Supporting Information

Theoretical Study of the Stress Transfer Effect on the Output of a Composite Piezoelectric Nanogenerator

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Supporting Note

Consider a system with space charge distribution shown in Figure Note a. The potential φ in the system is determined by the following governing equation (Equation S1) and boundary conditions (Equation S2).

$$\begin{cases} \frac{d^2\varphi}{dz^2} = \frac{\rho_0}{\varepsilon}, (0 \le z < z_0) \\ \frac{d^2\varphi}{dz^2} = 0, (0 \le z < l - x_0) \\ \frac{d^2\varphi}{dz^2} = -\frac{\rho_0}{\varepsilon}, (l - z_0 \le z < l) \end{cases} \tag{S1}$$

$$\begin{aligned} &\varphi\big|_{z=0} = 0 \\ &\frac{d\varphi}{dz}\Big|_{z=0} = 0 \\ &\varphi\big|_{z=z_{0+}} = \varphi\big|_{z=z_{0-}} \\ &\frac{d\varphi}{dz}\Big|_{z=z_{0+}} = \frac{\rho z_0}{\varepsilon} \\ &\varphi\big|_{z=l-z_{0+}} = \varphi\big|_{z=l-z_{0-}} \\ &\frac{d\varphi}{dz}\Big|_{z=l} = 0 \end{aligned} \tag{S2}$$

where, φ is the potential, ρ_0 is the space charge density, z_0 is the width of space charge density distribution, ε is the dielectric constant.

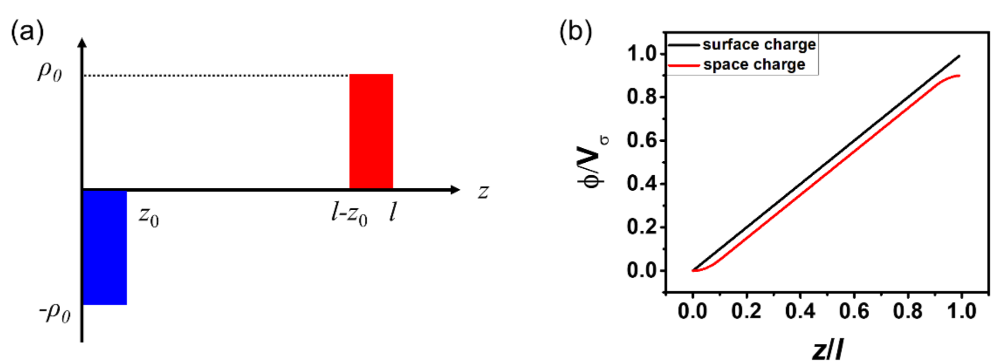

Figure Note. (a) The space charge density distribution profile. (b) The normalized potential generated by space charge and surface charge.

The calculated potential distribution in the system is a sectional function (Equation S3).

$$\varphi=\begin{cases}\dfrac{\rho}{2\varepsilon}z^2,\left(0\le z<z_0\right)\\ \dfrac{\rho x_0}{\varepsilon}z-\dfrac{\rho}{2\varepsilon}z_0^2,\left(0\le z<l-z_0\right)\\ -\dfrac{\rho}{2\varepsilon}z^2+\dfrac{\rho l}{\varepsilon}z+\dfrac{\rho l z_0}{\varepsilon}-\dfrac{\rho z_0^2}{\varepsilon}-\dfrac{\rho l^2}{2\varepsilon},\left(l-z_0\le z<l\right)\end{cases}\tag{S3}$$

The potential drop across the system is

$$V_\rho=\left(1-\frac{z_0}{l}\right)\frac{\rho z_0}{\varepsilon}l\tag{S4}$$

Consider a system with the same amount of charge as the system with space charge distribution, but with charge residing on the two ends surface, the potential φ in the system is determined by the following governing equation (Equation S5) and boundary conditions (Equation S6).

$$\frac{d^2\varphi}{dz^2}=0,\left(0\le z<l\right)\tag{S5}$$

$$\begin{aligned}&\varphi\big|_{z=0}=0\\ &\frac{d\varphi}{dz}\Big|_{z=z_{0+}}=\frac{\rho z_0}{\varepsilon}\end{aligned}\tag{S6}$$

The calculated potential distribution in the system is shown in Equation S7.

$$\varphi=\frac{\rho z_0}{\varepsilon}z\tag{S7}$$

The potential drop across the system is

$$V_\sigma=\frac{\rho z_0}{\varepsilon}l\tag{S8}$$

The ratio of V_ρ to V_σ is shown in Equation S9

$$\frac{V_\rho}{V_\sigma}=1-\frac{z_0}{l}\tag{S9}$$

From Equation S9, it can be found that the difference between potential across the system generated by the same amount of space charge and surface charge lies in the first order series of z_0/l. As the space charge gradually distributes throughout the system, the potential drop across the system decreases. The normalized potential distribution by normalizing the potential to V_σ is shown in Figure Note b. The concave in the negative space charge region and convex in the positive space charge region of the potential distribution results in the decreased potential drop compared with the surface charge case.

Supporting Figures

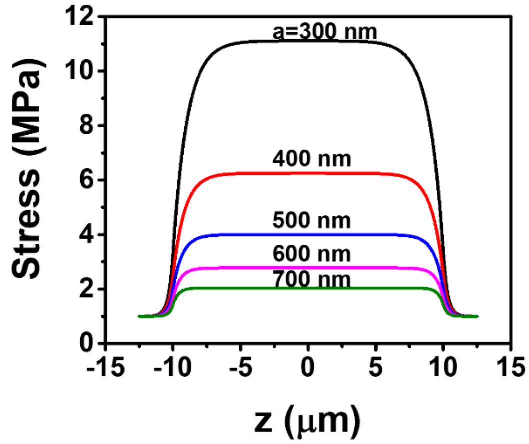

Figure S1. The stress profile for different size of $BaTiO_3$ particles in PDMS matrix with *b*=1 μm, *l*=12.5 μm.

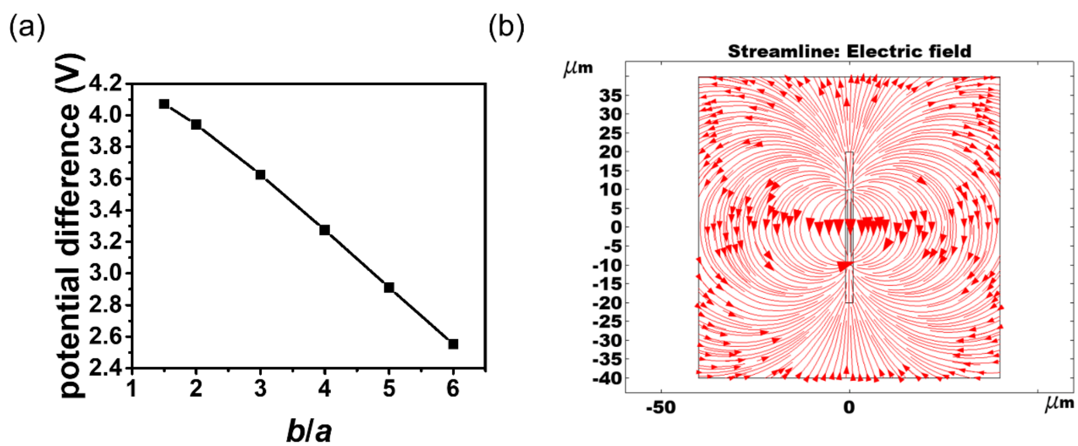

Figure S2. (a) The potential difference across the fiber under different *b*/*a* ratios. (b) The electric field around the $BaTiO_3$ fiber/PDMS composite.

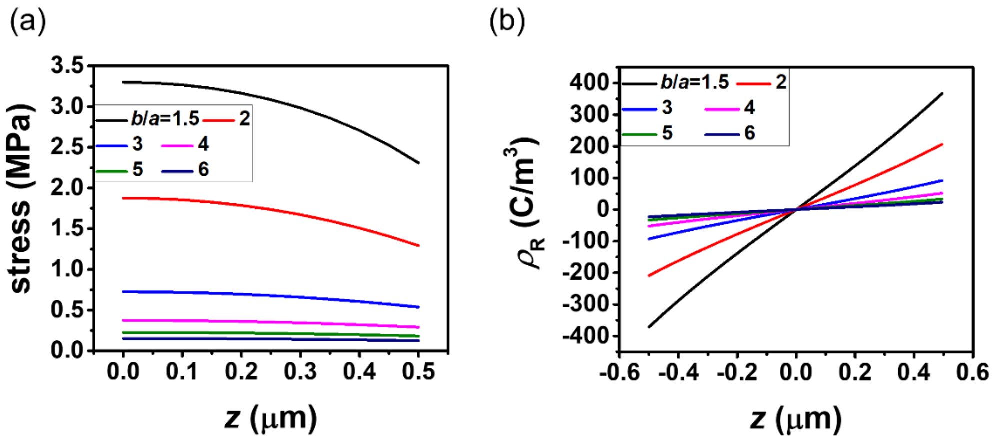

Figure S3. (a) The axial stress distribution in the upper half part of the $BaTiO_3$ fiber in the composite. (b) The axial body remnant charge distribution (ρ_R) in the $BaTiO_3$ fiber with different *b*/*a* ratios.

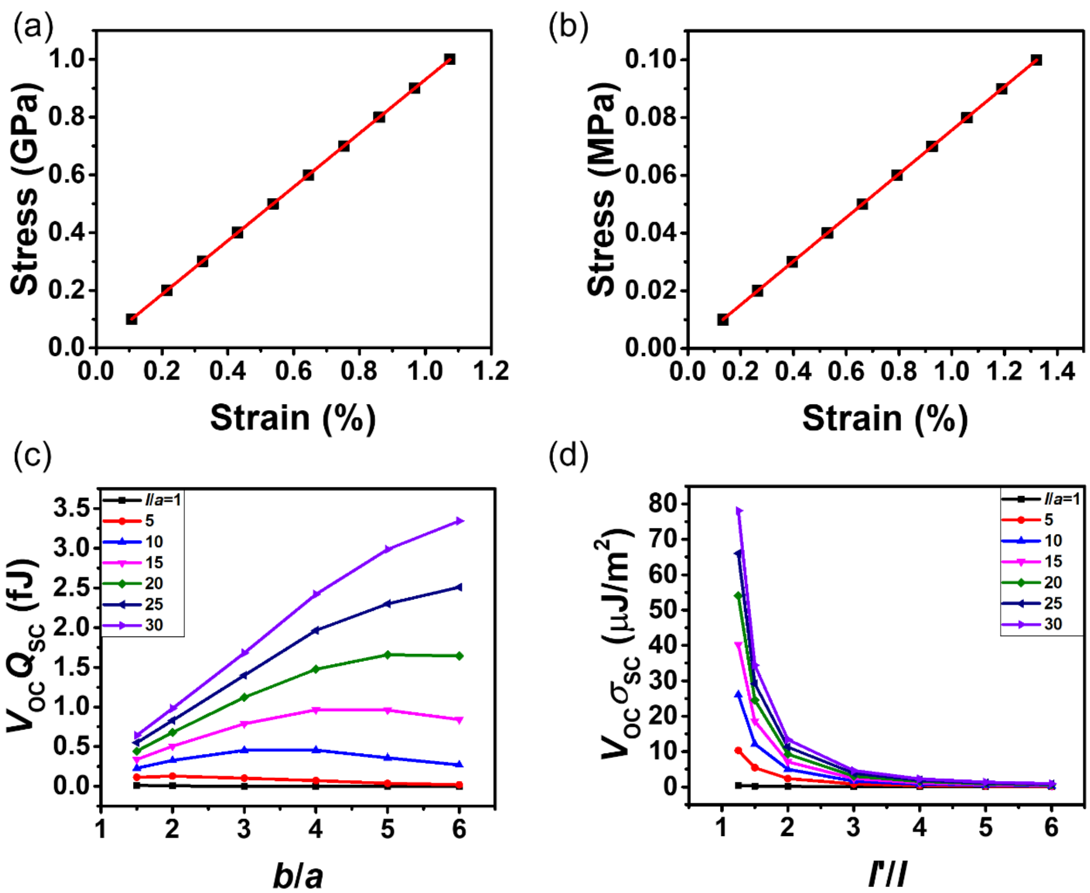

Figure S4. The strain stress relationship for $BaTiO_3$ fiber (a) and $BaTiO_3$ fiber/PDMS composite (b). (c) The product of the open circuit voltage (V_{oc}) and electrode charge in the short circuit condition (Q_{sc}) of the composite PENG under different b/a ratios for fibers with different l/a ratios. (d) The product of the open circuit voltage (V_{oc}) and electrode charge density in the short circuit condition (σ_{sc}) of the composite PENG under different l'/l ratios for fibers with different l/a ratios.