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**Electronic Supplementary Information (ESI)**

# A strategy to develop high efficient composite based TENG through dielectric constant, internal resistance optimization, and surface texture modification

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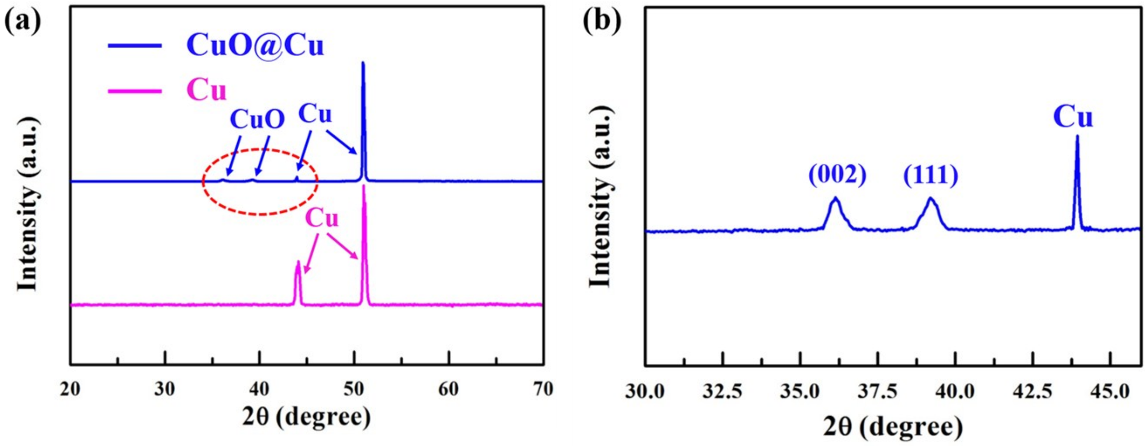


**Fig. S1** (a) XRD of Cu and CuO@Cu foil, (b) Enlarged view of the marked area in (a) of Fig. S1.

It has been observed that both the two XRD patterns consist of two intense peaks at 2θ ≈ 44° and 51° Cu foil. In Fig. b, CuO@Cu foil exhibits two extra peaks at 2θ ≈ 35.5°, 38.6°, corresponds to (002), (111) crystal planes of CuO [JCPDS card no. 005–0661].[1]

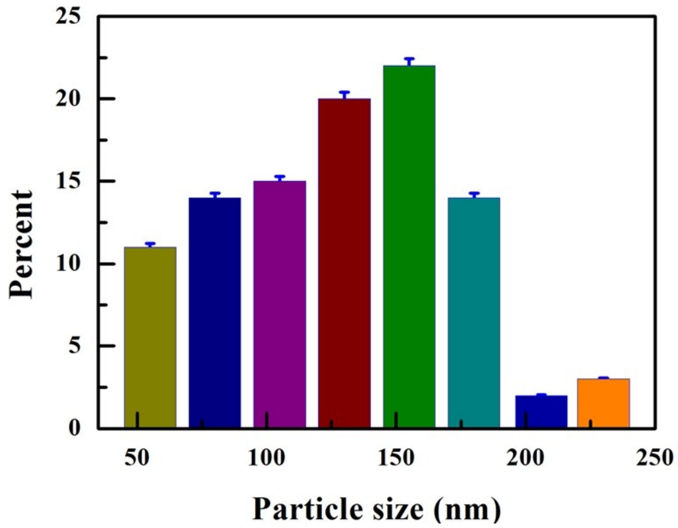


**Fig. S2** Size distribution profile of the as synthesized $ZnSnO_3$ nanocubes.

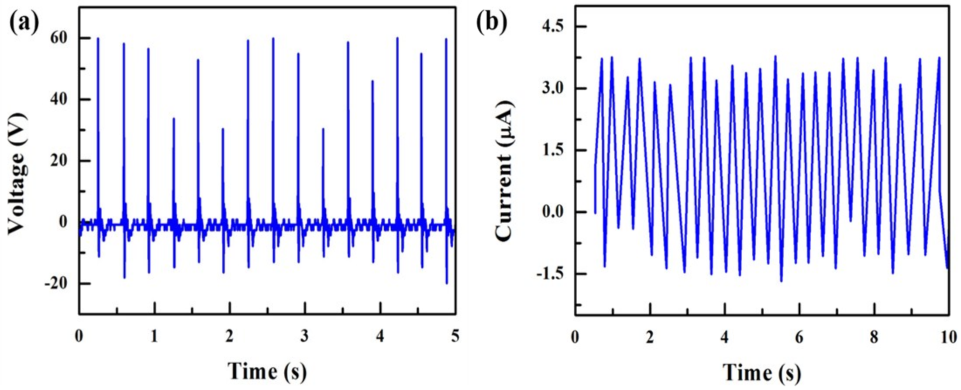


**Fig. S3** Generated voltage (a) and current (b) from the TENG with pure PDMS as active friction layer.

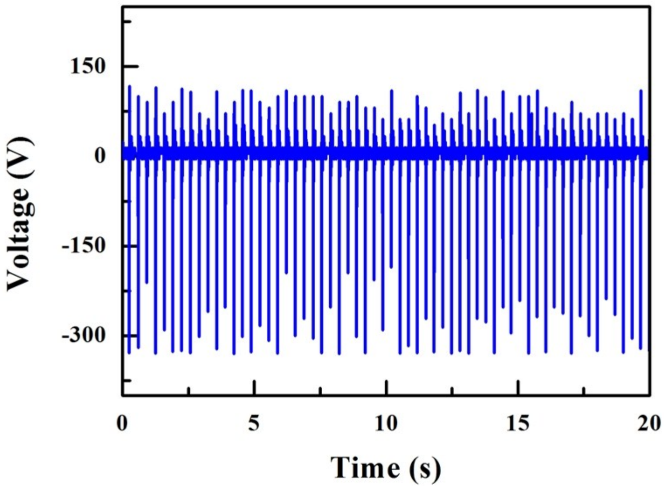


**Fig. S4** Output voltage generation performance of the TENG reverse connection.

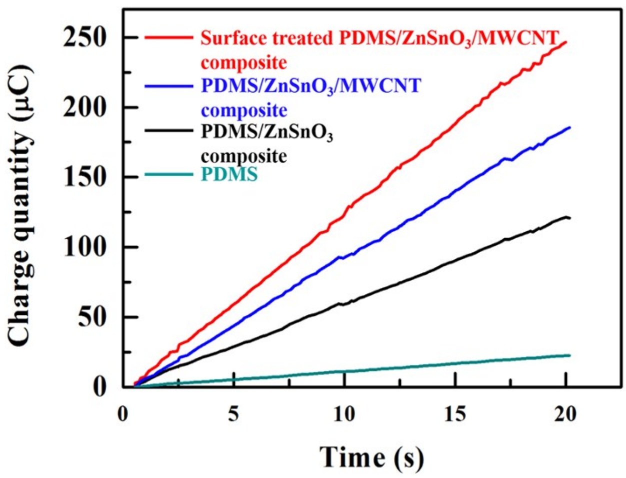


**Fig. S5** Transferred charges of the fabricated TENGs during finger tapping, pure PDMS (22 μC), $PDMS/ZnSnO_3$ (120 μC), $PDMS/ZnSnO_3/MWCNT$ (186 μC), surface treated $PDMS/ZnSnO_3/MWCNT$ (247 μC).

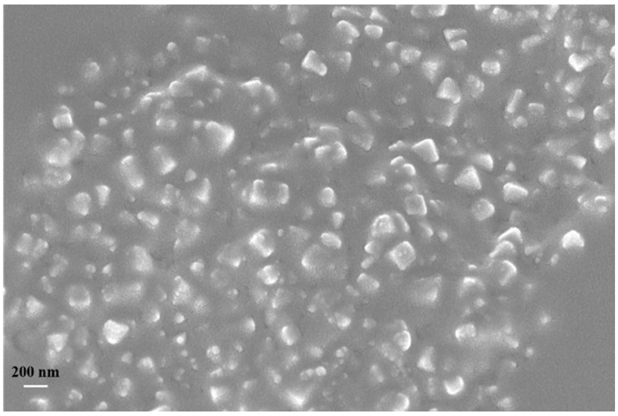


**Fig. S6** FESEM image of the surface of the PDMS/ZnSnO3 composite at 9 wt% loading.

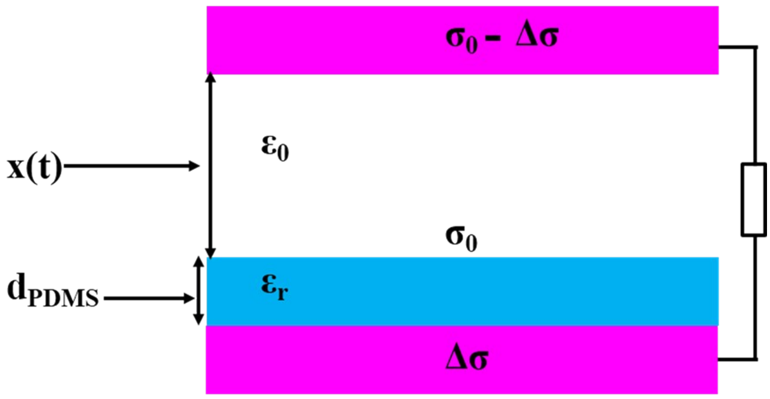


**Fig. S7** The cross-section of the capacitance structure of the TENG.

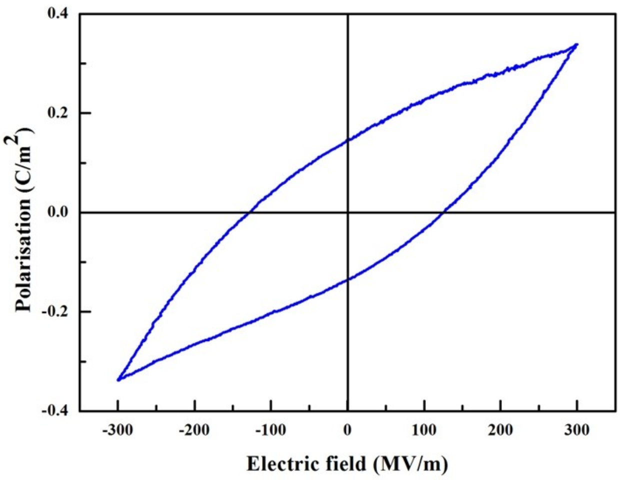


**Fig. S8** Polarization–electric field hysteresis loop measured on the 300 μm PDMS/$ZnSnO_3$ composite film at 7 wt% $ZnSnO_3$ loading at room temperature.

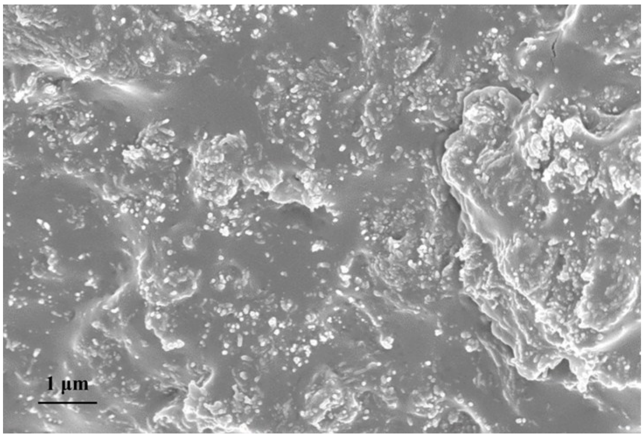


**Fig. S9** FESEM image of the cryo-fractured surface of the PDMS/$ZnSnO_3$/MWCNT composite at 7 wt% $ZnSnO_3$ and 1 wt% MWCNT loading.

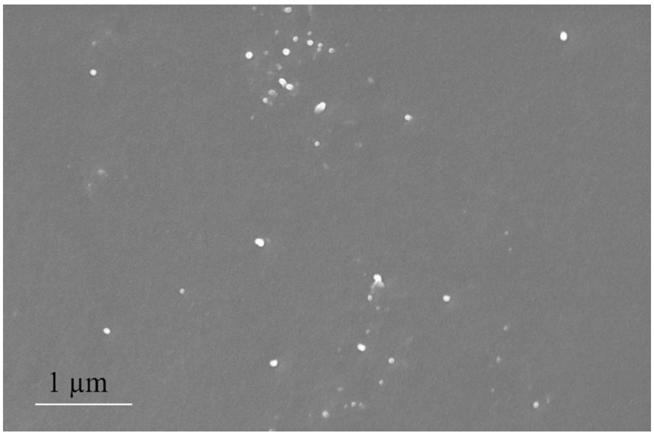


**Fig. S10** FESEM image of the surface of the PDMS/$ZnSnO_3$/MWCNT composite at 7 wt% $ZnSnO_3$ and 1.5 wt% MWCNT loading.

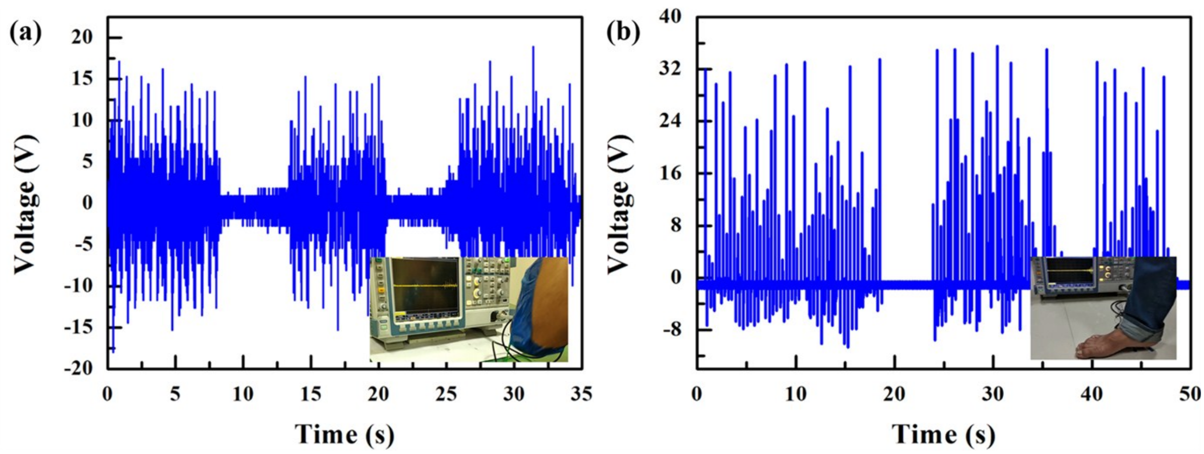


**Fig. S11** Generated open circuit voltage of the fabricated TENG under elbow pressing (a) and heel pressing (b).

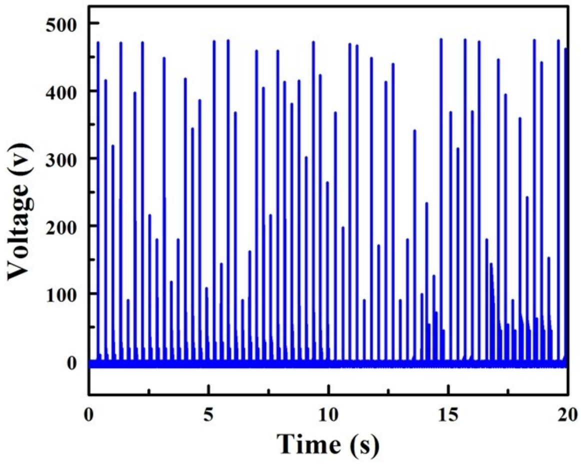


**Fig. S12** (a) Rectified open circuit voltage of the fabricated TENG.

**Calculation of applied force and pressure on the TENG:**

The calculation of the applied pressure produced by finger impact includes the physical model combining the gravity and pulse term.[2] When a body (here finger) falls on TENG, there two processes can be expected 1) initially touching the surface of the film, and 2) completely acting on the film. The velocity of the body increases and reaches to maximum value in the first process and gradually decreases to zero in the second process. Hence, the calculation depends on the kinetic energy and momentum theorem; we have the following basic equations:

$$mgh = \frac{1}{2}mv^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$(F - mg)\Delta t = mv \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$\sigma = \frac{F}{S} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where, m is the mass of the tapping finger, h is height of falling, v is the maximum velocity of falling, σ is the pressure developed during contact or applied stress, F is the contact force, S is the contact area, and $\Delta t$ is the time spanning during second process. Here, S= 400 $mm^2$ is the electrode area of the TENG, m= ~1.4 kg is measured by using a laboratory balance, $\Delta t$ = 0.34 s is the measured average time variation between the two successive voltage peaks, h = ~0.11 m and g = 9.8 N/kg. Therefore, the above values determines the input force, F ~19.8 N which gives the contact pressure, σ ~49.5 kPa.

**Calculation of energy conversion efficiency:**

Energy conversion efficiency is well-defined as the ratio between the output electrical energy recorded on the outer load resistance and the overall applied mechanical energy, which can be obtained using the subsequent equation.

Energy Conversion Efficiency (η%)

= registered electrical energy/total input mechanical energy

$$= \frac{\int_{t_1}^{t_2} I^2 R dt}{\frac{1}{2} m v^2 + m g \Delta h}$$

Where m is the weight of human finger (1.4 kg), v is the velocity of the finger in m/s, g is acceleration due to gravity (9.81m/$s^2$) and $\Delta h$ is the distance between TENG and maximum height of the finger. During the measurement of the output performance, the TENG device was subjected to two type forces, the press force and the gravity. The calculated total input mechanical energy is 2.18 mJ.

**Table S1:** Comparison of the output performance of PDMS/$ZnSnO_3$/MWCNT based TENG device with other nanogenerators earlier reported elsewhere.

| Nanogenerators | Output voltage | Current or current density | Power or power density |
|---|---|---|---|
| PDMS-PDMS/MWCNT [3] | 30 V | 3.5 µA | 130 µW |
| Graphene-PDMS/ZnO[4] | 271 V | 7.8 µA | 0.39 mW |
| Al-PDMS/CNT[5] | 77.8 V | 25.7 µA | 1.98 mW |
| PA6-PVDF/$ZnSnO_3$[6] | 1200 V | 20 µA | 0.47 mW $m^{-2}$ |
| Al-PDMS/$ZnSnO_3$[7] | 400 V | 28 µA | 3 mW |
| Al- PDMS/$BaTiO_3$[8] | 375 V | 6 µA | 2.25 mW |
| Cu-PDMS /$SrTiO_3$[9] | 338 V | 9.06µAcm$^{-2}$ | 6.47 W $m^{-2}$ |
| Cu-PDMS/$NaNbO_3$[10] | 550 V | 16 µA | 5.5 W $m^{-2}$ |
| This work | 475 V | 36 µA | 4.2 mW |

**Table S2:** Comparison of the energy conversion efficiency of PDMS/$ZnSnO_3$/MWCNT based TENG device with other nanogenerators earlier reported elsewhere.

| Reference | Technique | Active Materials | Efficiency |
|---|---|---|---|
| Nano Energy, 2017[11] | TENG | PTFE pellets | 13.1% |
| Nat. Commun., 2016[12] | TENG | Mesoporous PDMS | 22.4% |
| Nano Res., 2017[13] | Piezo+TENG | P(VDF-TrFE) | 5.6% |
| Adv. Mater., 2014[14] | TENG | FEP and Al | 85% |
| Energy Conv. Manag., 2017[15] | Thermoelectric | Human skin | 24% |
| ACS Nano, 2017[16] | TENG+EMG | Magnet array and FEP | 36.4% |
| Nanoscale,2017[17] | TENG | PDMS/cellulose | 17% |
| This work | TENG | PDMS/$ZnSnO_3$/MWCNT | 68% |

**Calculation of response time:**

Calculation of response time for finger assisted tapping

X1 ……..3.74697014 sec

X2……….3.77579072 sec

X2-X1= 0.02882058

Calculation of response time for human elbow press

X1 ……..16.2935323 sec

X2……….16.3984426 sec

X2-X1= 0.1049103 sec

Calculation of response time for human heel press

X1 ……..23.8643738 sec

X2……….24.0947437 sec

X2-X1= 0.2303699 sec

**Video file:** Sensitivity of TENG under elbow, heel and sewing machine pressing and powering of several colour LEDs under finger tapping

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