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Review of MXenes as a component in smart textiles and an adsorbent for textile wastewater remediation

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ABSTRACT

Two-dimensional (2D) MXenes have emerged as an archetypical layered material combining the properties of an organic-inorganic hybrid offering materials sustainability for a range of applications. Their surface functional groups and the associated chemical properties' tailorability through functionalizing MXenes with other materials as well as hydrophilicity and high conductivity enable them to be the best successor for various applications in textile industries, especially in the advancement of smart textiles and remediation of textile wastewater. MXene-based textile composite performs superb smartness in high-performance wearables as well as in the reduction of textile dyes from wastewater. This article critically reviews the significance of MXenes in two sectors of the textile industry. Firstly, we review the improvement of textile raw materials such as fiber, yarn, and fabric by using MXene as electrodes in supercapacitors, pressure sensors. Secondly, we review advancements in the removal of dyes from textile wastewater utilizing MXene as an absorbent by the adsorption process. MXene-based textiles demonstrated superior strength through the strong bonding between MXene and textile structures as well as the treatment of adsorbate by adsorbent (MXene in the adsorption process). We identify critical gaps for further research to enable their real-life applications.

1. Introduction

Textiles rank among the top five fundamental demands of human life and are the most indispensable for civilized life. Over eighty billion pieces of cloth are consumed every year globally for a wide variety of needs in addition to the fundamental clothing, such as electronic devices for a range of applications including energy conversion and storage, healthcare, sensing, automotive, protective, sports [1–5]. The revolution of textiles over centuries has enabled much control of the fabric production process for developing multipurpose cloths with durability, washable, wearability, fashionable, and reusability [6–10]. Smart or intelligent textiles are the next generation in the evolution of textiles owing to the incessant demands on miniaturization and multifunctionality [11–15]. These functionalized textiles can be upgraded extensively by using nanomaterials as nanofibers or nanocomposite substrates [16–19]. Nanofinishing [20–22] and nanocoating [23–25] processes can provide various functional or high-performance characteristics to textile substrates. Dip-coating, plasma polymerization, layer-by-layer coating, sol-gel, and spray coating are the most relevant nanocoating approaches to preparing smart textiles [26–28]. Further, the emergence of two-dimensional (2D) materials such as graphene, MXenes, transition metal dichalcogenides, etc. with superior properties to their 3D analogs has also contributed to enhancing the functionalities of smart textiles [29,30].

Among the 2D materials, MXenes [31,32] are a family of early transition eco-friendly metal carbides and carbonitrides by Gogotsi *et al.* [33,34] and are designed to be appropriate for a wide range of applications, from medical and optoelectronics owing to their promising chemical, physical and mechanical attributes [35–40]. Significant investments in this material for various technologies have raised a growing academic interest as can be seen from the exponential growth of science and engineering research papers (Fig. 1A) besides the emergence of a market sector (Fig. 1B). One would easily observe the increasing attention on this material by

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