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DEVELOPMENT OF CORRECTIVE STRUCTURAL SCHEMES FOR SEMICONDUCTOR CONVERTERS TEMPERATURE AND HUMIDITY

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Abstract. Corrective block diagrams for semiconductor temperature and humidity converters using new elements and devices of modern microelectronics have been developed.

Keywords: semiconductor, converter, temperature, humidity, diffusion, doping, nickel, silicon, correction circuit.

It is known that to obtain efficient semiconductor nanomaterials used as measuring transducers, a high-quality vacuum is required, obtained using modern vacuum installations to carry out the process of thermal vacuum deposition on the surface of a metal, a semiconductor and a dielectric.

In the process of thermal vacuum deposition, a vapor of a substance is formed in a vacuum, where it propagates from the source to the substrates and a film containing nanoparticles is formed on its surface. Metals, semiconductors and dielectrics are used as a substrate, depending on the formation of nanolayers. Film growth, i.e. film thickness, depends on the deposition rate of the film and the temperature of the substrate. The process of thermal vacuum deposition is characterized by a high degree of purity and allows obtaining high quality films, which the process takes place in a high vacuum at relatively low substrate temperatures [1].

Analyzing the common methods of film deposition and taking into account the need for subsequent thermal diffusion of impurities into the bulk of silicon and obtaining reproducible electrical, optical, and other characteristics of silicon, it is necessary to highlight the method of chemical deposition of nickel on the silicon surface, which does not require special equipment and is distinguished by the simplicity of the process.

On the development of high-speed and accurate nanotransducers of various physical quantities using doping of active semiconductor materials, increasing the linearity of the static characteristics and improving the technology, various research works are being carried out related to the introduction of transition elements in silicon semiconductor structures, which is characterized by the creation of new, sensitive and efficient semiconductor converters. For equal resistivities, the concentration of holes in a p-type semiconductor is greater than the concentration of electrons in an n-type semiconductor due to the lower mobility of holes in comparison with electrons. A high concentration of charge carriers in a p-type semiconductor leads to a shallower depth of the Fermi level, and, consequently, to a lower coefficient of temperature sensitivity [2].

This work presents a number of new original results on the study of the properties of temperature and humidity converters based on silicon with nanoclusters of nickel atoms. As is
known, among the transition elements in silicon, nickel has a fairly high solubility and a large diffusion coefficient.

We have developed a new doping method, the so-called low-temperature diffusion, which allows all introduced nickel atoms to participate in the formation of nanoclusters with specified characteristics. The essence of this method is to carry out a stage-by-stage diffusion of nickel into silicon with a given rate, heating and holding at each stage with a certain time. By controlling the heating rate and holding time at each stage of diffusion, it is possible to control the concentration of the distribution and the parameters of nanoclusters of nickel atoms in the silicon lattice.

Experimental data show that the thermal sensitivity of the developed temperature sensors is very high, it is 25 ... 50 times higher than that of the most sensitive existing temperature sensors. The peculiarity of the developed temperature converters is that they have a high speed of response both in establishing and in restoring the temperature of an object. The current consumed by a semiconductor temperature converter is approximately 2 μA.

The accuracy of semiconductor temperature and humidity converters depends on the design and technological features of the main elements, functionality, linearization of static characteristics and information and measurement parameters. Methods for improving the accuracy of semiconductor temperature and humidity converters can be subdivided into functional, structural and technological, and static linearization. Functional minimization methods consist in the fact that they are reduced to a minimum of the component errors by introducing corrective elements and devices into the measuring circuit that operate under extreme conditions taking into account the ambient temperature. To improve the accuracy of the output signals of semiconductor temperature and humidity converters, we have developed corrective structural diagrams using new elements and devices of modern microelectronics [3].

Let us consider the sequential correction of the dynamic error of semiconductor converters of temperature and humidity of the parameters of dispersed media using the basic structural schemes for converting the input quantity, in which two series-connected correcting links are used, which significantly increases the speed of the circuit and significantly expands the frequency range (Fig. 1).

![Fig. 1. Block diagram of the device for sequential correction of the dynamic error of semiconductor temperature and humidity converters](image-url)
The main elements of the structural diagram: 1-semiconductor-capacitive converter with a current sensor $R_i$; 2- matching scheme; 3- amplitude converter; 4- mismatch diagram; 5- correction circuit based on a silicon converter $R_i$; 6 - a comparison diagram; 7-cycle amplifier; 8- generator; 9- analog digital converter. A correction circuit of capacitors $C_1$ and $C_2$ resistances $R_1, R_2$ and a silicon converter $R_i$ reproduces the output voltage proportional as a function of temperature and humidity. The block diagram of the transformation of the input quantity consists of correcting elements of compensation 1, overcompensation 2, undercompensation 3.

Fig. 2 shows the curves of the transient process of a semiconductor transducer of temperature and humidity of the parameters of dispersed media with abrupt changes in the output signal.

![Fig. 2. Curves of transient processes in a semiconductor converter of temperature and humidity of dispersed media](image)

Fig. 3 shows a block diagram of parallel correction, which implements modern principles of synthesis of information-measuring systems and a new element base. A moisture converter for dispersed media with ring electrodes and silicon-based semiconductor converters are included in the measuring circuits of the IG1 and IG2 generators, tuned to the frequency. After immersion of the converter in the controlled environment, the frequency of the generator of the push-pull circuit with capacitive-resistive couplings based on integrated circuits.

The resistive element, which is two parallel-connected humidity $C_a$ and humidity converters $R_i$, shunts the oscillatory circuit of the measuring generator, because the signal frequency is independent of the active conductivity of the medium. The active loss stabilizer maintains a constant active conductivity in the oscillatory circuit of the generator over the entire measured humidity range. The instability of the generators in this system was possible to obtain no more
The signals from the generators are transmitted to the pulse shapers $PSh$, which are designed to convert the analog signals coming from the reference and measuring generators into rectangular signals of the same frequency. From the pulse shaper measured $f_{\text{mea}}$ and reference $f_{\text{ref}}$ signals are transmitted to the subtraction devices $SD$, that implement the operation $f_{\text{mea}} - f_{\text{ref}} = \Delta f$.  

![Block diagram of parallel error correction of semiconductor temperature and humidity converters](image)

Fig. 3. Block diagram of parallel error correction of semiconductor temperature and humidity converters

The main elements of the structural diagram of the parallel error correction of semiconductor temperature and humidity converters: $G1$ and $G2$ - measuring alternating signal generators; $QR1$ and $QR2$ - AC voltage stabilizers based on quartz resonator circuits; $PG1$ and $PG2$ are pulse signal generators; $RG1$ and $RG2$ - reference-clock generators; $CG$ - clock generator; $FD$ - frequency divider; $P$ - frequency divider distributor; $SD$ - subtraction devices; $DD$ - digital device; $DAC$ - digital-to-analog converter; $ADC$ - analog-to-digital converter; $DP$ - digital printing device.

The resistive element, which is two parallel-connected humidity $C_n$ and humidity converters $R_i$, shunts the oscillatory circuit of the measuring generator, because the signal frequency is independent of the active conductivity of the medium. The active loss stabilizer maintains a constant active conductivity in the oscillatory circuit of the generator over the entire measured humidity range. The instability of the generators in this system was possible to obtain no more $\pm 5Hz$. The signals from the generators are transmitted to the pulse shapers $PSh$, which are designed to convert the analog signals coming from the reference and measuring generators into rectangular signals of the same frequency. From the pulse shaper measured $f_{\text{mea}}$ and reference $f_{\text{ref}}$ signals are transmitted to the subtraction devices $SD$, that implement the operation $f_{\text{mea}} - f_{\text{ref}} = \Delta f$.

At the same time, signals are sent from the distributor that control the subtraction operation. The distributor consists of three blocks: the clock pulse generator $CG$, the frequency divider $FD$ and the distributor itself $D$, which formed a series of four clock pulses with a duration of 1s and pauses between them 1s. A series of pulses from the measuring generator will enter the counter countdown input 1 after recording a series of pulses from the reference generator.
Considering that \( f_{\text{ref}} \leq f_{\text{mea}} \) is in reverse mode, less than 500 thousand pulses will enter the counter and \( f_{\text{ref}} \) will be subtracted from \( f_{\text{mea}} \) and the result will be a difference \( \Delta f = f_{\text{mea}} - f_{\text{ref}} \), the value of which is encoded in binary-decimal code. The digital-to-analog converter (DAC) of the measuring system consists of two boards.

The block diagram of the measuring system with semiconductor converters in the mode of measuring the capacitance ratios, shown in Fig. 3, will improve the measurement accuracy and significantly reduce the level of dynamic error. Converters \( C_n \) and \( R_i \) are included in the measuring circuit of the \( IG1 \) and \( IG2 \) generators, operating with separate resonator elements that stabilize the frequency of the generators. After immersion of capacitive RFPs in the measured medium, the generator frequency will change by a certain amount \( f_0 + \Delta f \). The signals from the generators are fed to the capacitance meters \( CM1 \), \( CM2 \) and are measured, but here the \( IG2 \) generator functions in conjunction with the capacitance divider and, therefore, the signal at the generator output decreases by value \( f_1 \).

The signals are transmitted to the dividing devices \( DD \) that implement the operation \( f_0 + \Delta f / f_0 + \Delta f - f_1 \). The DAC converts information about the current humidity, expressed in a binary digital code, into a DC voltage, the level of which is a linear function of humidity.

**References**

