

Empowering healthcare through wearable electronics



This Focus issue examines how wearable electronics, leveraging embedded systems, are advancing healthcare, while addressing integration, usability and scalability challenges.

The convergence of electronic engineering with materials science and biomedical technologies is driving a transformative shift in the way we monitor, interpret and intervene in human health. Wearable electronics – engineered to be on-skin, textile-integrated or implantable – are rapidly evolving from basic activity trackers to multifunctional platforms capable of real-time physiological monitoring, data analysis and personalized therapeutic feedback. This growth is driven by factors such as the increasing prevalence of chronic diseases such as diabetes and cardiovascular disorders, demand for remote patient-monitoring solutions (the post-pandemic surge in telehealth adoption, for example) or consumer interest in preventive care, and is enabled by technological advancements in sensor technology, artificial intelligence (AI), and Internet of Things connectivity. As the boundaries between the body and technology continue to blur, the promise is clear: seamless, minimally invasive tools to manage disease, enhance rehabilitation, improve general wellbeing, and empower users in their own care.

Key to this evolution is the development of conformable and stretchable electronics. Devices are increasingly designed to interface directly with the skin, taking advantage of soft, stretchable materials. Innovations in substrate materials, such as hydrogels or biodegradable polymers, are combined with advanced fabrication methods to enable conformability to the body's complex, dynamic surfaces without sacrificing electrical integrity. As the need for devices with improved mechanical adaptability and spatial resolution grows, 3D fabrication techniques that range from direct ink writing to multi-material printing are emerging as effective manufacturing processes. In their [Review](#) article, Jianfeng Ping and colleagues discuss how automated processes in 3D manufacturing can leverage AI integration to facilitate the scalable production of reliable multifunctional medical devices.

The integration of diverse sensor modalities, such as electrocardiogram, heart rate, temperature, hydration and strain, into compact form factors poses marked challenges, particularly around managing power, signal processing, and transmitting data reliably¹. Researchers are tackling these issues by designing systems that consume very little power, often using energy harvested directly from the body or environment². Advances in ultra-low-power analogue

front ends, energy-harvesting modules, and miniaturized power management integrated circuits make it possible to run sophisticated sensors without bulky batteries^{3,4}. Simultaneously, improvements in wireless communication protocols such as Bluetooth low energy, near-field communication, and increasingly, long-range and ultra-wideband and edge computing have expanded the capabilities of wearable devices, enabling onboard data processing, anomaly detection, and cloud interfacing. In their [Review](#), Ahmed M. Eltawil and colleagues examine the human body as a communication medium, an approach that marks a departure from conventional wireless systems and could lead to more secure and power-efficient communication strategies for body area networks.

These devices not only gather data but also transmit, interpret and act on it in real time. In their [Review](#), Samuel J. Lin and colleagues discuss bioelectronics for pain management, a domain in which wearable systems are already beginning to influence clinical practice, emphasizing the clinical translation of these technologies and discussing key considerations in device safety, efficacy and patient compliance.

Furthermore, industry is gearing up to translate the latest research findings into scalable products. In their [Lab to Fab](#) article, Kyeongsu Shi and Kyoungchul Kong describe the development of wearable assistive robots for patients to use in home settings. In a second [Lab to Fab](#) piece, Roozbeh Ghaffari and colleagues describe the development of hydration sensors to improve worker safety in energy, construction, power utilities and manufacturing sectors.

However, engineering challenges persist. Manufacturing high-resolution, biocompatible and robust yet unobtrusive devices while ensuring data security and reliable data transmission from the body and developing meaningful digital interfaces for diverse users all remain active areas of investigation. In their [Perspective](#) on wearable devices for digital information interaction, Yan Ma and colleagues address a crucial but often overlooked aspect of the field: the accessibility and usability of information. As sensor networks become more advanced, bottlenecks in human-machine interactions, cognitive load and data interpretation must be carefully considered for the devices to reach their full potential ethically and sustainably.

Finally, as highlighted in a [Comment](#) by Annalisa Bonfiglio, future progress in wearable electronics for healthcare will require sustained collaboration across disciplines, and the involvement of research, industry and consumers to create devices that are not only technically sophisticated and clinically and commercially viable but also accessible to everyone.

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References

1. Mahato, K. et al. Hybrid multimodal wearable sensors for comprehensive health monitoring. *Nat. Electron.* **7**, 735–750 (2024).
2. Zhang, B. et al. Nature-inspired interfacial engineering for energy harvesting. *Nat. Rev. Electr. Eng.* **1**, 218–233 (2024).
3. Yan, F. & Liu, J. Analog front-end input-impedance boosting techniques for bio-potential monitoring—a review. *IEEE Trans. Instrum. Meas.* **73**, 1–14 (2024).
4. Ates, H. C. et al. End-to-end design of wearable sensors. *Nat. Rev. Mater.* **7**, 887–907 (2022).