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On the Possibility of Creating Humidity Sensors for Agriculture Based on Silicon-Germanium

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Abstract: This paper shows the possibility of creating a new type of sensor - semiconductor humidity sensors using silicon-germanium solid solutions. It has been proven that it is possible to create humidity sensors based on Si_{1}-xGe_{x} solid solutions in the form of a Schottky barrier with a wide range of sensitivity to the relative humidity of the environment.

Key words: Soil moisture meters, laboratory methods, soil moisture, soil acidity, Schottky barrier, highly sensitive hygrometer, liquid-phase method, current-voltage characteristic, range extension

Introduction

Knowledge of the humidity of various environments is very important, both in everyday life and in various sectors of the national economy. Because humidity is a very important parameter that is widely controlled practically in all spheres of human activity, from the environment to complex high-tech industries. Traditional laboratory methods for determining humidity in most cases are not suitable for modern requirements, when ex-pressive and constant monitoring of this parameter is necessary.

For example, the currently existing modern hygrometers (humidity meters) are mainly built on the capacitive principle. Where to measure humidity, for example, air, the latter must be blown into a pipe where a humidity sensor is installed (condenser plates). In other cases, for example, when measuring the moisture content of raw cotton during acceptance at its reception points, or when measuring soil moisture, these methods are not acceptable. So, to measure soil moisture, soil moisture meters are used, in which moisture sensors are made in the form of a pin and the operation of the moisture meter is based on the principle of measuring the electrical resistance of the soil depending on humidity. In cases of heterogeneous soil moisture, this method gives a large error and does not allow to accurately determine the soil moisture, since the soil resistance can vary depending on both the acidity of the soil and the depth of the pins [1-3].

To create a high-precision humidity control device that meets modern requirements, it is extremely important to choose a sensor, its principles of operation and design. Among them, the electrometric method with the use of semiconductor humidity sensors attracts attention for its relative simplicity of feasibility, small dimensions, low cost combined with high metrological characteristics, and wide possibilities of improvement. However, so far this method has found limited use due to the low perfection of the humidity sensor. Consequently, at present there is a very urgent problem in electrical engineering of creating highly sensitive and efficient humidity sensors. The solution of this problem makes it possible to dramatically increase the accuracy of the measurement of moisture [4-6].

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The purpose of this work is to show the possibilities of creating highly sensitive semiconductor humidity sensors and their applicability for the manufacture of a highly sensitive hygrometer - a humidity measurement device.

Materials And Methods

The paper considers the possibility of creating a new type of sensor - semiconductor humidity sensors with the use of silicon–germanium solid solutions. To create such a structure, two technological methods were used - the method of liquid–phase epitaxy (for growing films of a silicon-germanium solid solution on silicon substrates) and a method for creating a Schottky barrier on them that is sensitive to the humidity of the medium.

For this purpose, solid solutions of $Si_{1-x}Ge_x$ were grown on silicon substrates of p-type conductivity with a resistivity of = 0.1 om·sm by the liquid-phase method given in [4, 5] (on the surface of the film, the composition of the solid solution has x ~ 0.95) also of *p*-type conductivity with the level of N_A acceptors ~ 1×10^{18} cm^{-3}.

After proper processing, the $Si_{1-x}Ge_x$ epitaxial film substrates were cut into separate pieces with dimensions of 3 mm × 3 mm. Therefore, current contacts were obtained on these pieces – omics contacts on the back side, and on the surface of the epitaxial film in the form of a Schottky barrier. The back omics contact was made by thermal spraying in vacuum (with a residual pressure of 10^{-5} Torr), first of a thin sublayer of titanium (Ti), and then a layer of nickel (Ni) on it. At the same time, in order to ensure good adhesion and omics contact, the temperature of the table was maintained in the range of 320-350°C. The Schottky barrier was also made by thermal evaporation of palladium (Pd) in vacuum, but only in this case the temperature of the sample table was maintained within 130-150°C. Pd spraying was carried out through a metal mask with a quadrant "window" with side dimensions of 1 mm × 1 mm.

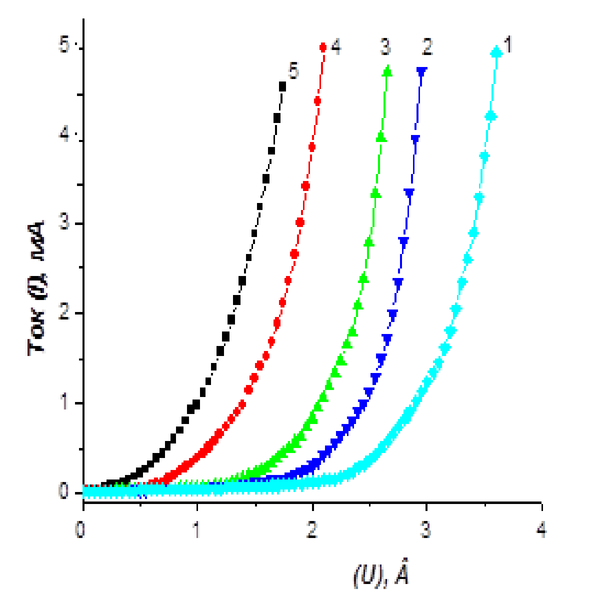

Fig.1. Current–voltage characteristic of the Pd - $Si_{1-x}Ge_x$ Schottky barrier, at discrete values of relative humidity 20 (1), 30 (2), 40 (3), 50(4) and 60% (5), respectively.

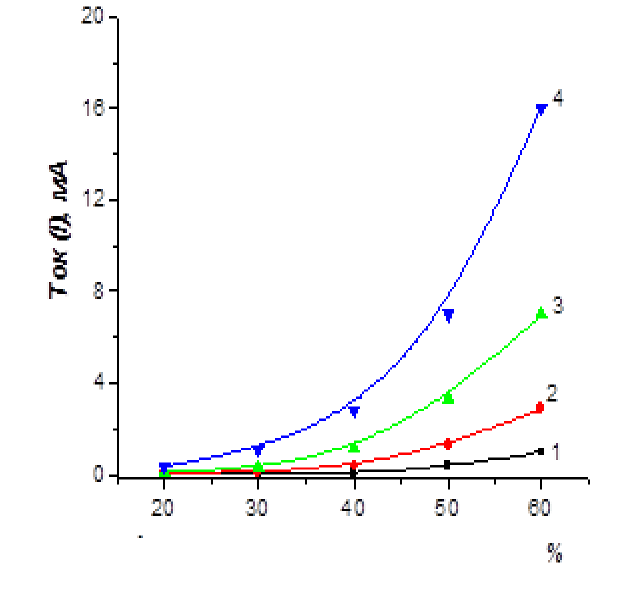

Fig.2. Dependence of the current of the Pd – $Si_{1-x}Ge_x$ Schottky barrier on the relative humidity of the environment at offset values 1,0 (1); 1,5 (2); 2,0 (3) and 2.0 V (4), respectively.

Results And Discussion.

The current-voltage characteristics (VAC) of the manufactured samples were measured at room temperature (300 K) under various conditions of relative humidity of the environment where the samples of the manufactured humidity sensors were located. Fig.1 shows the VAC samples measured at discrete values of relative humidity 20 (1), 30 (2), 40 (3), 50(4) and 60% (5), respectively, and Figure 2 shows the dependence of the Schottky barrier current on the relative humidity of the surrounding environments with offset values 1,0 (1); 1,5 (2); 2,0 (3) and 2.0 V (4), respectively.

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As can be seen from Fig.1, as the relative humidity of the environment increases, the breakdown voltage of the Schottky barrier junction decreases almost proportionally with humidity. It can be seen from Fig.2 that the sensitivity of samples to relative humidity increases with an increase in the offset value. This shows that when using such humidity sensors, it is possible to change the range of their sensitivity by changing the bias voltage. It should also be noted that in order to expand the sensitivity range of such sensors, it is necessary to increase the breakdown voltage of the Schottky barrier, which, apparently, is achieved by reducing the amount of germanium in the Si1-xGex solid solution, and this in turn requires further research in this direction.

Conclusion

We have proved that it is possible to create humidity sensors based on $Si_{1-x}Ge_x$ solid solutions in the form of a Schottky barrier with a wide range of sensitivity to the relative humidity of the environment.

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