Supporting Information for

Ultra High Energy Density Nanocomposite Capacitors with Fast Discharge Using $Ba_{0.2}Sr_{0.8}TiO_3$ Nanowires

Haixiong Tang and Henry A. Sodano[*]

Department of Materials Science and Engineering, University of Florida, Gainesville, FL 32611, USA

Email:hsodano@ufl.edu

Method:

Preparation of Nanocomposites: The synthesis of $Ba_{0.2}Sr_{0.8}TiO_3$ NWs was approached by a two step hydrothermal reaction. First sodium titanate nanowires were synthesized by hydrothermal reaction.[S1, S2] Typically, 91 ml of a 10M aqueous sodium hydroxide (Fisher, ACS, 99%) was added to a 130 ml Teflon-lined autoclave followed by the addition of 1.88 g titanium dioxide powder (anatase, Sigma-Aldrich, ACS, 99%) and then bath sonicated for 20 min. The stainless steel autoclave was sealed and stirred at 200 °C for 24 hours. After the autoclave was cooled to room temperature, the obtained powder was sequentially washed with water and then soaked with 0.2M hydrochloric acid (Fisher, 37%) aqueous solution for 3 hours. Then, the powders were washed with water four times through centrifugation and vortex mixing, and subsequently dried on a hotplate at 60 °C overnight. Subsequently, the hydrogen titanate nanowires were converted to $Ba_{0.2}Sr_{0.8}TiO_3$ NWs by a second hydrothermal reaction with an aqueous solution containing $Ba(OH)_2{\cdot}8H_2O$ (Aldrich, 98%) and $Sr(OH)_2{\cdot}8H_2O$ (Aldrich, 95%). The precipitate was collected, washed with 0.2M HCl aqueous solution, water and ethanol. The surface of the $Ba_{0.2}Sr_{0.8}TiO_3$ NWs was functionalized with ethylenediamine to improve the dispersion and interaction with the PVDF matrix. The functionalization was carried out by

mixing the BST powder with ethylenediamine followed by vortex mixing for 5 minutes then sonicating for 1 hour, following by heated the solution to 90 °C in a water bath for one hour. The precipitate was separated by centrifugation and dried at 70 °C under vacuum overnight.

The nanocomposite capacitive films were prepared by dispersing $Ba_{0.2}Sr_{0.8}TiO_3$ NWs into a 7% weight fraction of PVDF in dimethylformamide (DMF) solution by sonicating for 2 hours, followed by solution casting onto a high temperature glass plate to obtain thin films approximately 10 μm thick. The films were then dried at 40 °C under vacuum overnight followed by heating at 200 °C for 5 min, then immediately quenched in an ice-water bath. The films were then dried at room temperature for 24 hours, and peeled from the glass plate. Finally, gold electrodes were sputtered onto both surfaces of the film with a thickness of approximately 10 nm for the low field measurements and high electric field electric displacement - field (D-E) loop measurements. All the processes of fabrication of nanocomposite capacitors with $Ba_{0.2}Sr_{0.8}TiO_3$ NWs are shown in the Figure S1.

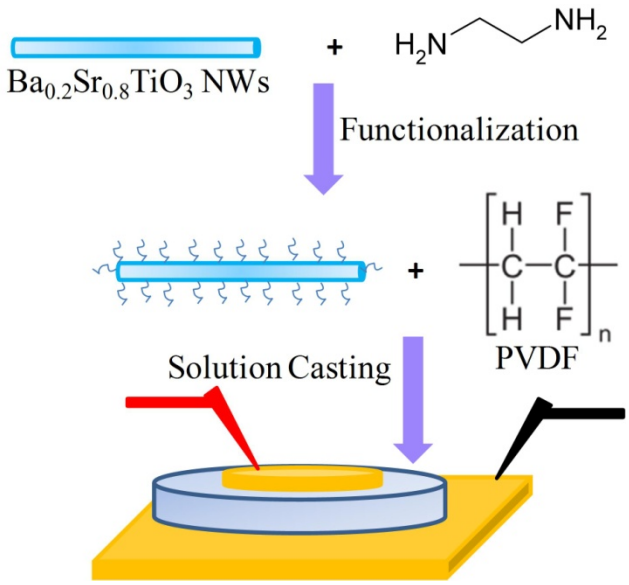

Figure S1. The process of fabrication of nanocomposite capacitors with $Ba_{0.2}Sr_{0.8}TiO_3$ NWs

Materials Characterization: The morphology and crystalline structure of the nanowires were characterized by Scanning Electron Microscopy (FE-SEM; 6335F, JEOL), Transmission Electron Microscopy (TEM, JEOL TEM-1011) operated at 200 kV, and X-ray diffractometer (XRD) equipped

with a curved position sensitive detector (CPS120, Inel) with Cu Kα radiation. Energy-dispersive X-ray spectroscopy (EDX, GENESIS) was performed to study the chemical composition of the nanowires. Fourier-transform infrared (FTIR) spectroscopy was performed with a Nicolet 6700 FTIR with a Smart Orbit ATR accessory to determine the functionalization of the nanowires. Frequency-dependent dielectric permittivity constant and loss tangent (dissipation factor) were measured using an Agilent 4980A LCR meter with a frequency range from 1000 Hz to 1 MHz at 1 V_{rms} with a parallel equivalent circuit. Dielectric breakdown strength measurements were performed using an electrostatic pull-down method on an Acopian high voltage supply (PO30HP2M) by sweeping the applied voltage with ramp rate approximately 500 V/s until sample failure, as evidenced by spurious current changes.[S3, S4] The D-E loops of the nanocomposites were measured by a Sawyer-Tower circuit, which allows direct computation of the energy density.[S5] The discharge speed and discharged energy were measured using a specially designed, high-speed capacitor discharge circuit similar to that reported in the literature.[S5]

Reference:

S1. Zhang, Y.; Li, G.; Jin, Y.; Zhang, Y.; Zhang, J.; Zhang, L. *Chem. Phys. Lett.* **2002**, 365, 300.

S2. Bao, N.; Shen, L.; Srinivasan, G.; Yanagisawa, K.; Gupta, A. *J. Phys. Chem. C* **2008***, 23,* 8634-8642.

S3. Claude, J.; Lu, Y.; Wang, Q. *Appl. Phys. Lett.* **2007***, 21,* 212904.

S4. Tomer, V.; Manias, E.; Randall, C. A. *J. Appl. Phys.* **2011***, 4,* 044107.

S5. Chu, B.; Zhou, X.; Ren, K.; Neese, B.; Lin, M.; Wang, Q.; Bauer, F.; Zhang, Q. M. *Science* **2006***, 5785,* 334-336.