Supporting Information

A Sensor-Integrated Face Mask Using Au@SnO$_2$ Nanoparticle Modified Fibers and Augmented Reality Technology

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SI-1 SEM images of Au@SnO$_2$ modified conductive fabric

![SEM images](image1)

**Figure S1.** (a) SEM images of Au@SnO$_2$ modified conductive fabric and (b) 500 times larger.

To disperse the nanoparticle in the solution and thereby have a good distribution on the fabric surface, the nanoparticles were sonicated for 10 min. To ensure the integrity of the nanoparticles after sonication treatment. We have examined the microstructure and crystallographic structure of Au@SnO$_2$ after sonification treatment. As revealed in Figure S5, no appreciable change can be observed, suggesting that Au@SnO$_2$ was not damaged.

![XRD pattern](image2)

**Figure S2.** (a) SEM image and (b) XRD pattern of Au@SnO$_2$ after sonification treatment.
SI-2 The calibration of the body temperature sensor

The LM35DZ sensor is one of the precision integrated circuit temperature devices with an output voltage linearly proportional to the centigrade temperature. The low output impedance, linear output, and accurate inherent calibration of the LM35DZ make it particularly easy to interact with reading or control circuits. In this research, it was used to detect body temperature. The output voltage of the LM35DZ is proportional to the temperature (degree Celsius), and the temperature sensitivity is ten millivolts per degree Celsius. For example, if the difference in voltage output is 100 millivolts, the temperature change is 10 degrees Celsius. The measurement range of the LM35DZ is approximately -50 °C to 150 °C. The following equation expressed the correlation between the output voltages and the temperature.

Voltage output of LM35DZ  \( V_{\text{out}} = 10^{\text{mv/}°\text{C}} \times T(°\text{C})^x + \text{constant} \)

However, each sensor is slightly different when measuring the temperature. Therefore, calibration is required to find the precious correlation between output voltages and temperature, as in Figure S3.

![LM35 VOUT V.S. Temp](image)

**Figure S3** The plot of the temperature and output voltages of the temperature sensor. (Calibration curve according to the official user manual)

The calibration curve for the temperature sensor in this work is as follows.

\[ V_{\text{out}} = 10.403 \times T(°\text{C})^{0.3493} \]

After calibration, the temperature sensor was able to detect the ambient temperature, which was approximately 35 °C in summer (Figure S4). The sensitivity and precision of the LM35DZ sensor was examined by comparing it with a commercially available thermometer.
Figure S4 Temperature measured by the LM35DZ sensor in the air after calibration.

The body movement of the face mask user may interfere with the LM35DZ temperature sensor. The reason is that the distance between the sensor and the skin can determine the measured temperature. When the test subject was walking or moving, the temperature sensor was severely affected. Therefore, a sudden temperature drop means that the temperature sensor has lost contact with the skin and the sensor. The sudden temperature drop peaks were modified and corrected as shown in Figure S5.

Figure S5 Comparison before and after calibration.
SI-3 The optimization of the breathing rate sensor

To fabricate the respiration rate sensor, we took advantage of piezoelectric materials for air pressure sensing. Piezoelectric materials can be roughly divided into a single crystal, ceramic, and thin film. The most common materials are ceramics, titanate (BaTiO$_3$), and zirconate titanate (Pb(ZrTi)O$_3$, PZT) compound. When a compressive force is applied to the piezoelectric material, the piezoelectric material will generate an instantaneous current that can be observed from the external ammeter. The positive piezoelectric effect is the phenomenon of converting mechanical energy into electrical energy. On the contrary, the inverse piezoelectric effect converts electrical energy into mechanical energy, as shown in Figure S6.

![Figure S6 Forward and reverse piezoelectric effect.](image)

To collect the signal of the respiration frequency, we used piezoelectric ceramic patches through the piezoelectric effect to obtain the corresponding voltage when it vibrates, as Figure S7 shows. After a vibration caused by breathing, the sensor generated an offset of positive and negative charges to create a voltage. Therefore, when the piezoelectric patch was placed on the face mask, the corresponding signals could be collected during breathing.

![Figure S7 Voltage signal change after applying air stress to the piezoelectric ceramic patch.](image)
SI-4 Collection of voltage signals caused by respiration

For the collection of voltage signals caused by respiration, we connected the Arduino MCU through the voltage divider circuit, as shown in Figure S8. When the ceramic patch vibrates, we can get its voltage change. When we touch the sensor, squeeze it to make the $R_{sensor}$ smaller; this time, the voltage through $R_1$ will increase to confirm the generation of breathing movement.

$$V_{out} = V_{in} \times \frac{R_1}{(R_{sensor} + R_1)}$$

Figure S8 Circuit diagram to collect changes in the respiration signal.
SI-5 Eliminating noise from body movement

Body movement will cause interference when measuring respiratory signals. Therefore, a noise filter system must be used to calibrate the respiratory rate. Figure S9 shows the typical respiration rate measured by the piezoelectric patch. If the difference between the next signal and the previous signal is too significant, we can easily distinguish the signal caused by shaking or touching instead of breathing.

The equation for recognizing breathing movement

\[
\begin{align*}
a_{(n+1)} &= a_{(n+1)} \text{ if } (a_{(n+1)} - a_n) < |R| \\
a_{(n+1)} &= a_n \text{ if } (a_{(n+1)} - a_n) > |R|
\end{align*}
\]

Since the conductivity and condition of each piezoelectric ceramic patch are different, the R value needs to be adjusted according to the situation and is not a fixed value. In this study, we used the R-value of 5.
**SI-6 Calculation of the respiration rate**

After identifying the breathing status, the breathing frequency can be calculated. We defined the exhalation and inhalation peaks. After obtaining the signal of breathing time, a threshold was set according to the recorded waveform. If the voltage signal exceeds a certain value, the current signals were recorded. At time T1. When the signal falls below the threshold and again exceeds the threshold, the current time T2 is recorded and the user's breathing frequency is calculated from the difference between the two time points, as shown in Figure S9.

**Equation to calculate the respiration rate:**

\[
\text{Respiration rate} = \frac{1}{(T2 - T1)} \times 60
\]

*Figure S9* The interval between breaths.