Research on Ethyl Cellulose Flexible Inductive Humidity Sensor Based on Biomass Hair Modification

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Introduction

To overcome the shortcomings of traditional humidity sensor design, a flexible inductive humidity sensor based on ethyl cellulose based on hair modification was proposed for the first time[1]. Based on the high temperature dehydration and degreasing treatment of hair with high humidity expansion coefficient characteristics, the ethyl cellulose moisture-sensitive material is modified. The thermal purification working mode of the humidity sensor is studied, and its performance is tested by the data acquisition system.

Structural design and simulation

The structure of the flexible inductive humidity sensor is shown in Figure 1. It adopts a planar spiral inductance structure. The inductor coil is a mixture of low-temperature conductive silver paste and graphene conductive paste. The humidity sensitive medium is composed of ethyl cellulose modified by hair after high temperature dehydration and degreasing treatment, and the humidity sensitive chip carrier adopts a silicon rubber film material with a thickness of 0.01mm. The inductor coil is fixedly connected to the top surface of the flexible substrate, and the humidity sensitive medium is filled in the gap between the inductor coils and covers the top surface of the inductor coil to improve the transport rate of adsorbed and desorbed water molecules.

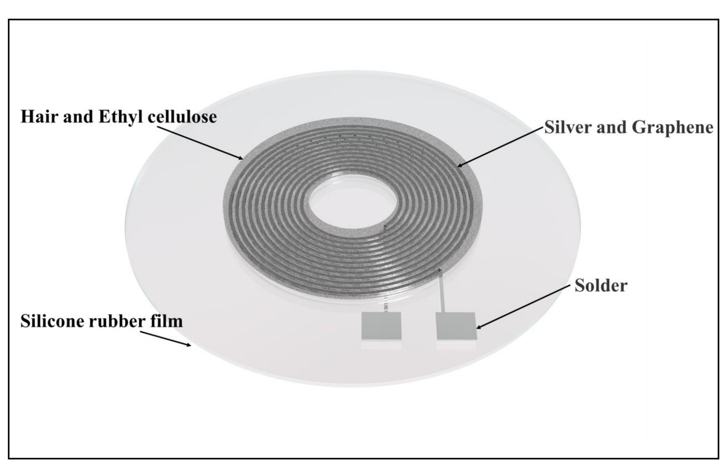

Figure 1(a)

Top view of sensor structure

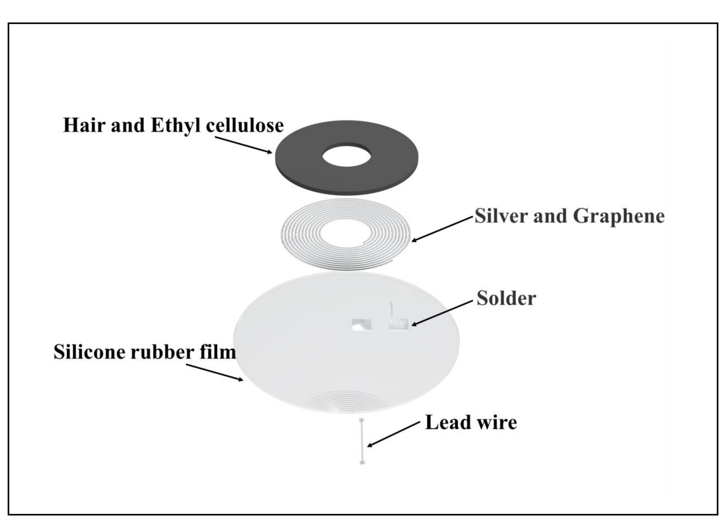

Figure 1(b)

Exploded view of sensor structure

Use COMSOL to simulate the flexible inductive humidity sensor and model the main part of the sensor.

The solid mechanics module is used to simulate the process of the displacement change caused by the humidity-sensitive material absorbing the humidity in the air. The displacement change of the humidity-sensitive strain layer is shown in Figure 2 when it absorbs water and expands. Select points a, b, and c on the sensor that are located on the humidity sensitive layer, inductance coil, and silicone rubber substrate. The lateral displacement curves of these three points with time are shown in Figure 3.

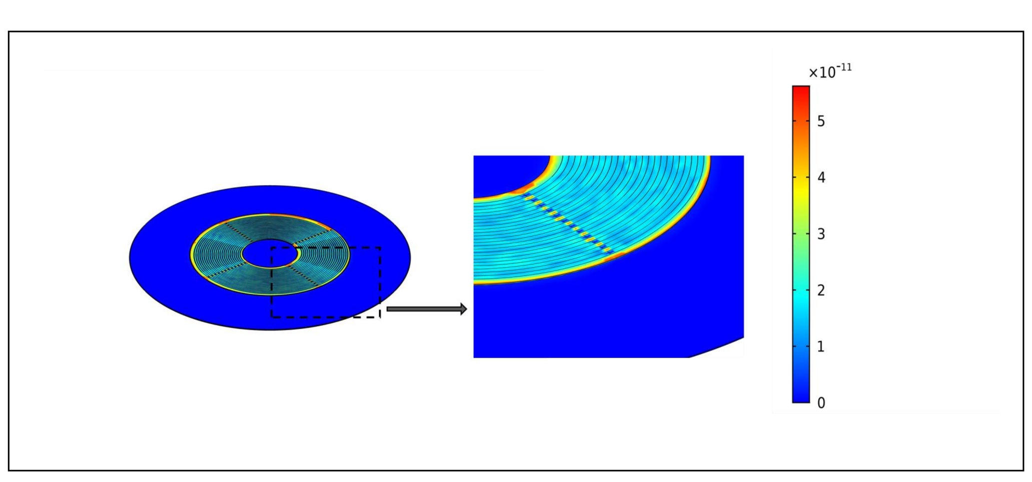

Figure 2 *Displacement change diagram of humidity sensor*

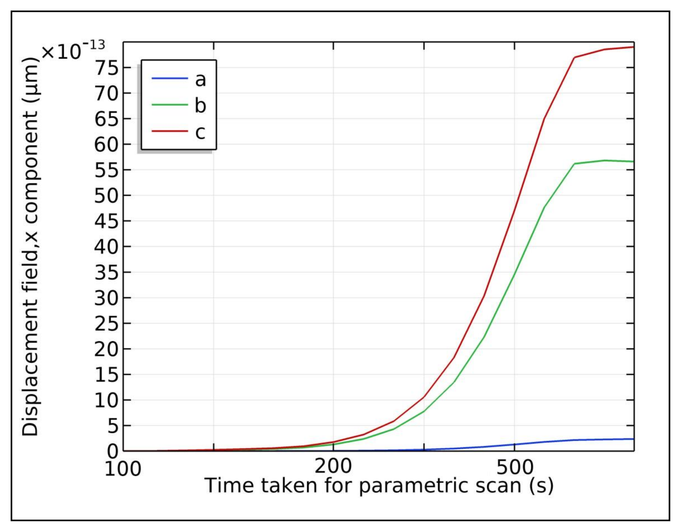

Figure 3

Three-point displacement curve of the humidity sensor

Sensor performance test experiment and results

To realize the sensing performance detection of the flexible humidity sensor, a humidity dynamic test system as shown in Figure 4 is built, which includes a humidity generation system, a signal detection system and a data acquisition system[2].

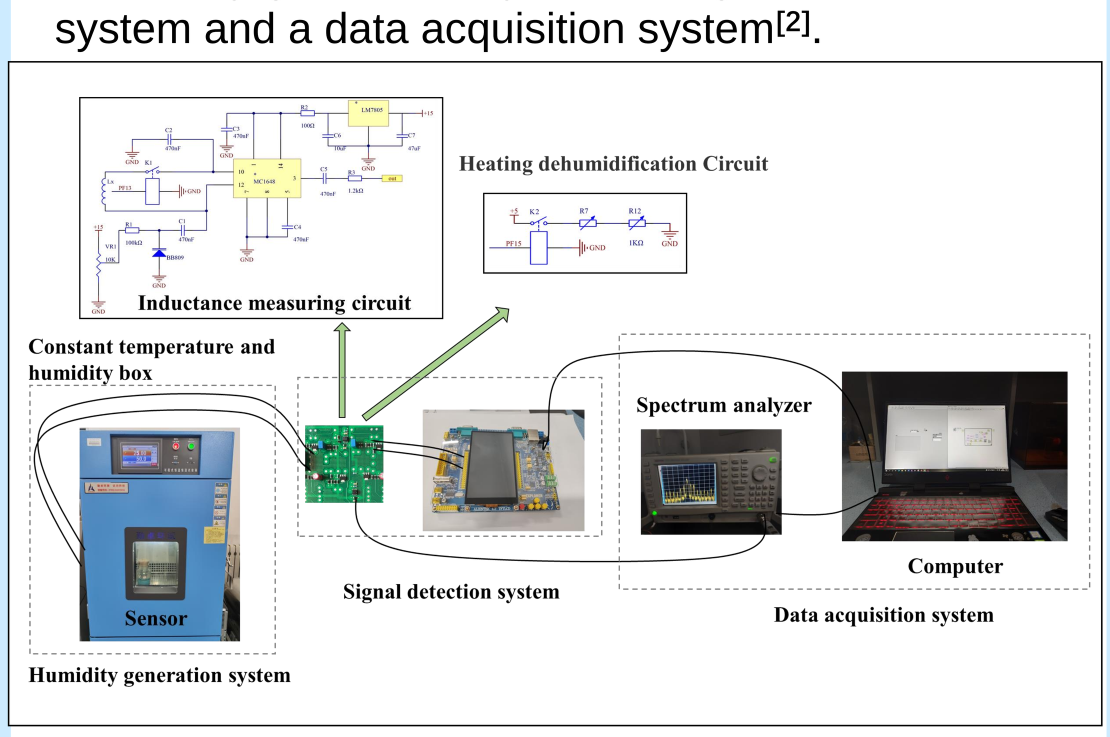

Figure 4 *Humidity dynamic test system diagram*

Controlling the different types of salt solution in the saturated salt shaker provides six different constant humidity environments for the humidity sensor. The humidity sensor characteristic curve of humidity sensor is shown in Figure 5.The linear fitting function is y=-0.000119x+7.284006, the coefficient of determination is R^2=0.97,the sensitivity of the inductive humidity sensor is calculated to be 118.92Hz/%RH and the range of the humidity sensor is 10%RH~95%RH.

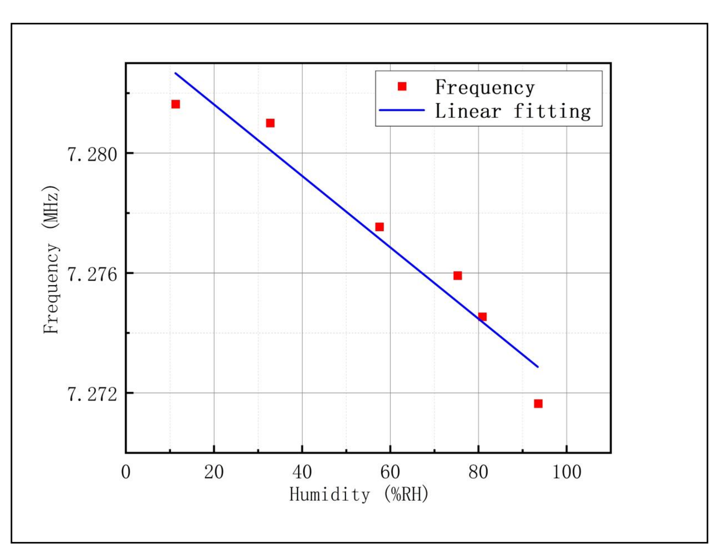

Figure 5

Humidity sensing characteristic curve of humidity sensor

Saturated salt solution is NaCl, KBr and KNO3, respectively to test the relationship between the humidity sensor's absorption of humidity and time changes in different humidity environments. The result is shown in Figure 6. The response time is defined as the time required for 63% of the humidity change. Therefore, the response time of the sensor in the saturated salt solution is 478.8s, 604.8s and 680.4s, respectively.

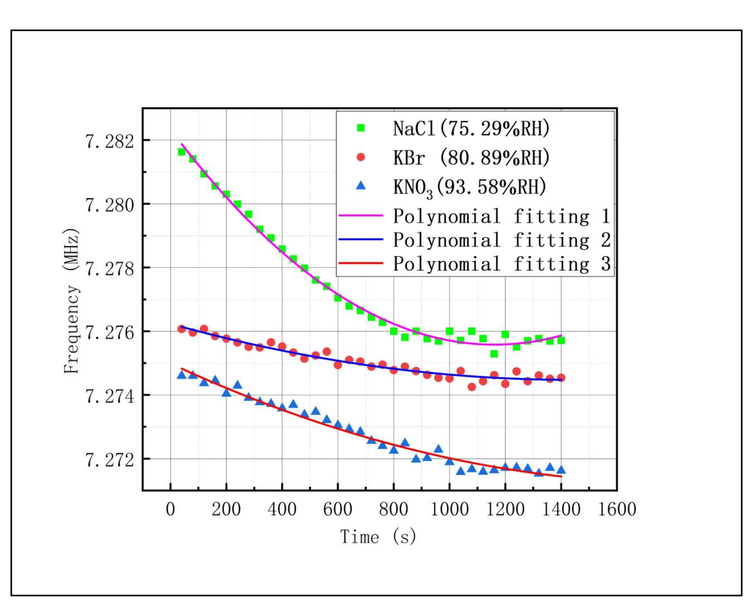

Figure 6

Frequency-time relationship curve of humidity sensor

Observing the hygroscopic characteristics of the moisture absorption curve and the dehumidification curve through Figure 7, the results show that the hysteresis of the humidity sensor is relatively small, about 3%RH[3].

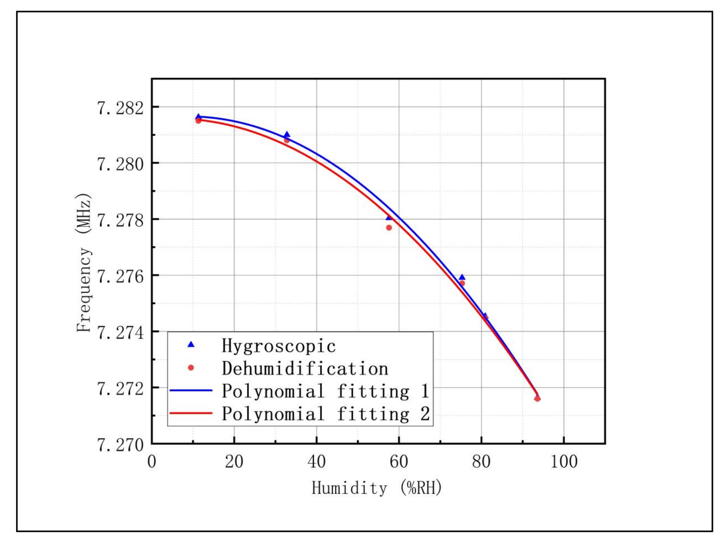

Figure 7

Hysteresis characteristic curve of humidity sensor

Figure 8 shows the average humidity drift of three flexible humidity sensors after a week. The saturated salt solution is NaCl, KBr and KNO3, respectively. The average humidity drift of each humidity point is less than±3%RH, the humidity sensor has good long-term stability.

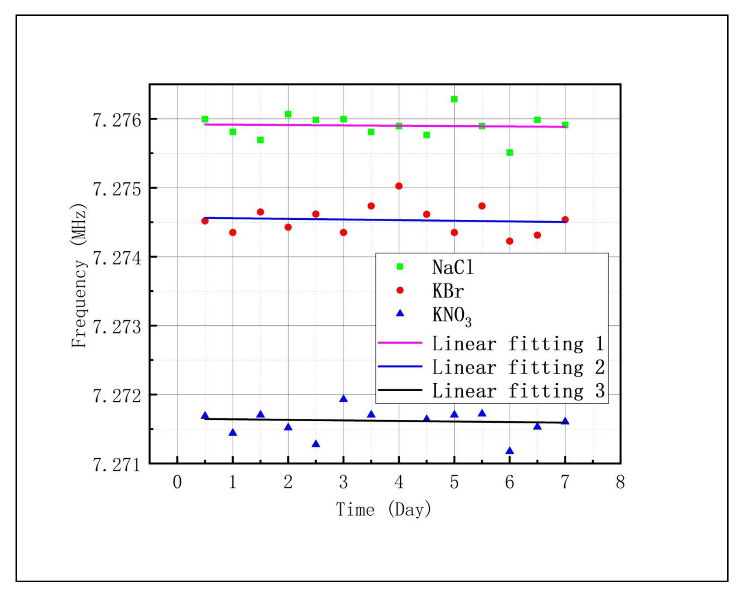

Figure 8

Stability curve of humidity sensor

Conclusion

In this study, a flexible inductive humidity sensor based on ethyl cellulose modified by biomass hair is designed, and a new method of measuring humidity through inductance is verified. Based on the high humidity expansion coefficient of human hair, this study prepares a moisture-sensitive material with excellent moisture-sensing properties by dehydrating and degreasing the hair at high temperature. The test system of the inductive humidity sensor was built, and the characteristics of the sensor were analyzed, and the following conclusions were drawn: the linear determination coefficient of the sensor is 0.97, the sensitivity is 118.92Hz/%RH, the response time is less than 700s, the hysteresis is 3%RH, and the drift in a week is less than ±3%RH. The results show that the sensor is an inductive humidity sensor with wide range, good linearity, fast dehumidification, and small hysteresis, which has a wide range of application potential for humidity detection.

Reference

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