AN IMPROVED DESIGN OF PIEZOELECTRIC RAINDROP ENERGY HARVESTER

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By

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LIST OF ABBREVIATIONS

AC	-	Alternative Current
ACE	-	Acetone
AIN	-	Aluminium Nitride
CNC	-	Computer Numerical Control
CVD	-	Chemical Vapour Deposition
DBS	-	Dual Beam Spectropluviometer
DC	-	Direct Current
DMAc	-	N,N-Dimethylacetamide
DMF	-	N,N-Dimethylformamide
DMSO	-	Dimethyl Sulfoxide
EHD	-	Electrohydrodynamic
FEM	-	Finite Element Method
FESEM	-	Field Emission Scanning Electron Microscopy
FTIR	-	Fourier Transform Infrared Spectrometer
ITO	-	Indium Tin Oxide
LPM	-	Laser Precipitation Monitor
MEK	-	Methyl Ethyl Ketone
NMP	-	N-Methyl-Pyrrolidene
PMMA/GO	-	Poly(Methyl Methacrylate)/Graphene Oxide

PREH	-	Piezoelectric Raindrop Energy Harvester
PTFE	-	Polytetrafluoroethylene
PVD	-	Physical Vapour Deposition
PVDF	-	Polyvinylidene Fluoride
PZT	-	Zirconate Titanate
TEP	-	Triethylphosphate
THF	-	Tetrahydrofuran
XRD	-	X-Ray Diffraction

LIST OF SYMBOL

$\bar{E}$	-	Vector of electrical field
$\bar{D}$	-	Electric charge density displacement
$\bar{\sigma}$	-	Vector of component mechanical stress
A	-	Electrode area
A_d	-	Area of droplet in pixel
A_α	-	α-phase absorbance bands
A_β	-	β-phase absorbance bands
Ag	-	Silver
Al	-	Aluminium
Au	-	Gold
$BaTiO_3$	-	Barium Titanate
C	-	Capacitor
C_E	-	Elasticity
C_f	-	Friction coefficient
C_{piezo}	-	Piezoelectric capacitance
Cr	-	Chromium
c	-	Elastic constant
D_{drop}	-	Droplet diameter
D_{needle}	-	External diameter of the blunt needle

d	-	Gauge between the electrodes plates
d_{ij}	-	Piezoelectric strain coefficient
E_K	-	Kinetic energy
E_U	-	Electrical energy
E_{cap}	-	Energy stored
e	-	Piezoelectric coupling
F_{impact}	-	Impact force
f_{bridge}	-	Bridge resonance frequency
$f_{cantilever}$	-	Cantilever resonance frequency
f_{nar}	-	Natural frequency
g	-	Gravitational constant
g_{ij}	-	Piezoelectric stress constant
h	-	Droplet fall height
I	-	Moment of inertia
k	-	Stiffness constant
k_{bridge}	-	Stiffness constant of bridge
$k_{cantilever}$	-	Stiffness constant of cantilever
k_{ij}	-	Electromechanical coupling constant
k_{em}	-	Electromechanical coupling coefficient
L_{Al_bottom}	-	Al bottom layer
L_{Al_top}	-	Al top layer

L_{PVDF}	-	PVDF layer
l	-	Length
m	-	Mass of droplet
m_{beam}	-	Mass of beam
O_h	-	Ohnesorge number
P	-	Power
Pt	-	Platinum
P_{impact}	-	Impact pressure
P_{max}	-	Output power without loss
P_{out}	-	Output power
P_{out_eff}	-	Output power with loss
Q	-	Charge
R	-	Resistance
S	-	Average volume deformation
S_E	-	Compliance
T_c	-	Curie temperature
t_{impact}	-	Period of water droplet impact
t_{vib}	-	Vibration period
V	-	Voltage
V_{AC}	-	Alternative current voltage
V_{DC}	-	Direct current voltage

V_{DC_AVE}	-	Average DC voltage
$V_{DC\_SINGLE\text{-}DC}$	-	Voltage from single drop
V_c	-	Poling voltage
V_g	-	Grid voltage
V_{oc}	-	Open circuit voltage
V_p	-	Peak voltage
v	-	Droplet Fall Velocity
W_e	-	Weber number
w	-	Width
Y	-	Young's modulus
ZnO	-	Zinc Oxide
γ	-	Water surface stress
δ	-	Deflection
δ_{bridge}	-	Bridge deflection
$\delta_{cantilever}$	-	Cantilever deflection
ε	-	Electrical permittivity coefficients
ε_0	-	Electrical permittivity in vacuum
ε_r	-	Relative permittivity of medium
ϑ	-	Active volume
ρ	-	Density
ρ_{air}	-	Density of air

ρ_{PVDF}	-	PVDF density
ρ_{water}	-	Water density, water density
υ	-	Poisson's ratio

PENAMBAHBAIKAN REKABENTUK PENUAI PIEZOELEKTRIK TENAGA TITISAN HUJAN

ABSTRAK

Penuaian tenaga titisan hujan memberikan sumber tenaga alternatif yang boleh digunakan semasa hujan. Walaupun penyelidikan yang ekstensif telah disiasat berkenaan penuaian tenaga titisan hujan mengunakan mekanisme piezoelektrik, penuai piezoelektrik tenaga titisan hujan (*Piezoelectric Raindrop Energy Harvester* (PREH)) yang bercekapan tinggi masih dalam penyelidikan. Kajian penyelidikan ini membentangkan rekabentuk dan pembangunan penambahbaikan rekabentuk baik PREH. Untuk mencapai rekabentuk yang lebih baik, beberapa langkah telah dilaksanakan. Ini termasuk siasatan ke atas profil titisan hujan untuk meramalkan tenaga kinetik dalam titisan hujan. Hasil kajian mendapati bahawa jumlah tenaga kinetik bergantung kepada saiz titisan dan halaju jatuh. Kedua, eksperimen telah dijalankan untuk membandingkan prestasi transduser PVDF komersial yang sering digunakan iaitu struktur jambatan dan julur yang tertakluk kepada titisan hujan simulasi. Keputusan eksperimen menunjukkan bahawa transduser berstruktur jambatan dengan dimensi 30 mm × 4 mm × 25 μm menjana voltan litar terbuka lebih tinggi daripada struktur julur, iaitu 4.22 V dan 0.41 V masing-masing. Langkah seterusnya adalah analisis kaedah unsur terhingga (FEM) melalui perisian COMSOL Multiphysics untuk menyiasat voltan litar terbuka, ketumpatan cas, pesongan transducer, dan frekuensi resonans. Berdasarkan struktur jambatan itu, pelbagai jenis struktur telah diubahsuai iaitu transduser berbentuk S, berbentuk zigzag, berbentuk H, dan berbentuk-X telah disiasat dengan lebih lanjut melalui simulasi FEM. Berdasarkan keputusan simulasi, struktur optimum PREH adalah struktur enam jejari