MECHANICAL CHARACTERIZATION OF A SINGLE NANOFIBER

Experimental Techniques

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Abstract: Biodegradable polymeric nanofibrous scaffolds have been used extensively for tissue engineering. The stiffness of the individual nanofibers in these scaffolds can determine not only the structural integrity of the scaffold, but also the various functions of the living cells seeded on it. Therefore, there is a need to study the nanomechanical properties of these individual nanofibers. However, mechanical testing of these fibers individually at the nanoscale can pose great challenges and difficulties. Here, we present experimental techniques to test single polymeric nanofibers - namely tensile test, three-point bend test and indentation test at the nanoscale. For demonstration of the nano tensile test, we proposed the use of a nano tensile tester to perform pull test of a single nanofiber. For three-point bend test, a nanofiber is suspended across a microsized groove etched on a silicon wafer. An AFM tip is then used to apply a point load on the mid-span of the suspended nanofiber. For nanoindentation test, a nanofiber is deposited on a mica substrate and an AFM tip is used to indent the nanofiber. Mechanical properties such as Young’s modulus, stress and strain at break of a single ultrafine fiber can then be obtained from these tests.

Key words: Nanomechanical characterization, polymer nanofibers, tensile test, three-point bend test, nanoindentation.

1. INTRODUCTION

Biodegradable polymeric nanofibrous scaffolds have been widely used for engineering artificial tissues such as nerve [1], cardiac [2] and blood vessel [3] tissues. Although factors such as biocompatibility, suitable porosity and sufficient surface area for cell attachment [4] are vital for the survival and growth of cells seeded within or on the scaffold, mechanical properties of the scaffold are just as important.

Studies have shown that the stiffness of the scaffold can affect various cellular functions at the micro level such as cell growth, differentiation and motility [5-7]. The scaffold should also have the structural integrity and mechanical strength to maintain the desired shape before the new tissue is fully regenerated [4]. Therefore, there is a need to study the nanomechanical properties of individual nanofibers that make up the entire scaffold.

The difficulty in isolating and handling single ultrafine fibers is one of the main challenges experienced in the mechanical testing of single nanofibers. Devices that are able to measure the minute forces and deformations involved in the mechanical tests are also required. These issues are now addressed by the nanomechanical characterization techniques of single nanofibers proposed here - namely tensile test, three-point bend test and indentation test performed at the nanoscale. Mechanical properties such as Young’s modulus, stress and strain at break of a single ultrafine fiber can then be obtained from these tests.

2. TENSILE TEST

We have previously performed tensile tests of a single nanofiber using three approaches. The first approach involves the innovative use of a nanoindenter to perform pull test of a single ultrafine fiber [8]. The second approach requires one end of the nanofiber to be attached to a piezo-resistive atomic force microscope (AFM) cantilever tip and the other end to a movable optical microscope stage [9]. The AFM tip acts a force sensor while the microscope stage is used to stretch the nanofiber. The third approach which will be presented here uses a nano tensile tester [10].

Due to the difficulty in manipulating and gripping single nanofibers, the most feasible way of conducting tensile tests of such samples is to collect the as-fabricated fibers on a jig or frame that can be directly mounted on a tensile tester. Here, aligned electrospun microsized polycaprolactone (PCL) fibers are used to demonstrate the tensile test using nano tensile tester. These fibers are first produced by collecting the fibers on two parallel,