CHAPTER I
INTRODUCTION

The exchange of electrical energy for mechanical energy has been of scientific and technological interests for many decades. Electromechanical energy conversion has been applied in many applications such as muscle/insect-like actuators, robotic, etc (Wichiansee *et al.*, 2009). The development of electroactive materials for artificial muscle or actuator is very attractive because it has many advantages. First, the electroactive biomaterials resemble natural living tissues more than any other class of synthetic biomaterials because to their high water contents, soft consistency, and their activation mode. Secondly it is biocompatible and not biodegradable. Thirdly, their physical and chemical properties vary with composition and can be tailored as desired. Fourth, they can take various shapes and they are a low-cost material.

Previously, electroactive materials are made from metal alloys or electroceramics, in which have high thermal stability and high mechanical properties. But metal alloys and electroceramics have high weight, high cost and low corrosive resistance which limit artificial muscle applications. The new classes of electroactive material are the conductive polymers and carbon nanofillers. Conductive polymers are lighter and their potential striction capability is superior to that of electroceramics. Moreover, their response time is significantly shorter than those alloys (Cohen, 1997). Conductive polymers (CPs) have been extensively studied as they provide a unique class of material. Polypyrrole (PPy) is one of many important CPs with high electrical conductivity, good stability in air, nontoxicity. It has been used in the preparation of nanoparticles with some degree of success (Wang *et al.*, 2005).

Carbon based nanomaterials ,such as carbon nanotubes (CNTs), graphene, graphite, carbon black, and etc, have been used in various actuator application. CNTs and graphene are very promising nanofiller in this field due to high electrical conductivity, good thermal properties, high surface area, and great mechanical strength (Kuilla *et al.*, 2010; Sengupta *et al.*, 2011)

Nanoscale actuators are required for the development of nanorobots and other nanoelectromechanical systems (NEMS) of the future. Actuators based on electrochemically-induced volumetric changes in electroactive polymers (EAPs) have been demonstrated at the macro and microscales, and have been usedas artificial muscles and other applications (Carpi, 2003).

Gelatin is a one of viscoelastic materials derived from partial hydrolysis of native collagens, which are the most abundant structural proteins found in the animal body of skin, tendon, cartilage and bone (Ward, 1977). Viscoelastic properties are often used to refer to the material chemical-microstructural relationship, as viscoelastics involve both solid-state and liquid-like behaviors (Mayer and Chawla, 2009). Therefore, studies of viscoelastic materials, including stress relaxation, deformation, mechanical properties, swelling, stability, and etc (Zhang *et al.*, 2008), are so important properties for actuator application as well.

Stress relaxation is the decrease in an internal stress when a material is held at a constant and finite strain. When an external strain is introduced to an elastic material, the applied strain causes a reversible deformation, and when the strain is removed, the residual stress rapidly relaxes to zero. Most materials are viscoelastic; when the material is subjected to an external strain, a stress is generated within the material and the generated stress relaxes through the process of stress relaxation (Matsuoka, 1992).

In this work, various types of nano-reinforcement and gelatin hydrogel composites were investigated as candidates for bio-actuators. The mechanical properties, viscoelastic properties, and electrical properties were investigated in terms of nano-reinforcement concentration, electric field strength, and temperature. Also, in the stress relaxation behavior was investigated as an important property for viscoelastic materials. Uncrosslinked and crosslinked gelatin hydrogels were prepared by adding a glutaraldehyde solution into a gelatin solution followed by a casting method. Stress relaxation functions of the uncrosslinked and crosslinked gelatin hydrogels were measured to study the effects of electric field strength and the crosslinking ratio.

Scope of Research Work

Research Work 1: Improvements of Electromechanical Properties of Gelatin Hydrogels by Blending with Nanowire-Polypyrrole: Effects of Electrical Field and Temperature

Nanowire PPy was synthesized by chemical oxidation polymerization. The resulting conductive polymer was embedded in gelatin solution by using dodecylbenzene sulfonic acid (DBSA) as a dispersant. The nanowire PPy/gelatin hydrogels were fabricated by solvent casting. The samples were characterized through solid rheometer in the influence of electric field strength and temperature on the elctromechanical properties.

Research Work 2: Stress Relaxation Behavior of (Ala-Gly-Pro-Arg-Gly-Glu-4Hyp-Gly-Pro-) Gelatin Hydrogels under Electric Field: Time-Electric Field Superposition

The stress relaxation behavior of gelatin (Ala-Gly-Pro-Arg-Gly-Glu-4Hyp-Gly-Pro-) was investigated under the effect of degree of crosslinking and applied electric field strength. The characteristic relaxation time can be estimated by three methods; KWW; the dynamic crossover; and the relaxation time distribution spectrum $H(\tau)$. The horizontal shift factors ($a_{E,exp}$) were experimentally obtained from both the stress relaxation function and the storage–loss moduli at various electric field strengths. These experimental shift factors ($a_{E,exp}$) allow the time–electric field superpositions of the moduli and the stress relaxation function to be possible. Furthermore, it will be shown that $a_{E,exp}$ could be calculated by the calculated shift factor ($a_{E,cal}$), obtained from the ratio of the effective time scales incorporated with the material constant (c_τ).

Research Work 3: Electromechanical properties of multi–walled carbon nanotube/gelatin hydrogel composites: Effects of aspect ratios, electric field, and temperature

The effects of multi-walled carbon nanotube (MWNT) aspect ratios, electric field strength, and temperature were studied on electromechanical properties of

MWNT/gelatin hydrogel composites; the srorage modulus response ($\Delta G'$). the storage modulus sensitivity ($\Delta G'/G'_o$), the bending distance (d), the bending angle (θ), and the dielectrophoresis force (F_d).

Research Work 4: Graphene/gelatin hydrogel composites with high storage modulus sensitivity for using as actuator: Effects of surface areas and electric field strength

The electromechanical properties of graphene/gelatin hydrogel composites were investigated under the effects of graphene surface areas, electric field strength and temperature to enhance sensing of materials for actuator application: the srorage modulus response ($\Delta G'$), the storage modulus sensitivity ($\Delta G'/G'_o$), the bending distance (d), the bending angle (θ), and the dielectrophoresis force (F_d).