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Advances in Metal-Organic Frameworks (MOFs) Based Flexible Sweat Sensors

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Abstract

Metal-organic frameworks (MOFs) demonstrate great potential in biosensing applications, particularly in sweat sensing, due to their high specific surface area, adjustable pore sizes, and unique catalytic properties. This review presents the advancements, fabrication techniques and potential applications of flexible sweat sensors utilizing MOFs. The background and importance of MOFs in sweat sensing were introduced, underscoring their capacity to elevate the efficiency and precision of such sensors. The structural optimisation, ligand choice, and fabrication techniques of MOFs were discussed. Various synthesis methods were explored, including electrochemical, solvothermal, room-temperature, and microwave/ultrasound-assisted approaches. The applications of MOF-based sweat sensors in trace element detection, colourimetric sensing, sports monitoring, and biomedicine were highlighted. MOFs' high sensitivity, selectivity, and stability in these contexts underscore their potential to enhance sensor performance. The review concludes by discussing the challenges faced by flexible sweat sensors based on Metal-Organic Frameworks (MOFs), such as the diversification of detectable substances. It outlines future directions, particularly towards intelligence and high efficiency. It emphasizes the necessity of achieving high precision and multifunctionality. This review comprehensively analyses the current status and future prospects of flexible sweat sensors utilising MOFs, highlighting their significant role in advancing sweat-sensing technology.

Keywords: MOF; Sweat Sensors; Smart Wearables; Preparing Technology; Application

1 Introduction

Nowadays, porous materials have attracted much attention in many fields of exploration, including physics, chemistry, and material science [1-4]. Using porous materials has played significant roles in adsorption, separation, biomedicine, and catalysis, and it also plays an essential role in our daily lives. There is a growing interest in a class of materials MOFs, PCPs [5]. These materials

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have attracted great research attention due to their noteworthy properties, such as the ability to modify pore size, high surface area, exceptional biosensing performance, and good thermal stability [6-8]. Because of its good biosensing performance, the research of MOF-based sweat sensors has attracted great attention. Sweat sensors can detect different categories of substances, such as glucose, Vitamin C, H_2S and Carbamide. Due to the high accuracy of measuring trace elements, the consumption of MOF can be controlled. Therefore, developing MOF-based sweat sensors capable of precisely detecting microelements to replace traditional sweat sensors based on semiconductors with low accuracy and durability is of great realistic meaning.

This review discusses the latest progress in the design and production strategies of sweat sensors based on MOFs to enhance overall sweat-sensing efficiency. Firstly, we focus on the distinct types of MOFs and introduce the structure and ligand of representative MOFs because the choice of structure and ligand will influence preparation. In addition, we offer different methods of preparing MOFs, such as electrochemical, solvothermal methods, room-temperature synthesis and microwave/ultrasound-assisted synthesis. These methods simplify the complexity of preparing MOFs and improve the performance of detecting trace elements in sweat. The applications of MOF-based sweat sensors show great capability in trace element monitoring and colourimetric sensing. Different ligands can change the detecting category of elements, such as carboxylate ligands, nitrogen-containing heterocyclic ligands, and phenolate ligands. Finally, we anticipate that this review article, in conjunction with previously published reviews, will offer significant insights into the systematic development of new MOFs for the widespread sweat-sensing field.

2 Materials and Techniques for Preparing MOFs

2.1 Structure Optimization and Ligand Selection

The types of MOFs discovered through research have been growing rapidly, most of which have been identified with the help of computer simulations and big data analytics. The most famous and widely used MOFs include MOF-5, MOF-505, and MOF-525. In sweat sensing, MOFs mainly achieve catalysis through their high specific surface area, thereby increasing the reaction rate of substances. However, different MOF structures can affect catalytic speed and target substances differently [9]. The choice of ions can also lead to significant differences in the final MOFs. MOFs consist of an organic framework and metal ions, and its framework is also known as secondary building units (SBUs). To date, representative SBUs in sweat sensing have gradually increased their catalytic function in MOFs, and frameworks derived from SBUs have also altered the catalytic rate for different substances [10]. As a porous material that has garnered significant attention recently, MOFs largely owe their unique structures and properties to their organic frameworks. These organic frameworks play a pivotal role in MOFs, constructing their basic skeletons and providing rich functionality and broad application prospects.

The core structure of a MOF is a three-dimensional network formed by metal ions or metal clusters connected to organic ligands through coordination bonds. High crystallinity, regular pore sizes, and a large specific surface area characterise this network structure. The organic framework, a crucial network component, is a key bridging element. Organic ligands connect various metal centres through coordination with the metal centres, forming a stable three-dimensional porous structure. The stability and porosity of this structure endow MOFs with excellent performance in detecting glucose, Vitamin C, H_2S and Carbamide.