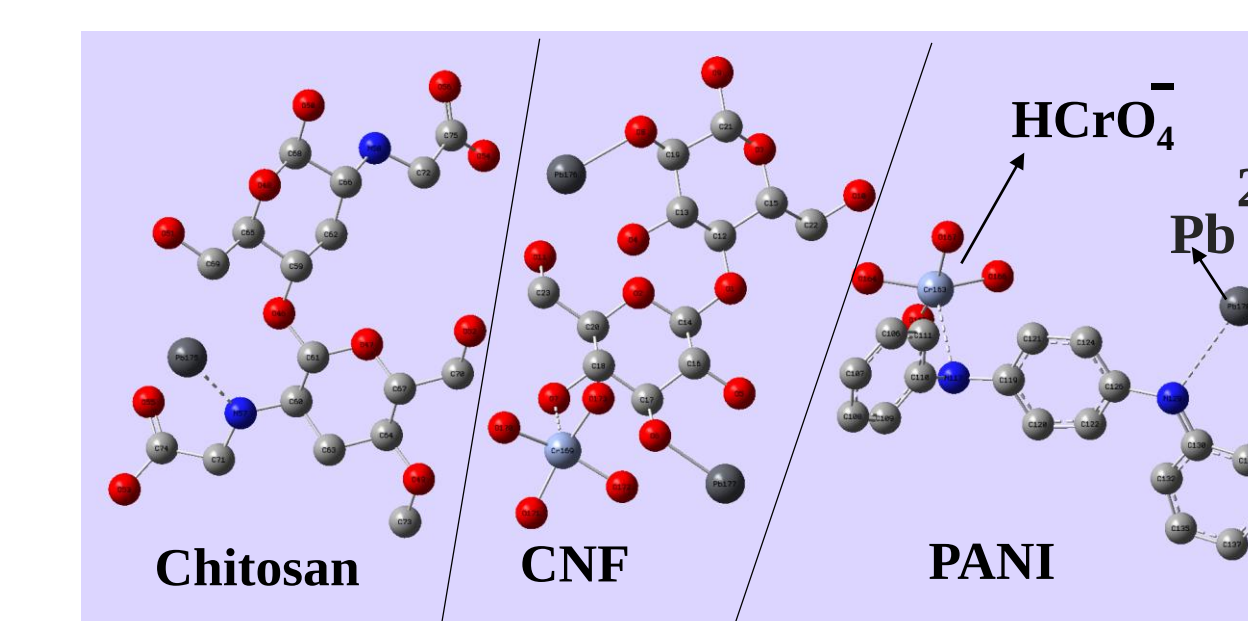


Fig.4: Detection of various metal ion through potentiostat



- Pb^{2+} binds via coordination (O/N donor groups).
- Cr^{6+} binds via electrostatic attraction to protonated amines and hydrogen bonding.

References

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