Battery-free flexible patch for multi-parameter wound monitoring and electrically controlled drug delivery

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Abstract

Chronic wound is a major health concern which causes patients physical and mental sufferings worldwide. They are often susceptible to infections and result in changes of biological, chemical, and physiological parameters [1]. Monitoring these parameters and providing timely feedback therapies can help us know the wound condition and accelerate wound healing [2, 3]. Flexible devices are suitable for *in situ* wound monitoring and drug delivery as they can conform to the unique profile of the wound area with minimum damages [4]. However, most flexible platforms can detect only one or two kind of parameters, which could not comprehensively report the wound conditions[2]. Also, the high power consumption of drug delivery solutions, such as thermal activation, limit the miniaturization of the platform[1, 5, 6]. Here, we developed a battery-free and flexible smart patch, which can simultaneously detect biological, chemical, physiological parameters of the wound, and provide on-demand drug delivery. The top layer of the patch is an NFC-enabled flexible circuit board which enables wireless power harvesting, on site signal processing, drug delivery controlling, and wireless data transmission with widely-used smartphones (Figure 1A). Without the restrictions of on-board batteries, the circuit board is ultrathin and could bend to a great extent. The bottom layer of the patch is a flexible electrode array based on polyethylene terephthalate (PET) substrate, including uric acid sensor, pH sensor, temperature sensor, and a drug electrode with cefazolin sodium coated in the membrane of polypyrrole (Figure 1B). In the application (Figure 1C), the two layers are adhered together with silica gel and electrically connected with conductive pads. The temperature sensor on the reverse side of the circuit board will then embed into the corresponding hole of the electrode array. Figure 1D illustrates the schematic block diagram of the system. While the wound area is infected with bacteria, the changes of uric acid, pH value and temperature will be recorded by the platform and transmitted to the smartphone (Figure 1E to 1G). If necessary, the command will be sent by the phone and the polypyrrole electrode will be activated to release on-demand antibacterial agents to the wound area (Figure 1H). The smart patch provides a powerful sensing platform, which cover three main types of biomedical parameters, including biological, chemical, and physiological signals. With the low-power electrically activated drug delivery module, the feedback therapy was firstly achieved on the battery-free and flexible platform. It can be widely applied in dynamic wound monitoring and therapies.

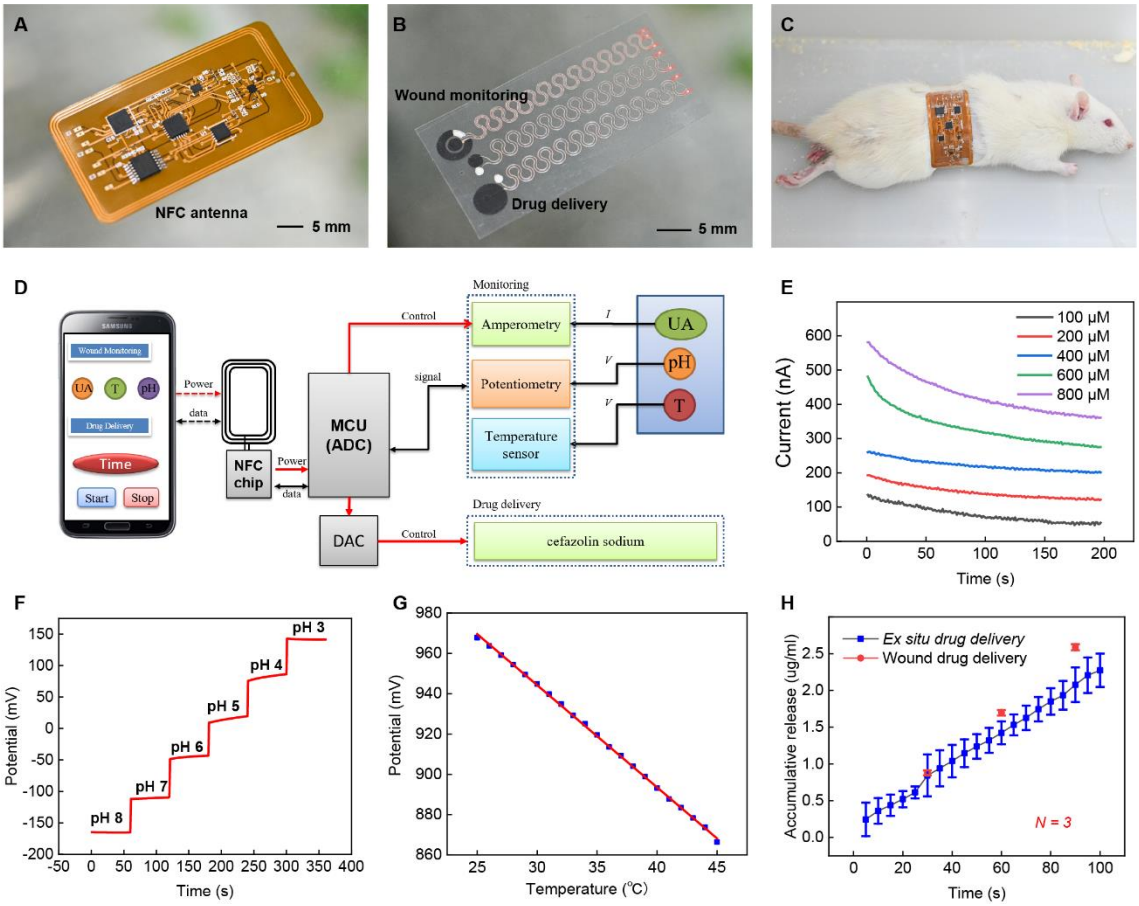

Fig. 1. Battery-free flexible patch for multi-parameter wound monitoring and electrically controlled drug delivery. (**A**) Optical of the NFC-enabled flexible circuit board. (**B**) Optical image of the flexible electrode array. (**C**) The patch mounted on the chronic wound of the rat for *in situ* wound monitoring and drug delivery. (**D**) The schematic block diagram of the system. (**E** to **G**) The responses of uric acid sensor (E), pH sensor (F), and temperature sensor (G). (**H**) The illustration of *ex situ* and wound *in situ* drug delivery.

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