CHAPTER II
LITERATURE SURVEY

2.1 Electrospinning

2.1.1 Experimental Set-up

There are basically three components to fulfill the process: a high voltage supplier, a capillary tube with a pipette or needle of small diameter, and a metal collecting screen. In the electrospinning process a high voltage is used to create an electrically charged jet of polymer solution or melt out of the pipette. Before reaching the collecting screen, the solution jet evaporates or solidifies, and is collected as an interconnected web of small fibers (Deitzel, 2001, Fong H, 2001). One electrode is placed into the spinning solution melt and the other attached to the collector. As shown in fig. 2.1

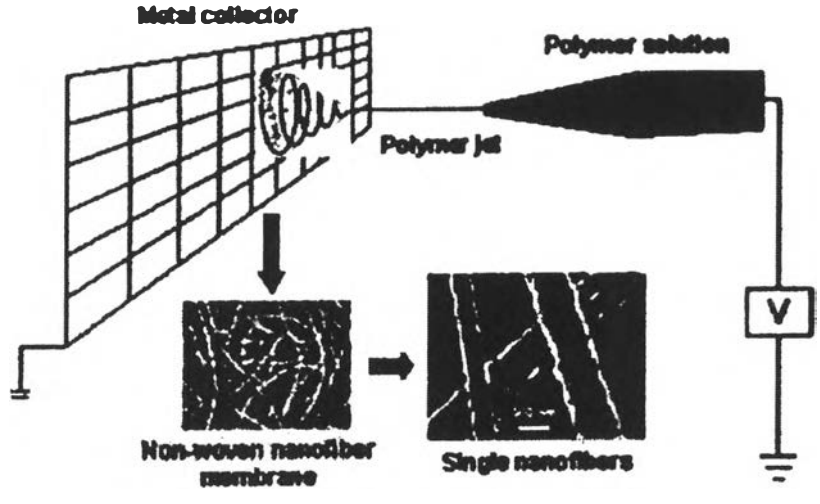

Figure 2.1 Schematic diagram to show polymer nanofibers by electrospinning.

The electrostatic field is subjected to the end of the capillary tube that contains the solution fluid held by its surface tension. This induces a charge on the surface of the liquid. Mutual charge repulsion and the contraction of the surface charges to the counter electrode cause a force directly opposite to the surface tension (Fang X, 1997).

In general, the experimental setup can be divided into two types based on direction of polymer supplying nozzle including horizontally and vertically. The two kinds of polymer supplying nozzle are glass pipette and metal needle. For the experimental setup where glass pipette is used, the external potential was supplied by directly inserting a metal electrode to the capillary tube filled with a polymer solution (Reneker, 1995). Schematic drawing of this is shown in Figure 2.1. In case of the metal needle setup, the external potential was attached outside of the metal needle (Baumgaten, 1971, Norris, 2000).

Screens of different geometry were used as collecting devices for the charge fibers such as metal sieve, even metal screen. Recently, Warner *et al.* (2000) developed a novel rotor electrospinning unit to produce the first yarns (see Figure 2.2). This unit is capable of spinning from multiple spinners simultaneously. A rotating collector provides a mechanism for continuous removal of the non-woven fabric as a yarn.

2.1.2 Polymer Types

Many kinds of polymer have been successfully produced by electrospinning process from polymer solution and melts (Lorrando, 1981). At least 20 polymers have been electrospun in laboratory of Reneker *et al.* (1996). These are polyethylene oxide (PEO), which is the most often used to study parameters influencing the process, textile fiber polymers such as nylon, high performance polymers such as polyimide, and biopolymers including DNA (Fang, 1997). In addition, liquid crystal polymers such as polyaramid and polyaniline which is an electrically conducting polymer have also been successfully electrospun by this group. Moreover, polymer blends, for example, polyaniline/polyethylene oxide (Norris, 2000), can be produced by this process as well.

The list of other polymers that have already been electrospun are as followings: polyethylene, polypropylene (Lorrando,1981), polyamid acid, poly-gamma-benyzyl-glumate, poly(ethylene terephthalate), Nylon 6-polyimide, polyhydroxybutyratevalerate, polyetherimide,

polyferrocenyldimethylsilane, polyacrylonitrile, poly (p- phenylene terephthalamide) (Reneker, 2000), Nylon6-montmorillonite nanocomposite (Fong, 2002), and poly (D, L-lactic acid)(Zong, 2002).

Baumgarten (1971) spun fibers measuring less than 1 μm in diameter by electrostatic means from dimethyl formamide (DMF) solution of acrylic resin. High-speed photographs showed that a single fiber was drawn out from the electrically charged drop, which was suspended from a metal capillary. The effects on diameter and jet length of solution viscosity, surrounding gas, flow rate, voltage, and geometry were determined. With pure DMF, fine droplets were formed. Fiber formation started with a 7.5 wt% solution (1.7 poise) and continued to 20 wt% (215 poise). With 17.5 and 20 wt%, however, drying of the fiber was incomplete, and the fiber began to stick to itself in mid air. Fiber diameter increased with solution viscosity.

2.1.3 Microstructure and Morphology

The microstructure and morphology of electrospun fiber were investigated by scanning electron microscope (SEM), differential scanning calorimetry (DSC), synchrotron wide-angle X-ray diffraction/small angle X-ray scattering (Zong, 2002), atomic force microscopy (AFM) (Jeager, 1996), TEM (Buchko, 1999). and wide-angle X-ray scattering (WAXS) (Buchko, 1999). Baumgarten (1971) electrospun polyacrylonitrile from solution but did not characterize the molecular orientation of fiber.

In 1996, Jeager et al. observed the surface morphology of electrospun PEO by using AFM and also optical microscope to investigate the birefingence. They reported that, at the molecular level, the electrospun PEO fibers possess a highly ordered surface layer and the chain direction of the molecules was parallel to the fiber direction.

This property was also found in other electrospun fibers, for instance, semi-crystalline poly (D, L-lactic acid) exhibited non-crystalline but highly oriented chain when characterized by DSC and XRS (Zong, 2002), nylon displayed molecular orientation along the fiber axis but it was not uniform (Buchko, 1999), while electrospun SLPF thin films were not well

orientated. In addition, Buchko et al. (1999) suggested that thermal and solvent annealing could be a method for increasing the crystallinity of electrospun fibers.

2.1.4 Applications

The process that generates ultrafine fibers by using electrostatical field ("electrospinning") was discovered by Zeleny (1914). However, this process has just received a great deal of attention in the last decade. Because of the small fiber diameters, electrospun textiles inherently possess a very high specific surface area and small pore size. These properties make electrospun fabrics interesting candidates for a number of applications.

One of the most important applications of traditional (micro-size) fibers, especilally engineering fibers such as carbon, glass, and Kevlar fibers, is to be used as reinforcements in composite developments (Chand S, 2000). With these reinforcements, the composite materials can provide superior structural properties such as high modulus and strength to weight ration, which generally cannot be achieved by other engineered monolithic materials alone.

Other application fields based on electronspun polymer nanofibers have been steadily extended especially in recent years. One of the best representatives in this regard is shown by relevant US patents, in which most applications are in the field of filtration systems and medical prosthesis mainly grafts and vessels. Other applications which have been targeted include tissue template, electromagnetic shielding, composite delamination resistance, and liquid crystal device. A schematic diagram illustrating these patent applications is shown in Figure 2.2 More extended or perspective application areas are summarized in Figure 2.3.

They are high performance filters i.e., dust collecting system and air filter (Emig, 2002), soldier protective clothing (Gibson, 1999), biomedical application including scaffolding for tissue growth (Vyakarnam, 2001), drug delivery system and wound dressing materials (Doshi, 1995; Huang, 2001), electronic applications (Norris, I.D., 2000), composite reinforcement (Dzenis,

2001; Doshi, 1995), the design of solar sails, light sails, and mirrors for use in space, the application of pesticides to plants and as structural elements in artificial organs (Reneker, 2000).

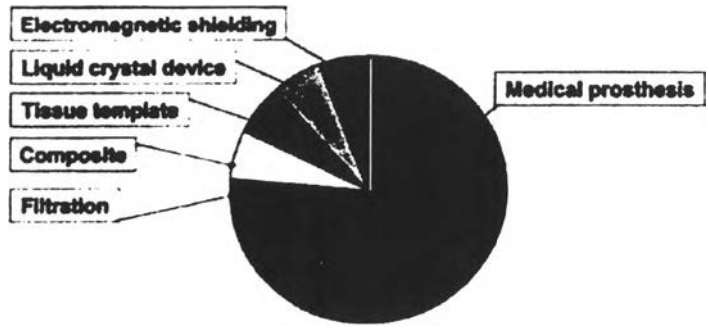

Figure 2.2 Application fields targeted by US patents on electrospun nanofiber.

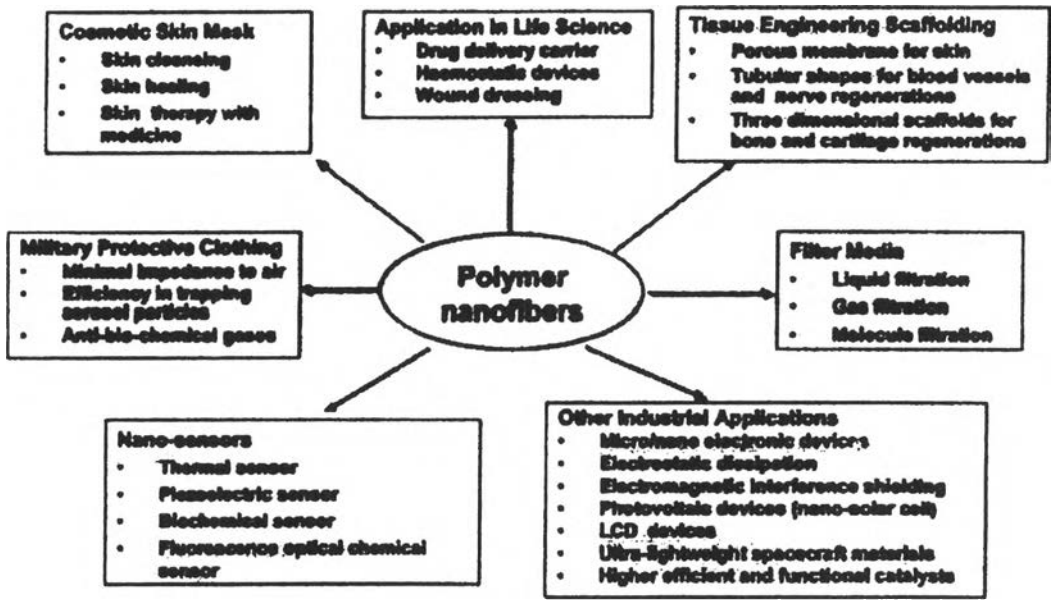

Figure 2.3 Potential applications of electrospun polymer nanofibers.

It should be realized that most of these applications have not reached their industry level, but just at a laboratory research and development stage. However, their promising potential is believed to be attracting attentions and investments from academia, governments, and industry all over the world.