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HUMIDITY SENSORS BASED ON COMPOSITE MATERIAL WITH NANO - DIMENSIONAL STRUCTURES

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Abstract. A humidity sensor based on a composite material nanoscale structures and it is developed and the main static characteristics with studied depending on the relative humidity of the air, and also used to measure the humidity of agricultural products. The efficiency of the proposed method for measuring the temperature and humidity of agricultural products was shown. The results experimental studies show that with the increase the sizes of the areas (contact) crystal shunts producing nanoparticles with simultaneous decrease the total porosity of the sensor material with an increase in the duration of heat treatment, which leads to an increase the volume of the sensor while decreasing its passive volume. This proves the efficiency of the application in sensors to assess the moisture content of silicon crystals.

Keywords: silicon, nanosize, composite material, temperature dependence, properties, stability, sensitivity, speed, technology, nanostructure, humidity.

It is impossible to imagine a modern specialist in the field of obtaining and using new materials without erudition in the world of nanotechnologies, especially without knowledge of polymer containing nano materials. No wonder the modern era is called the age of polymers and composite materials.

Scientific and technological progress presupposes the use of new and effective materials with a different set of properties for various purposes. The development and implementation of a moisture sensor based on a composite material that reliably operates in extreme conditions is a problem of great importance, the solution of which largely determines the acceleration of the pace of scientific and technological progress.

The existing sensors and their manufacturing technology have practically exhausted their capabilities in terms of sensitivity and speed. In this regard, scientists and developers are now facing scientific problems of increasing the sensitivity and speed of sensors; increasing the service life of the sensors; simplifying the process of operating sensors; remote measurement of humidity.

These problems are very science intensive, including fundamental research and development of new technological methods for manufacturing a fundamentally new class of sensors.

Based on the foregoing, it can be concluded that the development of technology and the creation of high-speed, highly sensitive moisture sensors is an urgent task. One of the ways to solve this problem is to develop a technology for producing highly sensitive materials with nano-sized particles.

The implementation of the proposed work makes it possible to create a fundamental class of universal sensors of physical quantities with improved degradation properties and stability of parameters, low energy consumption and miniaturization, the absence of additional amplification circuits that provide ease of operation, surpassing the threshold sensitivity and speed of similar
existing sensors in the form of the fact that they operate on based on fundamentally new physical phenomena. Therefore, to create sensors that are more sensitive, fast-acting, convenient for operation and do not require additional devices, it is necessary to develop fundamentally new materials and physical phenomena.

In this work, a number of studies were carried out to select the composition and ratio of components to increase the moisture sensitivity of a composite material with nano-sized particles. For the manufacture of sensors, an optimal design of moisture sensing elements and a technology for manufacturing an ohmic contact with stable parameters and good adhesion to the composite material were developed.

The technology, design and manufacture of a moisture sensitive sensor based on nano composites have been developed. The characteristics of the moisture sensitive sensor are studied experimentally. The measurement range of humidity is 0-98%, however, at humidity over 90%, the measurement error is up to 5%.

The principle of operation of the sensors is based on the well-known principle of changing its electrical resistance when absorbing moisture from the environment. At the same time, in contrast to previously known sensors, for example, in [1], the design does not use solutions of electrolytic dislocating salts, and the material conductivity has the character of hopping conductivity between nanoparticles, which changes when water is adsorbed on nanosized conducting particles located in porous dielectric matrix.

To assess the working range of voltages and stability of contacts, the volt-ampere characteristic of the sensors was investigated at \( T = 300 \) K in the dark. Working (linear) range, trying voltages of the unit volt, which shows the high sensitivity of the sensor.

The study of the temperature dependence of the sensor current is carried out in the range from 293 to 363 K. The conductivity of the sensor (at a constant supply voltage of 5 V) to 253 K increases, that is, it has an activation character, then a decline begins, due to drying (intensive moisture withdrawal from the volume) of the sensor substance...

On the basis of moisture sensors made of a composite material with conductive nano particles, a device has been created for measuring the absolute moisture of agricultural products [2-3].

Below are the results of the study, i.e. characteristics of moisture sensitive sensors based on nano composites. The current-voltage characteristic, the temperature dependence of the sensor current, as well as the speed of the sensors to changes in air humidity have been investigated. It is shown that the developed new composite material with conducting nano particles makes it possible to create not only sensitive, but also high-speed moisture sensors and use them in the Agro industry.

To determine the metrological characteristics of the developed sensors, calibration was carried out in terms of relative humidity using saturated solutions of some salts, the calibration was carried out at a temperature of 240\(^\circ\)C. The results of calibration of sensor 1 of 13 batches are shown in Table 1.

Based on the results obtained, the static characteristic of the sensor was constructed depending on the humidity (Fig. 1).

Measurement of the moisture resistance of the sensor's sensitive element from air humidity showed good sensitivity, weak nonlinearity and low temperature error of the sensor.
Table 1

<table>
<thead>
<tr>
<th>№</th>
<th>Salt</th>
<th>Relative humidity, $W$, %</th>
<th>Dry sensor initial resistance $R_0$, MOhm</th>
<th>Resistance of a sensor located above a saturated solution, $R$, MOhm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Magnesium chloride, $\text{MgCl}_2$</td>
<td>33</td>
<td>3,93</td>
<td>1,16</td>
</tr>
<tr>
<td>2</td>
<td>Magnesium nitrate, $\text{Mg(NO}_3\text{)}_2$</td>
<td>55</td>
<td>3,91</td>
<td>0,68</td>
</tr>
<tr>
<td>3</td>
<td>Sodium nitrate, $\text{NaNO}_2$</td>
<td>65</td>
<td>3,91</td>
<td>0,52</td>
</tr>
<tr>
<td>4</td>
<td>Sodium chloride, $\text{NaCl}$</td>
<td>76</td>
<td>3,92</td>
<td>0,48</td>
</tr>
<tr>
<td>5</td>
<td>Ammonium sulfate, $\text{(NH}_4\text{)}\text{SO}_4$</td>
<td>81</td>
<td>3,39</td>
<td>0,32</td>
</tr>
<tr>
<td>6</td>
<td>Potassium chloride, $\text{KCl}$</td>
<td>86</td>
<td>3,91</td>
<td>0,28</td>
</tr>
</tbody>
</table>

Fig. 1. Static characteristic of the sensor depending on the relative humidity of the air

The humidity sensor developed by us can be practically used to measure not only air humidity, but also the absolute humidity of some agricultural products. The principle of measuring the absolute moisture content of the product is based on a regular (usually monotonous) change in the air humidity of the product surrounding the grain, with a change in its absolute moisture content.

Table 2 shows the characteristics of the sensors obtained under the same conditions, depending on the annealing temperature of the ceramic mixture.
Table 2

<table>
<thead>
<tr>
<th>№</th>
<th>Annealing temperature of sensors, °C</th>
<th>Dry sensor resistance, R₀, 10⁻⁶ Mohm</th>
<th>Sensor resistances at 100% RH, R₀, 10⁻⁶ Mohm</th>
<th>Response time humidity change, t, min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-batch</td>
<td>600</td>
<td>6,4</td>
<td>4,2</td>
<td>2</td>
</tr>
<tr>
<td>8-batch</td>
<td>650</td>
<td>4,8</td>
<td>3,2</td>
<td>2</td>
</tr>
<tr>
<td>9-batch</td>
<td>700</td>
<td>5,9</td>
<td>3,4</td>
<td>2</td>
</tr>
<tr>
<td>10-batch</td>
<td>750</td>
<td>4,6</td>
<td>1,9</td>
<td>1</td>
</tr>
<tr>
<td>11-batch</td>
<td>800</td>
<td>3,9</td>
<td>1,6</td>
<td>1</td>
</tr>
<tr>
<td>12-batch</td>
<td>850</td>
<td>4,2</td>
<td>1,8</td>
<td>1</td>
</tr>
<tr>
<td>13-batch</td>
<td>900</td>
<td>2,3</td>
<td>0,5</td>
<td>0,96</td>
</tr>
</tbody>
</table>

With an increase in the annealing temperature, the sensitivity of the sensor increases significantly, therefore, the response time to changes in humidity also increases [4].

The results of experimental studies show that with an increase in the area of the "contact" areas, the crystal of the shunts of conducting nanoparticles with the same decrease in the total porosity of the sensor material with an increase in the duration of heat treatment, which leads to an increase in the active volume of the sensors while reducing its passive volume.

A further increase in the annealing temperature leads to an increase and deterioration in the characteristics of moisture sensors.

Measurement of the moisture resistance of the sensitive element of the sensors from air humidity showed good sensitivity, weak nonlinearity, and low temperature error of the sensors.

Thus, the humidity sensors we have developed can be used to measure not only air humidity, but also the absolute humidity of some agricultural products.

References