CHAPTER I
INTRODUCTION

Electroactive materials can be utilized in various forms such as artificial muscles, muscle/insect-like actuators, and robotics (Krause *et al.*, 2001). They have recently received much attention and continuously developed since these materials can converse electrical energy into mechanical energy. Electroactive polymers, belonging to a type of electroactive materials, offer novel characteristics such as light weight, flexibility, and high energy density. Elastomer, a dielectric material, is one type of electric-field-activated electroactive polymers. It is capable of producing fast response, large strains, and relatively high efficiency (Kornbluh *et al.*, 2002).

Therefore, several elastomers have been used as the dielectric elastomer. Polyisoprene has many advantageous characteristics such as flexibility, low swelling in water, high tensile strength, good resilience, high tensile, and well behaved hysteresis. These characteristics are important to induce large actuation strain when polyisoprene is subjected to an electric field. Nevertheless, crosslinking is required to obtain those properties of polyisoprene (Puvaratvttana *et al.*, 2006) through a difficult process. Thus, using styrene-isoprene-styrene triblock copolymer (SIS) is an interesting and alternative material. SIS is a thermoplastic elastomer, which is a composite material of two immiscible polymer phases. It also has hard and glassy domains of styrene acting as the reinforcing phase within the soft and rubbery isoprene matrix; therefore it can increase the modulus and the yield strength relative to polyisoprene alone. Moreover, SIS has elastomeric properties of crosslinked rubber that can easily be processed by conventional processing. The separation of two different polymer segments into two phases causes various resultant morphologies such as lamella, cylindrical, and micellar which could be obtained from variety of techniques such as adding its homopolymer, melting, shearing, different cast solvents (Wang *et al.*, 2001) and solvent casting of different copolymer compositions (Winter *et al.*, 1993). The last one is a widely used technique to prepare those morphologies. But why do we need distinct morphologies? It is because the morphology affects mechanical properties.

Recently, the blending of dielectric elastomers with conductive polymers has been investigated towards many applications. For instances, the polyaniline-polyisoprene blend film for selective determination of H_2O_2 detection biosensor (H. Xue *et al*., 2001), the blending of polyaniline/EPDM elastomer to improve thermal stability (Schmidt *et al.*, 2004), a solid state actuator based on the PEDOT/NBR system (Cho *et al.*, 2006), and the blended polythiophene/polyisoprene elastomer for electroactive actuator application (Puvaratvattana *et al.*, 2006) are just a few. There are many possible conductive polymers that can be used. Polydiphenylamine is an interesting conductive polymer since it has a molecular structure similar to polyaniline. It also can be easily synthesized by oxidative polymerization and easily doped with the acid solution of pH below 6.

In our work, we are interested in developing and testing blended polydiphenylamine/SIS thermoplastic elastomer for actuator applications. The mechanical properties, viscoelastic properties, and electrical properties will be investigated in terms of morphologies and polydiphenalamine particle concentration, and electric field strength.

THEORETICAL BACKGROUND

Conductive Polymers

Conductive polymers are organic materials that generally are comprised of C, H and simple heteroatoms such as N and S. which consisting of unique π-conjugation electrons. The materials differ from typical organic polymers due to their unique π-conjugation electrons properties which impart higher electrical conductivity at room temperature on oxidation or reduction than ordinary polymers that are usually insulating materials relative to metals such as copper (Chandrasekhar, 1999; Deependra *et al.*, 2004). The conductive polymers were discovered when Shirikawa and coworkers accidentally discovered and developed an electrically conductive polymer, polyacetylene, which was found to exhibit an increase in electrical conductivity when subjected to iodine vapor. Polyacetylene remains the most crystalline conductive polymer, but it can undergo an oxidation by the oxygen in air and it is sensitive to humidity.

Other conductive polymers studied extensively since the early 1980s include polypyrrole, polythiophene, polyphenylenevinylene, and polyaniline. Polypyrrole and polythiophene have been of interest more than polyacetylene because they can be synthesized directly in the doped form and are very stable in air (Kumar and Sharma, 1998; Chandrasekhar, 1999; Deependra *et al.*, 2004). Conductive polymers are widely used in a great number of applications because of their several advantages: low density and cost, ease of processing, relative robustness, and lightweight. Conductive polymers have been developed commercially towards gas sensing, light-emitting cells and diodes, rechargeable batteries, electronic cells, controlled-release applications, actuators, and polymeric electronics such as transistors (Van Vught *et al.*, 2000).

Polydiphenylamine is conductive polymer which can be synthesized by the electrochemical method or be the oxidative polymerizations. It consists of *N*-substituted and π-conjugation as the following (Suganandam *et al.*, 2005 ;Wen *et al.*, 2002).

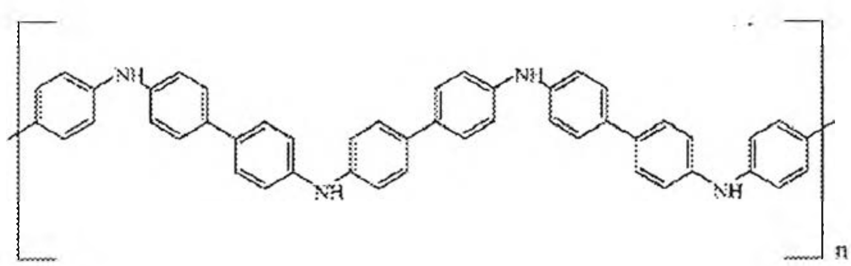

Figure1.1 Polydiphenylamine in neutral form.

The significant characteristic of all conductive polymers or polydiphenylamine is the conjugated structure. The conjugation length is an important parameter influencing the conductivity due to the carrier mobility (related to conductivity) which increases with increasing conjugation length. The conduction mechanism of all conductive polymers is divided into two paths: charge carriers move along the extent of the π-conjugated system backbone (intrachain conductivity); or they move between the individual molecules (interchain conductivity). The conjugational defects or charge carriers are formed through solitons, polarons or bipolarons in the polymer chain when these conductive polymers are exposed to oxidation/reduction condition or doping. In case of polydiphenylamine, it can be synthesized directly in the doped form or easily doped with HCl solution to obtain polaron or bipolaron forms as the following Figure 1.2 and Figure 1.3.

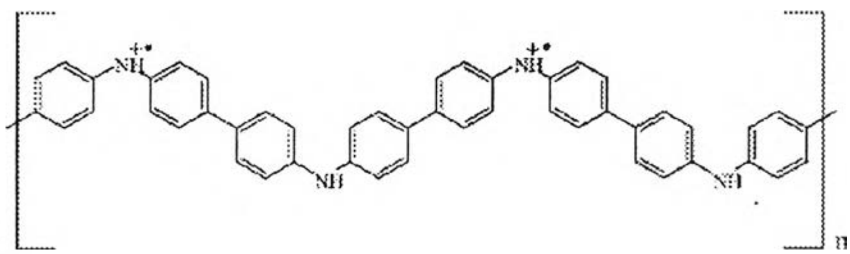

Figure 1.2 Polydiphenylamine in the polaron form.

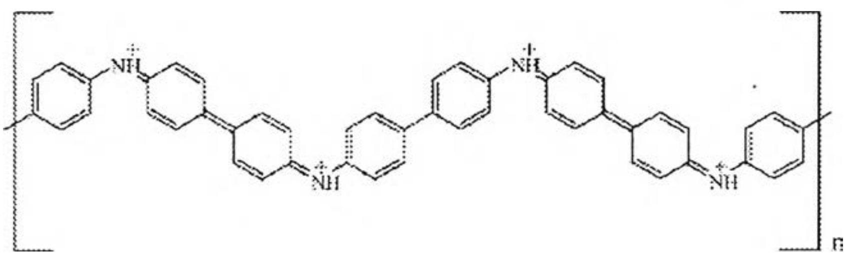

Figure 1.3 Polydiphenylamine in the bipolaron form.

Styrene-Isoprene-Styrene triblock copolymer

SIS belongs to a thermoplastic elastomer which has elastomeric properties of crosslinked rubber but it can easily be processed by a conventional processing as the thermoplastics polymer. The separation of two different polymer segments of polystyrene(hard) and polyisoprene(soft) into two phases causes various morphologies to appear such as lamella, cylindrical, and micellar. The different morphology can be obtained by using SIS with a suitable styrene content. The morphology affects their mechanicals properties because the styrene phase acts as a reinforcer in the soft segment of isoprene (Wang *et al.*, 2001).

OBJECTIVES

To investigate the electromechanical properties of styrene-isoprene-styrene triblock copolymer (SIS) under the influences of different morphologies and electrical field strengths. To fabricate Polydiphenylamine/SIS blends blends as a substitute for artificial muscles, which can be precisely controlled by electric field strength. Mechanical properties, viscoelastic properties and electrical properties of these blends will be investigated under various conditions.

SCOPE OF RESEARCH WORK

1. Study of electromechanical properties of styrene-isoprene-styrene triblock copolymer (SIS) films of three different morphologies: lamella, cylindrical, and micellar. The films are prepared from solvent casting by using toluene as a solvent.
2. PDPA will be synthesized and blended with SIS in various concentrations. The blended-polymers will be cast into films in order to study the effect of conductive polymer concentration on the electromechanical properties.