Enhancing Room-Temperature Thermoelectric Performance of PEDOT:PSS through Acid-Treated Multi-Walled Carbon Nanotubes and Polar Solvent Modification

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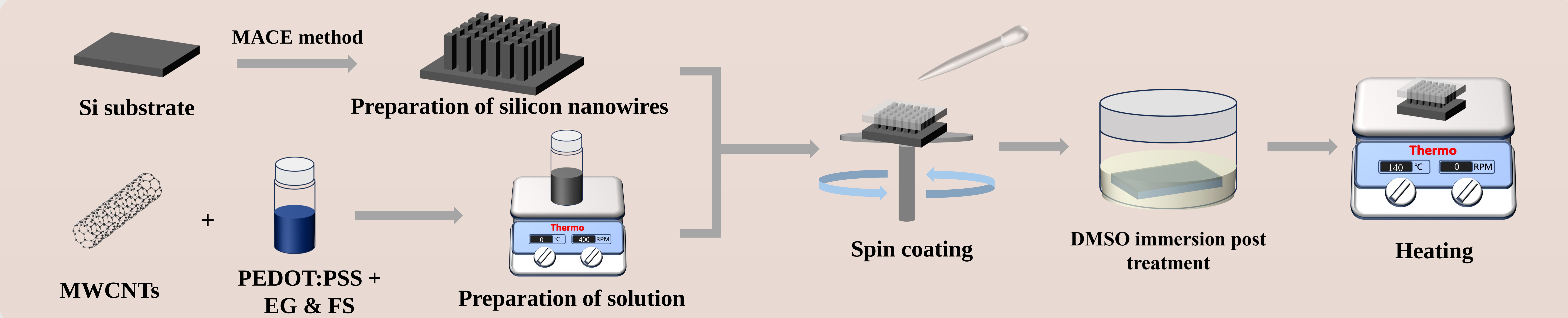
Abstract

In recent years, biomonitoring and artificial intelligence technologies have advanced rapidly, particularly in wearable electronic devices capable of monitoring human signals, which have shown great potential for development. For such devices, a stable and long-lasting power supply design is crucial. Thermoelectric generators based on the Seebeck effect can harvest waste heat emitted by the human body and directly convert it into electrical energy, achieving the goal of self-powering. This experiment focuses on a thin-film thermoelectric device based on a composite of PEDOT:PSS and MWCNTs. First, a thin film was fabricated using the spin-coating method and deposited onto silicon nanowires to form a heterojunction. By controlling the length of the silicon nanowires, the optimal thermoelectric properties were achieved. PET was used as the substrate, and six legs were connected in series using a custom-made circuit to construct a flexible thermoelectric generator. Then, the human body serves as the heat source, while a hydrogel heat-absorbing sheet is used as the cold source, creating a larger ΔT to generate a higher voltage.

Experiment procedures



Results and Discussion

Structure of PEDOT:PSS/MWCNT on SiNWs

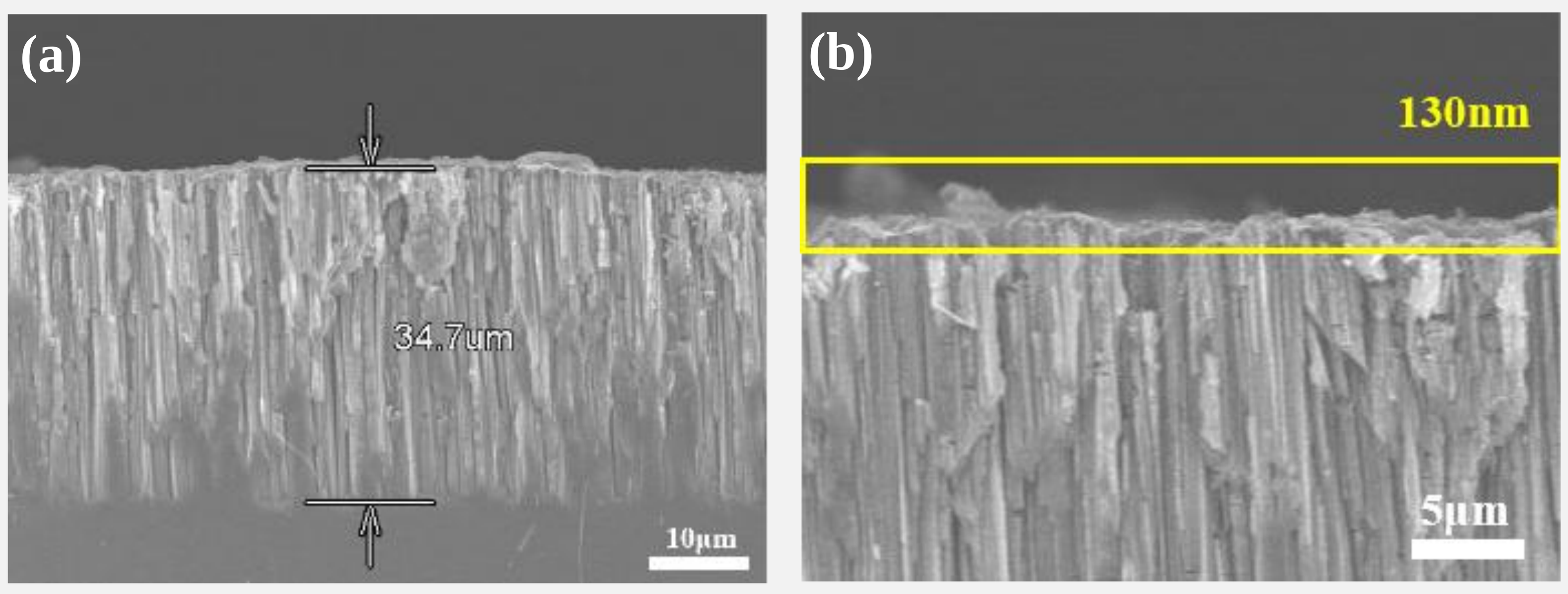


Fig. 1. (a) SEM image of silicon nanowire length. (b) SEM image of the size of PEDOT:PSS/CNT composite film above silicon nanowire.

Characterization of thin film

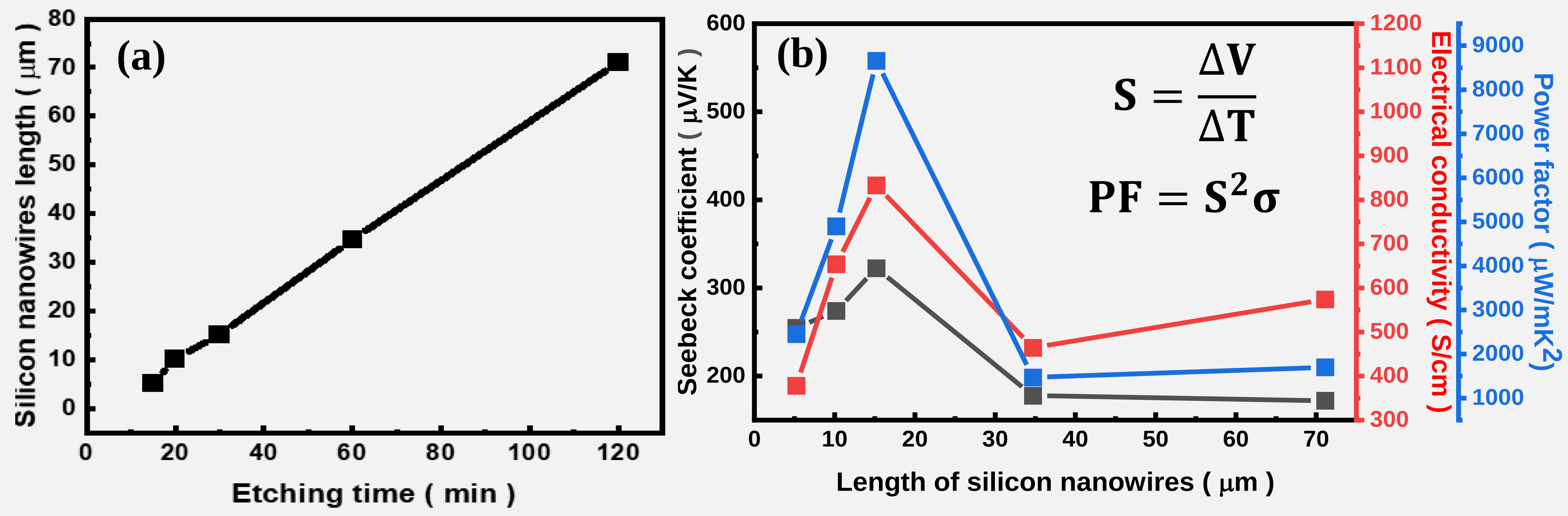
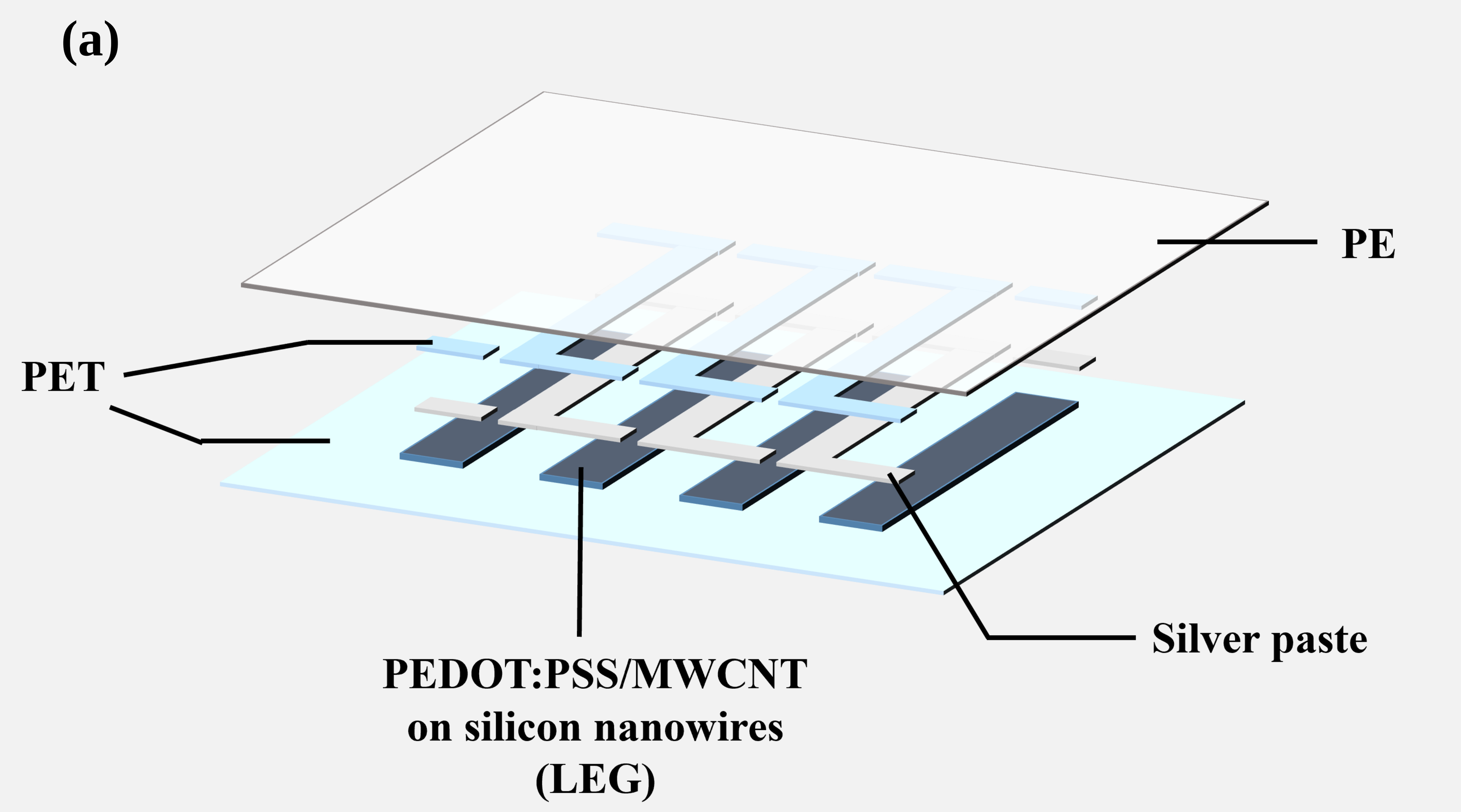


Fig. 2. (a) Measured silicon nanowires length with different etching time. (b)Measured Seebeck coefficient, electrical conductivity and output power of PEDOT:PSS/CNT composite film above different length of silicon nanowire.

Prototype of operating flexible TEG on human skins



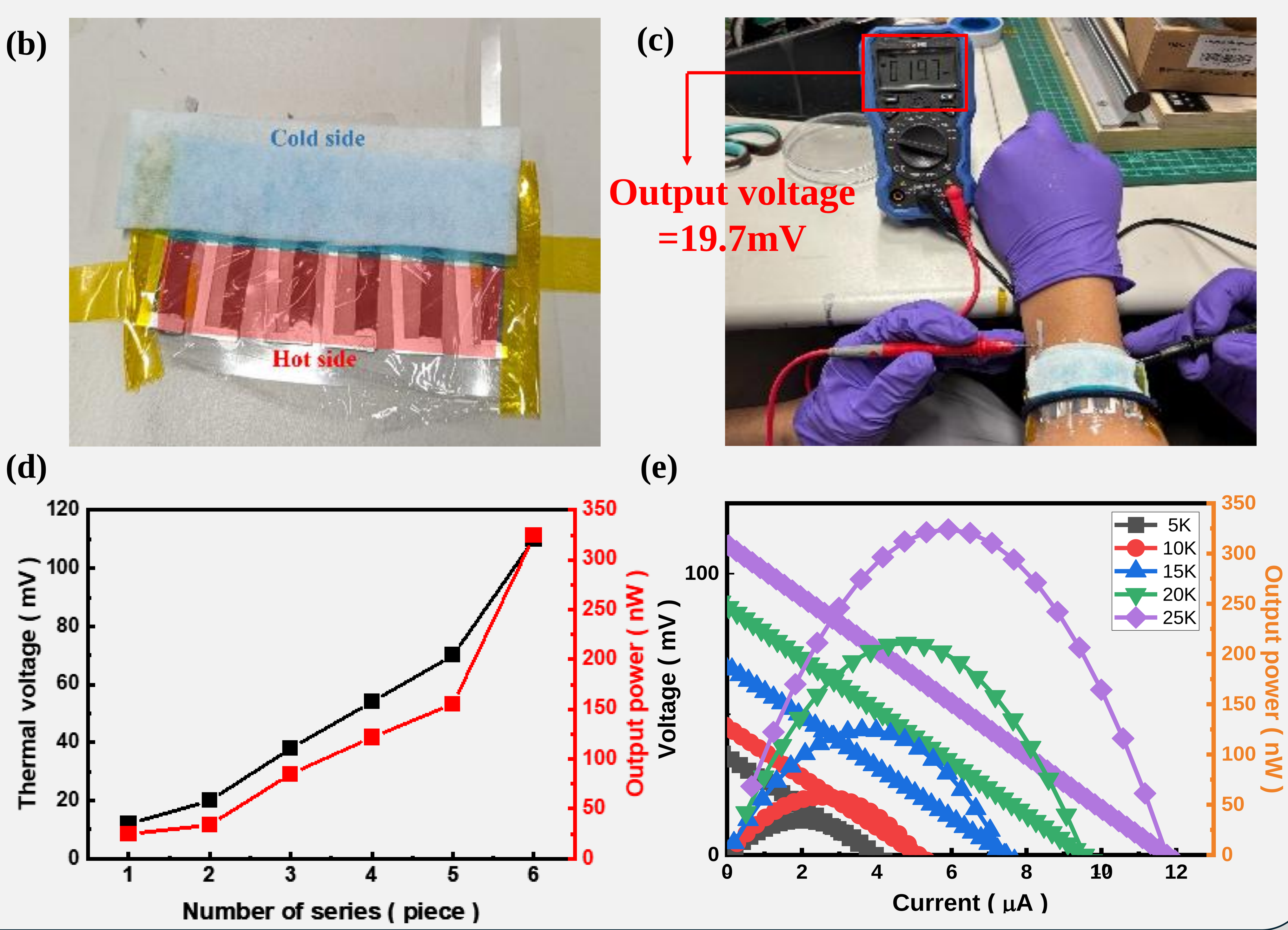


Fig. 3. (a) Schematic image of the device. (b) Actual picture of the device. (c) Output voltage measurement on human wrist by multimeter. (d) Measured Seebeck coefficient and output power of thermoelectric legs with different series connections. (e) I-V curve under various temperature.

Conclusion & Future work

From the experimental results, silicon nanowires with a length of 15.2 μm exhibited the highest power factor ($S^2\sigma$) of 2862.52 μW/mK², compared to only 1240.40 μW/mK² when deposited on a silicon substrate. The maximum measured power of the device in series reached 323.99 nW, and at ΔT of just 25K, a thermoelectric voltage of 109.64 mV was generated. This demonstrates that the PEDOT:PSS/MWCNT thin film deposited on silicon nanowires has superior thermoelectric conversion properties. In the future, this thermoelectric generator is expected to be integrated with other sensors to develop a fully self-powered human sensing device.