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Advances of Functional Inks for Printed E-textiles

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Abstract

Electronic textiles (E-textiles) have emerged as promising platforms for applications in healthcare, sports training, and human-machine interaction, owing to their flexibility, permeability and integration capability. Printing technologies such as inkjet, screen, stencil, gravure, and flexographic printing offer scalable and cost-effective routes for fabricating conductive pathways and embedding functional components onto textiles. Despite rapid progress, the development of high-performance printed E-textiles is hindered by challenges in ink formulation, printability, mechanical compatibility, and especially ink–textile adhesion. Current research lacks a systematic understanding of how ink properties influence long-term durability and device functionality under real-world use. This review aims to address these issues by discussing recent advances in functional inks for printed E-textiles, with a focus on ink composition, printing techniques, and adhesion strategies. Key insights into the relationship between material properties and textile performance are highlighted. Finally, future directions are proposed to guide the development of durable, stretchable, and reliable printed E-textiles.

Keywords: E-textiles, Functional inks, Printing technologies

1 Introduction

With the rapid advancement of wearable electronic garments, E-textiles have garnered significant attention due to their unique combination of comfort, flexibility, and seamless electronic integration capability [1, 2]. Unlike conventional rigid electronics, E-textiles leverage the intrinsic fibrous structure of textiles, allowing for enhanced breathability, mechanical compliance, and adaptability to dynamic human movements. These properties make E-textiles highly promising for a wide range of applications, including real-time healthcare monitoring, sports performance tracking, human-machine interaction, and even smart fashion [3-8]. Functional E-textiles, such as sensing textiles, integrate multiple electronic components within the textile structure. These components typically include power sources (e.g., printed batteries and supercapacitors), sensors

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(e.g., strain, pressure, and temperature sensors), signal processing units, display elements (e.g., electroluminescent and thermochromic materials), and conductive circuits [9]. To enhance the flexibility and wearability of E-textiles, these components must be designed to be soft, stretchable, and conformal to the fabric substrate while maintaining stable performance under mechanical deformation. The successful integration of such components without compromising the textile's inherent properties remains a critical challenge in the field. To construct conductive pathways for rigid electronic components or directly fabricate flexible electronic components, various printing technologies have been developed as scalable, low-cost, and material-efficient fabrication methods. Printing techniques such as inkjet printing, gravure printing, flexographic printing, screen printing, and stencil printing enable precise deposition of functional inks onto textile substrates, forming conductive, semiconductive, or dielectric structures required for device operation [10]. They offer advantages, including high resolution, reduced material wastage, and compatibility with a wide range of textile materials. Functional inks play a crucial role in determining the reliability and efficiency of printed E-textiles. Key parameters such as ink rheology, mechanical robustness, and electrical conductivity must be carefully optimised to ensure stable performance under repeated stretching, washing, and environmental exposure, while preserving the inherent flexibility of textiles. Additionally, improving ink–textile adhesion remains a significant challenge, as textile substrates often exhibit high surface roughness and porosity, which affect print uniformity and electrical connectivity. However, few review papers have systematically examined how ink properties and adhesion enhancement strategies collectively influence the performance of printed E-textiles.

This review provides a comprehensive overview of functional inks for printed E-textiles, covering ink composition, printing techniques, adhesion strategies, and emerging applications (Fig. 1).

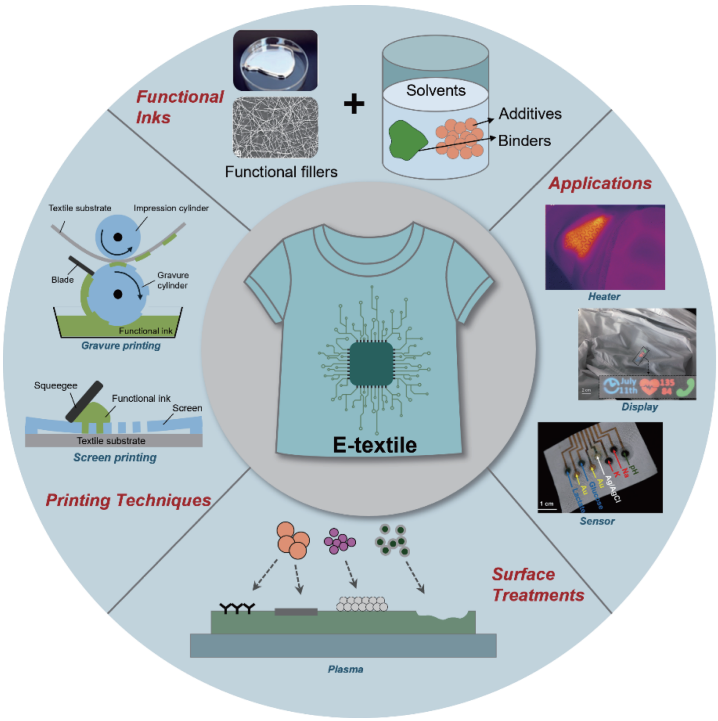

Fig. 1: Schematic illustration of inks, printing techniques, surface treatments and applications of printed E-textiles [6, 11-13]. Copyright 2007, American Chemical Society; Copyright 2023, The Royal Society of Chemistry; Copyright 2024, Springer Nature; Copyright 2020, Springer Nature.