Extended Abstracts of the 2017 International Conference on Solid State Devices and Materials, Sendai, 2017, pp1053-1054

PS-13-24 (Late News)

Sodium Dodecyl Sulfate-Functionalized Carbon Nanotube / Polydimethylsiloxane Composites for High Performance Triboelectric Nanogenerator

Nathakreat Ketama[1], Songsak Rattanamai[1], Winadda Wongwiriyapan[1*] and Annop Klamchuen[2]

[1] College of Nanotechnology, King Mongkut's Institute of Technology Ladkrabang
Chalongkrung Rd., Bangkok, 10520 Thailand
Phone: +66-2-329-8000 ext 3074 E-mail: winadda.wo@kmitl.ac.th
[2]National Nanotechnology Center (NANOTEC)
National Science and Technology Development Agency
Prathum Thani, 12120 Thailand

Abstract

This research presents a fabrication of triboelectric nanogenerator (TENG) using the sodium dodecyl sulfate (SDS)-functionalized carbon nanotube (CNT) / polydimethylsiloxane(PDMS) composites (SDS/CNT/PDMS) as a negative electrode and polyethylene terephthalate / indium tin oxide (PET/ITO) as a positive electrode. The effect of CNT concentration and the SDS concentration were on TENG performance were investigated. Experimental results indicate that the SDS/CNT/PDMS is an effective electrode to enhance the output voltage of TENG with a maximum voltage of 66.8 V enabled an approximately 6-fold improvement in voltage output compared to the pristine PDMS. CNT may help to the high conductivity and flexibility of CNT, resulting in fast charge transfer and fast shape-recovery, while SDS may help to increase charge density and furthermore CNT dispersion.

1. Introduction

In recent years, nanogenerator, a device that converts mechanical/thermal energy as produced by nano-scale physical change into electricity, has received considerable attention as an alternative energy to provide a route to create autonomous and self-powered low-power electronic devices. Triboelectric nanogenerator (TENG) is one type of nanogenerator that converting mechanical energy to electric energy based on the triboelectric effect and electrostatic effect. The triboelectric effect is a charge transfer by two materials after the material contacting. The charge transfers from positive material to negative material by electrostatic indcution. Normally, TENG has a very simple structure consisting of two different materials, such as two types of polymer, polymer and metal. Among the surface materials reported for the triboelectric effect, poly(dimethylsiloxane)(PDMS) and polyethylene terephthalate (PET) are of special interests due to their highly opposite positions in the triboelectric series, their low-cost and good manufacturability at micro/nano scale [1–4]. To achieve the high-output TENG, the high charge density and the fast shape-recovery for the fast charge transfer are the crucial parameters.

In this study, we proposed a high output TENG based on sodium dodecyl sulfate (SDS)-functionalized carbon nanotube (CNT) / PDMS composites (SDS/CNT/PDMS) as a negative electrode and PET / indium tin oxide (PET/ITO) as a positive electrode. CNT was used in the order to improve mechanical properties of PDMS, while SDS, which is anionic surfactant with negatively charged head groups, was used in order to increase charge density and improve CNT dispersion.

2. Experimental Methods

To prepare SDS/CNT/PDMS composites, firstly CNT was treated by oxygen plasma to modify its surface with oxygen-containing functional groups [5]. Oxygen plasma treatment was conducted using an expanded plasma cleaner (Harrick Scientific) at an RF frequency of 13.56 MHa and a power of 18 W for 15 min. The plasma-treated CNT was dispersed in hexane with a concentration of 0.5 wt%. The SDS was added to the CNT dispersion with different SDS:CNT ratios; 1, 2 and 4 wt% (hereafter referred to as SC1, SC2 and SC4, respectively). Next, PDMS elastomer and cross-linker (Sylgard 184, Tow Corning) were mixed in a 10:1 ratio (w/w). Each SDS/CNT dispersion was poured into a PDMS matrix, and then the mixture was degassed in a vacuum chamber. Then, the mixture was casted on the Si mold with an area of 1x4 cm^2 and incubated at 75 ºC for 1 h. The uniform CNT/PDMS was peeled off from Si mold and then placed on a piece of clean PET/ITO sheet. For comparison, pure PDMS and CNT/PDMS without SDS were also prepared (hereafter referred to as PDMS and SC0 respectively). Finally, another clean PET/ITO sheet was placed onto the prepared CNT/PDMS-PET/ITO substrate to form a sandwiched structure. Therefore, both of the top and bottom surfaces of this structure were covered with a conductive ITO layer which acts as charge generation via the electrostatic induction of the tribology generated potential at the interfacial region, and as common electrodes for connecting the device with an external circuit [6]. The schematic view of the TENG was shown in Fig. 1a. The Cu wires are attached to ITO thin film by means of Ag paste for the characterization of the output voltage and current.

3. Results and Discussion

Fig. 1b shows the open-circuit voltage output of the TENG devices using five different SDS/CNT/PDMS composites;

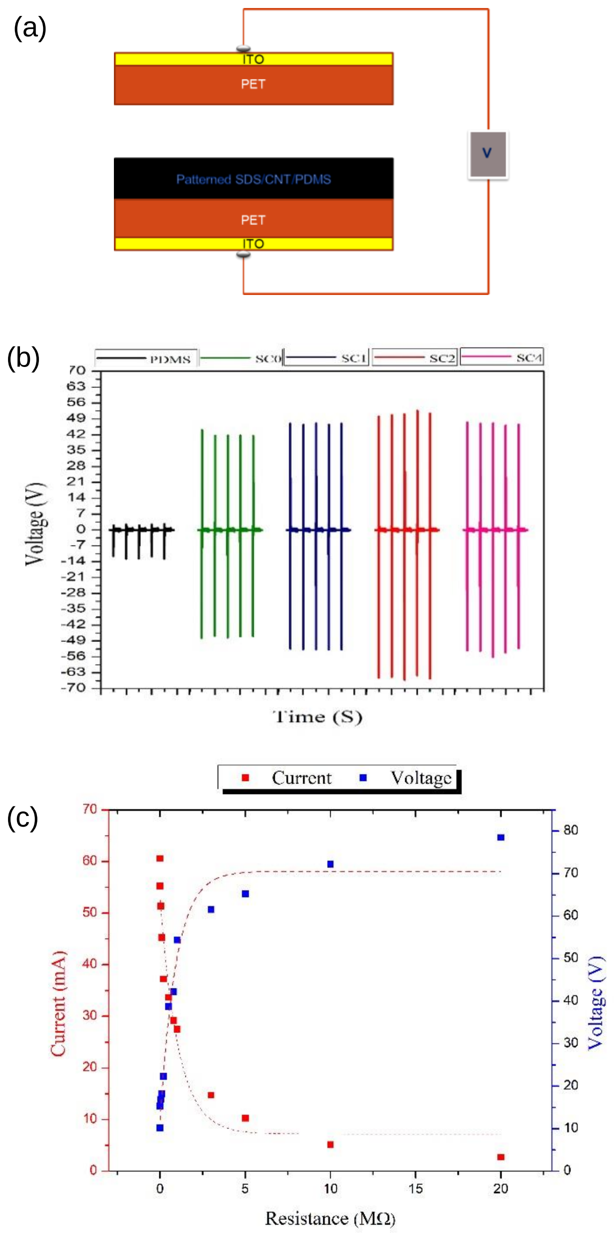

Fig. 1 (a) Schematic view of the TENG, (b) open-circuit voltage output of the TENG devices and (c) output voltage and current of the TENG (SC2) device under different external loads

PDMS, SC0, SC1, SC2, SC4 and SC6. The peaks of positive and negative voltages were observed during the periodically pressing or releasing process of the external force with a frequency of 1 Hz. The results clearly show that the output voltage depend on the composition of the SDS/CNT/PDMS composites. The SC2 shows the maximum voltage of 66.8 V, while the PDMS show the minimum voltage of 10.2 V, enabled an approximately 6-fold improvement in voltage output. The dramatic increase in the electrical output of the TENG can be attributed to the role of CNT as the effective dielectrics to donate electrons as well as fast shape recovery of the TENG [7], and the role of SDS to increase charge density and furthermore improve CNT dispersion.

Next, the output voltage and current of the TENG (SC2) device under different external loads were investigated as shown in Fig. 1b. It is apparent that the output current density decreases with an increment in the resistance, while the output voltage increases gradually and reaches saturation. Consequently, the maximum power of the TENG was calculated to be approximately 1.6 W/m^2 at 1 MΩ.

3. Conclusions

TENG based on SDS/CNT/PDMS composites as a negative electrode and PET as a positive electrode was successfully fabricated. The concentration of CNT and SDS has a significant influence on the performance of TENG. The fabricated SDS/CNT/PDMS with the concentration of SDS to CNT 2 wt% shows an output voltage of 66.8 V, which achieves approximately 6-fold improvement compared with the unmodified PDMS. The maximum power density of the TENG reaches 1.6 W/m^2 at an external load of 1 MΩ. The TENG based on SDS/CNT/PDMS composites shows promising potential application for wearable electronics.

.

Acknowledgements

We acknowledge the financial and facility support from the National Nanotechnology Center (NANOTEC), NSTDA, Ministry of Science and Technology, Thailand, through its program of Center of Excellence Network.

References

[1] A.F. Diaz, R.M. Felix-Navarro, J. Electrost. 62 (2004) 277.
[2] S. Wang, L. Lin, Z.L. Wang, Nano Lett. 12 (2012) 6339.
[3] F.-R. Fan, L. Lin, G. Zhu, W. Wu, R. Zhang, Z.L. Wang, Nano Lett. 12 (2012) 3109.
[4] F.R. Fan, J. Luo, W. Tang, C. Li, C. Zhang, Z. Tian, Z.L. Wang, J. Mater. Chem. A. 2 (2014) 13219.
[5] P. Dulyaseree, V. Yordsri, W. Wongwiriyapan, Jpn. J. Appl. Phys. 55 (2016) .
[6] F.-R. Fan, Z.-Q. Tian, Z. Lin Wang, Nano Energy. 1 (2012) 328.
[7] H. Wang, M. Shi, K. Zhu, Z. Su, X. Cheng, Y. Song, X. Chen, Z. Liao, M. Zhang, H. Zhang, Nanoscale. 8 (2016) 18489.