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Thermally Drawn Polycaprolactone Fibres with Customised Cross Sections

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ABSTRACT

There is growing demand for biodegradable polymer fibres in tissue engineering and nerve regeneration. We demonstrate a scalable and inexpensive fabrication technique to produce polycaproactone (PCL) fibres using fibre-drawing technique. Here we report on the first successful drawing of hollow-core and solid-core PCL fibres of different cross sections. The demonstrated capacity to tailor the surface morphology of PCL fibres, together with their biodegradability and tissue compatibility, makes them a unique material base for tissue engineering and nerve regeneration applications.

Keywords: biodegradable fibres, thermally drawn fibres, polymer fibres, polycaprolactone

1. INTRODUCTION

Over the last decades, natural and synthetic polymer scaffolds have emerged as an alternative to biological grafts in tissue engineering[1]. There have also been an increasing interest in using fibrous structures for biomedical applications[2]. Biodegradable polymers such as polycaprolactone (PCL) have attracted a particular attention as compared to other polymeric materials for applications such as tissue engineering[3] and optical neural interfaces[4]. Polymeric materials as substrates for cell growth are crucial for the production of platforms for cell culture and tissue engineering. Their high biocompatibility, tissue-like mechanical properties, and appropriate surface morphology are essential for biomedical applications[5].

Surface features such as grooves in polymer and fibre scaffolds have already been demonstrated to have a strong influence on nerve cell regeneration[6]. Following our previous works on drawing soft polymer fibre materials[7], here we report on the first time (to the best of our knowledge) successful drawing of solid-core and hollow-core PCL fibres with tailored cross sections using the well-established fibre drawing technique, used for making optical fibre, involving drawing in a furnace from a macroscale preform. Our fibres benefit from high flexibility (relatively low Young's modulus), biodegradability, tuneability of surface morphology, and ease of handling, which make them an ideal material base for tissue engineering, nerve regeneration, and implantable biomedical devices.

2. RESULTS AND DISCUSSION

The melting point and decomposition temperature of PCL (Polysciences, Inc., MW 80000) are the key parameters for drawing a polymer fibre. They were measured using differential scanning calorimetry (DSC) and thermal gravimetric analysis (TGA). According to Figure 1a and Figure 1b, the melting point of PCL is about 55°C while the decomposition of PCL starts at 350°C. These give us a relatively broad temperature range to work over.

Three preforms schematised in Figure 1c to Figure 1e were prepared to explore the possibility of drawing submillimetre PCL fibres with different internal and external features. The preforms were fabricated by melting PCL pellets inside polypropylene or Teflon moulds (with an outer diameter of 15 mm) at 80°C for 17 hours. The PCL fibres were then successfully drawn and collected on spools using a fibre drawing tower. The drop-off temperature was set to 90°C while the subsequent drawing was performed at 85°C. The preform was fed downwards into a furnace at a constant rate of 2 mm/min, and the fibres were drawn with a capstan wheel at rates of 0.5 to 1.5 m/min.

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Figure 1f to Figure 1h show the optical micrographs of the PCL fibres drawn from the preforms in Figure 1c to Figure 1e. The original external and internal features of the preforms were successfully preserved in submillimetre PCL fibres without pressurising the preforms over the draw process or without using a cladding material.

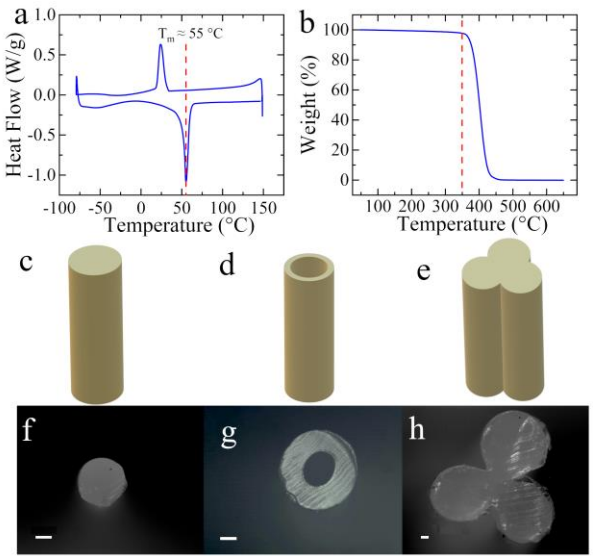

Figure 1. (a) DSC and (b) TGA spectra of PCL showing its melting point and decomposition temperature respectively, (c)-(e) preforms for making solid-core, hollow-core, and grooved PCL fibres, and (f)-(h) optical micrographs of the respective PCL fibres (all the scale bars are 100 µm) demonstrating the preservation of the shape of the preforms' cross section.

To summarise, we have successfully drawn submillimetre PCL polymer fibres with internal and external features using a well-established melt-drawing technique without pressurising the preforms or using an etchable cladding. The produced fibres are highly flexible, biocompatible, biodegradable, and easy to handle. These characteristics make them a promising material for various biomedical applications, including tissue engineering, nerve regrowth and implantable biomedical devices.

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