풀러린으로 강화된 셀룰로우스 아세테이트 기반의 나노 복합 작동기

Nano-Composite Actuator Based on Fullerene-Reinforced Cellulose Acetate

*이가 [1], 김시습 [1], 기창두 [1], 양성모 [2], #오일권 [3]
*Jia Li[1], S.S.Kim[1], C.D.Kee[1], S.M.Yang[2], #I.K.Oh(ikoh@kaist.ac.kr)[3]
[1] 전남대학교 기계공학부, [2] 전북대학교 기계공학부, [3]KAIST

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1. INTRODUCTION

Cellulose-based electroactive papers(EAPap) has been studied as a smart material for artificial muscles due to its fascination in terms of light weight, biodegradability, low lost, large displacement output, low actuation voltage and low power consumption. the pure cellulose actuator have shown limited bending displacement and force compared with the other smart materials. Our previous work have employed bacterial cellulose actuator with electrically driven bending deformation in hydrated condition[1].

In order to improve actuation and bending of cellulose, many researchers 'doped' the polymers with metal particles, such as carbon nano-tubes(CNT), carbon nano-fibers), fullerenes(C_{60}) and grapheme, etc. Benning and coworkers[2] discovered that the C_{60} fullerene and single wall carbon nano-tubes opened the possibility for a new class of smart materials based on nano-scale materials because of their remarkable physical properties of mechanical, electrochemical, and so on.

Fullerene have many interesting properties, such as high surface area, porosity, thermal stability, bio-compatibility, and hydrophilic fictionalization. So they have been used in our previous work on actuator based on fullerene-reinforced Nafion.

Ionic polymer metal composites(IMPC) are a class of EAPs that are well suited for a variety of application due to their electromechanical coupling capabilities. These ionomer-based actuators offer the capacity to convert energy between electrical and mechanical domains. Therefore, research on IPMC actuators for bio-mimetic and medical applications have been reported[3].

In this manuscript we report novel electrospun cellulose acetate dry actuators. Addition of minute quantities(0.1 and 0.5 wt%) of fullerenols(hydroxy terminated fullerenes) improved the electro-chemical properties of the electrospun nano fibers(Fig.1). This manuscript is also the first report of its kind on electrospun fullerene/polymer nanocomposites. Consequently an indepth study of structure-property characteristics is also reported. Stress-strain tests, thermal characterization by TGA and DSC are also reported.

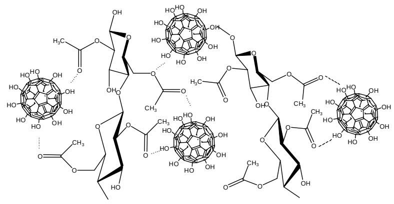

Fig.1. The linkage of CA with fullerene chain

2. EXPERIMENT DETAILS

2.1 Preparation of CA fullerene membrane via el ectrospinning

Cellulose Acetate(CA;white powder;M_n~30,000 by GPC, 39.8% acetyl groups) was purchased from Sigma-Aldrich. N,N-Dimethylacetamide (DMAc; Assay:99.0%) and Fullerene C_{60} were purchased from Sigma-Aldrich and used as received. Cellulose

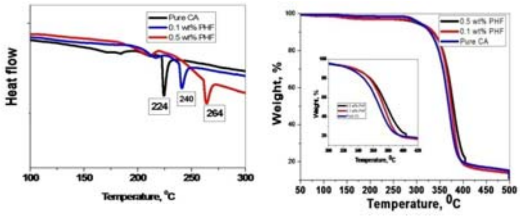

Fig.2. (a) DSC spectrum of CA-Fullerene (b) TGA analysis of CA and CA-Fullerene

acetate was dissolved in DMAc/Acetone (2:1 v/v) and further stirred to give a transparent solution at the room temperature (20wt/v%). After that, 0.1wt.% and 0.5wt.% fullerene were added respectively, homogenized the solution by using ultrasonic cleaner. A syringe pump was used to squeeze out the solution at speed of 2ml/h through a needle with an inner diameter of 0.21mm. The distance between the needle and the collector is 15cm and the voltage was 25kv that have been used to obtain a membrane with a thickness of 100μm. The membranes were immersed overnight in 1.5N aqueous solution of lithium chloride for surface modification can be attributed to the higher metal ion uptake and a decrease in the crystalline content.

2.2 Characterization of CA

To observe the electrochemical properties for cellulose acetate membranes, its ionic conductivity was calculated by measuring the resistance of each sample using a Zahner Electric IM6e impedance analyzer under the maximum voltage of 10mV at excitation frequency of 10Hz to 1MHz. The membranes 2.0cm ×2.0cm and two stainless steel electrodes were set in a Teflon cell. The distance between the two electrodes was 2.0cm.

In order to compare the textural structures, thermal property, and crystallinity of the CA that underwent the LiCl treatment, SEM (scamming electron microscope), TGA-50A thermo gravimetric analysis, and DSC-60A differential scanning calorimeter.

3. CONCLUSIONS

In this study, the cellulose acetate fullerene actuator with bio-compatible and biodegradable properties was newly developed as an electro-active biopolymer

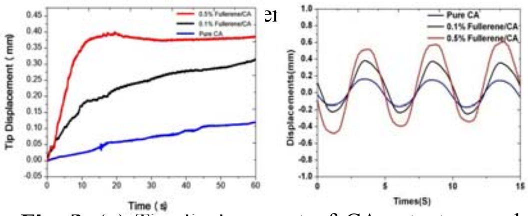

Fig. 3. (a) Tip displacement of CA actuators under DC (b) Harmonic responses of CA actuator

air. Marginal increase in thermal stability was observed in DSC(Fig.2(a)) and TGA(Fig.2(b)) tests. Our results show nearly three fold increase in tip displacement even with 0.5 wt% fullerenes under both DC(Fig.3(a)) and AC(Fig.3(b)) conditions. Present results show the potential of the bacterial cellulose as electro-active biopolymers in the air environments for implantable biomedical devices and confirmed that the LiCl treated cellulose acetate-fullerene can be adjusted to get better actuation performance by controlling the crystallinity.

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