The influence of weak impacts on certain processes of nanotechnology

V A Tupik, V I Margolin and M S Potekhin
Department of Radio Microelectronics and Radio Equipment Technology, Electrotechnical University “LETI”, Saint Petersburg 197376, Russia
E-mail: VATupik@etu.ru

Abstract. The article deals with the influence of weak and super weak impacts on certain technological processes in nanotechnology related to the synthesis of nanoscale films and coatings. We also touch upon the impacts of weak diffraction fields of complex shape on the formation of fractal films and coatings.

1. Introduction
The phenomenon of the weak impact of physical factors on physical, chemical and biological systems has long been a subject of scientific interest. Weak and super weak impacts have been registered and proven in numerous aspects of modern technology, but have not been fully explained so far. Of special interest are impacts on the process of synthesis of weak diffraction field nanoscale surface coatings generated by diffraction grates of complex shape, consisting of curved closed circuits [1].

The phenomenon is often explained in the light of resonance theories: resonance surface waves, dissipating resonance, stochastic resonance and electromagnetic acoustic conversion [2]. Active media with internal energy sources can have nonlinear processes of wave interactions. An electromagnetic field can have a necessary distribution of such characteristics as phase and amplitude on surface of a substrate due to the phenomenon of quantum teleportation, which will contribute to the creation of conditions for microcrystals formation and stimulate nanostructure synthesis on the molecular level [3].

2. The influence of weak impacts of physical fields on various physical objects
The scientific school of Gulyaev is currently engaged in studying the effect of highly ordered (coherent) electromagnetic fields of low intensity on biological and physical objects. Since not only electromagnetic oscillations are generated in this frequency range in physical and biological systems, but also acoustic and acoustoelectric oscillations and waves, and all these types of oscillations are transformed into each other, the term “extremely high-frequency (EHF) radiation and oscillations” was introduced [4].

The physical concept of the effect of EHF radio waves is based on the conclusion about their information (not energy) impact. The use of microwave radiometry allowed us to substantiate the idea of the dissipation of the EHF power introduced into the object and its transformation into the noise energy of the intrinsic radio emission of the object, i.e. its radio response, in a wide frequency range, from low frequencies to the microwave range. This is the fundamental difference between EHF/microwave radiospectroscopy and other types of radiospectroscopy [5]. Registering the internal fluctuation thermal electromagnetic field in a condensed medium, which is influenced by a fluctuation of charged particles of the medium and concentrated inside it, turned out to be fruitful [5].
The author of the work cited formulates the following fundamental thesis: in the studies of condensed media physical mechanisms of the impact of weak fields at the very primary level are not taken into account, which leads to contradictions between experiments and theoretical physics. Therefore, the solution of the problem must be based on understanding the properties of the fluctuation thermal electromagnetic field of the medium.

He also introduces the notion of organized external fields as composite fields that, in contrast to deterministic ones, can contain external noise MF, EF, GF and other fields [5].

The mechanism of the action of weak fields on particles of condensed matter is still unclear. Why does a diamagnetic medium change its behavior, for example, in a magnetic field, although the potential energy of interaction of particles with a magnetic field is 6 to 12 orders of magnitude less than the average energy of their thermal motion, determined by the value of \( kT \). Thermal energy must dilute all the results of the impact, [6] which is a generally accepted theoretical fact, but not corresponding to reality. In [7, 8] it is postulated that the basis for considering the influence of multiple fields on the particles of the medium are internal fluctuation of thermal electromagnetic fields and thermal magnetic fields – an integral part of any condensed macroscopic medium, both homogeneous and heterogeneous. The concept of the fluctuation field is introduced as a random inhomogeneous isotropic field that is distributed throughout the volume of the medium and includes all chaotic forces. It is the result of fluctuations, in time, of charged particles of the medium: electrons, ions, molecules, molecular structures, clusters, etc., caused by thermal motion. Only due to fluctuation thermal electromagnetic fields and thermal magnetic fields can weak influences of external fields appear on diamagnetic and paramagnetic media.

3. Electromagnetic field as an agent of low impact

Due to the fact that the body can be viewed, in a certain sense, as a wave structure, then in order not to assist it, it must react with a wave structure having similar characteristics, selecting, for this, the appropriate physical agent. Such a universal physical agent is an electromagnetic field (EMF), covering a range from hundreds of meters (radio waves) to fractions of angstrom (hard gamma quanta). The electromagnetic field can have the necessary distribution of its characteristics such as amplitude and phase on the surface of the material, which allows creating conditions for the formation of microcrystals and stimulate the synthesis of nanostructures at the molecular level. However, the usual irradiation of any EMF system, with a resonant frequency, will not lead to self-consistency and self-correction of the structure, since the field needs to be structured informatively.

There are experimental studies of fractal structures of silicon carbide, which showed that the fractal structures of this material absorb electromagnetic radiation 15 to 30 times more intensely than single crystal silicon carbide [10], and the longitudinal electric field, in combination with weak EMF, strongly influences the formation of ultrathin films, because it promotes the polarization of growing embryos and islands. In this case, the equilibrium shifts toward two-dimensional growth. Thus, there is an orienting effect on the migration of embryos and sets the direction of growth [11]. Resonance interaction, frequency and time structuring of the EM field does not allow achieving the desired result, therefore, it remains possible for the spatial structure of the EM field. A conventional diffraction grating, which is a system of plane-parallel lines or a combination thereof, will not achieve the desired result, since it covers only an extremely limited frequency range. Even a linear combination (such as the worlds used in metrology) will not give a result for the same reasons. The output can be found only on the way of development and application of complex curvilinear diffraction gratings, which are a regular and ordered combination of closed curvilinear structures. Only in this case, there is a real possibility to cover a significant part of the EM field range, since in closed curvilinear structures there is always a section of the lattice multiple of a certain wavelength [12]. The transformation of electromagnetic fields, by means of such lattices, is carried out by the scientific school of V A Soifer, who laid the foundations of a new science – computer optics [13]. The use of such diffraction gratings of a complex configuration, for the conversion of incoherent EMF, makes it possible to create, in space above the lattice, the substrate – the external medium, the interference field of a complex structure that act as additional technological factors.
At this boundary, the deposition processes of the material, in the production of nano-sized thin films, the formation and subsequent growth of the nuclei, occur under special conditions, since the nonequilibrium state arising from the interaction of the deposited material with the light flux initiates the processes of self-organization in the resulting films [14, 15].

![Figure 1. The structure of a diffraction grid.](image1)

![Figure 2. Latent ordered film microstructure.](image2)

To create an interference field, diffraction gratings of various configurations, combinations of closed curvilinear contours, made in the form of strokes of various metals, can be used, either in the form of grooves in a silicon or glass substrate [16] (the structure of such a lattice is shown in figure 1) or performed according to the golden section algorithm or Fibonacci series [17–19]. Interestingly, when etching such a structure in a silicon substrate, the process of etching proceeds to a depth of ~3–4 μm, after which it stops abruptly. It is impossible to etch deeper under any conditions. Such a diffraction grating has a complex structure, in which by crossing the lines forming it, a large number of fragments are obtained, which can be regarded as individual diffracting elements. The number of them can reach 400,000, and although they are all self-similar, they have different configurations and sizes [20].

The experimental investigations carried out on the interaction of diffraction gratings with electromagnetic radiation in the optical range have shown that when an visible light spectrum is irradiated from a non-point nonmonochromatic radiation source in space, an interference field is formed in space, which is a system of interference maxima and minima, located in a volume of space a few millimeters above the surface of the substrate and having its own complex internal structure. Such an interference field will in one way or another influence all physical processes taking place in the zone of its localization. In the films synthesized under the influence of the interference field diffraction grating, of great interest were the areas of the smooth film that completely repeated the relief of the substrate and, as it seemed at first glance, corresponded to films synthesized under ordinary conditions i.e. not having their own structure. The investigations were carried out by means of scanning electron microscopy. The available information obtained from the SEM sensors was subjected to additional analysis, using specially developed software. On the final micrograph of figure 2 is the previously revealed latent ordered microstructure of the film.

Similar structures such as diffraction gratings of complex curvilinear shape were used in the experiences on electrophoresis in the laboratories of the RPA “Mezon”. A special fluoroplastic bath filled with a solution of salts and tantalum powder and two electrodes with variable EMF from 10 to 120 V were used. A powder of about 1 mm thick settles on the negative electrode. The result of the changes is visible because the appearance of lines of force is found on the applied surface. The effect is that the powder thickens along the lines, these lines helping in the further forming. They act like capillaries and the forming takes place on the whole surface at a time, rather than gradually, as before, and these lines pass through the volume, and not along the plane. Also, a change in the structure of the deposited substance and a change in the field strength vector on the surface were observed.

4. Conclusions
The use of interference fields, initiated by diffraction gratings of complex shape, to affect various processes of nanotechnology and synthesis of nanoscale films with their own explicit or latent structure seems highly practical.
Differences of fractal nanoscale structures, from their usual nanosized analogs, can lie in the field of structure, surface morphology, electrophysical properties, optical properties, and so on. This opens great prospects for the use of fractal nanoscale structures, in particular, fractal nanosized films in engineering and technology.

The fractal structures obtained in nonequilibrium conditions, after the termination of the technological process, tend to an equilibrium state, as a result of which the process of structural evolution (relaxation) continues. Their condition can be compared to a sharp frost and a further slow evolutionary process of restructuring their structure.

Acknowledgments
The authors would like to acknowledge the financial support of this work by the Ministry of the Education and Science of the Russian Federation (basic state assignment No. 8.7130.2017).

References
[1] Grachev V I, Zhabrev V A, Margolin V I and Tupik V A 2015 Slabye i sverhslabye vozdeystviya na razlichnye struktury v nanotehnologiyah (Saint Petersburg: Izd-vo Saint-Petersburg Electrotechnical University “LETI”)
[2] Kolesnikov A A and Zarembo V I 2011 International Scientific Journal for Alternative Energy and Ecology (ISJAEE) 4 103–8
[3] Ilyushin G D 2002 Tez. Dokl 4-go Mezhd. Sem. “Nelineynye process i problem samoorganizacii v sovremennom materialovedenii” (Astrahan) pp 85–6
[4] Devyatkov N D 1985 Sh. Statey (Moscow: IRE AN SSSR) 21–36
[5] Popov I V 2011 Principy fiziki slabyh vozdeystviy na kondensirovannye sredy (Saint Petersburg: Izd-vo Politehn. un-ta)
[6] Zeldovich Ya B, Buchachenko A L and Frankevich E L 1988 Physics-Uspeshki (Advances in Physical Sciences) 1 3–45
[7] Novikov V V, Shvecov Yu P and Fesenko E E 1997 Biophysics 3 746–50
[8] Novikov V V and Lisicyn A S 1997 Biophysics 5 1003–7
[9] Zolotuhin I V, Gribanov S A, Popov A A, Zheleznyj V S and Ievlev V M 2000 Tez. dokl. 3-go Vseross. sem. “Nelineynye process I problem samoorganizacii v sovremennom materialovedenii” (Voronezh) pp 121–2
[10] Bochkarev V F and Bunin E Yu 2009 Russian Microelectronics 3 181
[11] Serov I N, Zhabrev V A and Margolin V I 2003 Glass Physics and Chemistry 4 241–55
[12] Soyfer V A 2000 Metody kompyuternoy optiki (Moscow: Fizmatlitt)
[13] Grachev V I, Margolin V I and Tupik V A 2016 Slabye I sverhslabye vozdeystviya v nanotehnologiyah, biologii i medicine (Izhevsk: Izd-vo “Udmurtiya”)
[14] Zhabrev V A, Lukyanov G N, Margolin V I, Tupik V A et al. Proc. of SPIE 6251 338–46
[15] Grushina N V, Korolenko P V and Markova S N 2008 Vestnik Moskovskogo universiteta. Seriya 3. Fizika, Astronomiya 2 40–3
[16] Zotov A M, Korolenko P V and Mishin A M 2010 Crystallography 8 965–71
[17] Serov I N and Margolin V I 2002 Patent RU 2212375 Method for obtaining thin films with a fractal structure