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Smart-Fabric-Based Supercapacitor with Long-Term Durability and Waterproof Properties toward Wearable Applications

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Overview

- With the increasing demands for energy storage devices, textile-based supercapacitors (SCs) play a vital role as a promising candidate due to their unique features of excellent flexibility, prominent energy storage properties, and feasibility of integration into fabrics and this study is aimed to prepare a high-performance multifunctional fabric-based SCs for wearable electronic systems and smart textile applications.

Current Issues

- The rapid evaporation of water in aqueous electrolytes even at room temperature creates a huge problem in energy storage devices and as a result of this, the durability of the SC is reduced because of dehydration of the gel electrolyte and hindering the ion transfer route within electrodes and the gel electrolyte.
- Sometimes, over evaporation may result in explosions due to increased pressure inside the SCs.

Introduction

It is a noticeable fact that textile-based SCs have been required to modify their features, improving resistivity to both normal and extreme conditions in various applications. Basically, with the arising of shortcomings in durability in energy storage devices, it is necessary to develop a method to keep the long-term high-performance of SCs. As a solution for this, PVA and polyacrylamide (PAM) composite gel electrolyte was introduced to a multidimensional hierarchical fabric (HF) which is used as a flexible substrate for fabricating the electrodes with the properties of water-retaining and water-proofing in order to enhance the performance of the fabric-based SCs for long-term usage. Developing a fabric-based SCs device while maintaining the above properties is a huge challenge in the field of multifunctional energy storage.

Materials and Methods

Materials: The multidimensional hierarchical fabric (HF), Graphene suspension, Sulfuric acid (H_2SO_4, 98 wt %), Aniline, PVA, PAM, and PVDF

Methods:

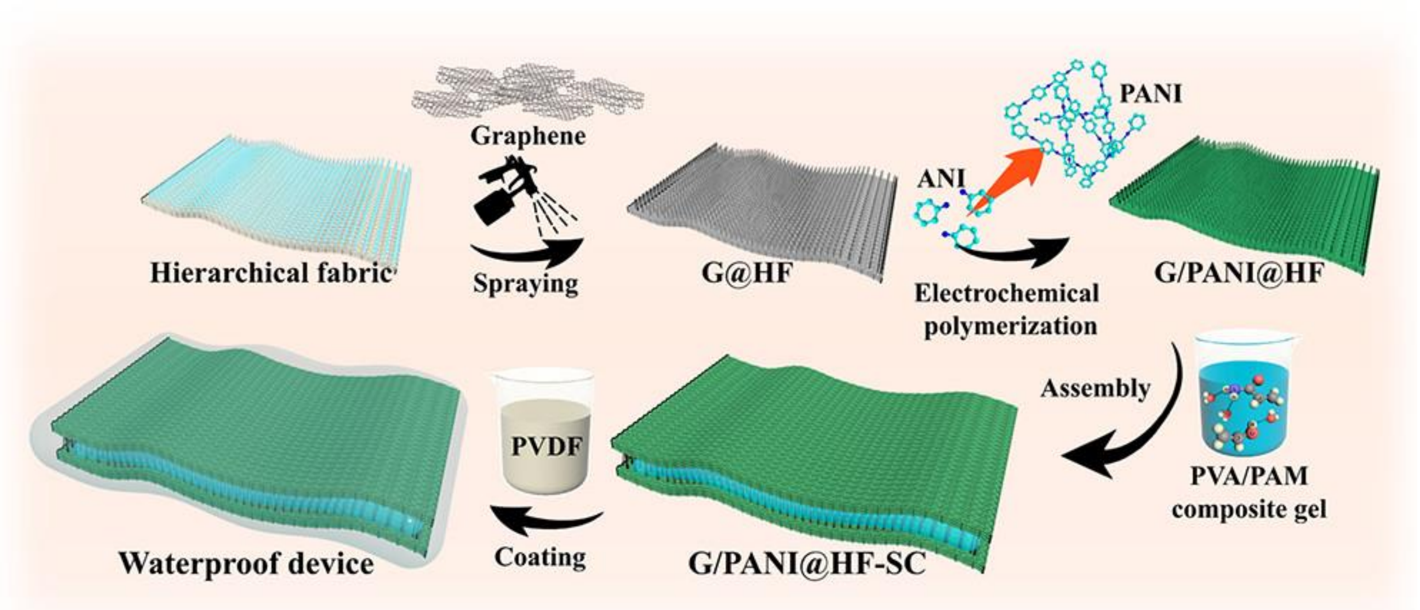

Fig 1: Schematic representation of the fabrication method of waterproof G/PANI@HF-SC.

Results & Discussion

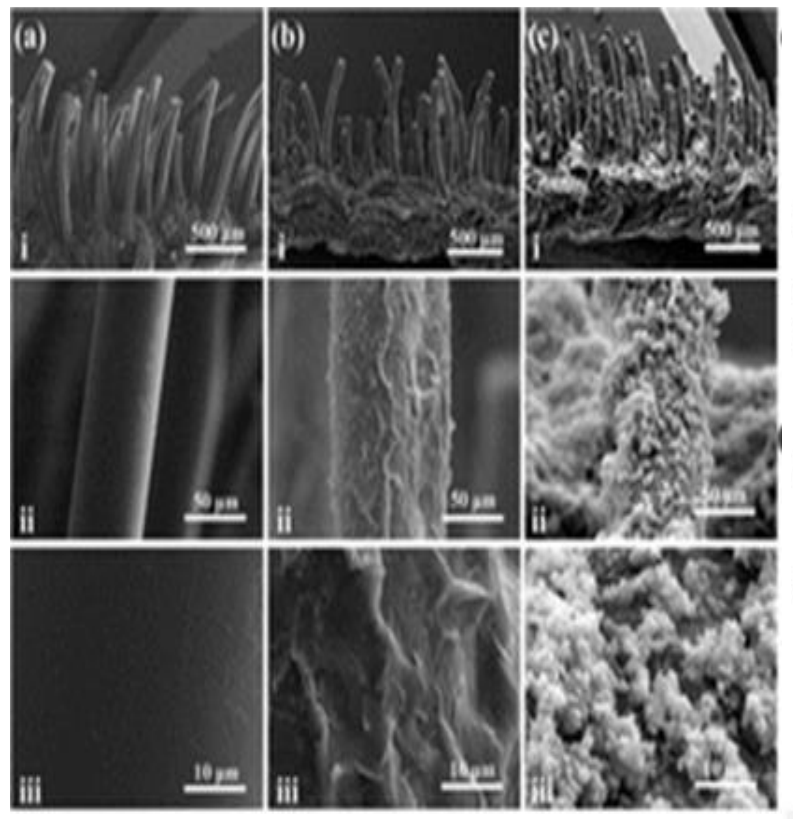

Fig 2: Surface SEM images (a) pristine HF, (b) G@HF, (c) G/PANI@HF

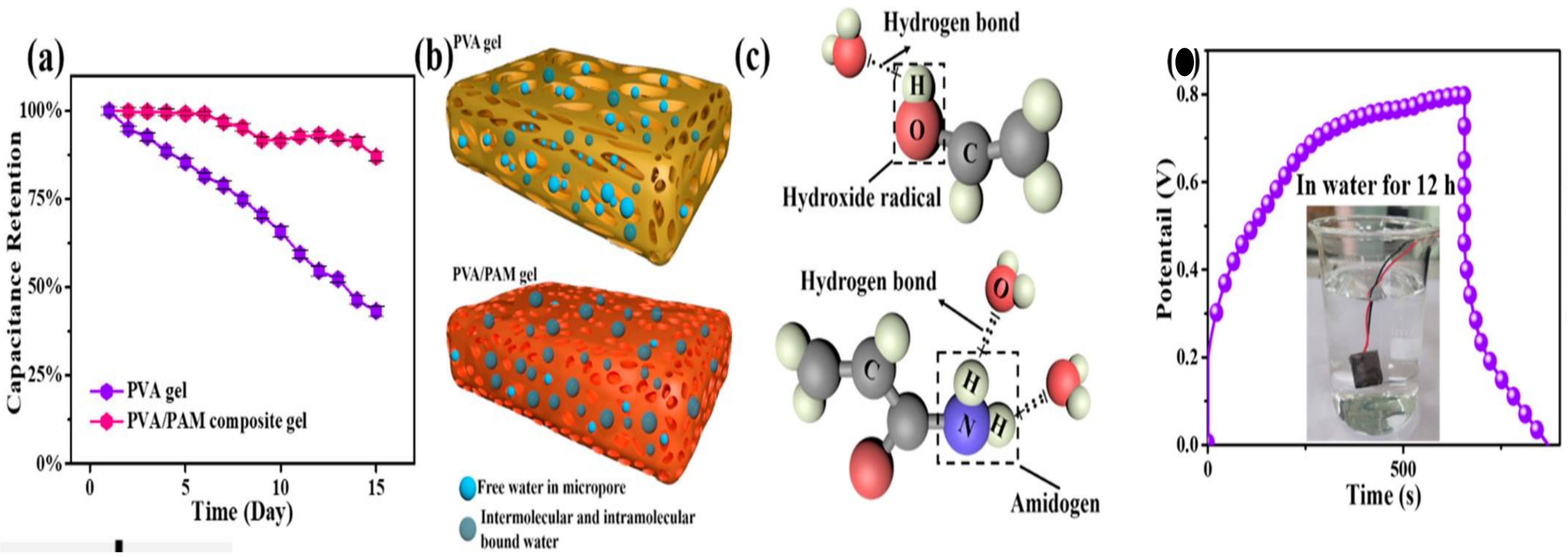

Fig 3: (a) Capacitance retention of G/PANI@HF-SCs based on PVA gel and PVA/PAM composite gel during 15 days, (b) water distribution in PVA gel and PVA/PAM composite gel, (c) the hydrogen bond between PVA and PAM molecule, (d) GCD curves of G/PANI@HF-SC in water for 1-12 h

- Here, graphene and PANI are uniformly deposited on the HF via the spraying method and the electrochemical polymerization process respectively.
- Due to the large surface area of the fiber microarrays on HF, more electrochemical active materials could be deposited and it may increase the energy storage performance during electrochemical reactions.
- The unique coating of the Polyvinylidene fluoride (PVDF) film showed excellent functioning stability of a waterproof energy storage device while working in water for 12hr without any issue.
- The G/PANI@HF-SC based on PVA/PAM composite gel showed a stable 93.29% capacitance retention during 15days while the G/PANI@HF-SC based on pure PVA gel significantly declined to 43.2% capacitance during the same days.
- This assembled SC showed improved specific capacitance of 707.9 mF/cm² and a high energy density of 62.92 µWh/ cm² and excellent cycle stability of 80.8% even after 10,000 cycles.
- The assembled device could be charged by a portable hand generator, indicating this is a very convenient device for use.

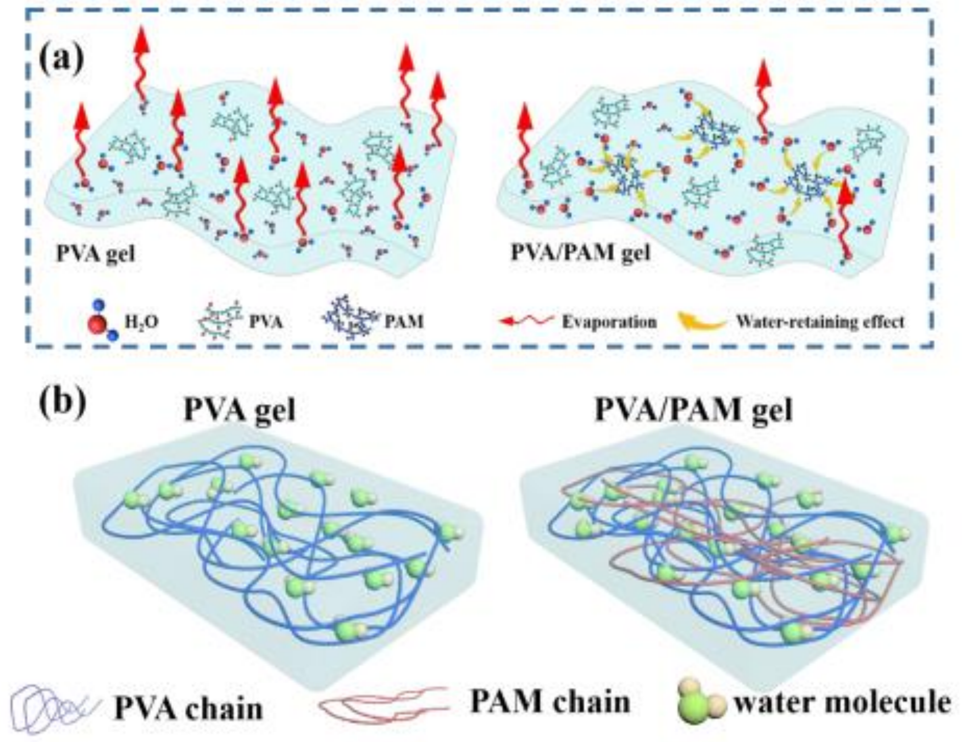

Fig 4: Schematic representation of the evaporation of water in gel electrolyte and water-retaining effect of PAM, and (b) crosslinked structure of PVA/PAM composite gel electrolyte.

Conclusion & Future work

- The ideal electric conductive and higher pseudo-capacitance of composite active materials efficiently contributed to improving the electrochemical performance of the flexible energy storage devices with water retaining and water-proofing properties.
- Overall, this is a great innovation for the performance enhancement of flexible wearable electronics which can be applied to different fields, such as rescue and military applications which can be used even on rainy days,
- This research can be further developed as a sensor to determine water pollution by introducing sensitive materials which can detect multiple water quality parameters such as pH, temperature, DO, and nitrogen concentration etc.

Reference

Li, Z., Li, M., Fan, Q., Qi, X., Qu, L., & Tian, M. (2021). Smart-Fabric-Based Supercapacitor with Long-Term Durability and Waterproof Properties toward Wearable Applications. ACS Applied Materials and Interfaces, 13(12), 14778–14785.