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Nanostructured electrically conducting biofibres produced using a reactive wet-spinning process

Abstract

Electrically conducting, robust fibres comprised of both an alginate (Alg) biopolymer and a polypyrrole (PPy) component have been produced using reactive wet-spinning. Using this approach polypyrrole-biopolymer fibres were also produced with single-walled carbon nanotubes (CNTs), added to provide additional strength and conductivity. The fibres produced containing CNTs show a 78% increase in ultimate stress and 25% increase in elongation to break compared to PPy-alginate fibre. These properties are essential for studies involving the use of electrical stimulation to promote nerve regrowth and/or muscle regeneration. The resultant a novel fibres had been evaluated to develop a viable system in incorporating biological entities in the composite biomaterial. These results indicated fibres are biocompatible to living cells.

Keywords

wet, conducting, electrically, nanostructured, reactive, produced, spinning, biofibres, process

Disciplines

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Nanostructured Electrically Conducting Biofibres produced using a Reactive Wet-spinning Process

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Abstract— Electrically conducting, robust fibres comprised of both an alginate (Alg) biopolymer and a polypyrrole (PPy) component have been produced using reactive wet-spinning. Using this approach polypyrrole–biopolymer fibres were also produced with single-walled carbon nanotubes (CNTs), added to provide additional strength and conductivity. The fibres produced containing CNTs show a 78% increase in ultimate stress and 25% increase in elongation to break compared to PPy–alginate fibre. These properties are essential for studies involving the use of electrical stimulation to promote nerve regrowth and/or muscle regeneration. The resultant novel fibres had been evaluated to develop a viable system in incorporating biological entities in the composite biomaterial. These results indicated fibres are biocompatible to living cells.

Keywords—conducting polymer; biopolymer; alginate; CNT

I. INTRODUCTION

Conducting and biocompatible polymer fibres are likely to be important for in vivo bio engineering applications, as they allow the possibility to incorporate desirable features like chemical and/or biochemical sensing or actuation that are not feasible with metallic fibres. However, production of continuous conducting polymer fibres is complicated as their common forms are not soluble, and cannot be processed by melt spinning techniques like extrusion. PPy is a well known conducting polymer that has been used in a range of applications such as biological sensors, artificial muscle and biomedical applications [1]. Wet-spun biodegradable fibres on conducting PPy platforms for muscle regeneration have been developed using a two-step method; fibre spinning and coating with PPy [2, 3]. PPy fibres have been directly produced using a wet-spinning process [4, 5] however, this request the use of a specific dopant. Since the properties of PPy are greatly influenced by choice of dopant, it is desirable to develop a fibre spinning process that enables a wider range of dopants to be incorporated. Herein, we describe one such approach where a host polymer is used to form a fibre into which PPy is impregnated. Wet-spinning of the host polymer occurs simultaneously with chemical polymerization of pyrrole in a reactive spinning process. [6]. However, the lack of mechanical integrity of the alginate fibres in aqueous medium limits their use in biomedical applications. It has been demonstrated that introducing carbon nanotubes (CNTs) into a

polymer matrix can improve mechanical properties and electrical conductivity of the neat polymer matrix [7]. CNTs have also been readily incorporated into host polymers during wet-spinning.

The present work, considers the properties of novel nanostructured conducting fibres produced continuously using the reactive wet-spinning process. Electrically conducting and robust bicomponent fibres of biologically functionalized PPy have been successfully produced for the first time using a novel wet-spinning process with and without inclusion of CNTs in the polymer matrix [8].

II. RESULTS AND DISCUSSION

This approach employs *in situ* chemical polymerization of pyrrole monomer during the fibre spinning process. The polypyrrole-biopolymer fibres obtained with and without single-walled carbon nanotubes are shown to be electrochemically active with reasonable actuation performance. Electromechanical actuation of the PPy-Alg-CNT nanocomposite fibre was found to give a strain of 1% at high scan rate (100 mV s^{-1}). The SEM images of PPy-Alg composite fibres clearly demonstrate the tubular multifilament form of alginate fibre impregnated with PPy nanoparticles (Fig. 1a). This contrasts with the amorphous bulky structure of PPy-Alg-CNT shown in Fig. 1b. The latter novel nanocomposite fibre shows a 78% increase in ultimate stress and a 40% increase in elongation at break compared to PPy-Alg fibre. Similarly, the Young's modulus of PPy-Alg-CNTs shows a 30% increase compared to PPy-Alg fibre (Fig. 2). Raman spectroscopy and TGA were carried out to further elucidate the chemical interaction among components of the composite fibres. TGA data show significant change in thermal properties of alginate fibre after addition of PPy and CNTs. Also, the Raman signature of PPy-Alg-CNT fibre demonstrates a drastic difference compared to its individual components. This indicates significant chemical interaction between the constituents. These properties are essential for studies involving the use of electrical stimulation to promote nerve regrowth and/or muscle regeneration. The resultant novel nanocomposite fibres have been evaluated to develop a viable system incorporating biological entities in the composite biomaterial.

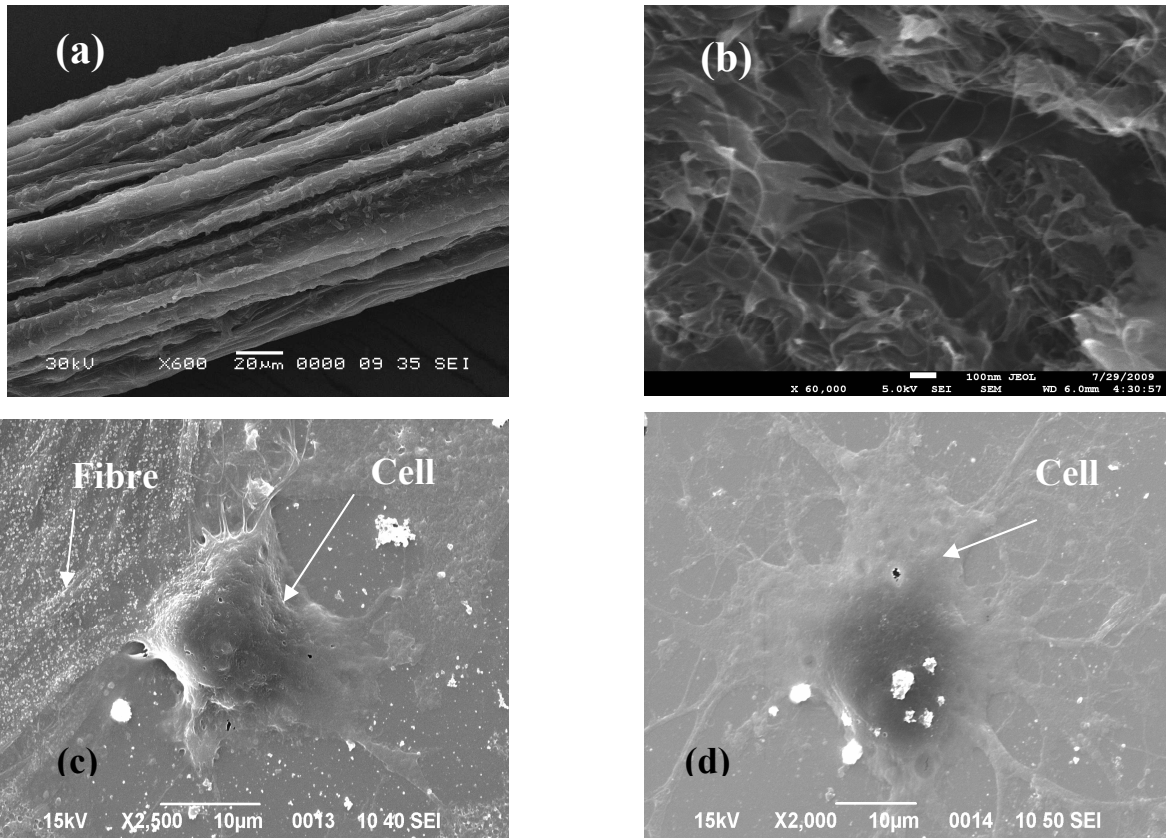


Figure 1: SEM micrographs of as-spun (a) PPy-Alg and (b) PPy-Alg-CNT nanocomposite fibres. (c-d) SEM micrographs showing the cell morphology observed along the novel biocompatible fibres

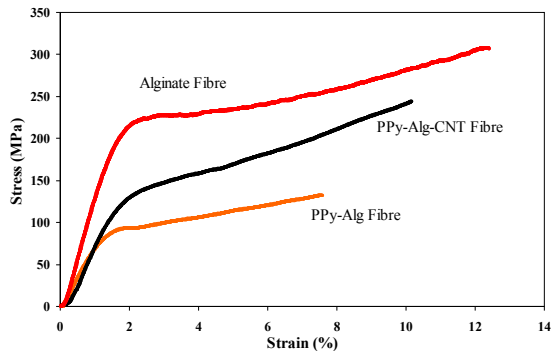


Figure 2: Stress-strain curves obtained from tensile tests of alginate fibre compared to PPy-Alg and PPy-Alg-CNT composite fibres

III CONCLUSION

Composite fibres of PPy–alginate with and without the inclusion of CNTs were produced using a reactive spinning procedure. The novel fibres are biocompatible with living cells (Fig. 1 (c-d)). Overall, the fibres appear sufficiently strong, conductive and electrochemically active to be used as unsupported substrate in nerve regrowth and/or muscle regeneration, actuators and artificial muscle. The results obtained suggest that the electrically conducting PPy containing biofibres produced here may be useful as sensors, actuators, and in some biomedical applications.

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