International Journal of Energy Research • 2022

Document type
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Source type
Journal

ISSN
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DOI
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Wearable thermoelectric generator with vertically aligned PEDOT:PSS and carbon nanotubes-basthermoelements for energy harvesting

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Abstract

Thermoelectric generators (TEGs) facilitate maintenance-free sustainable energy transduction, making them attractive and feasible options for self-powered wearable electronics. Nonetheless, their energy-conversion process suffers from inadequate design and rigidity owing to the use of brittle inorganic materials, making them inapt for wearable applications. Thus, the development of a TEG made of flexible materials with high deformability is required. In this study, a novel wearable TEG was designed

and fabricated with vertically aligned p-type PEDOT:PSS and n-type SWCNT film-based thermoelements. Finite element analysis was used to optimize the thermoelement length, which was essential for enhancing the overall TEG output performance. This study also examined the effects of acid-based post-treatment and polyethylenimine concentration on the thermoelectric properties of PEDOT:PSS and SWCNT films, respectively. As a proof of concept, the proposed TEG, composed of five pairs of thermoelements, generated an open-circuit voltage of 1.75 mV while produced a maximum power and a power density of ~6.1 nW and 10.17 $nWcm^{-2}$, respectively, at a ΔT of 11.24°C by harvesting energy from the wrist. The proposed design represents a significant step toward developing a next-generation flexible organic TEG that can pave the way for self-powered wearable electronics in a sustainable manner utilizing body heat. © 2022 John Wiley & Sons Ltd.

Author keywords

energy harvesting; PEDOT:PSS; SWCNT; thermoelectric generators; thermoelements

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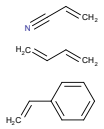

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1 Wang, Y., Zhou, Z., Zhou, J., Shao, L., Wang, Y., Deng, Y.

High-performance Stretchable Organic Thermoelectric Generator via Rational Thermal Interface Design for Wearable Electronics

(2022) *Advanced Energy Materials*, 12 (1), art. no. 2102835. Cited 3 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1614-6840
doi: 10.1002/aenm.202102835

View at Publisher

2 Hasan, M.N., Sahlan, S., Osman, K., Mohamed Ali, M.S.

Energy Harvesters for Wearable Electronics and Biomedical Devices

(2021) *Advanced Materials Technologies*, 6 (3), art. no. 2000771. Cited 16 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2365-709X
doi: 10.1002/admt.202000771

View at Publisher

3 Hou, Y., Yang, Y., Wang, Z., Li, Z., Zhang, X., Bethers, B., Xiong, R., (...), Yu, H.

Whole Fabric-Assisted Thermoelectric Devices for Wearable Electronics (Open Access)

(2022) *Advanced Science*, 9 (1), art. no. 2103574. Cited 5 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2198-3844http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2198-3844
doi: 10.1002/advs.202103574

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4 Hasan, M.N., Nafea, M., Nayan, N., Ali, M.S.M.
Thermoelectric generator: materials and applications in wearable health monitoring sensors and internet of things devices
(2021) *Adv Mater Technol*, 12, p. 2101203.

5 Yuan, J., Zhu, R., Li, G.

Self-Powered Electronic Skin with Multisensory Functions Based on Thermoelectric Conversion

(2020) *Advanced Materials Technologies*, 5 (9), art. no. 2000419. Cited 26 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2365-709X
doi: 10.1002/admt.202000419

View at Publisher

6 Kim, C.S., Yang, H.M., Lee, J., Lee, G.S., Choi, H., Kim, Y.J., Lim, S.H., (...), Cho, B.J.

Self-Powered Wearable Electrocardiography Using a Wearable Thermoelectric Power Generator

(2018) *ACS Energy Letters*, 3 (3), pp. 501-507. Cited 143 times.
http://pubs.acs.org/journal/aelccp
doi: 10.1021/acsenergylett.7b01237

View at Publisher

7 Kim, J., Khan, S., Wu, P., Park, S., Park, H., Yu, C., Kim, W.

Self-charging wearables for continuous health monitoring

(2021) *Nano Energy*, 79, art. no. 105419. Cited 28 times.
http://www.journals.elsevier.com/nano-energy/
doi: 10.1016/j.nanoen.2020.105419

View at Publisher

8 Kong, D., Zhu, W., Guo, Z., Deng, Y.

High-performance flexible Bi_2Te_3 films based wearable thermoelectric generator for energy harvesting

(2019) *Energy*, 175, pp. 292-299. Cited 53 times.
www.elsevier.com/inca/publications/store/4/8/3/
doi: 10.1016/j.energy.2019.03.060

View at Publisher

9 Lee, B., Cho, H., Park, K.T., Kim, J.-S., Park, M., Kim, H., Hong, Y., (...), Chung, S.

High-performance compliant thermoelectric generators with magnetically self-assembled soft heat conductors for self-powered wearable electronics (Open Access)

(2020) *Nature Communications*, 11 (1), art. no. 5948. Cited 61 times.
http://www.nature.com/ncomms/index.html
doi: 10.1038/s41467-020-19756-z

View at Publisher

10 Choi, H., Kim, Y.J., Song, J., Kim, C.S., Lee, G.S., Kim, S., Park, J., (...), Cho, B.J.

UV-Curable Silver Electrode for Screen-Printed Thermoelectric Generator

(2019) *Advanced Functional Materials*, 29 (20), art. no. 1901505. Cited 16 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1616-3028
doi: 10.1002/adfm.201901505

View at Publisher

11 Khan, S., Kim, J., Roh, K., Park, G., Kim, W.

High power density of radiative-cooled compact thermoelectric generator based on body heat harvesting

(2021) *Nano Energy*, 87, art. no. 106180. Cited 21 times.
http://www.journals.elsevier.com/nano-energy/
doi: 10.1016/j.nanoen.2021.106180

View at Publisher

12 Newbrook, D.W., Richards, S.P., Greenacre, V.K., Hector, A.L., Levason, W., Reid, G., De Groot, C.H.K., (...), Huang, R.

Selective Chemical Vapor Deposition Approach for Sb_2Te_3Thin Film Micro-thermoelectric Generators (Open Access)

(2020) *ACS Applied Energy Materials*, 3 (6), pp. 5840-5846. Cited 5 times.
pubs.acs.org/journal/aaemcq
doi: 10.1021/acsaem.0c00766

View at Publisher

13 Nozariasbmarz, A., Suarez, F., Dycus, J.H., Cabral, M.J., LeBeau, J.M., Öztürk, M.C., Vashaee, D.

Thermoelectric generators for wearable body heat harvesting: Material and device concurrent optimization (Open Access)

(2020) *Nano Energy*, 67, art. no. 104265. Cited 39 times.
http://www.journals.elsevier.com/nano-energy/
doi: 10.1016/j.nanoen.2019.104265

View at Publisher

14 Nandihalli, N., Liu, C.-J., Mori, T.

Polymer based thermoelectric nanocomposite materials and devices: Fabrication and characteristics (Open Access)

(2020) *Nano Energy*, 78, art. no. 105186. Cited 97 times.
http://www.journals.elsevier.com/nano-energy/
doi: 10.1016/j.nanoen.2020.105186

View at Publisher

15 Xu, S., Shi, X.-L., Dargusch, M., Di, C., Zou, J., Chen, Z.-G.

Conducting polymer-based flexible thermoelectric materials and devices: From mechanisms to applications

(2021) *Progress in Materials Science*, 121, art. no. 100840. Cited 52 times.
https://www.journals.elsevier.com/progress-in-materials-science
doi: 10.1016/j.pmatsci.2021.100840

View at Publisher

16 Petsagkourakis, I., Kim, N., Tybrandt, K., Zozoulenko, I., Crispin, X.

Poly(3,4-ethylenedioxythiophene): Chemical Synthesis, Transport Properties, and Thermoelectric Devices

(2019) *Advanced Electronic Materials*, 5 (11), art. no. 1800918. Cited 60 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2199-160Xhttp://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2199-160X
doi: 10.1002/aelm.201800918

View at Publisher

17 Xu, Y., Jia, Y., Liu, P., Jiang, Q., Hu, D., Ma, Y.

Poly(3,4-ethylenedioxythiophene) (PEDOT) as promising thermoelectric materials and devices

(2021) *Chemical Engineering Journal*, 404, art. no. 126552. Cited 40 times.
www.elsevier.com/inca/publications/store/6/0/1/2/7/3/index.htt
doi: 10.1016/j.cej.2020.126552

View at Publisher

18 Liu, D., Yan, Z., Zhao, Y., Zhang, Z., Zhen, Y., Zhang, B., Shi, P., (...), Xue, C.

Facile MWCNTs-SnSe/PEDOT:PSS ternary composite flexible thermoelectric films optimized by cold-pressing (Open Access)

(2021) *Journal of Materials Research and Technology*, 15, pp. 4452-4460. Cited 2 times.
http://www.elsevier.com/journals/journal-of-materials-research-and-technology/2238-7854
doi: 10.1016/j.jmrt.2021.10.075

View at Publisher

19 Song, H., Cai, K.

Preparation and properties of PEDOT:PSS/Te nanorod composite films for flexible thermoelectric power generator

(2017) *Energy*, 125, pp. 519-525. Cited 117 times.
https://www.journals.elsevier.com/energy
doi: 10.1016/j.energy.2017.01.037

View at Publisher

20 Wen, N., Fan, Z., Yang, S., Zhao, Y., Cong, T., Xu, S., Zhang, H., (...), Pan, L.

Highly conductive, ultra-flexible and continuously processable PEDOT:PSS fibers with high thermoelectric properties for wearable energy harvesting

(2020) *Nano Energy*, 78, art. no. 105361. Cited 40 times.
http://www.journals.elsevier.com/nano-energy/
doi: 10.1016/j.nanoen.2020.105361

View at Publisher

21 Wen, N., Fan, Z., Yang, S., Zhao, Y., Li, C., Cong, T., Huang, H., (...), Pan, L.

High-performance stretchable thermoelectric fibers for wearable electronics

(2021) *Chemical Engineering Journal*, 426, art. no. 130816. Cited 7 times.
www.elsevier.com/inca/publications/store/6/0/1/2/7/3/index.htt
doi: 10.1016/j.cej.2021.130816

View at Publisher

22 Selvan, K.V., Hasan, M.N., Mohamed Ali, M.S.

State-of-the-Art Reviews and Analyses of Emerging Research Findings and Achievements of Thermoelectric Materials over the Past Years

(2019) *Journal of Electronic Materials*, 48 (2), pp. 745-777. Cited 32 times.
https://rd.springer.com/journal/11664
doi: 10.1007/s11664-018-06838-4

View at Publisher

23 Culebras, M., Choi, K., Cho, C.

Recent progress in flexible organic thermoelectrics (Open Access)

(2018) *Micromachines*, 9 (12), art. no. 638. Cited 29 times.
https://www.mdpi.com/2072-666X/9/12/638/pdf
doi: 10.3390/mi9120638

View at Publisher

24 Kim, S., Mo, J.-H., Jang, K.-S.

Solution-Processed Carbon Nanotube Buckypapers for Foldable Thermoelectric Generators

(2019) *ACS Applied Materials and Interfaces*, 11 (39), pp. 35675-35682. Cited 19 times.
http://pubs.acs.org/journal/aamick
doi: 10.1021/acsami.9b10335

View at Publisher

25 Mo, J.-H., Kim, J.-Y., Kang, Y.H., Cho, S.Y., Jang, K.-S.

Carbon Nanotube/Cellulose Acetate Thermoelectric Papers

(2018) *ACS Sustainable Chemistry and Engineering*, 6 (12), pp. 15970-15975. Cited 17 times.
http://pubs.acs.org/journal/ascecg
doi: 10.1021/acssuschemeng.8b03670

View at Publisher

26 Mytafides, C.K., Tzounis, L., Karalis, G., Formanek, P., Paipetis, A.S.

High-Power All-Carbon Fully Printed and Wearable SWCNT-Based Organic Thermoelectric Generator (Open Access)

(2021) *ACS Applied Materials and Interfaces*, 13 (9), pp. 11151-11165. Cited 22 times.
http://pubs.acs.org/journal/aamick
doi: 10.1021/acsami.1c00414

View at Publisher

27 Mytafides, C.K., Tzounis, L., Karalis, G., Formanek, P., Paipetis, A.S.

Fully printed and flexible carbon nanotube-based thermoelectric generator capable for high-temperature applications

(2021) *Journal of Power Sources*, 507, art. no. 230323. Cited 5 times.
https://www.journals.elsevier.com/journal-of-power-sources
doi: 10.1016/j.jpowsour.2021.230323

View at Publisher

28 Park, S., Mo, J.-H., Kim, S., Hwang, H., Jang, K.-S.

Shape-deformable thermoelectric carbon nanotube doughs

(2020) *ACS Applied Materials and Interfaces*, 12 (17), pp. 19415-19422. Cited 8 times.
http://pubs.acs.org/journal/aamick
doi: 10.1021/acsami.0c00617

View at Publisher

29 Karalis, G., Tzounis, L., Tsirka, K., Mytafides, C.K., Voudouris Itskaras, A., Liebscher, M., Lambrou, E., (...), Paipetis, A.S.

Advanced Glass Fiber Polymer Composite Laminate Operating as a Thermoelectric Generator: A Structural Device for Micropower Generation and Potential Large-Scale Thermal Energy Harvesting

(2021) *ACS Applied Materials and Interfaces*, 13 (20), pp. 24138-24153. Cited 5 times.
http://pubs.acs.org/journal/aamick
doi: 10.1021/acsami.1c04527

View at Publisher

30 Hyland, M., Hunter, H., Liu, J., Veety, E., Vashaee, D.

Wearable thermoelectric generators for human body heat harvesting (Open Access)

(2016) *Applied Energy*, 182, pp. 518-524. Cited 202 times.
http://www.elsevier.com/inca/publications/store/4/0/5/8/9/1/index.htt
doi: 10.1016/j.apenergy.2016.08.150

View at Publisher

☐ 31 Hasan, M.N., Yunos, Y.M., Ali, M.S.M.

Structural Optimization of a Bismuth Telluride-Based Thermoelectric Generator Using Finite Element Analysis

(2021) *2021 IEEE International Power and Renewable Energy Conference, IPRECON 2021*
http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=9640537
ISBN: 978-166540137-1
doi: 10.1109/IPRECON52453.2021.9640629

View at Publisher

☐ 32 Hasan, M.N., Been Hashem, M.Y., Siddique, M.A., Md Yunus, M.A., Mohamed Ali, M.S.

Finite Element Analysis of Thermoelectric Power Generation from Human Wrist

(2021) *2021 IEEE Symposium on Industrial Electronics and Applications, ISIEA 2021*
http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=9509931
ISBN: 978-166541591-0
doi: 10.1109/ISIEA51897.2021.9510000

View at Publisher

☐ 33 Fan, Z., Li, P., Du, D., Ouyang, J.

Significantly Enhanced Thermoelectric Properties of PEDOT:PSS Films through Sequential Post-Treatments with Common Acids and Bases

(2017) *Advanced Energy Materials*, 7 (8). Cited 228 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1614-6840
doi: 10.1002/aenm.201602116

View at Publisher

☐ 34 Fan, Z., Ouyang, J.

Thermoelectric Properties of PEDOT:PSS

(2019) *Advanced Electronic Materials*, 5 (11), art. no. 1800769. Cited 136 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2199-160Xhttp://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2199-160X
doi: 10.1002/aelm.201800769

View at Publisher

☐ 35 Wang, C., Sun, K., Fu, J., Chen, R., Li, M., Zang, Z., Liu, X., (...), Ouyang, J.

Enhancement of Conductivity and Thermoelectric Property of PEDOT:PSS via Acid Doping and Single Post-Treatment for Flexible Power Generator

(2018) *Advanced Sustainable Systems*, 2 (12), art. no. 1800085. Cited 54 times.
www.advsustainsys.com
doi: 10.1002/adsu.201800085

View at Publisher

☐ 36 Jin Bae, E., Hun Kang, Y., Jang, K.S., Yun Cho, S.
Enhancement of thermoelectric properties of PEDOT: PSS and tellurium-PEDOT: PSS hybrid composites by simple chemical treatment
(2016) *Sci Rep*, 6, pp. 1-10.

37 Elmoughni, H.M., Menon, A.K., Wolfe, R.M.W., Yee, S.K.

A Textile-Integrated Polymer Thermoelectric Generator for Body Heat Harvesting (Open Access)

(2019) *Advanced Materials Technologies*, 4 (7), art. no. 1800708. Cited 50 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2365-709X
doi: 10.1002/admt.201800708

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