

**DEVELOPMENT OF POLY(P-PHENYLENE VINYLENE) FOR ACTUATOR
AND CONTROLLED DRUG DELIVERY APPLICATION**



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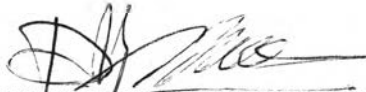
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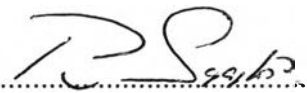
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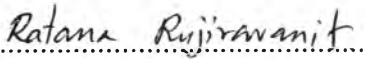

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ABSTRACT

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coefficient

This study evaluated and characterized the use of poly(p-phenylene vinylene) (PPV) as the electroactive polymer and in the controlled drug delivery application. Polydimethylsiloxane (PDMS) gel and PPV/PDMS blends were prepared and investigated as an electroactive polymer. The storage modulus, G' , of PDMS gel increases linearly with crosslink density but nonlinearly with electric field. The gel with the crosslink ratio of 0.01 possesses the highest G' sensitivity of 41% at 2 kV/mm. For PPV/PDMS blends, the storage modulus, G' , of each blends is higher than that of the purely crosslinked PDMS, due to PPV particles acting as a filler in the matrix. On application of an electric field of 2 kV/mm, the storage modulus response, G' , increases between 7-50%, depending on PPV volume fraction. The stress generated is caused by the induced polarized PPV particles leading to interparticle interactions. Salicylic acid-loaded polyacrylamide hydrogels, SA-loaded PAAM, and salicylic acid-doped poly(phenylene vinylene)/polyacrylamide hydrogels, SA-doped PPV/PAAM were prepared and investigated as the controlled drug delivery device. The apparent diffusion coefficient, D_{app} of SA-doped PPV/PAAM is higher than that of the SA-loaded PAAM, and increases with increasing electric field strength due to the combined mechanisms: the expansion of PPV chains inside the hydrogel; the reduction reaction under a negative potential driving the anionic SA through the PAAM matrix; and the electroporation of the matrix pore. Thus, the presences of the conductive polymer and applied electric field can be combined to control the drug release rate at an optimal desired level.

บทคัดย่อ

สุมนมาลย์ เนียมกลาง : การพัฒนาพอลิเมอร์นำไฟฟ้าพอลิพาราฟีนิลีนไวนิลีนสำหรับประยุกต์เป็นแอคชูเอเตอร์และวัสดุควบคุมการปลดปล่อยยา (Development of Poly(p-phenylene vinylene) for Actuator and Controlled Drug Delivery Applications) อ.ที่ปรึกษา : รศ.ดร.อนุวัฒน์ ศิริวัฒน์ 173 หน้า

ในงานวิจัยนี้ อนุภาคพอลิพาราฟีนิลีนไวนิลีน ได้ถูกสังเคราะห์ขึ้นเพื่อพัฒนาเป็นแอคชูเอเตอร์และวัสดุควบคุมการปลดปล่อยยา ขางพอลิไคเมทิลไซลอคเซนและยางผสมระหว่างพอลิไคเมทิลไซลอคเซนกับพอลิพาราฟีนิลีนไวนิลีนถูกเตรียมขึ้นเพื่อศึกษาคุณสมบัติการตอบสนองภายใต้กระแสไฟฟ้า โดยค่าสโตเรจมอดูลัสของขางพอลิไคเมทิลไซลอคเซนเพิ่มโดยมีความสัมพันธ์โดยตรงกับการเพิ่มขึ้นของอัตราส่วนร่างแห แต่มีความสัมพันธ์แบบไม่เป็นเส้นตรงกับการเพิ่มขึ้นของความต่างศักย์ไฟฟ้าที่จ่าย และที่อัตราส่วนร่างแห 0.01 นั้น ขางพอลิไคเมทิลไซลอคเซนแสดงการตอบสนองทางไฟฟ้ามากที่สุดถึง 41% เมื่อจ่ายไฟที่มีความต่างศักย์ไฟฟ้า 2 กิโลโวลต์/มิลลิเมตร การที่ระบบขางผสมระหว่างพอลิไคเมทิลไซลอคเซนและพอลิพาราฟีนิลีนไวนิลีนมีค่าสโตเรจมอดูลัสมากกว่าขางพอลิไคเมทิลไซลอคเซนบริสุทธิ์นั้นเนื่องมาจากอนุภาคพอลิพาราฟีนิลีนไวนิลีนนั้นทำหน้าที่เหมือนสารเติมแต่งเพิ่มความแข็งแรงในระบบขางผสม นอกจากนี้เมื่อจ่ายไฟที่ความต่างศักย์ 2 กิโลโวลต์/มิลลิเมตร ระบบขางผสมมีการเพิ่มขึ้นของสโตเรจมอดูลัสระหว่าง 7-50% ขึ้นอยู่กับปริมาณอนุภาคพอลิพาราฟีนิลีนไวนิลีนที่เติมลงไป การเพิ่มขึ้นของค่าสโตเรจมอดูลัสเมื่อมีการจ่ายไฟให้กับระบบนั้นน่าจะเกิดจากการที่อนุภาคถูกเหนี่ยวนำภายใต้กระแสไฟฟ้าและทำปฏิกิริยาดึงดูดซึ่งกันและกันระหว่างอนุภาค นอกจากนี้พอลิพาราฟีนิลีนไวนิลีนได้ถูกเตรียมและผสมกับพอลิอะคริลาไมด์เพื่อพัฒนาเพื่อเป็นวัสดุปลดปล่อยยาซาเลียไซคลิกภายใต้การควบคุมโดยไฟฟ้า จากการทดลองการปลดปล่อยยาพบว่า ค่าคงที่การแพร่ของยาซาเลียไซคลิกจากระบบผสมระหว่างพอลิพาราฟีนิลีนไวนิลีนและพอลิอะคริลาไมด์มากกว่าพอลิอะคริลาไมด์บริสุทธิ์ เนื่องมาจากสามปัจจัย คือ ระบบที่มีพอลิพาราฟีนิลีนไวนิลีนจะเกิดปฏิกิริยารีดักชันเมื่อมีการจ่ายไฟลงไปในระบบ, ช่องในพอลิอะคริลาไมด์จะขยายตัวเมื่อมีการจ่ายไฟ, และ กระแสไฟฟ้าจะช่วยผลักดันให้ยาซึ่งมีความเป็นขั้วลบออกมาจากพอลิอะคริลาไมด์ ดังนั้นเราสามารถสรุปได้ว่าการที่มีสารนำไฟฟ้าและการจ่ายไฟลงไปในจะสามารถช่วยควบคุมการปลดปล่อยยาในระดับที่ต้องการอย่างเหมาะสม

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ABBREVIATION

ER	Electrorheology
DC	Direct current
AC	Alternate current
PPV	Poly (p-phenylene vinylene)
PAAM	Polyacrylamide
PDMS	Polydimethylsiloxane
FT-IR	Fourier transform infrared spectrometer
UV-Vis	Ultraviolet-visible spectrometer
TGA	Thermogravimetric analysis
SA	Salicylic acid
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
α	scaling exponent
γ	scaling 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
F_D	dielectrophoresis force
F_d	elastic deflection force
N_c	mole of crosslinker
N_m	mole of monomer
v_l	the molar volume of solvent (M_w /density)
w_0	the original polymer weight
w_s	the swollen polymer weight
χ	the polymer-solvent interaction parameter
R	the universal gas constant, 8.29 N _m /mol.K,
δ	the solubility parameter
v	number density of strands
D_{app}	diffusion Coefficient
m_t	amount of drug release at time t

ξ	mesh size
ξ_e	electrical mesh size
M_c	molecular weight between crosslinks
M_n	the number-average molecular weight of the polymer before crosslinking
\bar{v}	the specific volume of PAAM (0.741 mL/g), and
\bar{V}_1	the molar volume of water (18.1 mL/mol).
$v_{2,r}$	the polymer volume fraction in the gel in the relaxed state
$v_{2,s}$	the polymer volume fraction in the gel in the swollen state
M_t	the amount of drug released from a hydrogel at time t
M_∞	the total amount of drug released
n	the diffusion scaling exponent, determining the dependence of the release rate on time that can be related to the drug transport mechanism
a	the size of the drug
D_0	the diffusion coefficient as the drug size approaches the mesh size