Supporting Information for

Flexible and Robust Hybrid Paper with Large Piezoelectric Coefficient

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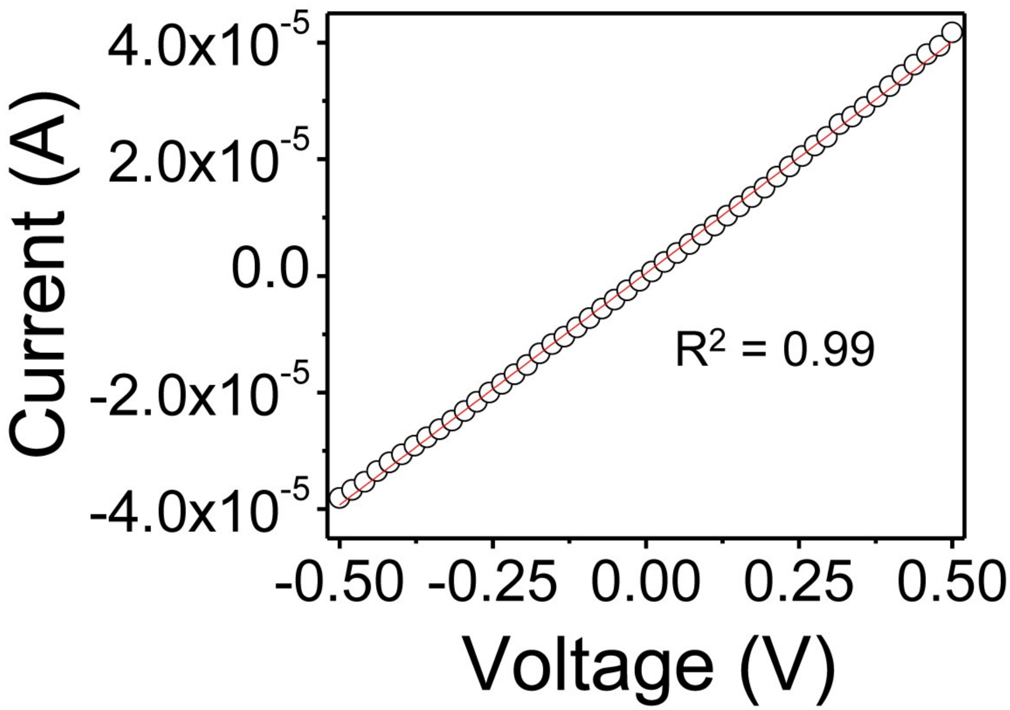


Figure S1. Current-Voltage (I-V) sweep curve of the piezoelectric paper, the voltage *V* was scanned between -0.5 V and +0.5 V and the resulting *dc* current *I* was measured using a source meter (Keithley 2635A). The electrical conductivity

$$\sigma_S = \frac{\Delta I}{\Delta V}\frac{L}{A}$$

was then calculated using the slope of the current versus voltage curve $\Delta I/\Delta V$, the thickness L = 0.011 cm, and the area A = 1 cm^2 of the sample, to yield $\sigma_S = 9.19\text{x}10^{-7}$ S/cm.

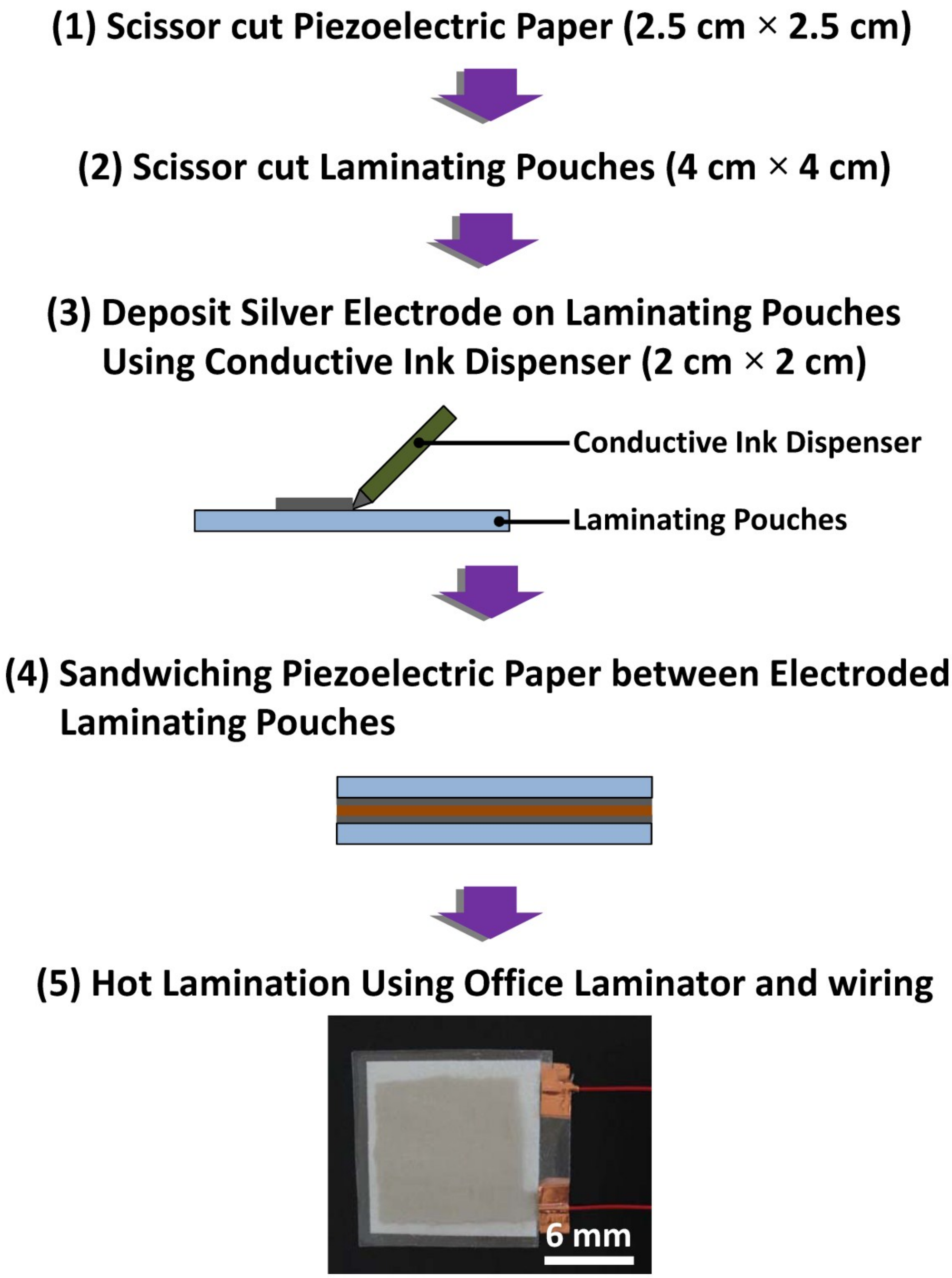


Figure S2. Step-by-step process showing a novel process for fabricating paper based accelerometer.

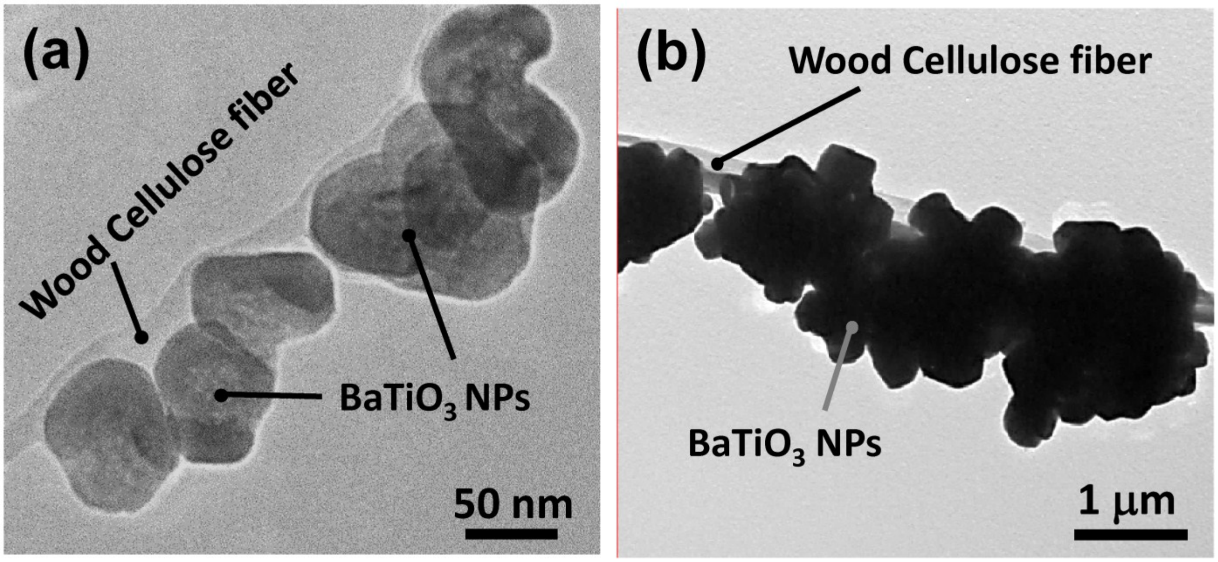


Figure S3: Compared TEM images of $BaTiO_3$ functionalized wood fiber before (a) and after (b) activating in CMC suspension, wood fibers appears larger than that of their counterparts due to coverage of CMC.

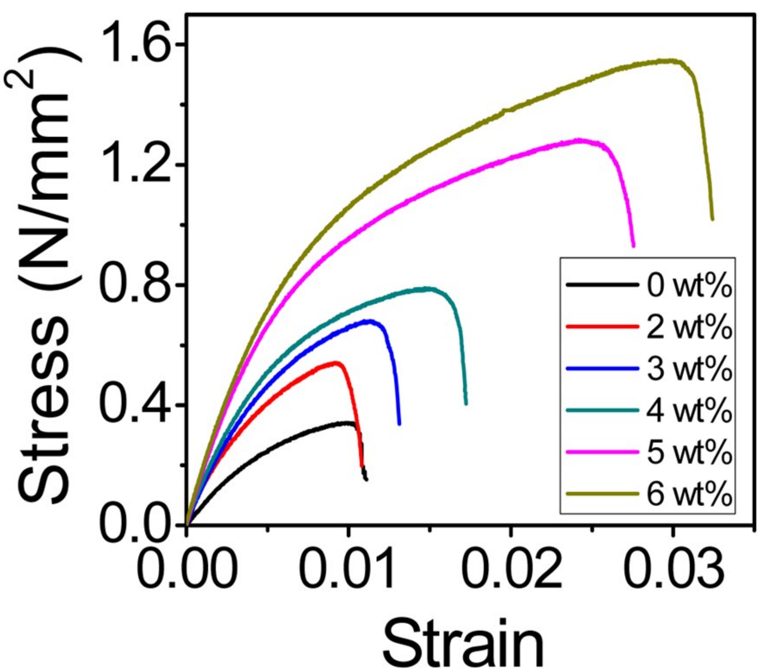


Figure S4. Stress-strain curves of hybrid paper as a function of CMC concentration.

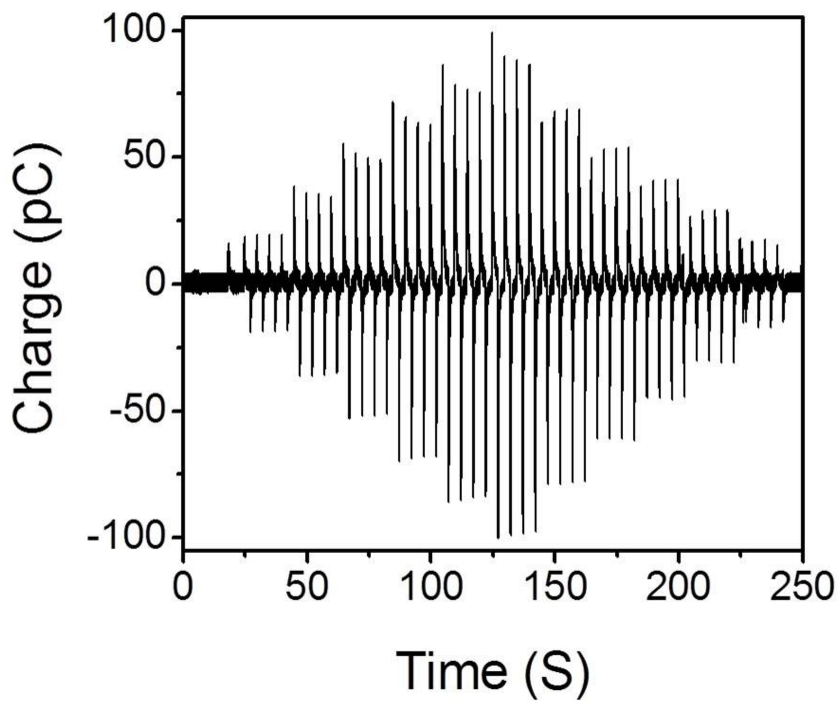


Figure S5. Piezoelectric response of hybrid paper aged for 14 months.

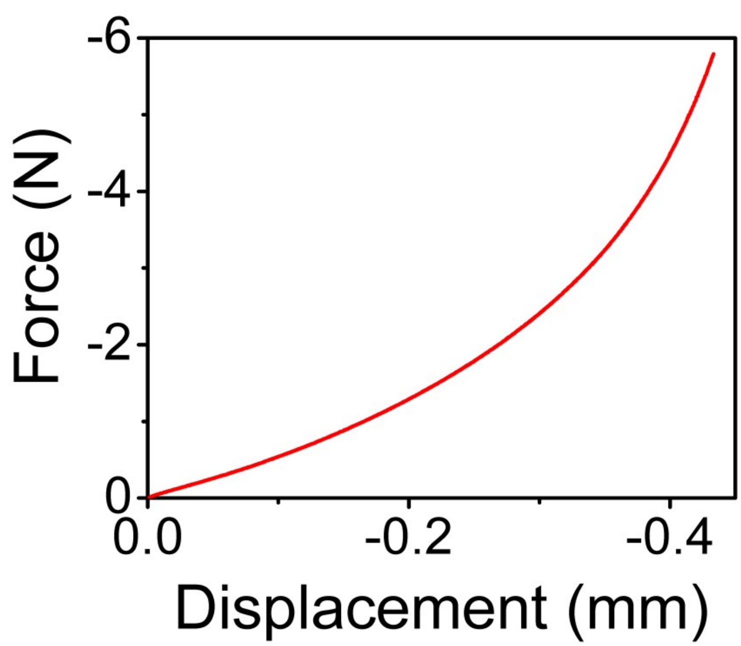


Figure S6. Force-displacement curve of paper laminate subjected to compression load using *Bose Electro force*.

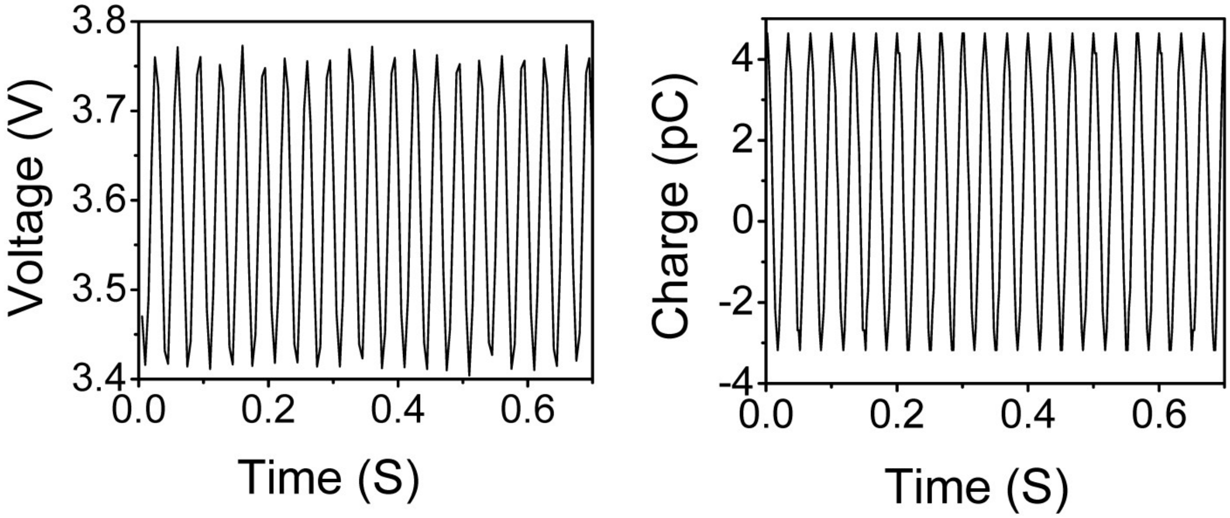


Figure S7. Compared output signal measured from commercial reference accelerometer; ADXL203 EB by Analog Devices (left), and paper accelerometer (right) at 30 Hz and 0.18 g acceleration amplitude. Note that output signal recorded from the paper accelerometer is similar and matches with a reference accelerometer.

Estimated Cost for Preparing ϕ11 cm Hybrid Piezoelectric Paper

Material Cost

Material	Quantity Required	Rate	Cost
Pulp	2 g	$1/kg	$0.002
NaCl	9 g	$10.5/kg	$0.095
PSS	1 g	$51.4/100g	$0.51
PDDA	2 g	$41.7/kg	$0.08
$BaTiO_3$ NPs	2.52 g	$263/kg	$0.66
NaCMC	0.5 g	$111/kg	$0.056
	Total Material Cost		$1.4

NaCl- sodium chloride, PSS- poly(sodium 4-styrenesulfonate), PDDA- poly(diallyldimethylammonium chloride), NaCMC- sodium carboxymethylcellulose, $BaTiO_3$ NPs- barium titanate nanoparticles

Electric Charges for Poling

Electric energy required for Poling

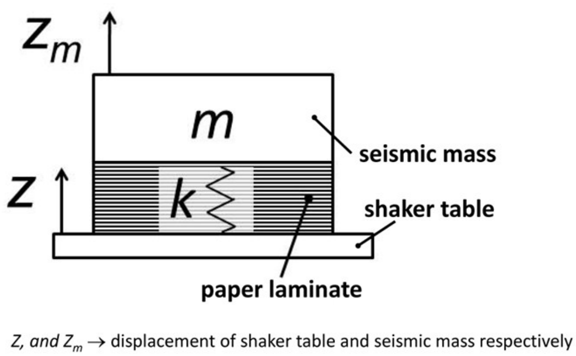
= Oven + Voltage source = 9.6 kWh + 0.12 kWh = 9.72 kWh

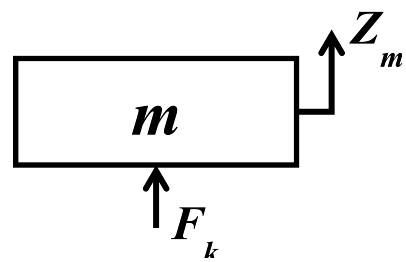
Electric tariff = $0.59/h

Electric Charges for Poling = 9.72 × $0.59 = $5.74

Cost for Preparing ϕ11 cm Hybrid Piezoelectric Paper = $1.4 + $5.74 = $7.14

Paper Accelerometer Model





Paper accelerometer configuration

Free-body diagram of seismic mass

$a = \ddot{Z} =- \omega Z$

$F_k = m\ddot{Z}_m$

$$F_k = k(Z - Z_m)$$

harmonics: $Z_m = \hat{Z}_m \omega_s \omega_t$

$\ddot{Z}_m =- \omega^2 \hat{Z}_m\, cos\omega t =- \omega^2 Z_m$

$F_m = m\ddot{Z}_m =- m\omega^2 Z_m = k(Z - Z_m)$

$Z_m = \frac{k}{k - m\omega^2}Z = \frac{Z}{1 - (\omega/\omega_0)^2}$ with $\omega_0 = \sqrt{k/m}$

$Q = D_3A_3 = d_{33}\underbrace{A_3\sigma_3}_{F_3 = F_m} = d_{33}m(- \omega^2)Z_m$

$$Q = \frac{d_{33}m}{1 - \left(\frac{\omega}{\omega_0}\right)^2}(- \omega^2)Z = \frac{d_{33}m}{1 - \left(\frac{\omega}{\omega_0}\right)^2}a$$

$$\frac{Q}{a} = \frac{d_{33}m}{1 - \left(\frac{\omega}{\omega_0}\right)^2}$$

$$f_0 = \frac{1}{2\pi}\sqrt{k/m}$$