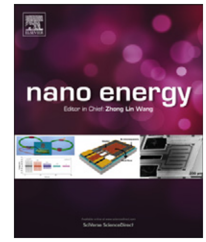
Nano Energy (2012) 1, 789–795

Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/nanoenergy



RAPID COMMUNICATION

Single crystalline lead zirconate titanate (PZT) nano/micro-wire based self-powered UV sensor

Suo Bai[a], Qi Xu[a], Long Gu[a], Fei Ma[a], Yong Qin[a,b,*], Zhong Lin Wang[b,c,]**

[a]*Institute of Nanoscience and Nanotechnology, Lanzhou University, Lanzhou 730000, China*
[b]*Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences, Beijing 100085, China*
[c]*School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0245, USA*

Received 24 August 2012; accepted 5 September 2012
Available online 19 September 2012

KEYWORDS
Nanowire;
Nanogenerator;
UV sensor;
Self-powered
nanodevice

Abstract
Ultra-long and flexible single-crystalline lead zirconate titanate $Pb(Zr_{0.52}Ti_{0.48})O_3$ (PZT) nano/micro-wires (N/MWs) were synthesized via a hydrothermal method. Owing to the self-polarization effect of the as-synthesized PZT N/MWs, the N/MWs can be used to directly fabricate a nanogenerator (NG) without being poled under electric field. Using such an NG, we demonstrated a flexible, self-powered system for detecting UV irradiance by utilizing the cycled contraction-expansion of a flexible rubber membrane.

Introduction

Collecting energy using nanomaterial from the environment has attracted extensive attention [1–6]. Compared with solar energy, thermal energy and other energy forms, mechanical energy is more popular in our living environment especially in biological system. NG fabricated using piezoelectric materials can be used to convert tiny mechanical energy in our living environment such as air flowing, heart beating and so on, to electricity. In addition, due to its small size, NG can be effectively integrated with the nano/micro-scale functional devices to form a self-powered nanosystem. NG based self-powered nanosystem has been proven viable by self-powered pH sensor, UV sensor, small liquid crystal display, commercial laser diode, pressure/speed sensor, environmental sensor and so on [7–11]. In order to get considerable output, these NGs are fabricated using NW arrays or NW textured film [9–11].

As a conventional piezoelectric material with the highest piezoelectric coefficient, bulk PZT ceramic has been widely used as transducers, sensors, actuators etc. for its high Curie point, large remnant polarization and stability over a large range of temperature [12,13]. However the

*Corresponding author at: Institute of Nanoscience and Nanotechnology, Lanzhou University, Lanzhou 730000, China.
**Corresponding author at: Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences, Beijing 100085, China.
E-mail addresses: qinyong@lzu.edu.cn (Y. Qin), zlwang@gatech.edu (Z.L. Wang).

2211-2855/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.nanoen.2012.09.001

conventional bulk piezoelectric transducer is very hard to drive and need to work near its resonant frequency, which greatly reduces its efficiency for harvesting irregular mechanical energy of tiny amplitude and low frequency. Compared with bulk materials, one dimensional nanostructure materials usually possess superior mechanical properties [14]. So using PZT NW's superior mechanical property and high intrinsic piezoelectric coefficient, it should be feasible to effectively collect irregular tiny mechanical energy of different amplitudes and frequencies in the environment. Recently, one dimensional single crystalline PZT NWs have been synthesized by the polymer assisted hydrothermal method [15,16]. Compared with PZT thin film and microfiber, the single crystalline PZT NW doesn't need high temperature to increase its crystallinity, which makes it compatible with the general fabrication methods of NG. However, the synthesized PZT NWs are too short to be used for the fabrication.

In this paper, the ultra-long and flexible single crystalline PZT N/MWs with diameters varying from hundreds of nanometers to several micrometers and lengths between 10 μm and 70 μm were synthesized via the polymer assisted hydrothermal method. A single crystalline PZT N/MW based NG was fabricated with open circuit voltage of 0.12 V and short circuit current of 1.1 nA. Combining the NG with a nano-scale UV sensor, we demonstrated a flexible self-powered system for detecting UV irradiance utilizing the pulses of a pressure pipe.

Results and discussion

Synthesis and characterization of the ultra-long single crystalline PZT N/MWs

The ultra-long and flexible single crystalline PZT N/MWs were synthesized via a polymer assisted hydrothermal method [15]. And their structure had been studied by electron microscopy and X-ray diffraction (XRD). The synthesized single crystalline PZT N/MWs have diameters varying from hundreds of nanometers to several micrometers and lengths between 10 μm and 70 μm (Figure 1a, inset). They possess good mechanical properties, and can even be bent to a curvature of 0.09 1/μm without destroying their structure, as shown in Figure 1a. XRD pattern of PZT N/MWs is shown in Figure 1b. It demonstrates that the final products were well crystallized and all diffraction peaks can be indexed with the tetragonal structure of PZT (Joint Committee on Powder Diffraction Standards [JCPDS] Card no. 33-0784); no additional diffraction peaks from the impurities were detected. Figure 1c shows the transmission electron microscopy (TEM) image of a representative single PZT N/MWs with diameter about 250 nm and length up to tens of micrometers. The dot-like selected area electron diffraction (SAED) pattern (Figure 1c, inset) can be indexed as the (001), (110) and (111) diffractions of the tetragonal PZT, illustrating that the N/MW was a single crystal. High-resolution TEM (HRTEM) was utilized to investigate the microstructure. Regular

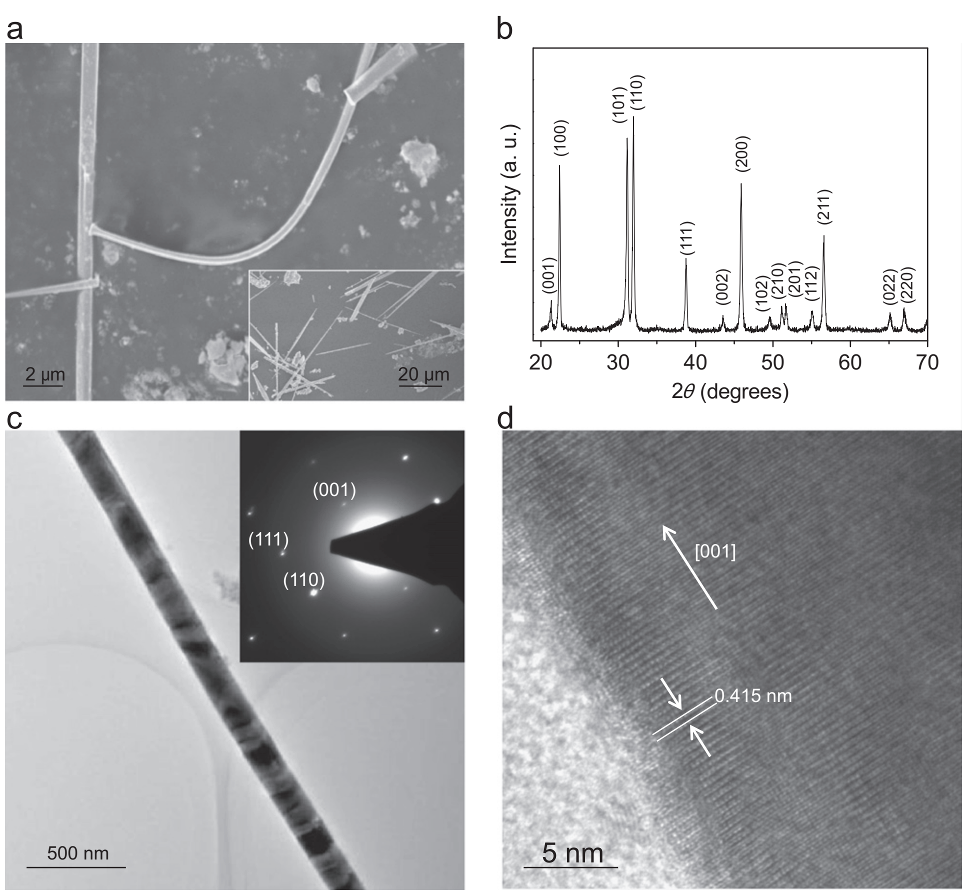


Figure 1 (a) SEM image of a bended single PZT N/MW. The inset shows an overall image of PZT N/MWs, (b) XRD pattern of the sample, (c) TEM image of a typical PZT NW. The inset shows the SAED pattern of that NW and (d) HRTEM image of PZT NW.