Extended Abstracts of the 2018 International Conference on Solid State Devices and Materials, Tokyo, 2018, pp1073-1074

Micropatterned Carbon Nanotube/Polydimethylsoloxane Composites using DVD Mold for Performance Enhancement of Triboelectric Generator

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

[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

In this research, high performance triboelectric nanogenerator (TENG) was demonstrated based on micropatterned sodium dodecyl sulfate/carbon nanotube/polydimethylsiloxane (SDS/CNT/PDMS)-composites. Micropattern on SDS/CNT/PDMS composites were fabricated by using DVD disk as a mold. TENG was assembled by utilizing the friction between micropatterned SDS/CNT/PDMS composites and polyethylene terephthalate (PET). TENG based on micropatterned SDS/CNT/PDMS using DVD mold generated the maximum voltage output of 98.7±2.7 V and the maximum current output of 31.6±1.7 μA with a power density of 2.5 W/m^2. The micropatterned SDS/CNT/PDMS-based TENG enabled an approximately 1.5-fold improvement in electrical output compared to the flat SDS/CNT/PDMS-based TENG. The micropatterned PDMS/CNT affords the large specific surface area, resulting in a high surface charge density.

1. Introduction

Recently, harvesting energy have been intensively explored as a renewable energy source. The piezoelectric is a main mechanism of harvesting energy, which can convert mechanical energy into electric energy [1]. Recently, a new mechanism of energy harvesting technology is proposed as triboelectric nanogenerator (TENG). TENG has a very simple structure consisting of two different materials, such as two types of polymer and polymer *vs* metal. Working mechanism of TENG is based on the coupling between the triboelectric effect and electrostatic induction effect [2, 3]. The triboelectric effect is a charge transfer by two materials after the material contacting. The charge transfers from positive material to negative materials by electrostatic induction Thus, one approach to enhance TENG performance is an increase in a triboelectric effect which is directly related to triboelectric charge density at the interface. Surface modification with microstructure is a promising approach. Replacing the relatively flat polymer sheets with the patterned structure could significantly improve the TENG power output [4]. However, the conventional lithography for mold fabrication is complicated process and time-consuming.

In this research, to demonstrate a simple method to fabricate the micropattern, CD-R and DVD-R disks are used a mold. Micropatterned carbon nanotube/polydimethylsoloxane composites was used for performance enhancement of TENG.

2. Experimental

SDS/CNT/PDMS composites were used in this research as one side of TENG. Firstly, oxygen plasma treatment was employed to modify surface of CNT by using the oxygen plasma cleaner (Harrick Scientific) at a power of 18 W and an RF frequency of 13.56 MHz for 15 min [5]. Next, the oxygen plasma-treated CNTs were dispersed in DI with a concentration of 0.5 wt%. The SDS was added to the CNT dispersion with a weight ratio of CNT:SDS of 500:1. The CNT and SDS dispersion in DI were mixed by ultrasonication for 15 min. Next, PDMS elastomer and cross-linker (Sylgard 184, Tow Corning) were mixed in a weight ratio of 10:1 ratio (w/w). The CNT dispersion was poured into a PDMS matrix, and then the mixture was further mixed by ultrasonication for 60 min, and the mixture were consequently degassed in a vacuum chamber.

Next, to prepare the patterned SDS/CNT/PDMS, new CD-R and DVD-R disks were used as a mold. The disks were cut into a small piece with an area of 1.5×4.5 cm^2. The mixture of SDS/CNT/PDMS were poured on a disk and incubated at 75^{O}C for 1 h. The micropatterned SDS/CNT/PDMS were peeled off from the disk and then placed on a piece of a clean PET/ITO sheet. The micropattern is different between CD-R and DVD-R disks (hereafter referred to as CD-, DVD-composites). For comparison, the SDS/CNT/PDMS without pattern was prepared by pouring on Si substrate (hereafter referred to as flat composites). The morphology of each sample was characterized by atomic force microscope (AFM, SEIKO, SPA400).

Next, to assemble TENG device, the SDS/CNT/PDMS on PET/ITO sheet was placed on a PET/ITO sheet with a gap of 5 mm. The conductive ITO layers at the top and bottom of the device act as a charge generation via the electrostatic induction between the tribology generated potential at the interfacial region, and as common electrodes for connecting the device with an external circuit [1].

3. Results and Discussion

Figs.1 show AFM images (a, c, e) and their corresponding line profiles (b, d, f) of flat, CD- and DVD-composites, respectively. AFM images clearly show different roughness of each sample depending the mold. The flat composites shows a relatively smooth surface. Meanwhile, the CD- and DVD-composites show a pattern on its surface corresponding to a pattern of CD and DVD disks with a pitch of 1.70±0.06 and 0.79±0.04 μm, respectively.

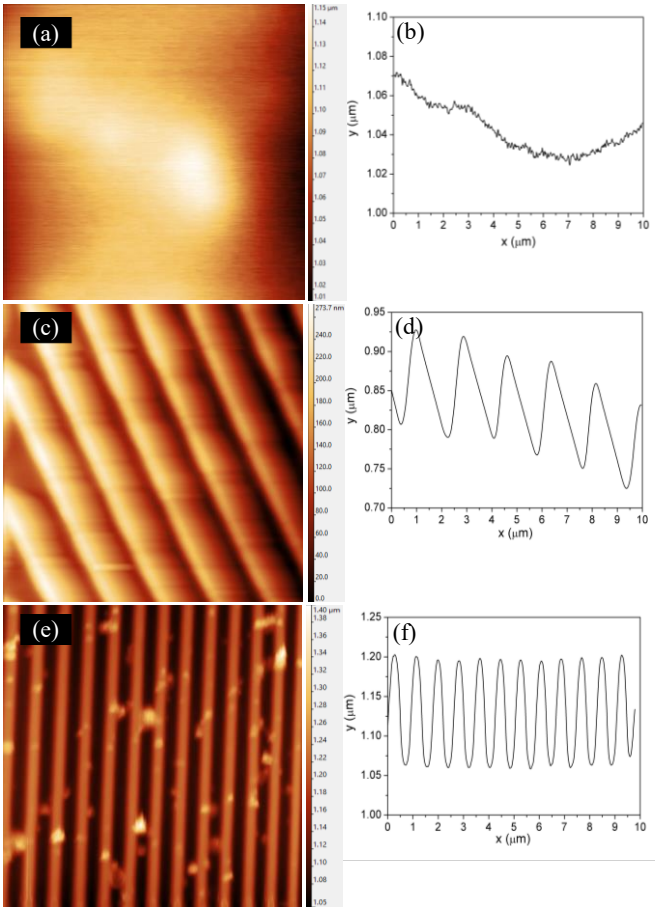

Fig.1 AFM images and line profiles of (a,b) flat- , (c,d) CD- and (e,f) DVD-composites

Figs. 2(a) and 2(b) show an open-circuit voltage and a short circuit current outputs of each device, respectively. The peaks of positive and negative voltages and currents were observed during the periodically pressing or releasing process of the external force in a vertical contact-separation mode with a frequency of 1 Hz. The voltage and current outputs of flat, CD- and DVD-composites are 66.8±1.2 , 82.9±2.2 , 98.7±2.7 V, and 27.5±1.5 , 29.4±1.8 , 31.6±1.7 μA, respectively. The DVD-composites shows the maximum outputs while the flat composites shows the minimum output, The DVD-composites enabled an approximately 1.5-fold improvement in outputs. The improvement in electrical output of the DVD-composites-based TENG can be attributed to the high surface area of the DVD-composites, resulting in an enhancement of surface charge density. Next, the power output was investigated. The maximum power of the DVD-composites is 2.5 W/m^2 at 1 MΩ.

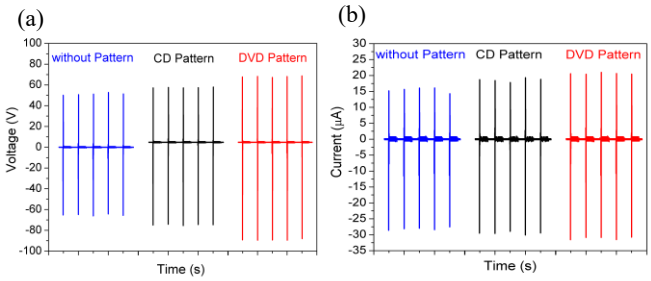

Fig.2 Output performance of TENG using flat-, CD- and DVD-composites. (a) Voltage and (b) current output.

4. Conclusions

Micropatterned SDS/CNT/PDMS composites were successfully fabricated using CD-R and DVD-R disks as a mold, and were successfully demonstrated as TENG with a high electrical output. Using CD-R and DVD-R disks as a mold is a simple approach to achieve micropatterned structure. DVD-composites-based TENG generated the maximum voltage, current and power outputs of 98.7±2.7 V, 29.4±1.8 μA and 2.5 W/m^2. The DVD-composites-based TENG enabled an approximately 1.5-fold improvement in electrical output compared to the flat composites-based TENG. The micropatterned SDS/CNT/PDMS affords a large specific area, resulting a high surface charge density.

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] H. S. Kim, J.-H. Kim, and J. Kim, International Journal of Precision Engineering and Manufacturing. 12 (2011) 1129-1141.

[2] G. Zhu, B. Peng, J. Chen, Q. Jing, and Z. Lin Wang, Nano Energy. 14 (2015) 126-138.

[3] N. Cui, J. Liu, L. Gu, S. Bai, X. Chen, and Y. Qin, ACS Appl Mater Interfaces. 7 (2015) 18225-30.

[4] F. R. Fan, L. Lin, G. Zhu, W. Wu, R. Zhang, and Z. L. Wang, Nano Lett. 12 (2012) 3109-14.

[5] P. Dulyaseree, V. Yordsri, and W. Wongwiriyapan, J. Appl. Phys. 55 (2016) 02BD05.