Guest Editorial
Special Issue on Self-Powered Sensors and Wearable Electronic Systems

WEARABLE sensing has recently been highly preferred due to its quick and accurate measurement of physiological parameters. These sensors have been devised using various polymers [1], [2] and nanomaterials [3], [4] suited for the chosen application. With the exponential growth of wearable electronics [5], [6], [7], there is a need to broaden their capabilities in terms of functionality and availability. Commercializing these wearable electronics needs further encouragement to use these sensors as point-of-care devices. Self-powered sensors [8], [9] are one of the growing aspects in the sector of wearable sensing. With the growing requirement for energy usage, self-powered sensing systems need to be developed to generate and harvest energy ubiquitously [10], [11]. This Special Issue highlights some of the published papers that work on using smart textiles and self-powered devices for efficient and sustainable sensing applications.

A comprehensive review by Majumder et al. [A1] illustrates the compelling usage of smart-textile-based sensors for in-home health care. The review highlights using textile-based wearables to monitor health and activities in a smart home. A thorough review is provided to showcase the current state of research and development on smart textiles and textile-based sensors, focusing on their application in the smart home environment. It is estimated that the smart-textile-based industry is expected to grow to over U.S. $4 billion by 2030. Certain factors, such as cost-effectiveness, manufacturing scalability, device performance, environmental and safety concerns, and privacy issues, may impede the market penetration of smart textiles.

Min et al. [A2] show us the fabrication and utilization of triboelectric nanogenerators (TENGs) for a wide range of self-powered flexible pressure sensors. The developed prototypes exhibited sensing of a wide pressure range of 3.2–1176 kPa. It should also have variable sensitivities in three different pressure ranges of low (1–10 kPa), medium-to-high (10–500 kPa), and ultra-high (>500 kPa). Sensitivities of 3.16, 0.023, and 0.031 V/kPa were obtained for these three pressure ranges. The sensors also obtained stable and repeatable responses for all the applied pressure ranges. The performances of these sensors highlighted their potential to be used for certain applications in the field of wearable devices, human–machine interfaces, and biomedical and automotive sectors. The real-time functionality of the sensors was shown by demonstrating the use of the device in the detection of human and robot finger tapping, collection of human gait information, and detection of impact forces.

The work by Toral et al. [A3] highlights developing and utilizing graphene-enabled sensors for monitoring physiological parameters. The graphene-based sensors were formed by developing laser-induced graphene (LIG) and laser-induced graphene oxide (LrGO) materials. Following the optical characterization of the LIG materials, they were used as micro-supercapacitors (MSCs) to detect dual physiological parameters, including temperature and heart rate. Due to the porous nature of the sensors, they performed well when operated as electrochemical and electrocardiogram (ECG) electrodes. The body temperature sensing of these prototypes was based on the temperature dependency of the electrical conductivity of LrGO. After the prototypes were encapsulated with polydimethylsiloxane (PDMS) for enhanced protection and increased linearity, they showed a sensitivity of -1.23 k$\Omega\cdot{}^\circ$C^{-1}. The real-time application of these sensors was carried out by attaching them to a rigid-flex printed circuit board (PCB). The sensing system was wirelessly operated by integrating it with a Bluetooth low energy (BLE) microcontroller. The power consumption of these systems was optimized for extended battery life when used for wireless transmission of physiological data to external monitoring devices. This allows the system to operate wirelessly for prolonged periods.

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ANINDYA NAG, *Lead Guest Editor*
Faculty of Electrical and Computer Engineering
Technische Universität Dresden
01062 Dresden, Germany
Centre for Tactile Internet with
Human-in-the-Loop (CeTI)
Technische Universität Dresden
01069 Dresden, Germany
e-mail: anindya.nag@tu-dresden.de

OLIVER OZIOKO, *Guest Editor*
Department of Electrical and Electronic
Engineering
University of Derby
DE22 1GB Derby, U.K. e-mail:
o.ozioko@derby.ac.uk

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WOO SOO KIM, *Guest Editor*
School of Mechatronic Systems Engineering
Simon Fraser University
Burnaby, BC V5A 1S6, Canada
e-mail: woosook@sfu.ca

JOSEPH ANDREWS, *Guest Editor*
Department of Mechanical Engineering and
Department of Electrical and Computer
Engineering
University of Wisconsin–Madison,
Madison, WI 53706 USA
e-mail: joseph.andrews@wisc.edu

APPENDIX: RELATED ARTICLES

[A1] S. Majumder, A. K. Roy, W. Jiang, T. Mondal, and M. J. Deen, "Smart textiles to enable in-home health care: State of the art, challenges, and future perspectives," *IEEE J. Flexible Electron.*, vol. 3, no. 4, pp. 120–150, Apr. 2024.

[A2] G. Min, G. Khandelwal, R. Chirila, A. S. Dahiya, D. M. Mulvihill, and R. Dahiya, "A triboelectric nanogenerator based wide range self-powered flexible pressure sensor," *IEEE J. Flexible Electron.*, vol. 3, no. 4, pp. 151–158, Apr. 2024.

[A3] V. Toral, Y. Houeix, D. Gerardo, I. Blasco-Pascual, A. Rivadeneyra, and F. Romero, "Graphene-enabled wearable for remote ECG and body temperature monitoring," *IEEE J. Flexible Electron.*, vol. 3, no. 4, pp. 159–168, Apr. 2024.

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[2] N. L. Torad and M. M. Ayad, "Gas sensors based on conducting polymers," in *Gas Sensors*. Saudi Arabia: IntechOpen, 2019, p. 125.

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[4] G. Balkourani, T. Damartzis, A. Brouzgou, and P. Tsiakaras, "Cost effective synthesis of graphene nanomaterials for non-enzymatic electrochemical sensors for glucose: A comprehensive review," *Sensors*, vol. 22, no. 1, p. 355, Jan. 2022.

[5] S. Sapra et al., "Printed, wearable e-skin force sensor array," *Measurement*, vol. 206, Jan. 2023, Art. no. 112348.

[6] S. C. Mukhopadhyay, N. K. Suryadevara, and A. Nag, "Wearable sensors and systems in the IoT," in *Proc. MDPI*, 2021, p. 7880

[7] A. Nag, S. C. Mukhopadhyay, and J. Kosel, "Wearable flexible sensors: A review," *IEEE Sensors J.*, vol. 17, no. 13, pp. 3949–3960, Jul. 2017.

[8] A. A. Mathew and V. Shanmugasundaram, "Fabrication of screen-printed single-electrode triboelectric nanogenerator-based self-powered sensor for pulse measurement and its characterization," *Energy Technol.*, vol. 11, no. 7, Jul. 2023, Art. no. 2300174.

[9] C. Y. Shie et al., "Flexible and self-powered thermal sensor based on graphene-modified intumescent flame-retardant coating with hybridized nanogenerators," *ACS Appl. Nano Mater.*, vol. 6, no. 4, pp. 2429–2437, Feb. 2023.

[10] A. Proto, M. Penhaker, D. Bibbo, D. Vala, S. Conforto, and M. Schmid, "Measurements of generated energy/electrical quantities from locomotion activities using piezoelectric wearable sensors for body motion energy harvesting," *Sensors*, vol. 16, no. 4, p. 524, Apr. 2016.

[11] W. Akram, Q. Chen, G. Xia, and J. Fang, "A review of single electrode triboelectric nanogenerators," *Nano Energy*, vol. 106, Feb. 2023, Art. no. 108043.