EFFECT OF MOLECULAR WEIGHT ON PIEZOELECTRIC PROPERTIES OF ELECTROSPUN POLYVINYLIDENE FLUORIDE BLENDED WITH CELLULOSE NANOCRYSTALS

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ABSTRAK

Polivinilidina fluorida (PVDF) telah digunakan secara meluas sebagai bahan piezoelectrik dalam sensor, penggerak, penapis dan juga peralatan perubatan. Oleh sebab ciri-ciri berkualiti tinggi seperti fleksibiliti tinggi, kos rendah dan ringan, PVDF sangat diminati di dalam industri. PVDF mempunyai lima fasa kristal iaitu fasa $\alpha, \beta, \gamma, \delta$ dan ε. Semua fasa kristal dibina berdasarkan molekul berantai konformasi $–CH_2CF_2$- dalam PVDF. Dua jenis fasa kristal yang biasa dijumpai dalam PVDF adalah fasa α dan β sedangkan fasa α mudah dijumpai dalam PVDF lebur sementara fasa β dihasilkan melalui poling dan penyepuhlindapan pada tekanan tinggi. Kekuatan kepiezoelektrikan bergantung pada fasa kristal. Oleh itu, untuk meningkatkan pembentukan fasa β , nanokristal selulosa (CNCs) dengan pelbagai berat (1-5%) dimasukkan ke dalam PVDF menggunakan kaedah elektrospinning. Kaedah ini menggunakan voltan tinggi untuk membuat membran elektrospun PVDF/CNCs. Kaedah analisis seperti FESEM, FTIR, XRD, mesin ujian universal (UTM), spektroskopi impedans electrokimia (EIS) dan meter piezoelektrik digunakan untuk menilai kesan CNCs pada ciri-ciri struktur dan elektrik elektrospun PVDF. Berdasarkan FTIR dan XRD, CNCs meningkatkan pembentukan fasa β dan peningkatan kehabluran hingga 75.62%. PVDF dengan 4% CNCs mempunyai kandungan fasa β terbesar hingga 91.74% dengan pemalar piezoelektrik maksimum 45 pC/N dan pemalar dielektrik, 5.4. Sifat mekanikal membran elektrospun PVDF/CNCs juga meningkat setelah memasukkan CNCs ke dalam PVDF. Ciri-ciri membran elektrospun PVDF/CNCs kemudian ditingkatkan dengan ketara menggunakan CNCs.

ABSTRACT

Polyvinylidene fluoride (PVDF) has become widely used as a piezoelectric material in sensors, actuators, filters, and medical equipment. It is in high demand in industries owing to its high-quality features such as high flexibility, low cost, and light weight. PVDF is available in five types of crystalline phases, namely α, β, γ, δ and ε -phases. All the crystalline phases are built based on the molecular chain conformation of -CH_2CF_2- in PVDF. Two common crystalline phases found in PVDF are α and β-phases. The α-phase is easily found in PVDF melt, while the β-phase is produced via poling and annealing at high pressure. The piezoelectricity is dependent on the β-phase crystalline structure. Therefore, in order to increase the formation of the β -phase, cellulose nanocrystals (CNCs) with various weights (1%-5%) were incorporated into PVDF using the electrospinning method. This method uses high voltage to fabricate electrospun PVDF/CNCs membranes. Analytical methods such as field emission scanning electron microscopy (FESEM), Fourier transform infrared (FTIR) spectroscopy, X-ray diffraction XRD, universal testing machine (UTM), electrochemical impedance spectroscopy (EIS), and a piezoelectric meter were used to evaluate the impact of CNCs on the structural and electrical properties of electrospun PVDF. Based on the FTIR and XRD results, CNCs promoted the development of β-phase and improved crystallinity up to 75.62%. PVDF with 4% CNCs recorded the highest β-phase content of up to 91.74% with a maximum piezoelectric constant of 45.0 pC/N and a dielectric constant of 5.4. The mechanical properties of electrospun PVDF/CNCs membranes also improved after incorporating CNCs into PVDF. Therefore, the characteristics of electrospun PVDF/CNCs membranes improved significantly using CNCs.

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LIST OF SYMBOLS

S	Mechanical strain
X	Stress
E	Electric field
D	Electric displacement
d	Piezoelectric effect
s^E	Material compliance
ε^X	Permittivity
P	Polarization
α	Alpha
β	Beta
γ	Gamma
δ	Delta
ε	Epsilon
g/ml	Gram per milliliter
%	Percentage
δ^+	Partially positive
δ^-	Partially negative
ºC	Degree Celcius
nm	nanometer
ml	milliliter
>	Greater than
eV	electronvolt
V	voltage
DC	Direct current
kV	kilovolt
ml/h	Milliliter per hour
K	Kelvin
cm	centimeter
cP	centipoise
F_β	Fraction of beta phase
°	Degree

σ	Stress
ε	Strain
MPa	Megapascal
ε'	Dielectric constant
$\tan \delta$	Dielectric loss
t	Thickness
A	Cross section area
$\varepsilon_{\circ}$	Permittivity of free space
Z'	Real part of the impedance
Z''	Imaginary part of the impedance
kHz	kilohertz
pC/N	picocoulombs per Newton
d_{33}	Piezoelectric constant

LIST OF ABBREVIATIONS

PZT	Lead zirconate titanate
$BaTiO_3$	Barium titanate
Pb	Lead
PVDF	Polyvinylidene fluoride
CNCs	Cellulose nanocrystals
FESEM	Field Emission Scanning Electron Microscopy
XRD	X-Ray Diffraction
FTIR	Fourier Transform Infrared Spectroscopy
ATR-FTIR	Attenuated Total Reflectance- Fourier Transform Infrared Spectros
UTM	Universal Testing Machine
EIS	Electrochemical Impedance Spectroscopy
DMAc	Dimethylacetamide
DMF	Dimethylformamide
DMSO	Dimethyl sulfoxide
NMP	N-Methyl-2-pyrrolidone
CNF	Cellulose nanofiber
BC	Bacterial cellulose

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