

**DEVELOPMENT OF DIELECTRIC ELASTOMERS AND BLENDS FOR
ACTUATOR APPLICATIONS**



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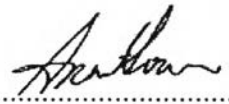
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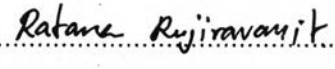
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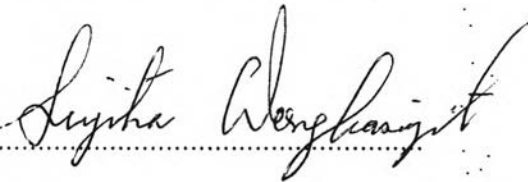

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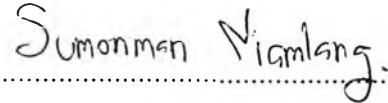
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ABSTRACT

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Keywords: Poly(p-phenylene)/Dielectric Elastomers/Actuator/ Electromechanical properties/Dielectrophoresis Force/Dielectric Constant/Electrostriction

This study evaluated and characterized the many types of dielectric elastomers and poly(p-phenylene)/dielectric elastomers blends towards the electroactive application. Dielectric elastomers films and AR71/PPP blends were prepared and investigated as an electroactive polymer. The acrylic elastomers (AR70, AR71, AR72) possess linearly positive storage modulus responses or sensitivities with increasing temperature and dielectric constant. On the other hand, the styrene copolymers (SAR, SBS, SIS) attain the maximum storage modulus responses or sensitivities at the glass transition temperature of the hard segments. For AR71/PPP blends, the dynamic moduli, G' and G'' of each blend, are higher than those of pure AR71. In addition, The effects of dielectric constant and DC/AC electric field strength on the deflection angle and the dielectrophoresis force of acrylic elastomers and styrene copolymers were investigated. As a DC electric field is applied, five elastomers, with the exception of SAR, deflect towards the anode side of the electrodes. For these elastomers, internal dipole moments are generated under electric field leading to the attractive force between the elastomers and the anode. SAR contains metal impurities (Cu and Zn) as determined by EDX. Their presence introduces a repulsive force between the Cu^{2+} and Zn^{2+} ions and the anodic electrode, leading to the bending towards the neutral electrode. The dielectrophoresis forces of the six elastomers generally increase with increasing electric field strength, and increase monotonically with the dielectric constants. For an AC electric field, the deflection angle and the dielectrophoresis force increase with amplitude but decreases with increasing frequency under AC electrical field. The optimum thickness

for acrylic elastomer is 0.25 mm which gives the highest deflection angle and force. For AR71/doped PPP blends, the cut-off frequency of each blend are higher than those of pure AR71. The conductive particles act as a filler and can be used to improve the electromechanical responses at high frequency.

บทคัดย่อ

รักษพงษ์ คุณานุรักษ์พงษ์: การพัฒนาขางไดอิเล็กทริกและพอลิเมอร์ผสมสำหรับประยุกต์เป็นแอกชูเอเตอร์ที่ตอบสนองต่อสนามไฟฟ้า (Development of Dielectric Elastomers and Blends for Actuator Applications) อ.ที่ปรึกษา: รศ. ดร. อนุวัฒน์ ศิริวัฒน์ 238 หน้า

ในงานวิจัยนี้เป็นการศึกษาถึงการนำขางไดอิเล็กทริกชนิดต่างๆและพอลิเมอร์ผสมระหว่าง ขางอะคริลิกและพอลิฟาราฟินีน สำหรับประยุกต์เป็นแอกชูเอเตอร์ที่ตอบสนองต่อสนามไฟฟ้า จากการทดลองพบว่าค่าการตอบสนองต่อมอดูลัสเฉือนและความว่องไวในการตอบสนองของมอดูลัสเฉือนของขางอะคริลิกทั้งสามชนิด จะมีค่าเพิ่มขึ้นตามการเพิ่มของอุณหภูมิ ในการทดลองและค่าคงที่ไดอิเล็กทริกของขาง ในทางตรงกันข้ามค่าการตอบสนองต่อมอดูลัสเฉือนและความว่องไวในการตอบสนองของมอดูลัสเฉือนของขางผสมที่มีสไตรีนเป็นส่วนประกอบทั้งสามชนิดนั้น จะมีค่าสูงที่สุด ณ อุณหภูมิทรานซิชันของส่วนแข็งในเนื้อขาง ในกรณีของพอลิเมอร์ผสมระหว่างขางอะคริลิกและพอลิฟาราฟินีนนั้น ค่ามอดูลัสเฉือนแบบสะสมและแบบสูญเสียบของพอลิเมอร์ผสมจะมีค่าสูงกว่าในกรณีของขางอะคริลิกบริสุทธิ์เสมอ นอกจากนี้ยังพบว่า ในการทดลองวัดค่าการบิดเบนภายใต้สนามไฟฟ้าแบบตรงและการคำนวณหาค่าแรงไดอิเล็กโตรโพลีซิส จะพบว่าค่าการบิดเบนภายใต้สนามไฟฟ้าและค่าแรงไดอิเล็กโตรโพลีซิสจะเพิ่มขึ้นตามการเพิ่มของความเข้มสนามไฟฟ้า และเพิ่มขึ้นตามการเพิ่มของค่าคงที่ไดอิเล็กทริกของขาง ไดอิเล็กทริก นอกจากนี้ยังพบอีกว่า เมื่อให้สนามไฟฟ้าแก่ขาง ขางทุกชนิดจะบิดเข้าไปหาขั้วแอโนดเสมอๆ ยกเว้นขางสไตรีน-อะคริลิก ที่เบนเข้าหาขั้วกลาง ซึ่งจากการศึกษาองค์ประกอบของขางด้วยเทคนิค อีดีเอกซ์ จะพบว่าในขางสไตรีน-อะคริลิกนั้นมีการปนเปื้อนด้วยธาตุ ทองแดง และ สังกะสี อยู่ซึ่งส่งผลกระทบต่อทิศทางการบิดของตัวขางภายใต้สนามไฟฟ้านั้นเอง ในการทดลองต่อมา ทางผู้ทดลองได้ทำการวัดค่าการบิดเบนภายใต้สนามไฟฟ้าแบบสลับและการคำนวณหาค่าแรงไดอิเล็กโตรโพลีซิส จากการทดลองพบว่า ค่าการบิดเบนภายใต้สนามไฟฟ้าและค่าแรงไดอิเล็กโตรโพลีซิสจะเพิ่มขึ้นตามการเพิ่มของขนาดสนามไฟฟ้าแบบสลับ แต่จะมีค่าลดลงตามการเพิ่มของความถี่ของสนามไฟฟ้าสลับ เนื่องมาจากขางไม่สามารถตอบสนองต่อความถี่ได้ทันนั่นเอง จากการทดลองปรับค่าความหนาของชิ้นงานเพื่อหาค่าที่เหมาะสมที่สุดจะพบว่า ที่ความหนาของขางอะคริลิกเท่ากับ 0.25 มิลลิเมตร จะให้ค่าการบิดเบนภายใต้สนามไฟฟ้าและค่าแรงไดอิเล็กโตรโพลีซิสสูงที่สุดในกรณีของพอลิเมอร์ผสมระหว่างขาง

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ABBREVIATION

ER	Electrorheology
DC	Direct current
AC	Alternate current
PPP	Poly (p-phenylene)
AR	Acrylic elastomers
SAR	Styrene-acrylic copolymers
SIS	Styrene-isoprene-styrene triblocks copolymers
SBR	Styrene-butadiene rubber
FT-IR	Fourier transform infrared spectrometer
UV-Vis	Ultraviolet-visible spectrometer
TGA	Thermogravimetric analysis
EDX	Energy dispersive X-ray spectroscopy
SEM	Scanning electron microscopy

LIST OF SYMBOL

E_0	applied electric field strength
G'	storage modulus (Pa/s)
G''	loss modulus (Pa/s)
t_{ind}	induction time
t_{rec}	recovery time
ϕ	volume fraction
σ	electrical conductivity
ϵ'	dielectric permittivity
ϵ''	dielectric loss
R	resistant
t	film thickness
K	geometric correction fractor
β	relative polarizability
K_f	dielectric permittivity of medium
η^*	complex oscillatory steady shear viscosity
ω	frequency
F_e	elastic force
F_d	dielectrophoresis force
E	Young's modulus
l_0	initial length of specimens
l	length of specimens
I	moment of inertia