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Development & Characterization of Alginate/Graphene Oxide Fibers with Improved Electrical Conductivity ⋆

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Abstract

Graphene has demonstrated extraordinary electrical, optical, thermal and mechanical properties. In last decade, a lot of research has been done to improve fabrication and solution processing of graphene to graphene oxide and reduced graphene oxide. Graphene oxide contains more number of oxygen containing functional groups which increase interlayer distance and make its dispersion easy in aqueous solutions. These advances in graphene have further improved its properties including tensile strength, elastic modulus, low resistance, carrier mobility and stability against higher temperatures and chemicals. Alginate is obtained from brown seaweeds and has potential applications in treatment of wounds and cell differentiation due to its non-toxicity, biodegradability and biocompatibility. It is a hydrophilic natural polysaccharide and provides moist and ideal environment for wound healing and cell growth. However, Alginate fibers still also display some unsatisfactory properties, such as low mechanical strength and electrical conductivity. Combining the intriguing properties of graphene and alginate, we develop smart composite fibers with suitable conductivity and mechanical strength which can be processed to nonwoven wound dressings and can be used as biosensors for medical applications. Sodium alginate/Graphene oxide fibers were fabricated by using wet spinning setup. The developed sodium alginate/graphene oxide fibers were further thermally and chemically reduced to improve conductivity. Their structure and properties were characterized by conductivity measurements, fiber strength testing, absorption behaviors, FT-IR (Fourier transform infrared spectroscopy) and SEM (scanning electron microscope). The addition of graphene oxide improves the strength of sodium alginate/graphene oxide fibers due to high compatibility and even distribution of graphene oxide fillers in alginate matrix. Thermal and chemical reduction methods increase the conductivity of sodium alginate/graphene oxide fibers due to removal of oxygen containing groups. Chemical reduction method seems to have greater effect in improving the conductive properties of sodium alginate/graphene oxide fibers. These fibers also have good ability to absorb fluid and forms hydrogel to keep appropriate moist environment for wound healing which make them ideal material to develop smart wound dressings.

Keywords: Alginate; Graphene; Conductivity; Fibers; Wet Spinning

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1 Introduction

Conductive textile products have been widely used in various applications because of its special properties in the wound care dressings and electromagnetic shielding field. However, many synthetic fibers that are used on electrical textile products have high resistivity, more than 10^{-15} Ω/cm^2, which is much higher than the resistivity in the desirable products. The resistivity in the shielding is usually lower than 10^{-2} Ω/cm^2 and the desirable resistivity in anti-electrostatic products is also lower than 10^{-15} Ω/cm^2. There are two main methods to generate conductive fibers. The first essence of the conductive fibers is the fiber itself is naturally conductive such as silver and copper whereas the other method is to use such treatments which can make the fibers conductive [1].

Graphene is a 2D monolayer of carbon atoms and it has extraordinary mechanical properties (high tensile strength and record elastic modulus), and high conductivity. Graphene based fibers and polymers have outstanding properties and they have been used in different areas because of its amazing mechanical properties and electronic performance [2]. Nowadays scientists focus more on a wide range of functional uses and applications.

Graphene oxide is also attracting attention in world of materials research due to its unique properties. It has low cost manufacturing process, contains large specific surface area and can be easily modified to compatibly mix with other polymer matrixes [3]. It contains higher number of functional groups which make it easily dispersible in water and aqueous solvents. Graphene oxide has also been used to enhance strength of natural polymers such chitosan films and chitosan-gelatin monoliths [4].

Alginate is a natural herb and anionic polysaccharide polymer that exists in cell walls. Alginate is extracted from natural brown seaweeds and it is relatively cheap in comparison with other advanced materials and has a lot of beneficial and unique properties [5]. It has been widely used in biomedical applications because of its high compatibility, non-toxicity and ability to absorb fluids. It quickly absorbs exudate from wound to provide suitable moist environment and accelerates the wound healing process [6]. It is non-toxic and reliable biomedical material to be fabricated into fibers because of its biological nature. The structure of alginate hydrogels is similar to extracellular matrices structure because hydrogels can be manufactured by cross-linking methods that exists in living tissue. This permits wider application to deliver other drugs/agents to cells. Hemostasis process is achieved by ions exchange between calcium ions and sodium ions in body fluids when calcium alginate fibers are transferred to sodium alginate (NaAlg) fiber [7].

Alginate is a popular biomaterial which have been used for wound healing dressings for many years but there are still some unsatisfactory properties such as low electric conductivity, mechanical strength and thermal properties. In the last few years, a wide range of research have been done to modify the alginate fibers with inorganic materials to improve its properties and graphene is one such inorganic material which improve mechanical strength of alginate fibers [4]. Kawaguchi et al describes that alginates scaffold can be reinforced by mixing them with carbon nanotubes and mechanical strength of composites can be improved [8].

In this research, graphene oxide suspension was mixed with sodium alginate to develop NaAlg/GO fibers. Graphene oxide itself has low conductivity, therefore reduction methods were used to improve the conductivity of sodium alginate/graphene oxide fibers.