ANNOTATION

of dissertation for the Philosophy Doctor (PhD) degree on «6D071900 - Radio Engineering, Electronics and Telecommunications» specialty

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Dynamical chaos in nanostructured self-sustained systems

General characteristics of the work.

This paper is devoted to theoretical and experimental studies, and computer modeling and investigation of electrical and physical properties of generators, constructed on the basis of thin semiconductor films. Also, this paper presents the results of the research of synchronization process in electrically uncoupled sensory cells ensemble under thermal influence, as well as the phase adjustment of the dynamics of neurons that also is considered as self-sustained system.

Actuality of the topic.

Currently, there is the problem of obtaining electronic sources of chaotic signals based on low-dimensional nanostructured systems. Due to the fact that such systems can contain up to tens of thousands atoms the actual problem is theoretical description and modeling of nanostructured systems, in particular structures based on thin films. Since the systems that are experiencing dynamical chaos are usually self-oscillating, an important scientific task is to study nanostructured self-oscillatory systems - generators of chaotic signals, in particular on the basis of thin solid films. Some self-oscillatory systems, in addition to dynamical chaos, the phenomenon of synchronization, which is also a consequence of the nonlinearity of the systems studied. Such systems are in particular biophysical objects - the sensory cells and neurons.

The goal of the work is theoretical and experimental study of nonlinear phenomena - dynamical chaos and synchronization in self-oscillatory systems consisting of nanostructures.

Objectives of research.

1. Modeling the surface structure of the porous silicon thin film used for the generation of chaotic signals. Establish quantitative parameters under which a porous surface is realized.

2. To carry out the circuit implementation of signal generator based on a thin film of porous silicon. Explore implemented generator for generating chaotic signals.

3. Using the methods of computer simulation to investigate the possibility of controlling the dynamics of biophysical cellular oscillatory systems with short heat pulses generated by optically excited metal nanoparticles.

4. To investigate the transient response of the self-oscillatory system based on neuron by external heat using the methods of computer simulation. In particular, to investigate the influence of adaptation ionic currents on the transient dynamics of the neuron.

Research objects: semiconductor thin films of porous silicon, chaotic signals generator based on thin films, system of electrically non-coupled sensory cells, the neuron model of Hodgkin-Huxley.

Research subjects: self-sustained oscillations and dynamical chaos in nanostructured systems - the generator on a thin film of porous silicon, partial synchronization of the system is not electrically interacting sensory cells and the phase adjustment in self-oscillatory systems on the basis of the neuron.

Research methods:

1. Theoretical study of thin nanostructured films used for the generation of chaotic signals by methods of nonlinear physics and dynamical chaos.
2. Experimental study of chaotic signal generator means radio engineering and electronics.
3. The experimental data signal generator of chaotic signals and nonlinear methods of statistical physics.
4. Computer simulation experiment on synchronization system of N = 1000 electrically interacting sensory cells by short heat pulses.
5. Computer simulation of the dynamics of neuronal oscillations under external thermal influence.

Scientific novelty of the work concluded in the following result:

1. The surface of thin films used for the random signal can be modeled based on a universal display fractal evolution steps.
2. On the basis of nanoscale films of porous silicon oscillator built with internal feedback (oscillator). It is shown that the output of the oscillator signal can be implemented dynamic chaos.
3. Using the methods of computer simulation shows the ability to synchronize the ensemble epithelial sensory cells with short thermal pulses.
4. Using the methods of computer simulation shows the possibility of effective control (phase control) self-oscillating system based on neuron with adaptation currents.

The main statements for the thesis defense:

1. Generation of chaotic signals can be carried out using a thin film of porous silicon having a structure described using the universal mapping the evolution of fractal measures.
2. Generator based on thin films of porous silicon, a source of random signals caused mainly internal feedback.
3. photothermal effect by short laser pulses (5-15 ms) allows you to control the collective dynamics of sensory cells and achieve their partial synchronization.
4. The presence of the adaptation of the current increases the sensitivity of a self-oscillating system based on neuron to static and dynamic changes in temperature. Short thermal exposure can be carried out effectively the phase adjustment of the system.

Theoretical and practical significance of the work.

1. Use the display fractal evolution of measures that describes chaotic process can be modeled surface of various nanostructures. In practice, this can mean that

for a given ratio of concentrations and other parameters known display can be obtained given nanostructure, including porous structure.

2. The generator of dynamical chaos based on porous silicon films shows the chaotic signal with parameters close to the parameters of a random signal in a wide range of frequencies. However, its parameters are adjustable, which follows directly from the chaotic nature of the signal. These generators may be used in wireless sensor networks for transmitting and receiving data in units of coding information, information security systems.

3. Study of the external action (electrical, thermal, etc.) on the biophysical self-oscillating system is necessary for the study and control their dynamics, such as neural networks. Since the investigated system is self-oscillating, then these results and methods can be generalized to other self-oscillating systems, such as neural networks.

4. Also, the implementation of the stimulated neuron phase shift allows us to apply the results in real electrical circuits. For this it is necessary to implement a mechanism of adaptation of the current and the equivalent temperature pulse in the system.

The degree of implementation. According to the materials of the thesis there were published 11 publications, including 3 papers - in editions recommended by the Committee for Education and Science Control of RK, 3 papers - in refereed journals with high impact factor, 5 papers of abstracts of international conferences, including 2 conferences abroad. Also by the results of the thesis the application for the patent was given.