Electrospun PVC Nanofibers

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Definition

Electrospun PVC Nanofibers means PVC nanofibers manufactured by electrospinning.

1. Introduction

PVC is one of the most common and cheapest synthetic polymers that can be found on the market. The history of PVC started during early 1870 when the first polymer was obtained by the polymerization of vinyl chloride. However, the material obtained from the polymerization of vinyl chloride was stiff and brittle. Hence, it was not ideal for industrial production. By 1926, American chemists discovered how to plasticize PVC and, since then, many PVC based products have been commercialized [1][2]. Nowadays, its demand is only lower than those of polyethylene and polypropylene, which are the materials with a higher demand on the market. In 2018, the global demand for PVC was close to 44.3 million tons and is expected to increase to nearly 60 million tons by 2025 [3]. PVC is used in many different fields, such as in the construction industry (pipes, windows, carpet, plumbing, etc.), electrical and electronic industry (instrument components, housing, sheaths for cables and wires, etc.), automotive industry, food packaging, medical equipment, and many others [4].

With the fast development of science and technologies, it is necessary to search for new materials with superior properties. In recent decades, nanomaterials have attracted the attention of many researchers due to their properties and applications [5]. In addition, polymer nanofibers are materials with many advantages and easy fabrication [6]. Compared to many known materials of the present time, polymer nanofibers have characteristics such as high aspect ratio (length to diameter), small pore size, large surface area, high porosity, high hydrophobic surface, optical transparency, and high mechanical properties (tensile strength, elastic modulus, stiffness, toughness) that make them more suitable in comparison with their macro-scale versions. Various fabrication techniques have been used to produce polymer nanofibers, such as drawing [7][8], template synthesis [9][10], self-assembly [11][12], melt-blown [13], phase separation [14], and electrospinning [15]. Among them, electrospinning is the most efficient method that can produce nanofibers from a variety of polymers. Due to nanofibers morphological characteristics, they exhibit numerous advantages, which made them suitable for their application in various fields such as air filtration systems [16][17][18][19], sensing devices [20][21], reinforcement composite [22], tissue engineering [23], energy storage systems [24], optical [22], drug delivery [25], catalyst [26], water treatment [27], and so forth.

The development of PVC nanofibers has increasingly attracted the attention of science and industry, thanks to PVC popularity and inexpensiveness [28]. PVC nanofibers present remarkable characteristics such as small diameter, high porosity, hydrophobicity, and a remarkable affinity for oil. Due to its excellent properties, previously mentioned, PVC nanofibers have expanded the area of application of PVC materials. PVC nanofibers have been used as a material for environmental applications (water filter, air filter, separator for water and oil), energy storage systems, anti-corrosive material, protective clothing, and so on [29][30][31].

2. Application of PVC Nanofiber

2.1. Water Filtration and Treatment

Because of pollution in freshwater sources all over the world, the problem of having a clean water supply has become more essential than ever. Industrial and agricultural activities are leading to water contamination by releasing heavy metals such as Pb, Cr, As, Hg, etc. [32]. As a result, freshwater cannot be used without any filtration treatment [33]. Materials for nanofiltration are being applied to obtain water with a high degree of purity. Electrospun nanofiber membranes present great potential for environmental applications. Based on some useful properties such as high surface area, high porosity (up to 80%) compared to conventional polymer membranes (5–35%), excellent functionalization ability, and good mechanical behavior, they are more effective when used for liquids separation and filtration [34]. PVC is a material that is insoluble in water, bases, and acids. Thus, it has great potential for use as a filter material.

2.2. Air Filtration

Due to the influence of the rapid growth of urban areas, and the development of industries, global air quality has been seriously degraded. The fine particles of particulate matter 2.5 (PM 2.5) seriously affect human health. Many types of filtration technology have been developed. Nanofibers have small pores size, large surface area, small diameter, high porosity, and the ability to incorporate active chemical agents on a nano-scale surface, making them a potential candidate for air filtration technology [35]. Electrospun PVC/PU (8/2 w/w) nanofiber mats with high abrasion resistance (134 cycles) and comparable air permeability (154.1 mm/s) showed fascinating filtration efficiency (99.5%). In addition, the low-pressure drop (144 Pa) performance for 300–500 nm sodium chloride aerosol particles suggests their use as a promising medium for a variety of potential applications in air filtration [36]. Lackowski et al. [37] obtained electrospun PVC/PVDF nanofibers for the filtration of smoke and nanoparticles. The results showed that PVC/PVDF nanofibers have a diameter of about 400–800 nm and offer better filtration efficiency compared with HEPA filtration.

On the market, we can find that the company RESPILON® (Brno, Czech Republic) has used PVC nanofibers to fabricate a window membrane. Such membranes are attached to the windows for air purification, dust resistance, and insulation. The membrane can block up to 90% of smoke, dust, and allergens and can remove particles larger than 150 nm. In addition, it is important to mention that the membrane is made from nanofibers. Hence, there is no release of harmful substances or particles [38].

2.3. Oil Spill Cleanup

Oil spills have serious and long-lasting effects on marine ecosystems and the environment in general. Removing oil spills quickly and efficiently is an issue that has never been more urgent. Recently, the research on using nanomaterials as sorbent membranes to separate oil and water has been increasingly concerned [39][40]. Using sorbents to concentrate and transform oil from the liquid phase to the semi-solid or solid phase and then removing this oil from water is an effective and economical mechanical method [41][42]. Electrospun nanofibers have many suitable properties for oil and water separation, such as superior hydrophobic–oleophilic behavior (no water sorption but oil sorption), high porosity, low density, small diameter, and fibrillary structure [43][44]. Therefore, nanofiber membranes are a potential material that can be used to separate oil from water [45][46].

PVC nanofibers are oleophilic, which means, is a material with a high affinity for oil; in other words, when oils are exposed to PVC nanofibers, they will absorb the oil [47][48]. Materials with hydrophobic and oleophilic characteristics are suitable when used to remove oil from water. Furthermore, these materials do not pollute the environment.

Messiry et al. [49] evaluated the oil absorption capacity of fibers from PVC and a mixture of PVC and CA with different concentrations (2%, 4%, 6%, 8%). The water contact angle of the nanofiber decreases as CA content increases. The nanofibers obtained from a PVC blend with 8% CA have diameters of 89 nm, which is significantly smaller than those from pure PVC nanofibers of (207 nm), thus, providing a better oil absorption. The oil sorption of the nanofiber sorbent using PVC and PVC/CA 8% was 17.4 g oil/1 g nanofiber and 25.8 oil/1 g nanofiber, respectively.

2.4. PVC Nanofiber for Energy Application

Fossil energy sources are limited, while natural sources such as solar, wind, water, etc., are quasi-infinite. Development of energy storage materials such as solar cells, lithium batteries, and accumulators to store energy is needed. Electrospun nanofiber can be used in electrodes and separators in lithium-based batteries, fuel cells, electrocatalysts for electrode materials, electrolyte membranes, photoelectrodes in dye-sensitized solar cells, etc. [50].

Because PVDF is a semi-crystalline material, the crystal part of PVDF interferes with the movement of lithium-ion. Therefore batteries with PVDF-based electrolytes polymer have low ion conductivity and charge/discharge capability [51]. Adding PVC to PVDF eliminates crystallinity and enhances ionic conductivity [52]. Electrospun PVDF/PVC nanofibers (8/2 w/w) can be used for electrolytes polymer in pin lithium-ion polymer [53]. The presence of PVC in the nanofiber membranes has increased electrolyte uptake and ionic conductivity of the composite polymer electrolytes. The composite PVDF–PVC PEs had a high ionic conductivity up to 2.25 × 10^{-3} S cm^{-1} at 25 °C.

2.5. Protective Clothing

Fibers from PVC are accessible and inexpensive materials. PVC nanofibers are characterized by their hydrophobicity, not water expansion, and not hygroscopicity. In addition, PVC nanofibers present high chemical-resistance to agents such as acids, bases, salts, and they are insoluble in most organic solvents; hence they can be used to manufacture protective clothing and lab coats for medical applications [54]. Having inherited these characteristic properties, PVC nanofibers have the potential to be used in the field of protective clothing. When using nanofibers as a part of protective clothing enhances the clothing’s filtration ability from harmful environmental agents, good air exchange, and water repellency. Figure 1 illustrates how nanofiber mats work when they are used as protective clothing.

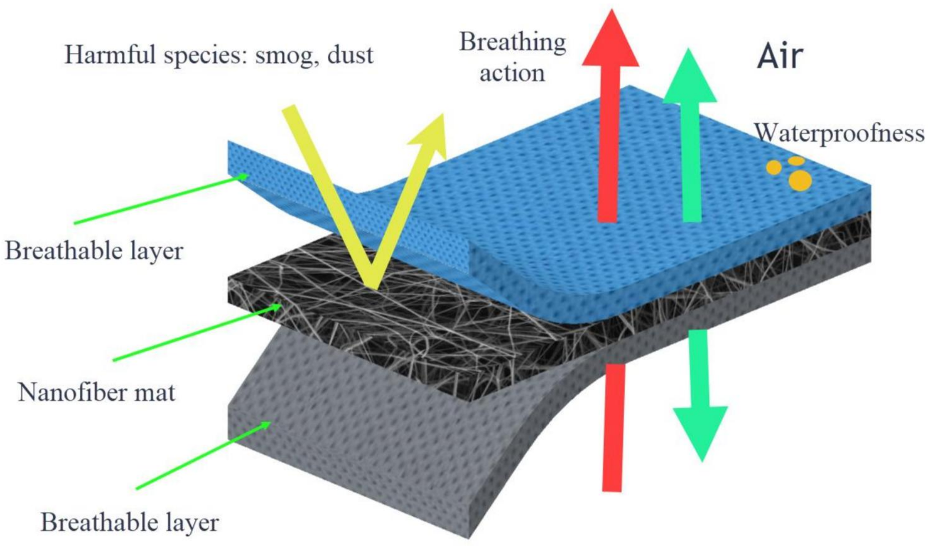

Figure 1. Graphical illustration for the operation of nanofiber mats when used as protective clothing.

2.6. Protection from Corrosion

Protecting surfaces from corrosion is a new application of electrospun nanofibers. It has been proposed to replace traditional chromate coatings, which not only affects the environment but affects human health as well. Essaheb et al. [55] fabricated electrospun PVC nanofiber coating on the surfaces of different metals such as aluminum, steel, and brass. The authors used cyclic potentiodynamic polarization and electrochemical impedance spectroscopy measurements to evaluate the protective effect of the coating in NaCl 3.5 wt%. The results showed that the nanofiber-coated samples had much lower corrosion rates, more passivated surfaces, and higher polarization resistance compared to the non-coated nanofiber samples.

2.7. Reinforcement in Composite

Composite polymer materials usually have two main components, one is the reinforcement, and the other is the matrix. When combined, they produce higher-quality materials such as high strength and high modulus, high flexibility, economic efficiency that one of the two components cannot achieve. Recently, nano-scale materials have been used as a reinforcement ingredient that has attracted the attention of scientists. Electrospun nanofiber material has many outstanding properties such as thin and light structure, high porosity, and higher mechanical properties than those of the same material in its bulk state [56]. Therefore, nanofiber polymer materials are considered as a potential material used as composite reinforcement [57][58][59].

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Keywords

polyvinyl chloride;electrospun nanofiber;nanofiber application;air filtration;water treatment;protective clothing;polymer nanofiber composite