Fiber-Based Flexible Magneto-Mechano-Electric Generators Enhanced by UV and IR Treatments for Sustainable IoT Sensors

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Data S1: Using the properties listed in Supporting Table S1, we conducted a two-dimensional finite element simulation with COMSOL Multiphysics 6.2. To analyze the motion and deformation of solid materials under external magnetic forces, we used the solid mechanics branch within the structural mechanics module, along with magnetic field modules. An air domain was included around the Metglas sheet to ensure accurate results. However, we encountered an error while modeling the magnetization of the magnetostrictive material due to the nonlinearity between stress and magnetic fields. To resolve this, we surrounded the magnetostrictive material with another magnetic medium, which was non-solid but shared the same magnetization characteristics as Metglas. A physics-controlled mesh was applied to all domains, and a stationary study was performed to investigate the magnetic flux density enhancement on the Metglas sheet.

Furthermore, to evaluate the voltage response of the MME generator we modeled a truncated MME generator, and a piezoelectric module was added to the piezoelectric phase. The Metglas acts as a top electrode and magnetostrictive material, Al acts as the bottom electrode, and

PVDF/AlN acts as piezoelectric material. One end was fixed to the MME generator and proof mass was attached to the other end to get the bending motion of the device. As shown in F**igure S1a**. The additional required properties are listed in the supporting **Table S2**.

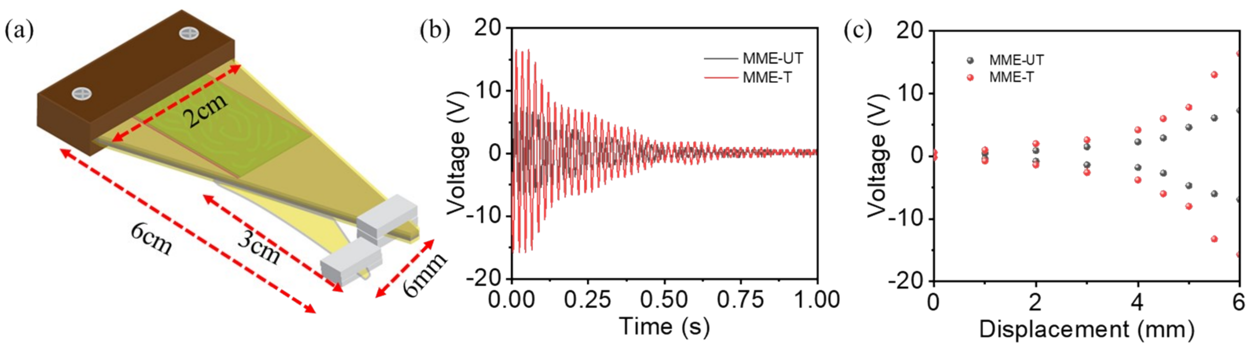
Table S1. Parameters are required for finite element modeling with Comsol Multiphysics of untreated Metglas (M1) and IR-treated Metglas (M2) for the magnetic flux density effect.

Property	M1	M2	Unit
Electrical conductivity	0.833	0.833	S/m
Young modulus	110	110	GPa
Poisson ratio	0.28	0.28	1
Density	7180	7180	Kg/m^3
Saturation magnetization	0.93×10^6	1.2×10^6	A/m
Initial magnetic susceptibility	1878	2248	1
Saturation magnetostriction	27×10^{-6}	27×10^{-6}	1
Magnetostriction constant	27×10^{-6}	27×10^{-6}	1

Table S2. Parameters are required for finite element modeling with Comsol Multiphysics of untreated PVDF-AlN (P1) and UV-treated PAVDF-AlN (P2) for Piezoelectric energy harvesting.

Property	P1	P2	Al	NdFeB	Air	Unit
Young modulus	2.5	2.5	70	160	-	GPa
Poisson ratio	0.33	0.33	0.32	0.28	-	1
Density	1676	1676	2700	7500	-	Kg/m^3
Relative permittivity (ε33)	1.5	3.06	-	-	1	1
Piezoelectric constant (d33)	4.02	9.19	-	-	-	pC/N
Flexibility factor (s11/s22)	0.378	0.378	-	-	-	1/GPa

Figure S1. (a) shows the schematic diagram of MME for d33 measurement (b) Shows the voltage damping and (c) shows the voltage–displacement relation of the MME generator.



Video S1. Recording of the real-time energy harvesting from the muffle furnace power code.

Video S2. Recording of the LEDs glowing using harvested energy.

Video S3. Recording of the flame sensor operation using harvested energy.

DATA S2:

The calculation of the β phase content was based on the Fourier Transform Infrared (FTIR) spectroscopy analysis. The formula used to estimate the β phase fraction (F_β) is derived from the relative intensities of the absorption peaks associated with the β and α phases in the FTIR spectrum. Specifically, the β phase content was calculated using the following equation []:

$$F_\beta = \frac{A_\beta}{\left(\frac{K_\alpha}{K_\beta} \times A_\alpha\right) + A_\beta} \times 100\%$$

where A_β and A_α are the absorbance of the characteristics β (841 cm^{-1}) and α (764 cm^{-1}) peak.

The values of the absorbance coefficients K_α (6.1e4 cm^2mol^{-1}) and K_β (7.7e4 cm^2mol^{-1}) used in this calculation were based on established literature values for PVDF, which correlate specific wavenumber peaks with the corresponding phase content. We found that the untreated and UV-treated samples have the β phase content of 83.5% and 91.9%, respectively.

Figure S2. EDS mapping image of PVDF-AlN composite nanofiber.

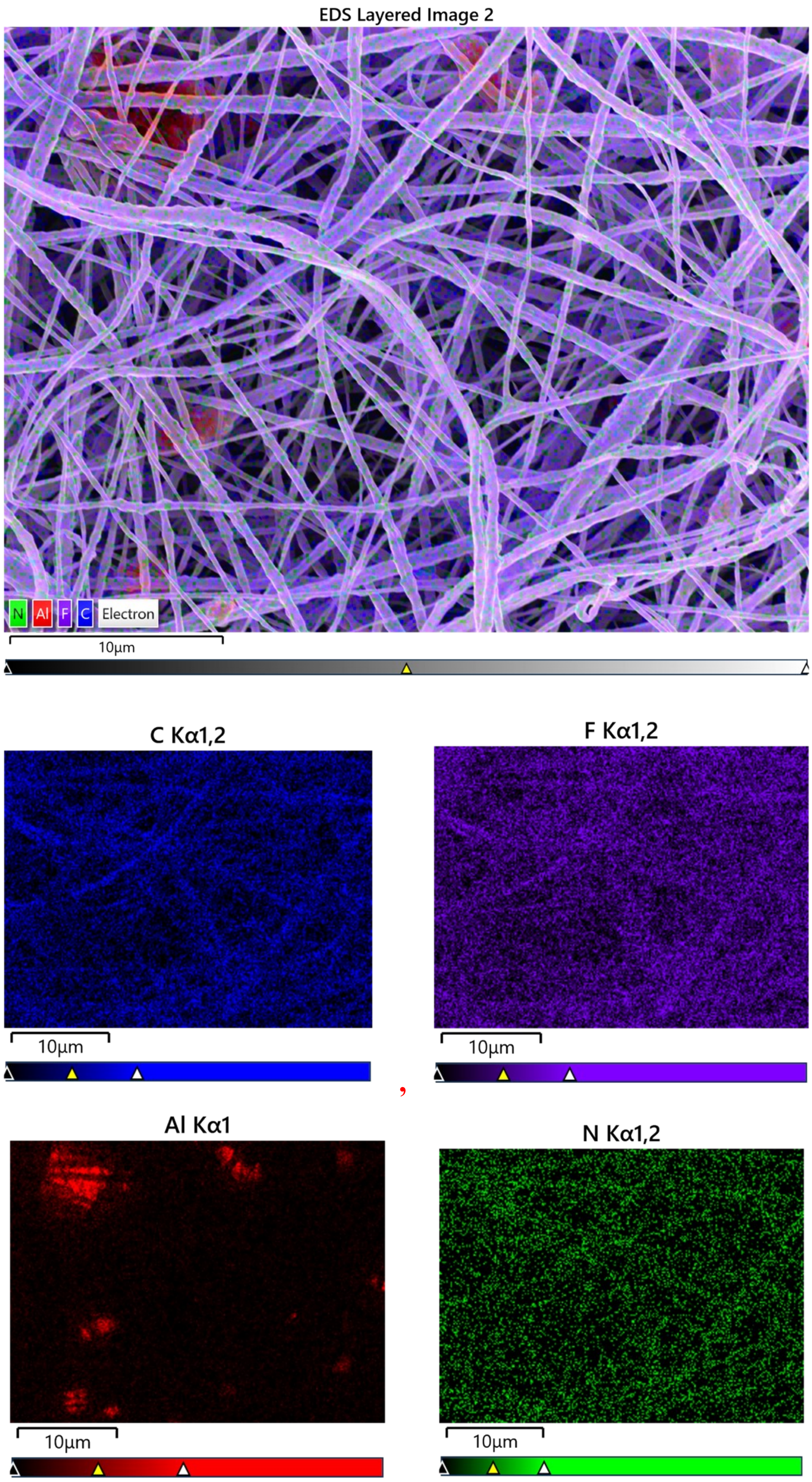

EDS Layered Image 2
N
Al
F
C
Electron
10μm
C Kα1,2
10μm
F Kα1,2
10μm
Al Kα1
10μm
N Kα1,2
10μm

Figure S3. XRD pattern of Untreated and IR-treated Metglas.