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Self-powered skin electronics for energy harvesting

Introduction

Skin electronics refers to flexible, stretchable and self-healing electronics that are able to mimic functionalities of human or animal skin. The broad class of materials often contain sensing abilities that are intended to reproduce the capabilities of human skin to respond to environmental factors such as changes in heat and pressure. Advances in electronic skin research focuses on designing materials that are stretchy, robust, and flexible. Research in the individual fields of flexible electronics and tactile sensing has progressed greatly; however, electronic skin design attempts to bring together advances in many areas of materials research without sacrificing individual benefits from each field. The successful combination of flexible and stretchable mechanical properties with sensors and the ability to self-heal would open the door to many possible applications including soft robotics, prosthetics, artificial intelligence and health monitoring.

In the recent decades, the research of skin electronics has acquired prominence, because these and other related systems are distinguished relative to technologies of the past by their compliant architectures and low bending stiffness as minimally invasive interfaces to curved, soft, and dynamic skin surfaces .Many innovations have also emerged in the sensing/actuating function of the skin electronics and sophisticated high-performance platforms of these types are increasingly well established. Embodiments range from precise measurements of pressure and temperature for skin function, to sweat sensing for human body and to continuous real-time monitoring of healthcare. Of particular interests are advanced platforms that establish large-area, high resolution and multifunctional flexible integrated interfaces intimately coupled to skin, with stable operational functions similar to or even beyond skins. Rapid advances in materials science and microfabrication technologies are facilitating the development of skin electronics that provide highly comfortable interfaces on human skin, creating new opportunities in the research study of biomedical engineering, in physiological signals tracking for fitness applications, and in the examination and treatment of clinical medicine. The burgeoning skin electronics are changing the way we interact with the real world, opening new markets in artificial intelligence and personalized healthcare monitoring and advancing us understand of human physiology. In the future, development of skin electronics that is self-powered, self-healing, printable, transparent, wireless communication, and biocompatible are highly essential These works present imagination and creativity, and will greatly expand the application potential of skin electronics.

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Self-powering

As energy conservation is gaining speed, it is not unnatural for the researchers to target even the solar power or the physical movements of the humans to harvest the energy for the skin electronics. The development of a sufficient and stable quantum of energy supply for skin electronics is vital to drive device operation reliably and continually. Primary cell and rechargeable battery are the most attractive choices in terms of their portable platforms. However, challenges remain in applying these batteries in skin electronics due to the following reasons: (1) A minor explosion may occur when the battery is overheated, thus inducing injuries to human body. Any related potential hazards must preclude their use in human-related devices. (2) The thicker volume and rigid format is fundamentally mismatched to the soft, curved skin surfaces while undergoing mechanical deformation such as stretching and twisting. In this context, the electronic devices must be flexible, stretchable and lightweight, in ultrathin film forms that are similar to the epidermis and capable of seamlessly coupling with skin, offering electrical performance characteristics that can approach those of conventional wafer-based devices. To solve the problem for this purpose, the concept of a self-powered electronic system was proposed by Zhong Lin Wang et al in 2006. They proposed an aligned arrangement of zinc oxide nanowires (ZnO NWs) array that converted mechanical energy into electronic energy, enable supply energy source for nanoscale electronics and make the devices operate independently. Besides, mechanical energy, biomass, chemical, solar, thermal, wind and tidal energy are potential green energy sources that facilitate self-powered devices. Recent studies on self-powered electronics provide additional options for energy harvesting in devices and systems in a biocompatible, safe fashion, not only at the level of functional materials but also in terms of design architectures with mechanical compliances and energy conversion mechanisms. The development of materials and devices for these self-powered devices are valuable, where these active systems demonstrate the rapid expansion of research emphasis in biomedical engineering. Based on the above discussion, the advantage of self-powered skin electronics is manifest and can be summed up as following: (1) Highly secure and environmentally friendly. Compared to intense chemical reaction and possible leakage in primary cell and rechargeable battery, self-powered skin electronics convert green energy harvested form surrounding environment or human motions into electrical energy in a mild way, which greatly improve the security of biosystem; (2) Durability and cost-effectiveness. It is well known that primary cells can only be used once, whereas the recharging cycle is limited in rechargeable batteries (on the order of tens to hundreds times). Studies have verified that self-powered electronics like triboelectric nano-generator (TENG) and piezoelectric nano-generator (PENG) can undergo more than thousands of times of deformation, demonstrating the long usage time and reduce the fabrication cost; (3) Flexibility and wear ability: the thin volume and simple structure afford the flexibility and wear ability in electronic systems; biocompatible and implantable. Most materials in self-powered skin electronics are biocompatible that made it possible to promote in vivo implantation.

Figure courtesy: Nano Energy, Volume 31, January 2017, Pg.37-48, authors: HaoxuanHe et al A flexible self-powered T-ZnO/PVDF/ fabric electronic-skin with multi-functions of tactile-perception, atmosphere-detection and self-clean

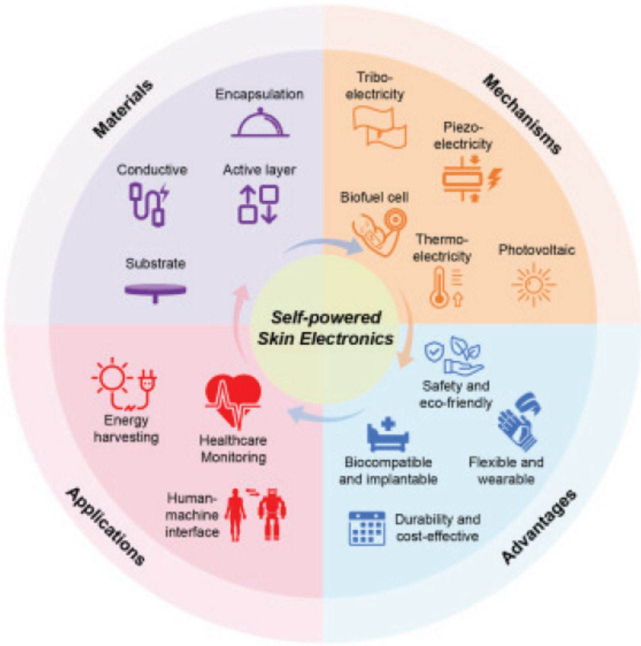

Figure Courtesy: Materials Today Energy Volume 21, September 2021, 100786Journal home page for Materials Today Energy, Self-powered skin electronics for energy harvesting and healthcare monitoring, Authors: M.Wu,et al

Source acknowledgement and further reading: Materials Today Energy Volume 21, September 2021, 100786Journal home page for Materials Today Energy, Self-powered skin electronics for energy harvesting and healthcare monitoring, Authors: M.Wu, et al

Outlook for the future

Over the past several years, work focused on energy harvesters has brought the promised high-performance, lightweight, mechanical robust self-powered skin electronics in fields of energy harvest and healthcare monitors. To enable these energy harvesters to meet the requirements of the skin electronic microsystems better and give full play to their functions, both electrical output that needs to provide continuous and stable energy supply and mechanical robustness that is built-in when attached to skin tissues seamlessly and ensure that the devices normally work in a coordinated manner and stable power and mechanical robustness should be realized simultaneously. According to this line of thought, advanced in working mechanism, functional materials, device configuration, and applications in skin electronics have been summarized and analyzed as outlined in the preceding sections. Energy supply devices based on piezoelectricity, triboelectricity, biofuel cell, photovoltaics, and thermoelectricity can harvest energy from human motions and ambient environment in a green way, thereby extending the device selection and application scenario. In general, the electrical output of these energy generators is transient that needs to combine with capacitors or supercapacitors to store energy. Furthermore, energy harvested from piezoelectricity or triboelectricity is not in a direct current form, thereby additional bridge rectifiers are needed to convert the harvested energy from alternating current to direct current.