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Smart Bandage: wound classification and bandage recommendation using DL

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Abstract: *This research shows a smart bandage with wireless features to monitor motion and temperature, while using a no-battery NFC chip. Rather than common parts, the sensors are built from a conducting polymer named PEDOT: PSS. A section contains micro-channels in flexible PDMS rubber, loaded with this fluid material to detect bending. If pulled only 10% longer, its electric resistance rises nearly x times more than usual. This results in a quick reaction - almost instant - so it picks up tiny shifts right away. Not only does it detect stretching, but also handles far more strain than human skin or the chest endures during breaths. Beyond testing stretch alone, researchers looked at bending too, spotting clear electrical signals with each degree change. What's more, it showed close to 12,000% resistance rise per single percent stretched. On top of that, a temperature-sensitive resistor built on PVC saw its resistance fall by about 60% when warmed, responding sharply - nearly per degree Celsius. To test actual use, one sensor along with an NFC chip was stuck on bandages - making them act like wearable smart patches. They work without wires when near a phone, pulling data smoothly from up to 25 mm distance through an app that runs the system. We prove such a patch might support medical needs - tracking healing cuts or lung problems like asthma, also virus- related conditions such as COVID-19. Here, sensing motion via flexible trackers together with temperature tools on body-worn gear makes a big difference.*

Key Words: *power-free design, soft electronics, short-link radio marker, responsive wrap, flex tracker, heat monitor.*

I.INTRODUCTION

This research shows a smart bandage with wireless tech to monitor stretch and warmth, while using an NFC tag that runs without power. Rather than typical stuff, both sensors depend on a conductive plastic known as PEDOT: PSS. A section includes micro tunnels inside flexible PDMS rubber loaded with this fluid material to detect motion. If stretched only 10%, its electrical resistance climbs nearly 1250 times more than usual. It hits a super quick reaction level - close to 12,500 GF - which means it picks up tiny shifts without delay. While tested, the sensor took on about 30% stretching, which is way beyond normal chest or skin movement during breaths. Rather than only tracking stretch, researchers looked at bending scenarios; each degree brought an electrical shift near 150%, while every percent of stretch changed output noticeably. On a PVC base, a resistive heat sensor showed resistance dropping around 60% when temps climbed from 25°C to 85°C, responding sharply by nearly 1% per °C change. For real- world checks, both sensors along with an NFC chip were stuck onto bandages, making them act like wearable smart patches. The smart bandage uses two sensor types - strain and temperature - alongside a battery-free near-field tag that sends key data wirelessly during wound checks [14]–[1]. Instead of needing power, the tag gets activated by a phone app built for this purpose, capturing readings live. Some earlier versions of intelligent dressings have been listed in Table S1 (found in SI), showing how others approached similar tasks. These rely on tracking things like pH levels for analysis. Still, unlike those, this one actually grabs both temp and stretch info at once - a combo missing in past models despite its importance. Take heat - it's long been linked to swelling or infection in injuries, often signaling delays in recovery before any visible change shows up
Stuff Used + How We Did It

A. Making the sensor that measures stress

The clear plastic PDMS made up the stretch sensor. Here, tiny channels were formed in PDMS by copying a mold shape. For that, a mix of 10 parts PDMS and one part hardener got stirred well with a glass stick. After mixing, it sat under vacuum for an hour to get rid of bubbles. Then, the liquid went into a round frame measuring 5.5 cm across.

A thin metal strand was put into the mold to form a tiny channel within the PDMS. Once heated in an oven for two hours, the material hardened. Then, the solidified block was pulled from the mold carefully. The wire came out, leaving behind a hollow passage. Next, a conductive fluid - PEDOT: PSS - was pushed through that space with a syringe. This filled tube was warmed again, this time for three hours. The injection and curing steps were done again three times. Because we checked the sensor's electrical resistance after every round, things got fine-tuned step by step.

A. Design and Fabrication of Temperature Sensor

The flexible temperature sensor was fabricated on a Commercial PVC substrate using the conductive silve4r paint The PVC was cut into 2×2cm pieces1, and then two electrodes were formed using the Ag ink on the flexible PVC substrate using silver6paste. The samples were then dried in a hot-air oven at fo1r 30 min. The gap between the two electrodes was A 10 µl of PEDOT: PSS was dispensed in the gap using a micropipette. Then, the samples were dried in an air oven at 50 ◦C for 1 h. After that, the samples were electrically characterized to investigate the temperature response.

B. NFC Antenna Design and Characterization

The key part inside the smart bandage is an NFC sensor called RF430FRL152H made by Texas Instruments in Dallas, USA. You'll find how it's built and designed in Sect. II of SI - focuses on the bendable circuit board around this chip. This particular NFC unit runs completely without power storage so gadgets don't need batteries, especially useful for mobile wireless sensors. Power comes from electromagnetic fields created by a nearby device - here, we used a phone that supports NFC. The custom antenna's a flat coil, its inductance tuned alongside the built-in capacitor, C_{int}, so it hits resonance at - the key frequency needed for NFC. Since resonance happens at Using the target frequency, around that value of inductance is needed for the tag to resonate. Still, to make the antenna smaller, a compact square-shaped coil with $L_{ant} = 1.85\mu H$ was made instead. Then, an extra cap was added alongside C_{int} to form the full tuning setup. The first inductor layout came from the Grover approach - check Section III in SI for how it worked.

Santa Clara, CA, USA). Look at Fig. 2(a) - the end result shows

The coil antenna featured seven loops, each made with 400 µm wide wire, separated by 350 µm gaps - total area roughly 26 mm². After construction, frequency behavior got tested via a Keysight device using a probe tip. Picture displays how electric flow moves along the coil's outer side while magnetism forms close around it. Another shot gives data recorded prior to attaching additional components such as caps or ICs, where numbers tweaked just a bit after hooking them up

II. FINDINGS PLUS HOW WE SEE THEM

A. Strain Sensing

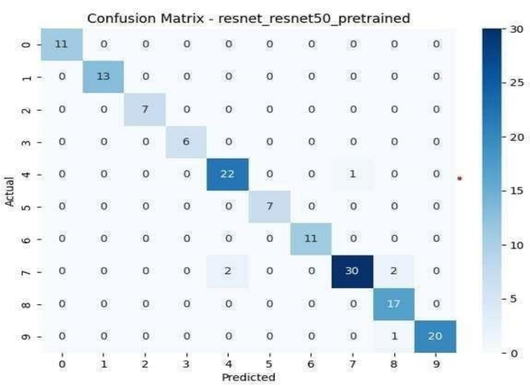
The custom strain sensor was tested with a setup driven by LabVIEW to apply tension, while an Agilent 34461A multimeter recorded the electrical output. The test frame had two movable clamps - these adjusted position to pull the sensor smoothly at controlled rates. Thin metal wires, not adhesive or tape, connected the unit to the circuit via the clamps. It stretched as much as 30%, advancing at 0.1 mm/s. Tests pushed it fully to 30% stretch to check performance under stress.

The usual stretch humans can handle varies across areas like fingers, wrists, knees, or elbows - this pulls collagen and tissue tight [53], [54]. Real shots plus a sketch of how bending affects materials appear in Fig. 3(a)–(c). Resistance shifts by around a thousand times (R/R_0 1250) were spotted. Here, starting resistance sat near 140, while max strain pushed it to about 180 k. This happens because flaws and brokenit'll mainly run between 30°C and 50°C. When that electric paths form in the material, as explained later. Look at Fig.

3(c) - it sketches how a smart bandage bends when actually worn. When someone wraps it around a joint or curved area, the sensor folds, causing stress along its surface. So, bending at an angle θ stretches the device by $l = 2w \sin(\theta/2)$, with l being sensor length and w the width of the body zone. That means you can link bend angle θ to stretch ratio l/l through $(2w \sin(\theta/2))/l$ - this math helped adjust the sensor's readings.Fig. 3(d) shows the temporal response of sensor for different stretching (10%, 20%, and 30%) conditions and

In this case, the effective length and diameter of the channel were 1.5 mm and 175 µm, respectively. Furthermore, the number of electrical discontinuities in the system (N) and the magnitude of percentage strain ($\gamma = (L/L)\times 100$) in the sensor change the areal fraction Df in the sensor. A linear relation $N = m\gamma + N_0$ was considered as the strain, in this case, was low [58], [59]. N_0 represents the initial electrical gaps exist in the setup; m (= $(E_1 \times A_1)/(E_2 \times A_2)$) stands for a ratio factor; E_1 means stiffness of the working layer (like

I11.RESULTS AND DISCUSSION



	precision	recall	f1-score	support
0	1	1	1	11
1	1	1	1	13
2	1	1	1	7
3	1	1	1	6
4	0.916667	0.956522	0.93617	23
5	1	1	1	7
6	1	1	1	11
7	0.967742	0.882353	0.923077	34
8	0.85	1	0.918919	17
9	1	0.952381	0.97561	21
accuracy	0.96	0.96	0.96	0.96
macro avg	0.973441	0.979126	0.975378	150
weighted a	0.96291	0.96	0.960173	150

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