Ultra-sensitive Wireless Flexible Humidity Sensor Based on Tunable RGO-WS_2 Heterojunction Composites

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Abstract

In recent years, wearable electronics and artificial intelligence (AI) have made great progress. Wearable electronics can collect human physiological information parameters, while AI can analyze the data to monitor human health [1-2]. However, due to limitations of measurement accuracy, response time and other factors, wearable sensors are difficult to analysis of human health real-time currently. As one of the essential components for human body, water molecules play a vital role in human health. In addition, water molecules in the human body contain a large amount of information about the state of human health [3-4]. Therefore, monitoring the water molecules metabolized by the human body and the skin humidity can monitor the state of human health in real time. In this paper, a wireless wearable humidity sensor based on RGO-WS_2 heterojunction was proposed.

Figure 1(a) shows the schematic of the wireless humidity sensor, the size of the sensor is 10×10 mm, the substrate is polyimide which is appropriate for the wearable sensor. The humidity sensing material RGO-WS_2 was fabricated by supercritical CO_2 method [5]. Due to the van der Waals force between the RGO and WS_2 [6], they can generate heterojunction naturally. As shown in Figure 1(b) and 1(c), they are SEM images of the RGO-WS_2. From Figure 1(b), it can be seen that the morphology is similar to that of a hexagon. Figure 1(c) shows WS_2 nanosheet attached on RGO nanosheet. As shown in Figure 1(d) and 1(e), it is the Raman spectroscopy of RGO, WS_2 and RGO-WS_2, respectively. The peaks of RGO-WS_2 for in-plane (E_{2g}^1) and out-of-plane (A_{1g}) are 354.1 and 420.3 cm^{-1}, respectively. Compared to the pristine WS_2, both the peaks of E_{2g}^1 and A_{1g} red shift (E_{2g}^1 from 353.1 cm^{-1} to 354.1 cm^{-1} and A_{1g} from 419.3 cm^{-1} to 420.3 cm^{-1}) maintaining the same gap 1 cm^{-1}, which means that WS_2 in RGO-WS_2 has the same layers as the pristine WS_2. And it can be also as an evidence of coupling between RGO and WS_2. In addition, RGO possess much larger area than WS_2 sheet, the peaks of RGO in RGO-WS_2 did not show obvious shift compared to the pristine RGO. They indicated van der Waals heterojunction was formation between RGO and WS_2 sheet.

As shown in Figure 1(f), it is the sensor performance under humidity ranged from 10% RH to 90% RH. Then extract the resonant frequency of the sensor under different humidity and the result is shown in Figure 1(g). As the increase of humidity, resonant frequency of sensor decrease accordingly. In Figure 1(h), it displays the results of the different distance from 1mm to 10mm between finger and sensor. In addition, human breathing pattern is a non-invasive, simple and repeatable monitoring method that can be widely used in medical fields. As shown in figure 6, it is the result of the sensor under different breathing frequency. The S_{11} parameter changed with the rate of respiration. It can distinguish the rapid and normal breathing pattern and indicated that the sensor possess ultra-sensitivity property. This indicates that the use of Rgo-WS_2 is a viable new and simple strategy to realize a humidity wireless sensor for use in wearable electronics.

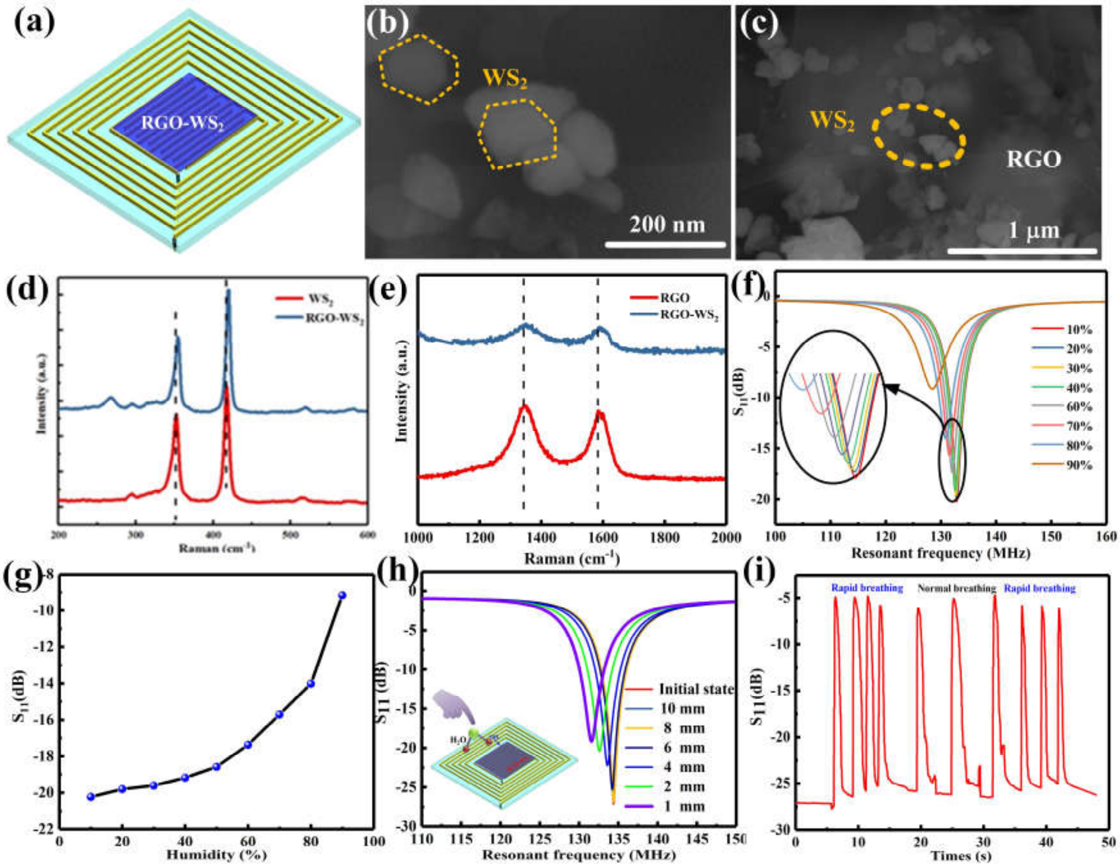

Figure 1: (a) Schematic diagram of the humidity wireless sensor.(b) The SEM image of the RGO-WS_2 nanosheet; (c) The enlarge image of the RGO-WS_2 nanosheet. (d)

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