Fig. 5 shows response time characteristic of capacitance change by water absorption and desorption for Au upper electrode of different thicknesses/morphology corresponding to Fig. 1. Curves A, B and C are in the absorption process and curves A′, B′ and C′ are in the desorption process. We can see the thicker film with large granularity has a very long response time, and for the thinner film the initial rise time up to the bend on the response curve is about 2 to 3 seconds. However, in the desorption process it takes a longer time than in the absorption process. This is mainly due to the properties of polymer thin film.

Using the samples in Fig. 1a and Fig. 3 the sensor element with fast-response, high sensitivity (0.7 pF/% RH) and good linearity were produced. From the experiments, it is shown that the suitable granularity thin film is about 14 nm thick deposited by ion-sputtering or carefully controlling evaporation. However, taking into account of cost ion-sputtering is a less expensive process that can bring down the price of a sensor.

3 Summary

The optimum thicleness and structrure/morphology of Au upper electrode of polymer capacitive humidity sensor are found by a series of experiments, and so is the relation between charucteristic and thichness. The optimum sensitivity and response time (~ 5 s) are also obtained.

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控制上电极微结构改善高分子湿敏电容特性

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摘 要 通过控制金上电极的表面结构,高分子电容式湿度传感器的湿敏特性得到了改善.找到离子溅射这种最佳工艺及金上电极的最佳厚度— 14 nm.还显示了金上电极的厚度与湿度传感器的特性之间的关系.

关键词 高分子电容式湿度传感器,上电极,溅射,响应时间,灵敏度
分类号 TP 202

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中山大学学报 (自然科学版)
第 36卷 第 3期 ACTA SCIENTIARUM NATURALIUM Vol. 36 No. 3
1997年 5月 UNIVERSITATIS SUNYATSENI May 1997

Improvement of Characteristics of Polymer Capacitive Humidity Sensor by Controlling Structure/Morphology of Au Upper Electrode*

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Abstract The sensitive characteristics of polymer capacitive humidity sensor has been improved by controlling surface structure/morphology of Au upper electrode. The optimum thickness, 14nm, and process of ion-sputtering were found. The characteristics related to thickness of Au upper electrodes were also shown.

Keywords polymer capacitive humidity sensor, upper electrode, sputter, response time, sensitivity

1 Introduction

The measurement of relative humidity has always been a difficult and challenging one to make because of the interaction of other variable such as temperature, and because of the lack of stable and reliable sensor. In recent years, a novel humidity sensor element, i.e. capacitive humidity sensor element, has been developed[1,2]. The construction of this element is a capacitor. An Au thin film was deposited as a lower electrode on glass by vacuum evaporation or ion-sputtering, and a polymer (PM) thin film was formed on the Au thin film. Then another porous Au thin film was deposited on the polymer thin film. This procedure produces a parallelplate capacitor in the form of Au-Pm-Au. Following a change of relative humidity, there is a change in dielectric constant of polymer due to water absorption or desorption through Au upper electrode[2]. As a novel humidity sensor, the most important characteristics include the problems of hysteresis, which were minimal, as well as relative speed of response and sensitivity. Although these are dependent of the behaviour of the humidity sensitive material, they are also related to the surface microstructure/morphology of Au upper electrode very much. Once a water-absorbing thin film was made which is suitable for device quality of the sensor, the behaviour of sensor element can be improved by controlling thickness and surface microstructure/morphology of Au upper electrode. The Au upper electrode must be made thin enough to transmit water vapour to the humidity sensitive film. However, a very thin Au film is an island-stage net-

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work or even isolated islands. A bad quality Au thin film will result in the sensor element to cut off or be insensitive to a humidity change, because the islands in the Au thin film are isolated or too big(i. e. the thin film is not sufficiently porous) to transmit more water vapour respectively. So homogeneous surface with small granularity and suitable thickness will be required for the Au upper electrode.

The quality of Au upper electrode depends mainly on deposited process, thickness of thin film and temperature of both source and substrate et. al., In this paper we report the effects of Au thin films thickness and different deposited process on the surface granularity, and their effect on the behaviour of sensor. We have carried out experiments to make two choices by using TEM: ① What thickness and surface granularity of Au thin film are proper for a good sensor element? ② Which process can prepare a good electrode and can bring down the gold consumption and so the cost of such sensor?

2 Experimental results and discussions

There are two processes that are commonly used to prepare Au upper electrode. The first is vacumm evaporation and the other is ion-sputtering. A series of gold upper electrode with different thickness were made by these two process on the polymer thin films with the same condition. The thicknesses of these samples were measured by SEM's electron probe, and the structure/morphology were observed by TEM. Fig. 1 and Fig. 2 show the TEM images with 40 K times enlargement. From these pictures, different structure/morphology were observed as the different thicknesses and deposited processes.

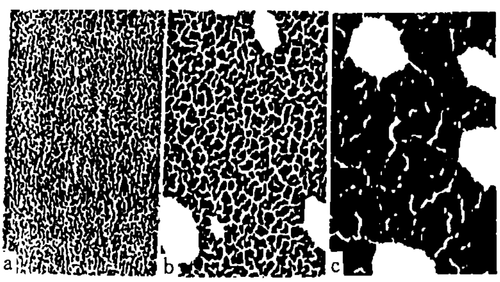

Fig. 1 TEM images of Au upper electrodes deposited by ion-sputtering process. For image (a), the specimen thickness was 14 nm, for (b) was 19 nm and for (c) was 26 nm

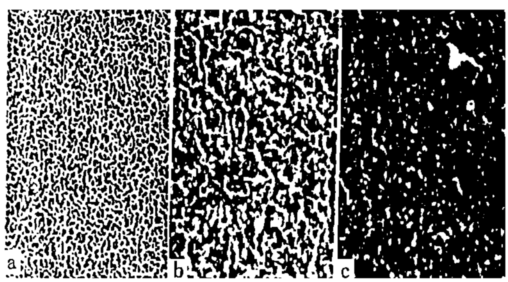

Fig. 2 TEM images of Au upper electrode deposited by vacuum evaporation. For image (a), the specimen thickness was 15 nm, for (b) was 20 nm and for (c) was 25 nm

In general, by ion-sputtering process the granularity of Au thin film is smaller and more homogeneous than by evaporation when the thickness is the same. A thin film of ion-sputtering has more islands or more porous network per unit area (see Fig. 1a and Fig. 2a). The process employed to obtain the electrode shown in Fig. 1a with homogeneous and small granularity is required for a good upper electrode which can transmit a large amount

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of water vapour to polymer thin film quickly.

As mentioned above granularity of Au thin film depends not only on the thickness, but on the deposited conditions very much. By controlling deposited conditions carefully, such as temperature of both source and substrate, the good granularity thin film was also made by evaporation, see Fig. 3. It was prepared at lower temperature.

Fig. 4 shows capacitance-relative humidity (RH) curves (a, b and c) for three Au upper electrodes of different thickness/morphology, corresponding to Fig. 1a, 1b and 1c, and the curve D corresponding to Fig. 2a. In these experiments we made all the polymer thin films having the same condition. We can see curve A is the most sensitive one. Although 14 nm thickness in Fig. 1a and Fig. 2a are the same thickness within the experimental error, the sensitivity corresponding to Fig. 2a is not so good as that one of Fig. 1a. This is due to their different surface microstructure/morphology. On the other hand, curves B and C corresponding to 19 nm and 26 nm thickness Au thin film. Fig. 1b and Fig. 1c respectively are undoubtedly less unsensitive than the film 14nm Fig. 1a. However, another curve E in Fig. 4 with good sensitivity to relative humidity is the sample that the Au upper electrode was deposited by evaporation under lower temperature. This shows the suitable electrode can also be made by evaporation process.

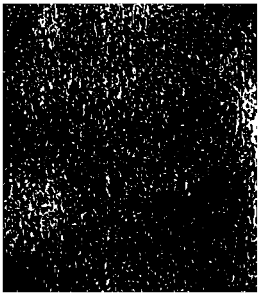

Fig. 3 TEM image of Au upper electrode deposited by vacuum evaporation under lower temperature of Au evaporation source

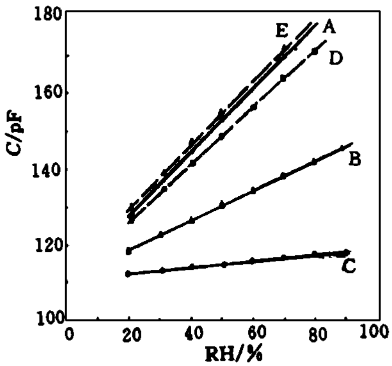

Fig. 4 Capacitance-relative humidity curves showing the effect of Au upper electrode morphology and thickness Curve A, B and C- sputtering; Curve D and E- evaporation

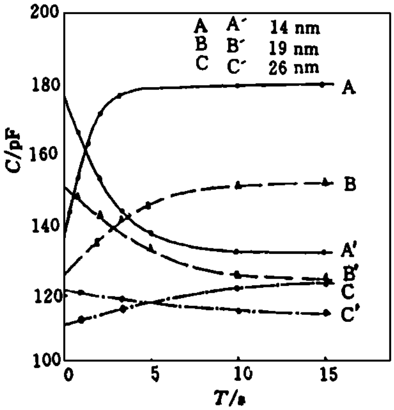

Fig. 5 Response time characteristics of capacitance change by water absorption (from 20% RH to 90% RH, curve A, B, C) and desorption (from 90% RH to 20% RH, curve A′, B′, C′) for Au upper electrode of different morphology and thickness

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