

**DEVELOPMENT OF SOFT AND FLEXIBLE
CONDUCTIVE POLYMER FOR ACTUATOR APPLICATIONS**

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ABSTRACT

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In this study, polyaniline (PANI) was synthesized via oxidative coupling polymerization in acid conditions and its conductivity was controlled by doping in camphorsulfonic acid (CSA) solution and de-doping in solution of ammonia. Under oscillatory shear, the dynamic moduli, G' and G'' , dramatically increase and the suspensions of PANI/silicone oil reach liquid to solid transition occurs at a critical electric field strength, whose value depends on particle concentration and host fluid viscosity as well as the shearing amplitude and the shearing frequency. The critical dimensionless parameter, the Mason number (Mn), varies with Peclet number (Pe) at the critical point according to a scaling relation $Mn \sim Pe^{0.091}$. The formation structure has a static yield strength τ_y , whose value scales with electric field strength as $\tau_y \sim E^{1.88}$. When the field is switched off a residual structure remains, whose yield stress increases with the strength of the applied field and particle concentration. The creep response of the suspensions was also studied. Creep resistance of the suspensions generally increases with the effects of electric field strength, particle concentration, and operating temperature. Electromechanical response of camphorsulfonic acid (CSA) – doped polyaniline (PANI) particles embedded in an elastic cross-linked PDMS matrix on the effects of electric field strength, particle concentration, and operating temperature was finally studied.

บทคัดย่อ

ปัญหา ที่เกี่ยวข้อง : การพัฒนาพอลิเมอร์นำไฟฟ้าสำหรับประยุกต์เป็นแอกชูเอเตอร์ (Development of Conductive Polymer for Actuator Applications) อ. ที่ปรึกษา : รศ.ดร. อนุวัฒน์ ศิริวัฒน์ และ ศ.ดร. อเล็กซานเดอร์ เอ็ม จาไมซัน 150 หน้า

ในงานวิจัยนี้ อนุภาคพอลิอะนิลีน ได้ถูกสังเคราะห์ด้วยการพอลิเมอร์ไรซ์แบบออกซิเดทีฟ ค่าการนำไฟฟ้าของอนุภาคจะถูกควบคุมโดยกระบวนการการโคปและดีโคปซึ่งหมายถึงกระบวนการเชื่อมต่ออนุภาคในสารละลายกรดแคมฟอร์ซัลโฟนิคแอซิดและด่างโซเดียมไฮดรอกไซด์ จากการทดลองภายใต้แรงเฉือนแบบกลับ ไปกลับมา พบว่าของไหลดังกล่าวแสดงสมบัติวิสโคอีลาสติก โดยค่าสตอเรจและลอสสมอดูลัสมีค่าเพิ่มขึ้น และเมื่อเพิ่มความแรงของสนามไฟฟ้าเมื่อให้สนามไฟฟ้ามีความแรงมากพอ พฤติกรรมของของไหลพอลิอะนิลีนจะเปลี่ยนไป โดยเปลี่ยนจากของไหลที่มีสมบัติคล้ายของเหลวเป็นของไหลที่มีสมบัติคล้ายของแข็งขึ้นอยู่กับความเข้มข้นของอนุภาคในสารแขวนลอย ความหนืดของซิลิโคนออกไซด์ รวมทั้งแรงเฉือนและความถี่ในการให้แรงเฉือนกับระบบ โดยได้มีการศึกษาค่าตัวแปรไร้นามสองตัวคือ ค่าตัวเลขเมสัน และ ค่าตัวเลขเพคเลต์ ณ จุดวิกฤตที่เกิดการเปลี่ยนแปลงดังกล่าวด้วย ภายใต้แรงเฉือนแบบต่อเนื่อง พบว่า ของไหลมีพฤติกรรมแบบของไหลบิงแฮมภายใต้สนามไฟฟ้าโดยจะมีค่าความเค้นวิกฤตค่าหนึ่งซึ่งมีความสัมพันธ์กับความแรงของสนามไฟฟ้าเป็นฟังก์ชันยกกำลัง โดยเลขดัชนีชี้กำลังของความสัมพันธ์ระหว่างค่าความเค้นวิกฤตและความแรงของสนามไฟฟ้ามีค่าเท่ากับ 1.88 จากการทดลองเปิด-ปิดสนามไฟฟ้าสลับไปมาพบว่าโครงสร้างสายโซ่ของอนุภาคที่จัดเรียงตัวกันภายใต้สนามไฟฟ้านั้นยังคงสภาพอยู่บางส่วน นอกจากนี้ยังได้ศึกษาปัจจัยด้านความเข้มข้นของสนามไฟฟ้า ปริมาณอนุภาค และอุณหภูมิที่มีผลต่อการเกิดครีปของสารแขวนลอย และสุดท้ายได้เปลี่ยนตัวกลางจากน้ำมันเหลวเป็นตัวกลางที่มีเป็นยางมีความอ่อนนุ่ม โดยผสมผงอนุภาคพอลิอะนิลีนที่โคปด้วยกรดแคมฟอร์ซัลโฟนิคแอซิดในยางพอลิไดเมทิลไซลลอกเซน และศึกษาการตอบสนองของสารผสมดังกล่าว ภายใต้สนามไฟฟ้า

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ABBREVIATIONS

ER	Electrorheology
DC	Direct current
AC	Alternate current
PANI	Polyaniline
FT-IR	Fourier transform infrared spectrometer
NMR	Nuclear magnetic resonance spectrometer
UV-Vis	Ultraviolet-visible spectrometer
TGA	Thermogravimetric analysis
CSS	Controlled shear stress

LIST OF SYMBOLS

τ	shear stress
τ_y	yield stress
$\dot{\gamma}$	shear rate
E_0	applied electric field strength
η	shear viscosity
G'	storage modulus (Pa/s)
G''	loss modulus (Pa/s)
t_{ind}	induction time
t_{rec}	recovery time
ϕ	volume fraction
α	scailing exponent
γ	scailing exponent
σ	electrical conductivity
R	resistant
t	disk thickness
K	geometric correction fractor
β	relative polarizability
K_f	dielectric permittivity of medium
η^*	complex oscillatory steady shear viscosity
ω	frequency
Hz	Hertz
J_C	equilibrium creep compliance
J_R	equilibrium recovery compliance