SUPPORTING INFORMATION

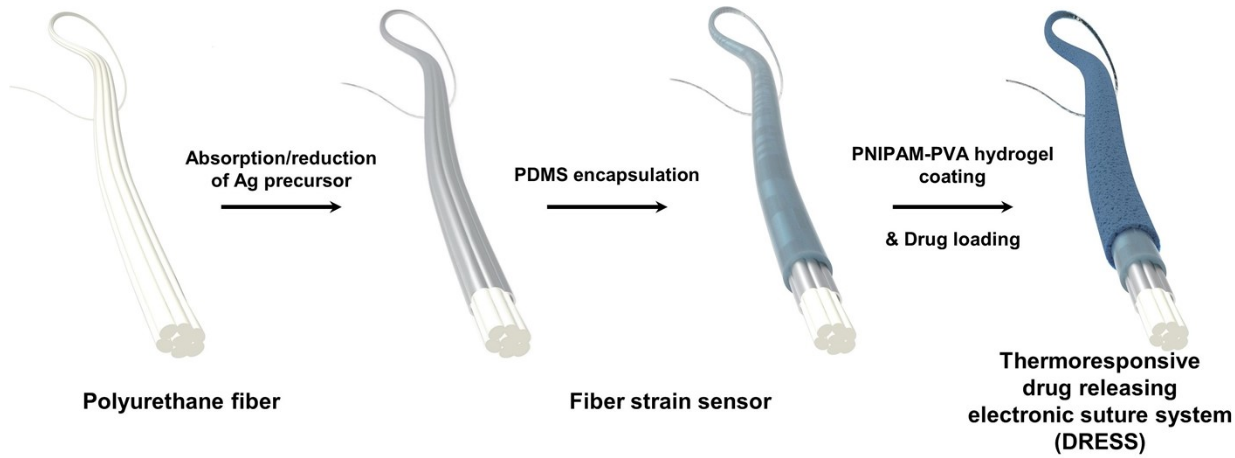

Fig. S1. A schematic illustration of the drug-releasing electronic suture system (DRESS) fabrication process. PDMS, poly(dimethylsiloxane); PNIPAm, poly(N-isopropylacrylamide); PVA, poly(vinyl alcohol).

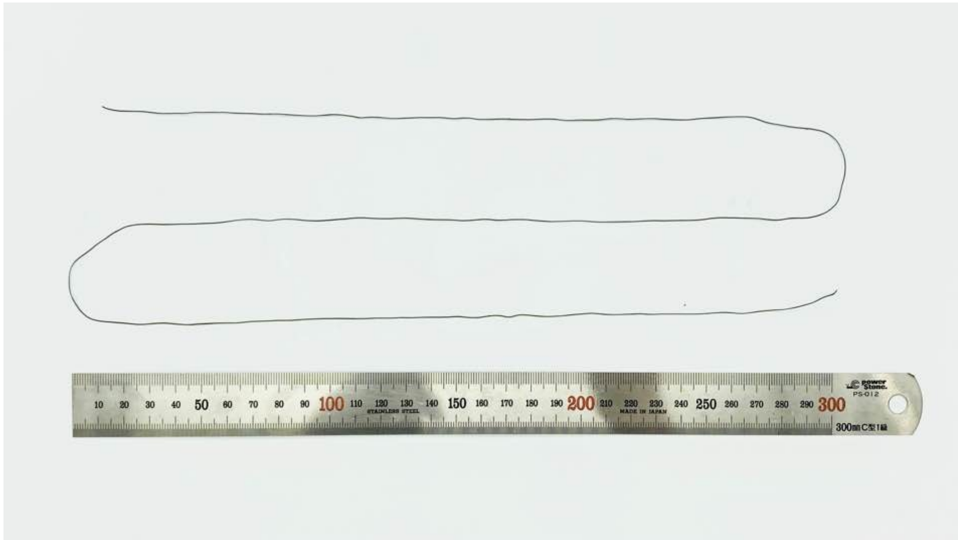

Fig. S2. Photograph of the 1m long DRESS.

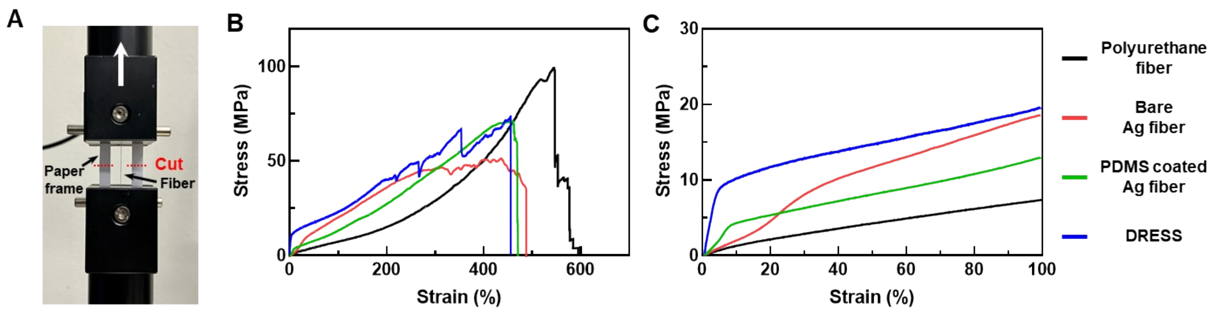

Fig. S3. Stress-strain curves of polyurethane fiber, Bare Ag fiber, PDMS-coated Ag fiber, and DRESS. (A) Experimental setup for the tensile test. The fibers' stress-strain curve (B) until fracture and (C) below 100% strain.

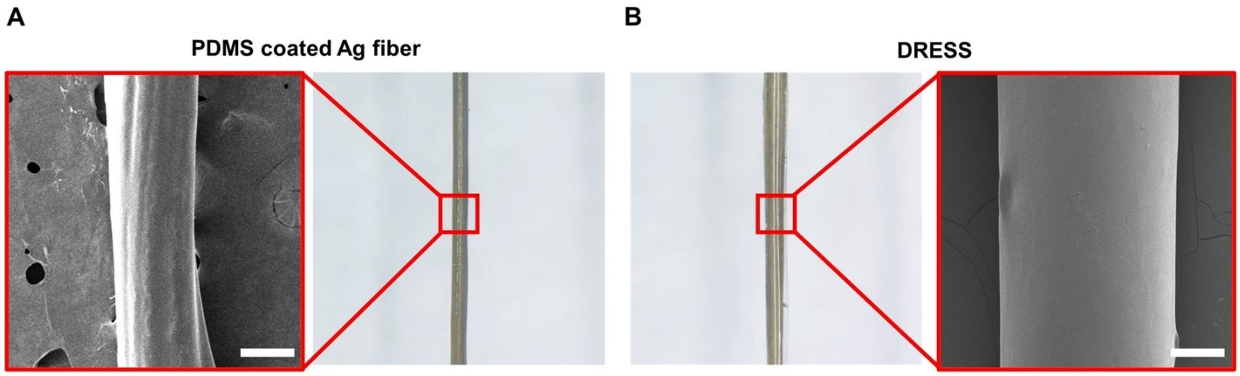

Fig. S4. Optical microscopy and scanning electron microscopy (SEM) images of (A) a PDMS-coated Ag fiber and (B) DRESS. (Scale bar = 200µm)

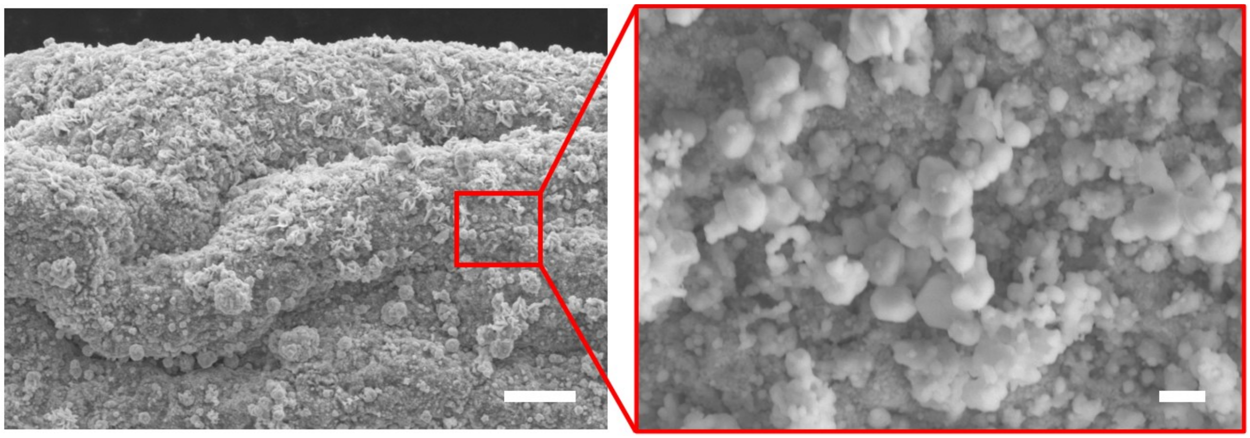

Fig. S5. Magnified SEM images showing the surface of the fiber strain sensor. Scale bar = 5µm (left panel), 800 nm (right panel).

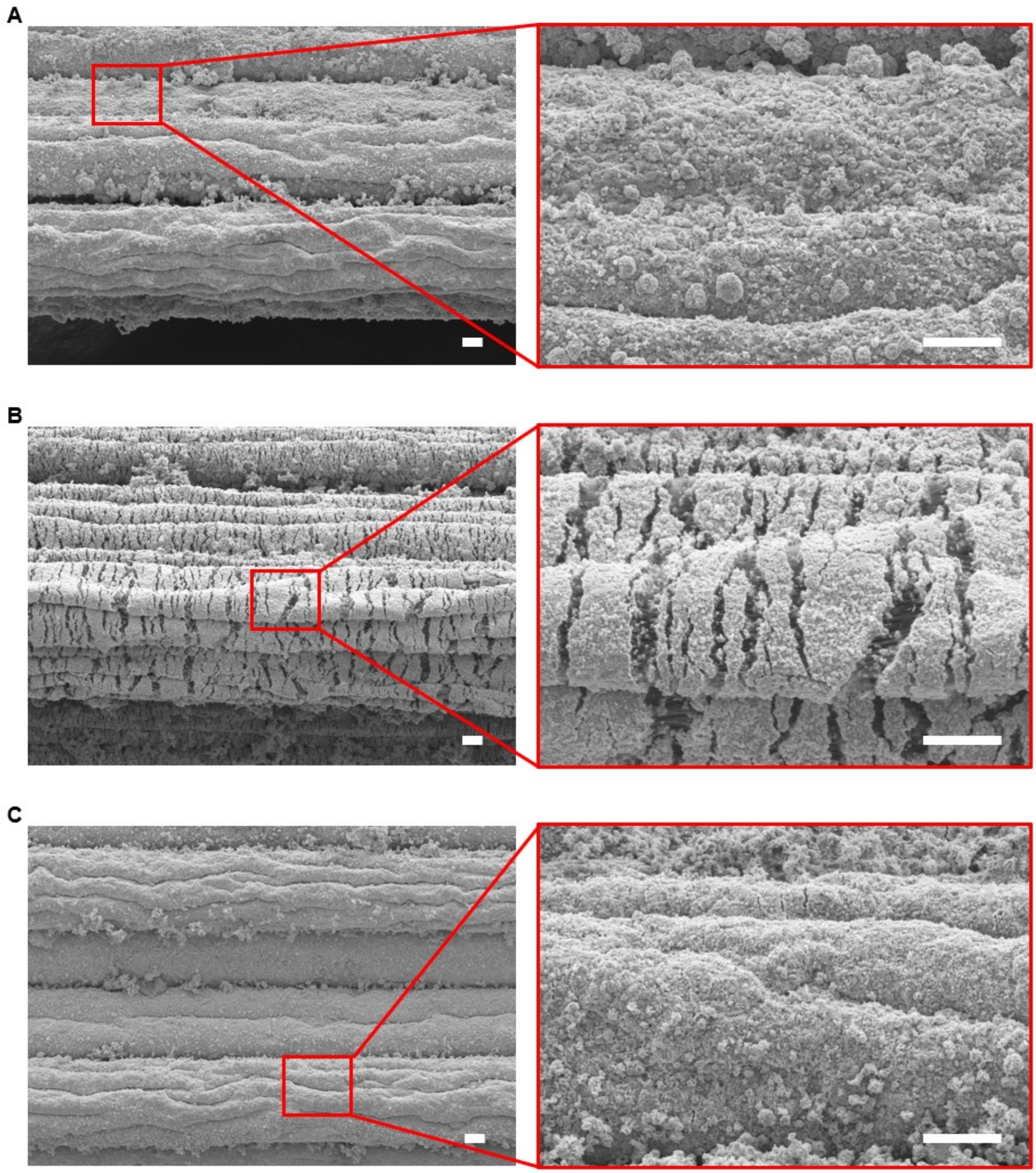

Fig. S6. SEM images showing the surface of the fiber strain sensor (A) before stretching, (B) after applying 50% strain, and (C) after removing the external tensile strain. (Scale bar = 10μm)

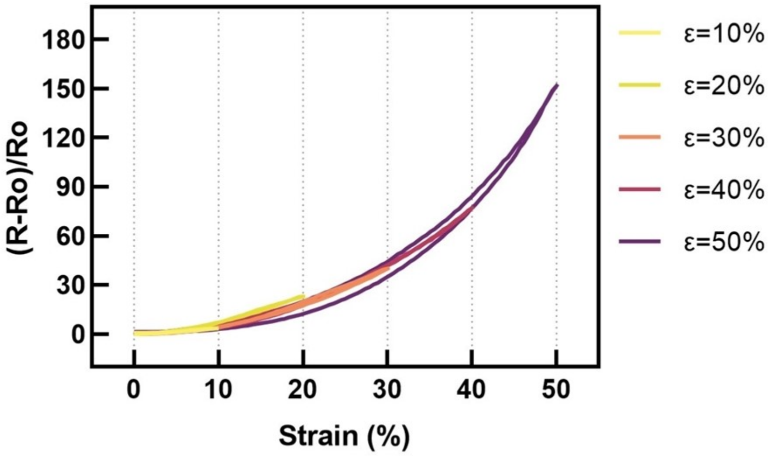

Figure S7. Hysteresis of the fiber strain sensor fabricated by applying 5 repeated cycles of the in-situ formation process according to the maximum strain levels of 10%, 20%, 30%, 40%, and 50%.

Analytical model on the thermal response of the fiber strain sensor

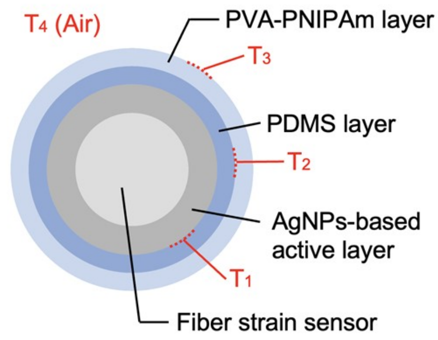

Figure S8. A schematic illustration of the cross-sectional structure and temperature distribution on each layer of DRESS.

The fundamental concept of heat transfer is that the total amount of heat entering and leaving a defined boundary layer is equivalent, i.e.

$$Pt = \Sigma Q_{in} = \Sigma Q_{out} \tag{1}$$

where P is the applied power for heat generation for duration t and Q is the heat energy generated by the input power. From the schematic illustration of the cross-sectional view of DRESS in Figure S4 and by using Equation (1), the following equations can be derived for considering thermal conduction and convection at the boundary between the two different layers in DRESS (the PDMS layer – the PVA-PNIPAm layer, the PVA-PNIPAm layer – air).

$$\frac{k_p}{L_p}(T_2 - T_1) = \frac{k_d}{L_d}(T_3 - T_2) \tag{2}$$

$$\frac{k_d}{L_d}(T_3 - T_2) = h(T_3 - T_4) \tag{3}$$

where T_1,T_2,T_3, and T_4 are the surface temperatures of the active layer in the fiber strain sensor, the PDMS layer, the PVA-PNIPAm layer, and the ambient temperature (21 ℃), respectively; T_0 indicates the equilibrium temperature of the system at an initial state (21 ℃); subscripts $a, p,$ and d indicate the Ag-based active layer, PDMS layer, and PVA-PNIPAm layer throughout this work; k is the thermal conductivity ($k_p = 0.15\ W/mK, k_d = 0.253\ W/mK$); L denotes the thickness of each layer in DRESS (~15 μm); and h is the convection heat transfer coefficient of air ($h = 6.8\ \mu W/mm^2K$).

In addition, the following equation can also be derived when considering that the generated heat should be equal to total heat loss in the entire system:

$$\frac{V^2t}{R} = C_am_a(T_1 - T_0) + C_pm_p(T_2 - T_0) + C_dm_d(T_3 - T_0) + hA_3(T_3 - T_4)t \tag{4}$$

where Cdenotes the heat capacity of each layer in DRESS ($C_a = 0.2387\ J/gK, C_p = 1.46\ J/gK, C_d = 1.26\ J/gK$), m indicates the approximate mass of each layer ($m_a = 1.4597 \times 10^{-3}\ g, m_p = 3.0121 \times 10^{-4}\ g, m_d = 4.7124 \times 10^{-4}\ g$), t is the saturation time for the equilibrium temperature of the system (5 s), R is the electrical resistance of the fiber strain sensor, V is the external electrical voltage applied to the sensor, and A indicates the surface area of DRESS ($1.3509 \times 10^{-5}\ mm^2$).

T_1 and T_2 can be described in terms of T_3 by combining Equations (2) and (3) as follows:

$$T_1 = T_3\left(1 - h\left(\frac{L_d}{k_d} + \frac{L_p}{k_p}\right)\right) + hT_4\left(\frac{L_d}{k_d} + \frac{L_p}{k_p}\right) \tag{5}$$

$$T_2 = T_3\left(1 - h\frac{L_d}{k_d}\right) + hT_4\frac{L_d}{k_d} \tag{6}$$

By substituting Equations (5) and (6) into Equation (4) followed by re-arrangement corresponding to T_3, the temperature generated in the PVA-PNIPAm layer under external input voltage V can be calculated as follows:

$$T_3 = \frac{\frac{V^2}{R}t + C_a m_a\left(T_0 - h(\frac{L_d}{k_d} + \frac{L_p}{k_p})T_4\right) + C_p m_p\left(T_0 - h\frac{L_d}{k_d}T_4\right) + C_d m_d T_0 + hAtT_4}{C_a m_a\left(1 - h(\frac{L_d}{k_d} + \frac{L_p}{k_p})\right) + C_p m_p(1 - h\frac{L_d}{k_d}) + C_d m_d + hAt} \quad (7)$$

The closed-loop voltage control system for DRESS

From Equation (7), the required input voltage V_{f0} for target temperature T_3 of DRESS can be calculated as follows:

$$V_{f0} = \sqrt{C_1 T_3 - C_2} \quad (8)$$

$$C_1 = \frac{R_{f0}}{t}(C_s m_s\left(1 - h\left(\frac{L_d}{k_d} + \frac{L_p}{k_p}\right)\right) + C_P m_P\left(1 - h\frac{L_d}{k_d}\right) + C_d m_d + hA_3 t) \quad (9)$$

$$C_2 = \frac{R_{f0}}{t}(C_s m_s\left(T_0 - h(\frac{L_d}{k_d} + \frac{L_p}{k_p})T_4\right) + C_P m_P\left(T_0 - h\frac{L_d}{k_d}T_4\right) + C_d m_d T_0 + hA_3 t T_4) \quad (10)$$

where R_{f0} indicates the initial electrical resistance of the fiber strain sensor in DRESS without external tensile strain. For the voltage control system, a simple voltage divider circuit was used based on Arduino Mega 2560 (Figure S5).

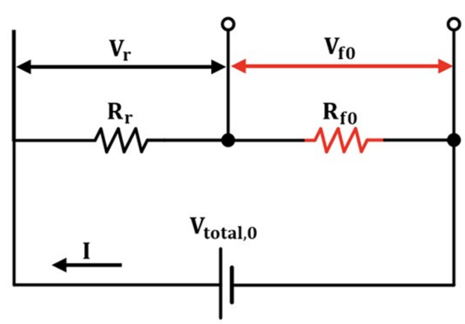

Figure S9. A schematic illustration of the voltage divider circuit for the voltage control system.

From the circuit, the total applied voltage $V_{total,0}$ required to apply the target input voltage V_{f0} to DRESS can be determined by using the following equation:

$$V_{total,0} = V_{f0}(1 + \frac{R_r}{R_{f0}}) \tag{11}$$

where R_r denotes the electrical resistance of the reference resistor in the circuit. By applying total voltage $V_{total,0}$ to the voltage divider circuit, target temperature T_3 can be applied to DRESS without external tensile strain. However, when the external tensile strain was applied to DRESS, the electrical resistance of the fiber strain sensor in DRESS, R_f, increased, which changed the input voltage V_f according to Equation (11). Because the changed input voltage V_f also led to a change in the Joule-heating level in DRESS, total voltage V_{total} was instantly adjusted to maintain the electrical voltage applied to DRESS as the target input voltage V_f based on Equation (11).

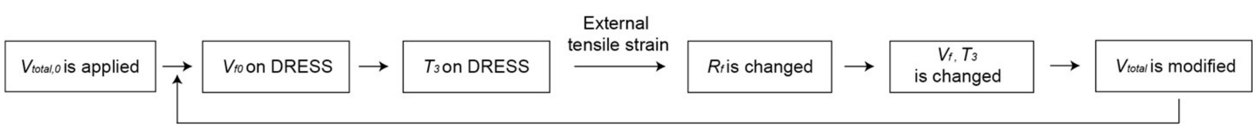

Figure S10. A block diagram of the closed-loop voltage control system.

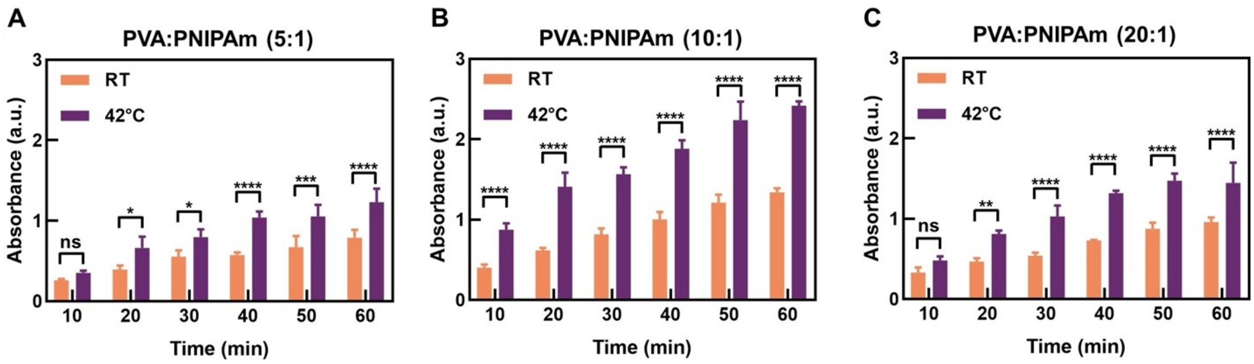

Figure S11. The drug release profile of PVA-PNIPAm with various ratios (PVA:PNIPAm; 5:1, 10:1, or 20:1) at room temperature and 42 °C.

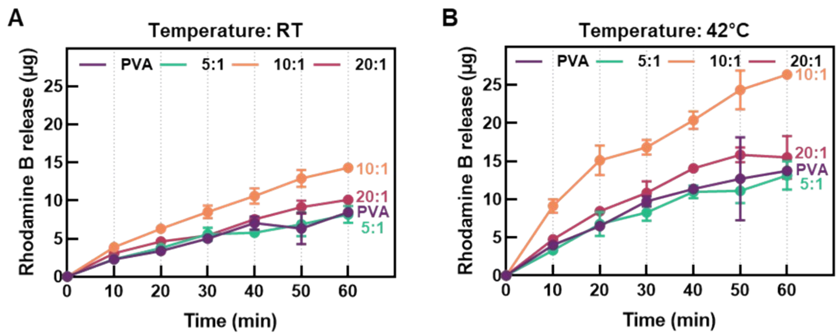

Figure S12. Rhodamine B release profile of PVA and PVA-PNIPAm with various weight ratios and temperatures.

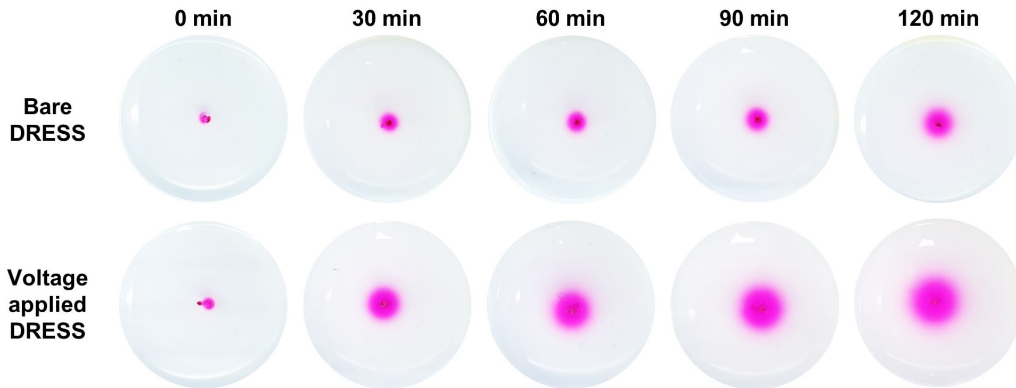

Figure S13. Optical images of drug diffusion in the skin phantom.

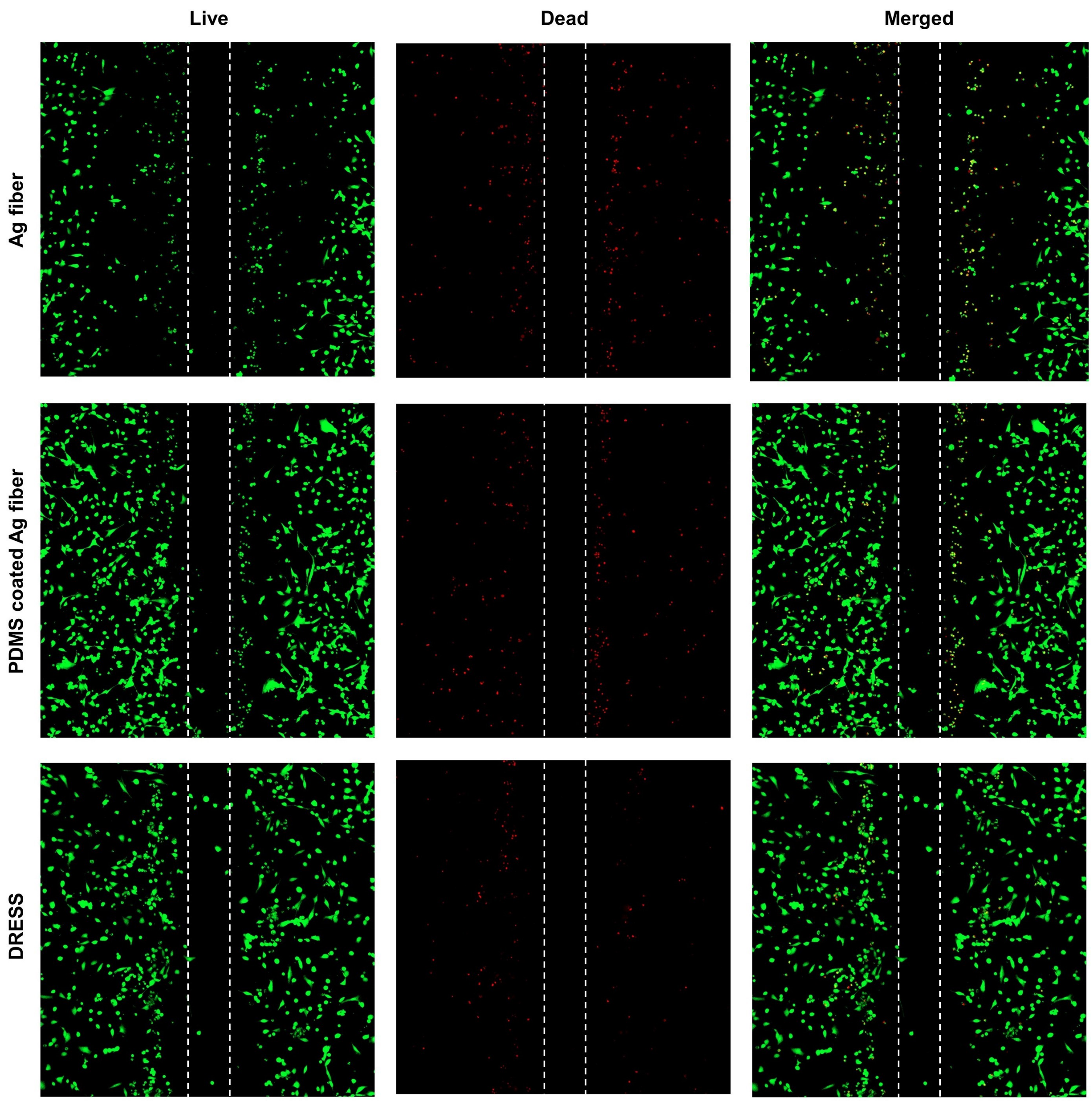

Figure S14. Split images of live (green) and dead (red) NIH-3T3 cells cultured with Ag fiber, PDMS-coated Ag fiber, or DRESS for 3 days.

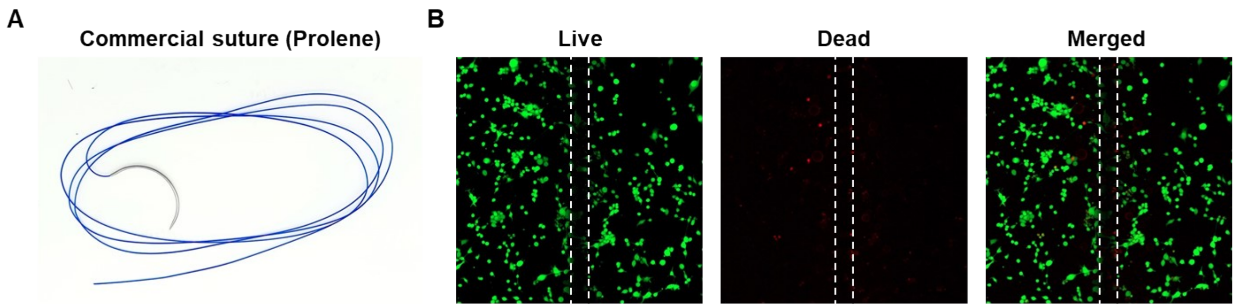

Figure S15. (A) Photograph of the commercial suture (Prolene). (B) Split images of live (green) and dead (red) NIH-3T3 cells cultured with commercial suture for 3 days.