Project Title: Thermal energy harvesting for self-powered wearable sensors and electronics

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Project Description

Advances in miniaturization of sensors are enabling the explosive growth of wearable electronics and sensing technologies for biomedical applications and structural engineering. Applications include body sensor networks, where small sensors are embedded in or surface-mounted on the body to monitor the wearer’s physiological parameters for preventive healthcare. A cluster of ‘smart’ sensors distributed in a building or a large-scale industrial site can monitor physical or environmental conditions collectively and in real-time for structural and environmental sustainability. These sensors are often installed in a place where the user’s access is inconvenient, and thus the frequent replacement or recharging of the batteries are not an option. Advances in wearable electronics and sensor miniaturization have enabled significant reduction in power consumption of the individual sensors, and now people have turned to various energy harvesting technologies to scavenge a small level of energy from environment to power those sensors instead of using batteries.

One possible solution for powering these distributed sensors and electronics without a battery is to harvest heat from the environment to generate electricity using a thermoelectric generator. A thermoelectric generator (TEG) is a solid-state device that can directly convert heat into electricity. In particular, when a TEG is attached on to the human skin, heat from the human body flows through the TEG due to the temperature difference between the skin and the ambient environment. This heat flow, or the temperature gradient, creates a voltage in the TEG by the thermoelectric effect called Seebeck effect, which can then supply an electric power when connected to an external load. There are a variety of different energy scavenging technologies other than thermoelectric: piezoelectric, pyroelectric, photovoltaic, ambient-radiation, electro-static, magnetic
induction, and so on. For the development of self-powered sensors, one must choose an appropriate technology as a power source to satisfy the requirements for power level, cost, durability, as well as environmental impact.

In this project, students will be able to participate in the development of flexible and wearable thermoelectric energy harvesting devices, as well as in advanced thermal and electrical testing of TEG devices to evaluate the usefulness of TEGs for self-powered wearable sensors and electronics. Special type of TE device structure called the transverse geometry will be employed for low-cost, high performance energy harvesting devices. Our transverse TEGs consist of tilted multiple alternating layers of metals and thermoelectric polymers. Flexible polymer-based thermoelectric materials will be synthesized using solution-processing techniques and tilted metallic layers will be 3D-printed at UCRI (Univ. Cincinnati Research Institute) Advanced Manufacturing Center. Thorough device characterization will be performed in this project with the developed energy harvesting devices to evaluate the power generation performances with applied temperature gradient in the lab environment and also in wearable applications on the human skin.

Participating students will be able to learn the following scientific and technical knowledge throughout the project:
(1) Physical principles of thermoelectric energy harvesting
(2) Fundamentals of thermoelectric energy conversion devices and materials
(3) Device fabrication with solution-processed polymers and 3D-printed metallic layers
(4) Device testing techniques for thermoelectric power generation
(5) Electrical and thermal characterization of metallic and semiconductor materials