CHAPTER I
INTRODUCTION

Ultrafine polymeric fibers characterized by small diameters in the range of several microns down to a few tens of nanometers are of considerable interest for various kinds of applications, due to their several amazing characteristics such as very large surface area to volume ratio, flexibility in surface functionalities, and superior mechanical performance (e.g. stiffness and tensile strength) compared with other known forms of the materials. These outstanding properties make polymeric fibers optimal candidates for many important applications. Examples are nanofiber-reinforced composites, polymeric fibrous scaffolds for tissue engineering, conductive fibers for sensor applications, etc. A number of processing techniques, such as drawing, template synthesis, phase separation, self-assembly, and electrospinning, have been used to prepare polymeric ultrafine fibers in recent years. It has been shown that electrospinning—as a production method—seems to be the only method which can be further developed for mass production of one-by-one continuous nanofibers from various polymers. Some advantages of electrospinning process are simple equipment, requiring a short time, and producing highly oriented fibers. As a result, the electrospinning process has gained much in recent years, due mainly to the world-wide interest in nanotechnology.

The electrospinning process involves the introduction of a strong electrostatic field to a capillary connected with a reservoir containing a polymer solution or melt. Under the influence of a high electrostatic field, a pendant droplet of the polymer solution or melt at the capillary tip is deformed into a conical shape. If the voltage surpasses a threshold value, electrostatic forces overcome the surface tension, and a fine charged jet is ejected. The jet moves towards an electrode of opposite polarity. Owing to the high enough viscosity of the polymer solution or melt, the ejected, charged jet remains stable and does not break up into spherical droplets as expected for a liquid cylindrical thread. This results in the deposition of thin polymeric fibers on a collector as a non-woven membrane. The properties of the fibers obtained from this process depend on two types of parameters. The first is the system parameters which include molecular weight, molecular weight distribution,

molecular architecture of the polymer (e.g. branched or linear chain), and the solvent or solution properties (e.g. viscosity, conductivity, surface tension, etc.). The second is the processing parameters which include electrical field strength, flow rate, solution concentration, collection distance, and the ambient parameters (e.g. temperature, humidity, etc.).

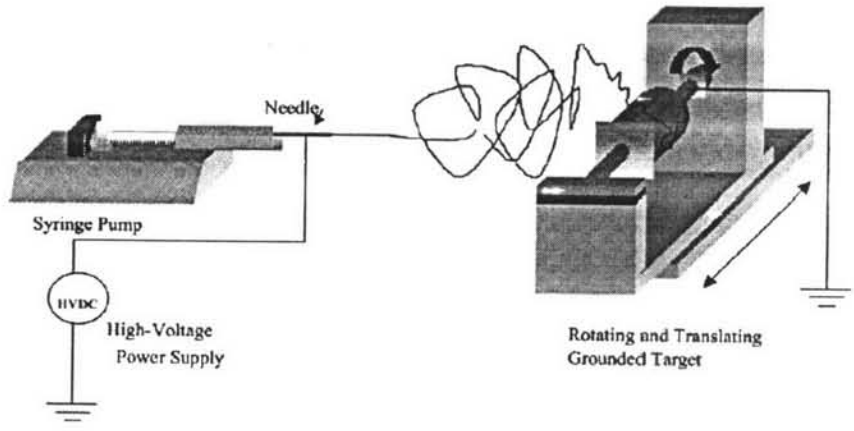

Figure 1.1 The electrospinning apparatus utilized in the production of ultrafine fibers.

Tissue engineering of bone requires cellular components, scaffolds as extracellular matrices, and growth and differentiation factors. Scaffolds must act as substrates for cellular attachment, proliferation, and differentiation. Various synthetic alternatives—such as metals, ceramics and polymers—have been tried for many years. Various materials show limited success due to low cell viability and slow vascularization. For a successful application of such materials, suitable mechanical characteristics and degradation behaviors are also essential. Osteoconductive matrices are fashioned from biodegradable materials of natural origin like collagen, gelatin, hyaluronic acid; biodegradable polymers like poly(3-hydroxybutyric acid-co-3-hydroxyvaleric acid) (PHBV); and synthetic polymers like poly(lactic acid) (PLA), poly(glycolic acid) (PGA), poly(lactic-co-glycolic acid) (PLGA). Scaffolds should be designed to allow diffusion of nutrients to the transplanted cells and guide cell organization, attachment, and migration. Pore size and porosity are important issues.

By electrospinning process, the ultrafine geometry of electrospun fibrous scaffolds satisfies the requirements.

Poly(hydroxyalkonate)s (PHA) are biodegradable and biocompatible, and they are thermoplastic polyesters produced by various microorganisms, soil bacteria, blue-green algae, and some genetically-modified plants. In microorganisms, PHA serves as an intracellular energy and carbon storage product in much the same way as glycogen in mammalian tissues. The most extensively studied PHA is poly(3-hydroxybutyrate) (PHB). Its copolymers in various ratios of hydroxyvalerate (HBV) are the most widely used members. The copolymers of hydroxybutyrate with hydroxyvaleric acid are less crystalline, more flexible, and more readily processable than PHB itself. Their various properties—such as natural origin, biodegradability, biocompatibility, streospecificity, piezoelectricity, optical activity, and thermoplasticity—make them suitable for a variety of applications in the health industry.

In this work, an attempt was made to understand the effect of processing parameters of PHA on the morphological appearance of the as-spun fibers which could influence the cytocompatibility for growth of osteoblasts in vitro and to evaluate the effect of PHBV content on the electrospun PHB/PHBV blend fibers. The characteristics of the as-prepared solutions will be evaluated by a viscometer, a conductivity meter, and the surface morphology. In addition, wettability and thermal properties, apparent melting temperature (Tm), melt-crystallization temperature (Tmc), subsequent melting temperature (Tms1 and Tms2), and degradation temperature (Td) of as-spun fiber in comparison with those of the as-received polymers were investigated by contact angle, DSC and TGA, respectively. The diameters and the morphology of the as-spun fibers were obtained by a scanning electron microscope. Mechanical integrity of the fibrous scaffolds was also investigated. Lastly, adhesion, proliferation, and biofunctionality of osteoblasts in contact with the as-prepared fibrous scaffolds were evaluated.