SYNERGETICS, FRACTALITY AND INFORMATION:

Application to the self-organized structures and intelligent materials

SYNERGETIKA, FRAKTÁLNOSŤ A INFORMÁCIE:

Aplikácia na samo organizované štruktúry a inteligentné materiály

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This book may be useful and interesting for the specialists in the field of research the self-organized structures, their involvement in solving educational, environmental and other problems, as well as for non-ordinary readers who seek to expand their worldview. The informational complementary environments and formation of self-organized fractal structures in them are considered. The peculiarity of the monograph is connected with the presented researches of the self-organization processes and fractality for diverse systems such as non-crystalline and intelligent materials, structured liquids, information & communication systems, artificial intelligence. The main emphasis is placed on the common nature of the self-organization processes formation and development, influence of external factors (cooling velocity, irradiation, random noise) on micro, nanoscale effects and structuring. The fractality of lifetime for self-organized structures is established and investigated, which is essential for the implementation of hypersensibility in information processing systems on their basis. Shown is the possibility of an implementation obtained results on the study of physical processes in the structuring and integrity of the information systems.

Keywords: Fractality, Information Systems, Non-Crystalline and Intelligent Materials, Self-Organized Structures, Synergetics

Táto kniha môže byť užitočná a zaujímavá pre špecialistov v oblasti výskumu samo organizovaných štruktúr, ich zapojenia do riešenia vzdelávacích, environmentálnych a iných problémov, ako aj pre neštandardných čitateľov, ktorí sa snažia rozšíriť svoj svetonázor. Uvažuje sa o informačno-komplementárnych prostrediach a vytváraní samo organizovaných fraktálnych štruktúr v nich. Zvláštnosť monografie súvisí s prezentovanými výskumami samo organizačných procesov a fraktality pre rôzne systémy, ako sú nekryštalické a inteligentné materiály, štruktúrované kvapaliny, informačné a komunikačné systémy, umelá inteligencia. Hlavný dôraz je kladený na spoločnú povahu procesov tvorby a rozvoja, vplyv vonkajších faktorov (rýchlosť ochladzovania, ožiarenie, náhodný hluk) na mikro, nanočinné efekty a štruktúrovanie. Je stanovená a skúmaná fraktálnosť života pre samo organizované štruktúry, čo je nevyhnutné pre implementáciu hypersenzibility v systémoch spracovania informácií na ich základe. Je ukázaná možnosť realizácie získaných výsledkov na štúdium fyzikálnych procesov v štruktúre a integrite informačných systémov.

Kľúčové slová: Fraktalita, Informačné Systémy, Nekryštalické a Inteligentné Materiály, Samo Organizované Štruktúry, Synergetiká

ABBREVIATION

BEC - Bose & Einstein Condensation

DLL - Dynamically Linked Libraries

HPF - Hetero-Phase Fluctuations

HOOM - Hyper Object-Oriented Modeling

HSI - Hyper Sensibility & Information

IF - Information & Fractality

IT - Information Technology

NCM - Non-Crystalline Material

NCS - Non-Crystalline State

OOP - Object-Oriented Programming

PTIS - Processing & Transmission of Information System

RAD - Rapid Application Development

R&CM - Research & Computer Modeling

R&T - Research & Technology

SAC - Soft Atomic Configurations

SDE - Stochastic Differential Equation

S&F - Synergetics & Fractality

SOIS - Self-Organized Information Structures

CONTENTS

PREFACE

Being part of what you do not understand is the most amazing feature of this life.

AGATHA CHRISTIE,

Writer

Nata Popova.
A Search.

The interest in the research of self-organization, problems of formation of self-organized structures and their functioning in various systems covers wide spheres of physics, information technology, environment, education: non-crystalline semiconductors, nanostructures, structured liquids, biocompatible environments, materials of artificial intelligence, smart homes etc. It is connected with the development of interdisciplinary science - synergetics, which studies the general principles of space-time structure formation in thermodynamically energy, mass and information open systems of diverse nature with significant deviations from equilibrium. One of the reasons contributing to the study of self-organization processes in non-crystalline solids is going beyond the boundary of the equilibrium and quasi, non-equilibrium thermodynamics and the related necessity of describing the behavior of systems in highly non-equilibrium conditions. Another reason is the necessity to analyze complex non-linear processes, for which external factors lead to a qualitatively new behavior of the system while solving a number of problems in physics and solid-state technology, information technology.

When considering problems in various areas of information systems, the formation of ordering, the creation and maintenance of the functional organization, its development and self-complication are either a goal of the study or its essential stage. The tasks related to the development and obtainment of intelligent materials with structural-sensitive properties and different levels of necessary spatial or spatial-temporal (functional) ordering occupy the prominent place. In such a situation, knowledge of the conditions and principles of self-organization, based on the study of the internal properties of the system, the laws of its obtaining, the formation of ordering in non-crystalline and other systems is difficult to overestimate. In view of this, the problem of studying the structure of intelligent materials, the functional ordering in them under the influence of external fields, and the study of the possibility of controlling their parameters in cyber systems, sensors, and hyper sensibility remains unresolved.

With significant deviations of the system from equilibrium and significant external fields, a decisive role is played by synergetic effects and mechanisms of energy transformation that can be investigated using the ideas of non-equilibrium thermodynamics and synergetics. The approach to the consideration of non-crystalline solids and intelligent materials, based on the consideration of self-organization processes and the formation of self-organized structures with different levels of spatial-temporal ordering, is at the initial stage of development. However, it provides an opportunity, based on a single information principle, to describe the formation of the self-organized structures, their peculiarities of interaction with external fields, which involves direct application in information & communication systems, information technologies, and secure communications.

Thus, the following problems are unavailable or insufficiently studied:

- *Consideration of information, its attributes, self-organization and fractality;*
- *Further development of the theory of non-crystalline state and transition to a non-crystalline state that takes into account dynamic stability, the influence of external factors on dynamic and thermodynamic properties;*
- *The manifestation of the processes of self-organization in the photo-, thermo-induced changes in optical and structural-sensitive parameters under the influence of electromagnetic radiation on layers of glass-like materials require further studies;*
- *Analyzis of low-temperature anomalies, two-level states, Bose-Einstein condensation;*
- *Research of the influence of external noise in the process of obtaining glass-like materials on their structural-sensitive parameters needs further investigation;*
- *Structuring of water and the role of water in information processes, hyper sensibility of self-organized structures in the diverse nature systems.*

The outlined problems are considered in this monograph. Consequently, the scientific interest in the fundamental problem of intelligent environments associated with the study of self-organization processes, the activation of attention to the processes of functional ordering, induced by the action of external factors, the need to study glass-like materials in order to predict pre-set properties and provide an elemental base of solid state and functional electronics determine the topicality of the problem “Self-organization processes and formation of the self-organized structures in the information and other systems”.

The emphasis of the monograph is devoted to the development of object-oriented modeling, which adapts to the peculiarities of certain scientific areas of research (physics, mathematics, biology, society, etc.), and provides the opportunity to reach a new level of abstraction. At the present stage of scientific research, computer modeling is actively developing and becoming an integral part of both Research and Computer Modeling (R&CM).

The material presented in the monograph is information interconnected and encapsulated. That is, if the development of modern programming environments directly utilizes the tools and information technologies of algorithmic languages, which allows one to self-sufficiently implement and dynamically develop the necessary operating environment, then during the formation of this monograph, the mentioned approach use for creating a new complementary information environment of functioning. Thus, the natural interaction between different sections and branches of knowledge and the possibility of forming a self-sufficient structure is manifested. Therefore, a reading of the monograph is above all a movement. It is first and foremost a complementary and educating journey.

This book may be useful and interesting for the specialists in the field of research the self-organized structures, their involvement in solving educational, environmental and other problems, as well as for non-ordinary readers who seek to expand their worldview.

Chapter 1

INFORMATION

Other chess players play against Fisher, while I play just in chess.

BOBBY FISHER,

World Chess Champion

Nata Popova.
The Movement.

1.1. Integrity & Wholeness

Information is a holistic process (flow of a sequence of characters, a field), the presence of which manifests itself through physical-chemical and signal-code links. Information about the environment, as usually interpreted information, is just the "imprint, trace, stamp" of information. Such "imprint" is formed by an "observer" within a certain statistically-dynamic system, beyond which it is never able to get out. The element of constraint, separation, incompleteness is dominant in this approach. This approach removes the integrity of the information, the ability to create, transform. It is integrity that defines information, its independence, self-sufficiency. Information contains everything you need; is capable of creating the same holistic self-sufficient, really new structure. The synonym of integrity is the completeness of information, its synergy.

1.2. Self-organization & Completeness

Information is **creative**. It is this feature is mostly removed or replaced in information & communication systems - educational, environmental, scientific and technological, and others. (According to R. Kiyosaki (Kiyosaki, 2013), author of the bestseller "Rich Daddy, poor father" - you want to be rich and happy, do not go to school. It is important to restore information as an asset rather than turn it into a passive, nobody needs an imbalance. Creating a smart home, smart garden, smart things starts with information.)

A self-organization based on the integrity of information is a guarantor of the completeness and complementarity of the system, its functional organization and structuring, sustainability and development. In this case, all the necessary resources of the system are disseverly attracted or new ones are created. By what parameter and in what way the minimum energy dissipation is achieved, the system itself determines the information (Fig. 1.1). Thus, the without dissipation becomes an internal attribute of information, a way of its functioning.

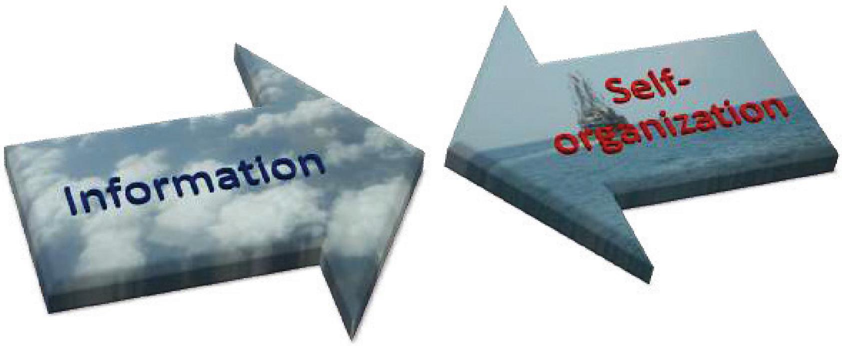


Fig. 1.1. Formation of the self-organization for open systems.

Creativity is one of the basic attributes and foundations of information (Fig. 1.2). The term *“Information”* itself contains this attribute: *“In Formation” - Origination.*

The next attribute of information is saving, indestructibility. Known laws of the saving of the mass and energy, their interconversion (Holovatch, 2017). These laws are defined and supported by information. The information is not destroyed, it is capable of self-reproducing in a holistic manner and stored. What is often interpreted as information, at best, is its "reflection" - an interpretation. Separating "reflection" from information, their further spread and manipulation causes misinformation, entropy of the system. Synentropy, negative entropy - restoration of the relationship of information. Mass and energy act as characteristics of the level of perception of the environment: mass - the measure of inertia of the system, energy - the measure of the field. Changing the level of perception of the environment, restoration of access to information causes and recovery of mass and energy as a manifestation of information. This is without a dissipative way of restoring reality through information - ecology, education, full functioning, development, civilization.

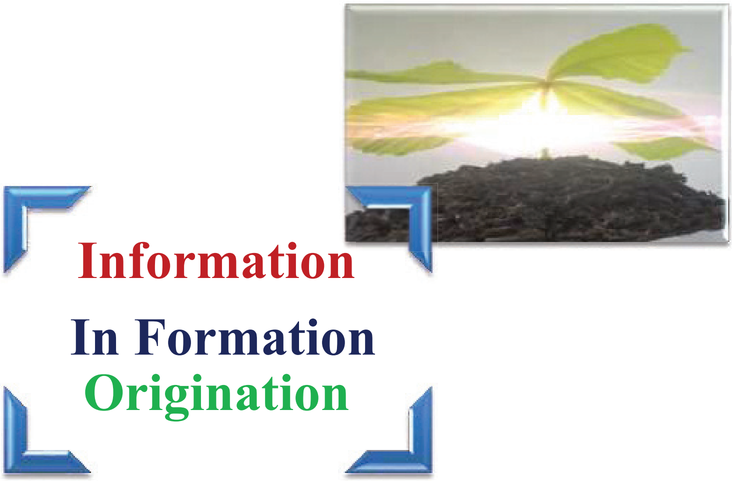


Fig. 1.2. Unique information.

Information defines and forms **self-organization** - spontaneous, without dissipative formation of order and corresponding levels of structuring. This aspect of self-organization is largely omitted; the focus is only on external features. So, self-organization, also called spontaneous order, is a process where some form of overall order arises from local interactions between parts of an initially disordered or homogeneous system precisely through the flow of information. The process can be spontaneous when sufficient energy and information is available, not needing control by any external factor. The resulting organization is wholly distributed over all the components of the system. As such, the organization is typically stability and self-sufficient. Self-organization is perceived in terms of islands of predictability in a sea of chaotic unpredictability (Fig. 1.1).

Self-organization occurs in many physical, chemical, biological, robotic, and cognitive systems. Examples of self-organization include formation of intelligent materials, thermal convection of fluids, chemical oscillation, animal swarming, neural circuits, and artificial neural networks.

Chapter 2

FRACTALITY

The touchstone of a first-class intelligence is the ability to hold two opposing ideas in one's head and at the same time maintain the ability to act.

FRANCIS S. FITZGERALD,
Writer

Nata Popova.
The Development.

2.1. Fractality of the Information

Self-organization and fractality are manifestations of the availability of information. To better understand and perceive this, let's take the following example. There are remarkable information objects of regular geometry (Fig. 2.1).

Point dimension in space (time) ***d=0 (0D)***.

Line dimension in space (time) ***d=1 (1D)***.

Square dimension in space (time) ***d=2 (2D)***.

Box dimension in space (time) ***d=3 (3D)***.

Fig. 2.1. The information objects of the regular geometry.

At one time, when they were offered and investigated in the future, it was a masterpiece of science, philosophy, geometry, knowledge of the environment. For today, these are generally accepted standard information objects, although their beauty and capabilities remain the same (this is followed at least by Object-Oriented Programing (OOP)). We will show their originality and uniqueness, unlimited resources when transitioning to the perception of fractality of information.

Let's take one of these information objects, for example, line **Line**. As part of the standard approach that we can do with this information object? Line (***a***) can be lengthened (***b***), you can bend and curvature when you get the curve line (***c***), you can move it in a plane, and get a sector, it's already a measure of ***2D*** (***d***), you can move in space and get a surface, it's already a measure ***3D*** (***e, f***). However, for all of the cases listed below, we remain within the framework of ordinary perception, commonly accepted in the society (Fig. 2.2). Fractality involves a completely new look at the object, the formation of space and time d_f (<> ***0D, 1D, 2D, 3D, ..***), filled with information and energy. An essential is the restructuring and change in perception of the "observer" and the surrounding information environment. What will be the new information structure, what will be its functioning and time life, is determined by information. However, this fractal structure already functions outside the ordinary perception and cannot be reduced to it (reduction to the level of interpretations, reflections, justifications leads to dissipation and collapse of the fractal structure).

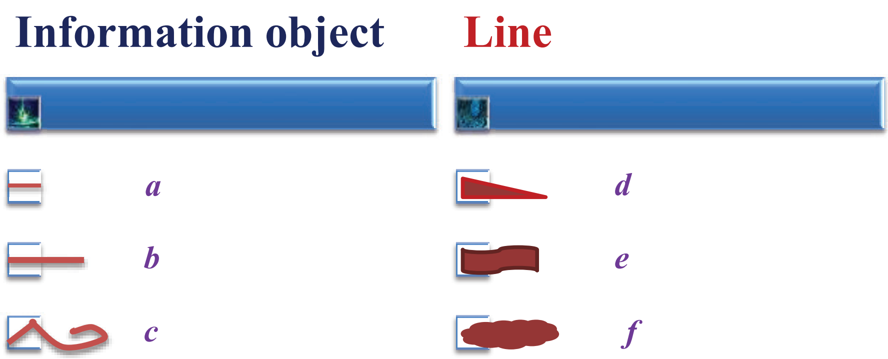


Fig. 2.2. Examples of regular forms for information object ***Line***.

The approach to the formation of each fractal structure is an unique. He manifests and restores those internal informational and energetic patterns that are inherent in the real nature. One can cite an example that has happened to the well-known mathematician Euler. When a mathematics teacher suggested classmates find the sum of natural numbers *1, 2, 3 ... 98, 99, 100*, and then the ordinary approach implied a direct calculation of the sum $1 + 2 + 3 \ldots\ldots 98 + 99 + 100$. (This way of functioning also has the right to use.) Euler provided another calculation option based on the laws of natural numbers: $1 + 100 = 101, 2 + 99 = 101, \ldots , 50 + 51 = 101$. And, consequently, the sum of numbers will be equal to $50x101 = 2550$. Changes in the algorithm of the calculation, changes in the way of functioning - changes in the information environment.

Approach to information objects can also be original, which implies fractal information. One such variant is the known Koch's fractal (Frame & Mandelbrot, 2002; Falconer, 2003). Divide one-dimensional segment into three parts, remove the central part and replace it with a triangle (Fig. 2.3). This is not a one-dimensional structure, but at the same time not a two-dimensional one. A cardinal new property of an information object is self-similarity on spatial scales, a new method and a new algorithm - a method of propagation in dimension with space ***d_f=1.262***. Self-sufficiency determines the absence of forced compulsory division into blocks, interpretations, and, thus, self-organizing lays the way for the functioning of a coherent structure. This is already a masterpiece of the functioning of informational nature.

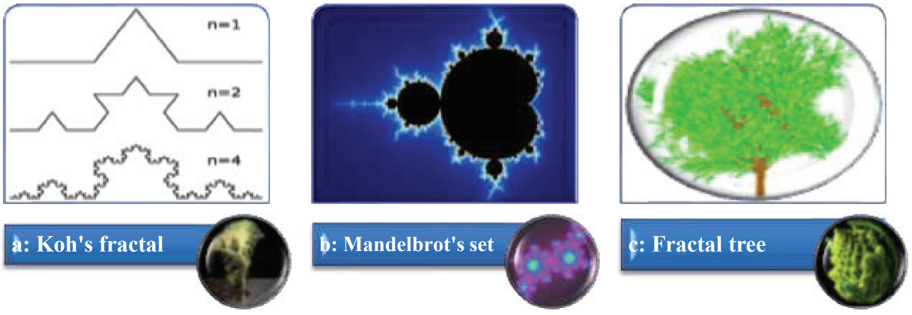


Fig. 2.3. Examples of the fractals: Koch's fractal (***a***), Mandelbrot's set (***b***), fractal tree (***c***).

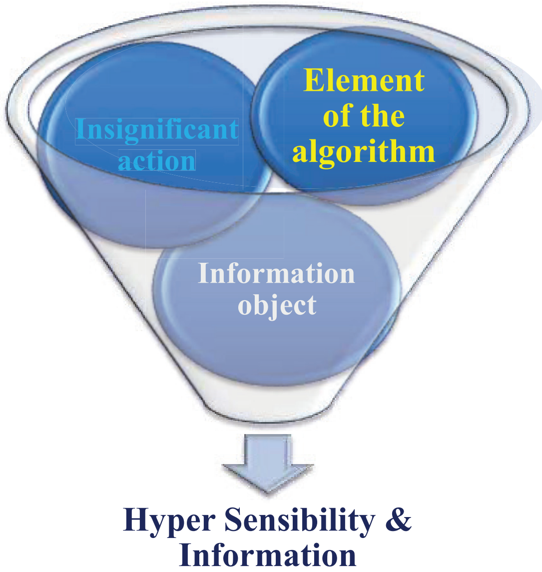
The same type of the fractal structures are present and determines the extraordinary principles of the functioning and properties of self-organized structures in non-crystalline materials (Mar'yan & Yurkovych, 2015, Mar'yan & Yurkovych, 2018), information technologies (Gates, 2008), education (Kiyosaki, 2013; Yurkovych, Seben & Mar'yan, 2017) and others.

2.2. Hyper Sensibility & Information

Hyper Sensibility of information involves and generates synchronization, coherence and correlation of processes. This is manifested in particular in the fact that a small "**Action**", a change in the initial conditions, is capable of initiating the development and spread of processes. Known for " **Butterfly Effect**", "**Cybernetic Effect**", "**Transistor Effect**", "**Signal-Code Connection**", which may be inherent in self-organized systems of diverse nature. It is important here that the small "**Action**" is directly correlated and related to the information.

The application of algorithmic object-oriented high-level languages and the corresponding software environments is extremely relevant in the current conditions of the development of an information society. This creates its own unique *Processing & Transmission of Information System* (**PTIS**) both in the software environment and in the environment, and the identification of the principles of the operation of information & communication systems. *Hyper Sensibility & Information* (**HSI**) can also be crucial here. What is unique to such kind of information systems? This is the fact that not only the insignificant "**Action**", but also the algorithm of self-organization and algorithmic complexity becomes significant. Insignificant changes in the algorithm can lead to radically new ways of functioning of systems and their respective environments.

Such an approach can be realized without dissipative ways of functioning of self-organized systems, which is considered in detail in this monograph. An example of this kind of information systems is the fractal structures and their corresponding ways of functioning. Another example is *Hyper Object-Oriented Modeling* (**HOOM**), which also evolves in a monograph (Fig. 2.4).



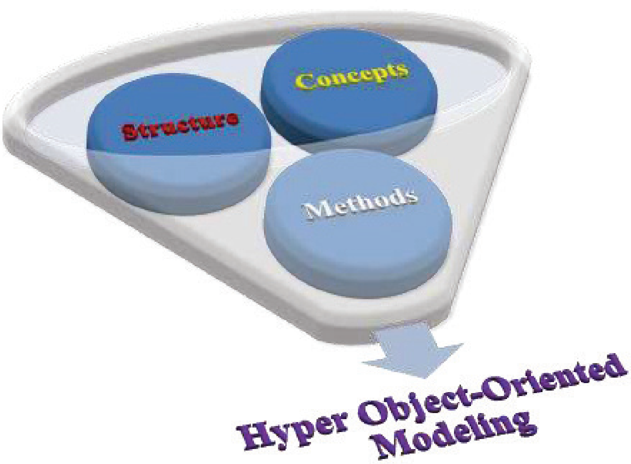


Fig. 2.4. Hyper Object-Oriented Modeling: Methods & Concepts.

Chapter 3

SYNERGETICS TODAY & TOMORROW

Why "A" Students Work for "C" Students and "B" Students Work for the Government: Rich Dad's Guide to Financial Education for Parents.

ROBERT T. KIYOSAKI,

Author bestseller

Nata Popova.
The Wanderer.

3.1. Wholeness: *Self-Organization to the Fractality*

The **synergy** is a manifestation of synchronous action from information and a self-consistent transition to another level of system structuring. In this context, **synergetics** defines the paths and development of the integral functioning of the system, that is, integrity forms a holistic one (Fig. 3.1).

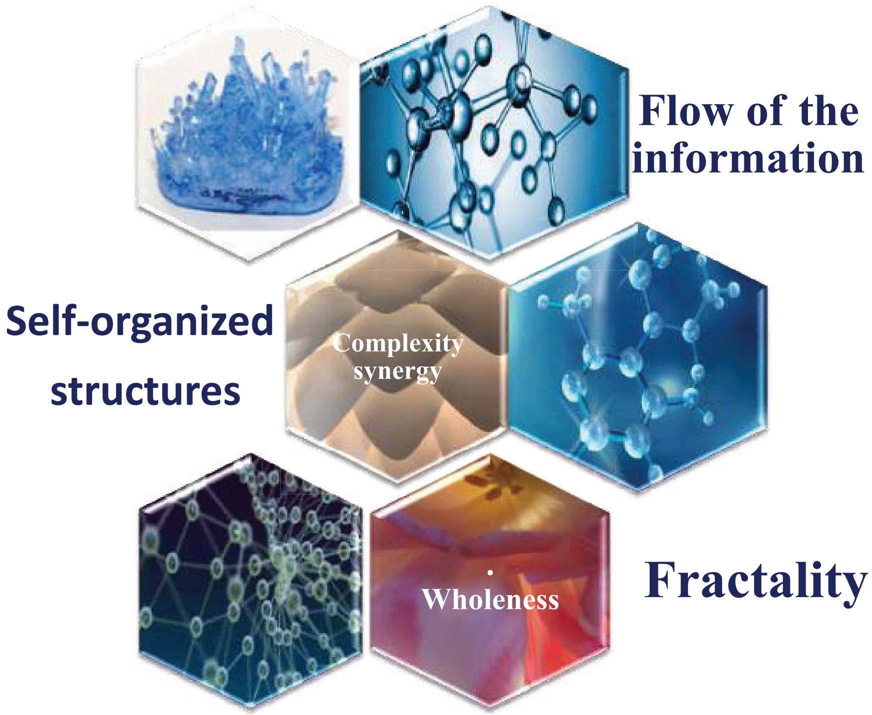


Fig. 3.1. Complexity of the information systems and fractality.

Synergetics today & tomorrow is a prolific and active direction, producing many outstanding results obtained in a variety of subject areas. The developed methods for structuring and classifying various types and ways of ordering have shown that most systems demonstrate close transitions from chaos and instability to order and information in case of changing external conditions. This universal behavior points to the prospect and possibilities of information remediation and transition to the without dissipative ways of system functioning. The today & tomorrow considerable hopes are pinned on synergetics in solving knowledge-intensive, ecological, educational, economic, and social problems (Mar'yan & Yurkovych, 2018; Mar'yan, Yurkovych & Seben, 2019).

This is primarily due to the flow of information, their organization and information-processing systems for synergetic systems. This aspect is fundamentally different in the functioning of synergetics. All that is necessary for the integral functioning of the system is available; and the very necessary thing is the presence of information. If for classical information systems, information and related flows are defined in units of bit, Mbit, Gbit (it is still limited in information flows, and their respective information & processing systems are distributed and separated), then in the presence of synentropy (negative entropy or integral information), the system receives information flows that cannot be (and have no meaning) reduced to standard units and streams. This is already a qubit, fractal information. It is fractal most adequately reflects the integrity of information, the diversity and structuring of information flows (Fig. 3.2).

The quantum information qubit and the fractal approach to information are more in common than eliminating (by the way, the quantum-mechanical approach to synergy, information, causality is the most developed and argued in scientific circles to date (Haken, 2006; Panochko, Pastukhov & Vakarchuk, 2017; Mar'yan & Yurkovych, 2018). This is confirmed by the well-known Bloch's sphere that's used to interpret the quantum unit of information - qubit (Fig. 3.3). Unlike a regular element, a bit that can take values of 0 and 1, the qubit can be in any superposition of these two states (Panochko, Pastukhov & Vakarchuk, 2017). The classical bit on the

Bloch's sphere can only be located at the "north pole" (state / 0>) or at the "south pole" (state / 1>). The rest of the surface of the Bloch's sphere is not available for the classical bit, but the qubit state can occupy any point in the sphere. The surface of a sphere is a two-dimensional space representing the space of pure states of a qubit.

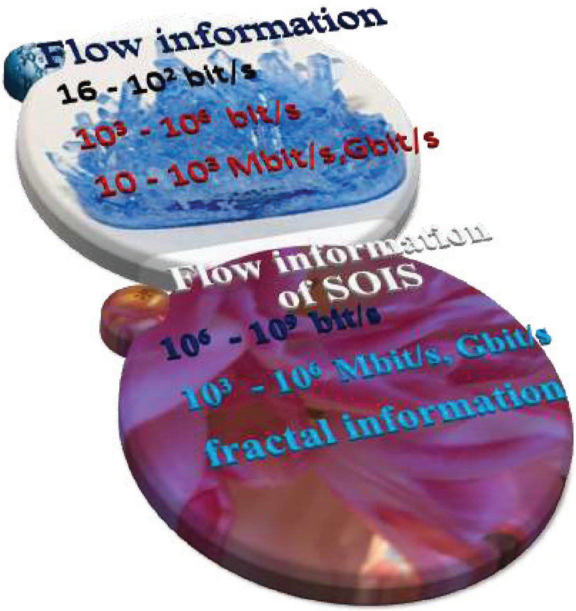


Fig. 3.2. The information flows of SOIS' structures.

Any two-level quantum system can be used as a qubit. You can also use multilevel quantum systems, if separation of two states from others is possible (for example, the main and first excited states of a nonlinear oscillator). Some of the physical implementations of the qubit, which in one way or another can be considered a two-level system, have been successfully implemented. Like a regular computer that uses classic bits in different embodiments, for example, the state of the transistor in the processor, the magnetization of the surface of the hard disk or the presence of current in the wire, a hypothetical quantum computer will use a variety of implementations of qubits (https://uk.wikipedia.org/wiki).

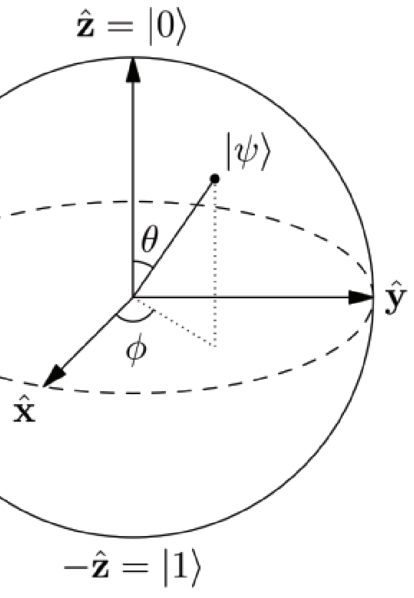


Fig. 3.3. Bloch's sphere (Holovatch, 2017).

When using the fractal approach, we, like in the Bloch's sphere, have the opportunity to use the full spectrum of possible states of itself, which ensures the integrity of the information process. If the use of the bit-approach allows you to see the "imprint" of information (this is also good), then the fractal approach retains the information structure of the process as a whole. This is adequately followed by the application of a mathematical model of attractors, which is used in nonlinear physics, synergetics, mathematics, evolutionary biology, ecology and other sciences that describe the organization of complex systems. Four types of attractors are known: Point, Cyclic, Toras attractor and Strange attractor (Fig. 3.4).

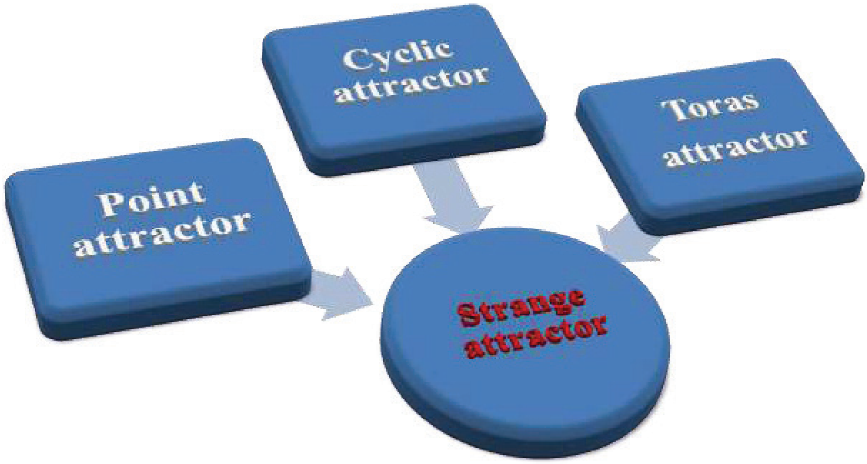


Fig. 3.4. Types of the attractors.

A Point attractor determines the set of trajectories in the phase space of attraction (repulsion) to a certain state. This state can also be specified as a bit of information - attraction or repulsion. Known Cantor's fractal (Frame & Mandelbrot, 2002; Falconer, 2003), which defines a plurality of ***1D*** -space to ***0D-*** space with dimensionality $d_f = 0.631$, and this new space goes beyond the limits of perception at the bit-level. To reduce the Cantor's fractal to ***1D***, ***0D*** perception of space is the loss of access to information and information itself. Cyclic attractor - within the bit-approach, it's a cycle (day, night), (forward movement, movement back); the main emphasis is placed on the game of opposites, which is the basis for this approach. In the fractal approach, the cyclic attractor is the formation of a spectrum of cardinally new states, a new self-consistent synchronized transformation without opposites, that is, without compilation to interpretations, and functioning only through the process. The informational nature of the cyclic attractor in the smog can be adequately reproduced and provided only by fractal structure (Mar'yan & Yurkovych, 2018). Attractor Toras is a complex circulation of ***0D, 1D, 2D***-dimensional objects, which repeats itself as it moves forward and is directly fractal structure. And the Strange attractor is a complex, multidimensional fractal structure with its unique space and time of functioning d_f. Everything that happens for this structure is logical, interconnected, correlated in terms of fractal approach; and at the same time chaotic, strange when applying bit, Mbit, Gbit-information.

Thus, the synergetics of the formation of self-organized structures is informationally manifested through the formation in the space and time of the fractal system for ways of functioning. What will be this fractal structure in a variety of environments and systems? Using bit, Mbit, Gbit-information, we can only identify the individual attributes of this structure (which is also important).

3.2. Self-Organized Information Structures: *Further Development*

The processes of self-organization and the formation of self-organized structures in systems of diverse nature (Fig. 3.5) are the main direction that we present in this monograph. The dominant emphasis is the informational nature of self-organized structures, and is the development of previous studies (Mar'yan, Seben & Yurkovych, 2018; Mar'yan & Yurkovych, 2018; Mar'yan & Yurkovych, 2019).

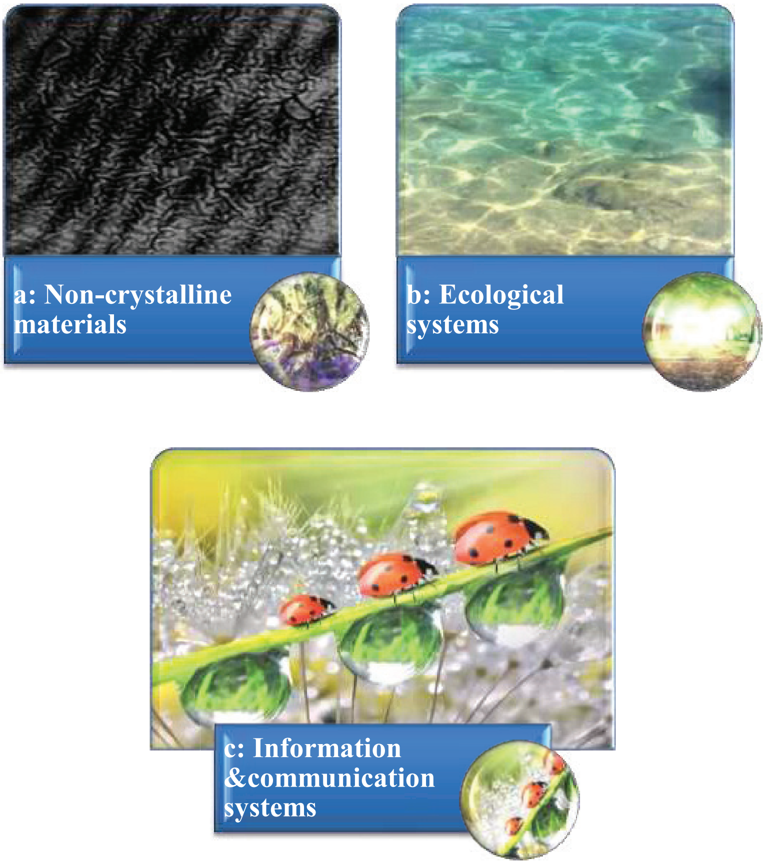


Fig. 3.5. Self-organized structures in the different systems: non-crystalline materials (***a***), ecological systems (***b***), information & communication systems (***c***).

Common features of the functioning and structuring of systems with the saving of its uniqueness and identity is a natural phenomenon ***Information & Fractality*** (**IF**).

Chapter 4

SYNERGETICS FORMATION OF THE NON-CRYSTALLINE STATE: FRACTALITY

Irregularity, chaos leads to complex systems. This is not a disorder. On the contrary, I would say that chaos is what makes biological life and mental activity possible. The brain has such a selectivity and instability that the slightest effort is enough to establish order.

ILYA PRIGOGINE,
Nobel Prize Laureate

Nata Popova.
The Process.

4.1. Self-Organized Structures in the Non-Crystalline Solids

The peculiarities of structure, properties for non-crystalline solids, their interrelation with methods of obtaining are analyzed. Existing model approaches to describing the structure of non-crystalline solids and the transition to a non-crystalline state (NCS) consider either individual characteristic time scales of their formation, or a separate group of properties and features of the structure. With significant deviations of the system from equilibrium and in external fields more than critical, synergistic effects and the mechanism of transformation of energy and information play a decisive role (Mar'yan & Yurkovych, 2018). The integrity of the formation of a state NCS can be taken into account with the use of a synergetic approach within the framework of the theory of self-organized structures, which makes it possible to determine the mode of formation in conjunction with the technological conditions of obtaining and to predict the possibility of using information technologies (Fig. 4.1).

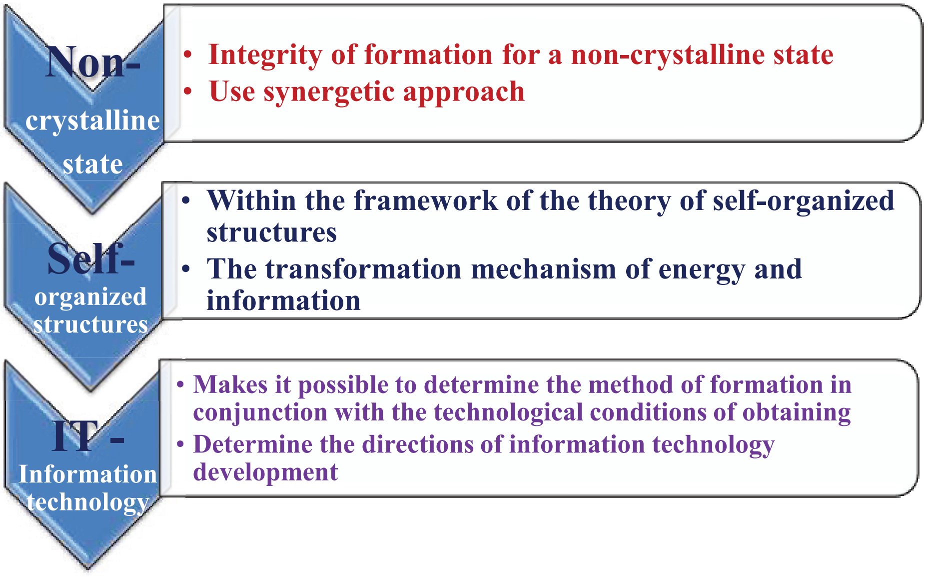


Fig. 4.1. Integrity of the formation of a non-crystalline state.

The investigations of the influence of soft atomic configurations (SAC) on the dynamic stability of crystalline and noncrystalline solids, the processes of self-organization and branching of solutions of a self-consistent system of equations in the transition to a non-crystalline state are presented. The synergetic model of temperature behavior of microscopic (mean square displacements, frequency of oscillations of atoms, force constant) and macroscopic (volume, heat capacity, coefficient of thermal expansion) of characteristics at small and significant deviations from the state of equilibrium, taking into account branching solutions of self-consistent system of equations, is developed. Gives an opportunity to investigate its stability under various external control parameters (Mar'yan & Yurkovych, 2015).

Fig. 4.2, 4.3 shows the results of calculating the temperature dependence of the fraction of atoms in SAC's configurations σ and reduced mean square displacements y_l:

$$y_l = \frac{36D_l^{\alpha\alpha}}{a_0^2},\ y_t = \frac{4D_t^{\alpha\alpha}}{a_0^2}\ . \qquad (4.1)$$

Here are reduced to the interatomic distance a_0 in harmonic approximation, the mean square displacements of atoms along the bond $D_l^{\alpha\alpha}$ and perpendicular to it $D_t^{\alpha\alpha}$; $\tau = k_B T / V_0$ is a reduced temperature (V_0 is the energy of dissociation of bond); $P^* = \frac{Pa_0^3}{\sqrt{2}V_0}$ is the reduced pressure; ***ab*** is the region of dynamic stability of the crystalline state, ***ef*** is the region of the loss of the dynamic stability of the crystalline state, ***bc*** and ***de*** are the metastable states).

As a parameter of the order of the system, a fraction of atoms in atomic configurations SAC can be used, in combination with the sizes of self-organized regions on the micro, nanolevels

$$\eta_m = \sigma(\tau << \tau_m)\ . \qquad (4.2)$$

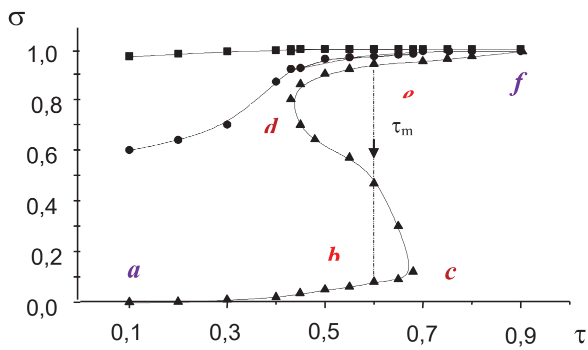


Fig. 4.2. Temperature dependence of the fraction for atoms in soft configurations σ in the region of dynamic stability at different cooling velocity q (▲ – $q = 0$, ● – $q = 5 \cdot q_c$, ■ – $q = 21 \cdot q_c$).

It has been shown for the first time that SAC's configurations exist in a wide temperature region and can play an essential role not only near the temperature of loss of dynamic stability τ_m and have a significant effect on the behavior of the system at significant deviations from equilibrium (Fig. 4.2, $q \geq q_c$, q_c is a limit cooling velocity). In the temperature range of the loss of dynamic stability, there is a jump of reduced mean square displacements of atoms (in the ***ab*** region we have $y_l \approx 0.3 \div 0.5$, $y_t \approx 0.2 \div 0.3$ and the relative amplitudes of neighboring atoms displacements $\sqrt{D_l^{\alpha\alpha}} / a_0^2 \approx 5 \cdot 10^{-3} \div 10^{-2}$), which is the result of a strong anharmonicity of atomic oscillations, the formation of the SAC's configurations areas and the growth of their fraction at $\tau \to \tau_m$, $\sigma(\tau_m) \approx 0.07$) (Fig. 4.2, 4.3). At the same time, the change is interatomic distance $(r - a_0) / a_0 \approx 10^{-2}$ at $\tau \to \tau_m$ is insignificant, which indicates the preservation of the near-order in the loss of dynamic stability (Mar'yan & Yurkovych, 2018). The transition temperature τ_m is depends on pressure, increasing with growth P^* according to the ratio

$$\tau_m(P^*) \approx 0.52(1 + 0.34P^*) \tag{4.3}$$

and approximated to the melting curve of the real crystal.

Model ideas are presented on the formation of the self-organized structure of non-crystalline solids as a method of self-organization of the system, which is carried out in accordance with the technological conditions of obtaining and under the influence of external fields. Above the point of loss of stability of a thermodynamically equilibrium state is shown the existence of cooling velocities above the limiting velocity q_c of a self-organized structure. It is established that in a system which, when $q < q_c$ it was uniformly stable, with a cooling rate $q \geq q_c$ spontaneously generates

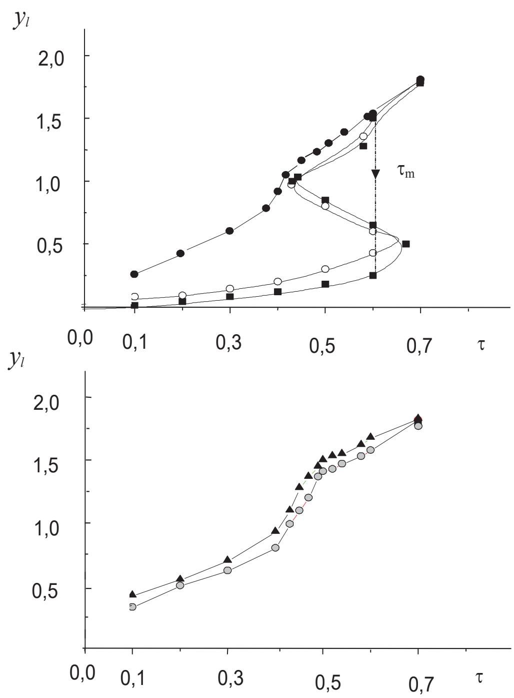


Fig. 4.3. Temperature dependence of the reduced mean square displacements of atoms along the bond y_l (■ − $q = 0$, ○ − $q = 0.5 \cdot q_c$, ● − $q = q_c$, ◍ − $q = 5 \cdot q_c$, ▲− $q = 21 \cdot q_c$).

own scale of ordering L_c. The dependence of the timelife and the period of self-organized structures on the cooling velocity are studied. In particular, for non-crystalline materials systems $As - S(Se)$ with characteristic values $q_c = 5 \cdot 10^{-3} K/s$, $q = (1.5 \cdot 10^{-2} \div 1) K/s$ period $L_c \approx (10 \div 10^2)$ Å and correlates with the size of the middle order (Mar'yan & Yurkovych, 2019). A comparison of the obtained temperature dependences for structural-sensitive parameters of NCM's materials with Kauzmann's empirical equation for the softening temperature, Ritland-Bartenev for the dependence of the softening temperature on the cooling rate, elastic constants and the sizes of the average order for non-crystalline semiconductor glass systems $As-S(Se)$ (Adam & Zhang, 2014). The synergistic approach analyzes the common features of the transition to state NCS for chalcogenide, oxide, metallic, and organic glasses, namely the presence of self-organizing processes and the formation of self-organized structures (Svoboda & Malek, 2015; Mar'yan & Szasz, 2016).

The three-dimensional bifurcation diagram in coordinates is a parameter of order, temperature, and cooling rate that takes into account the thermodynamic and kinetic aspects of the transition to a non-crystalline state. The existence of a triple point is shown, in which the three states coinciding at a critical temperature and the cooling velocity: crystalline, liquid and non-crystalline (Fig. 4.4, 4.5).

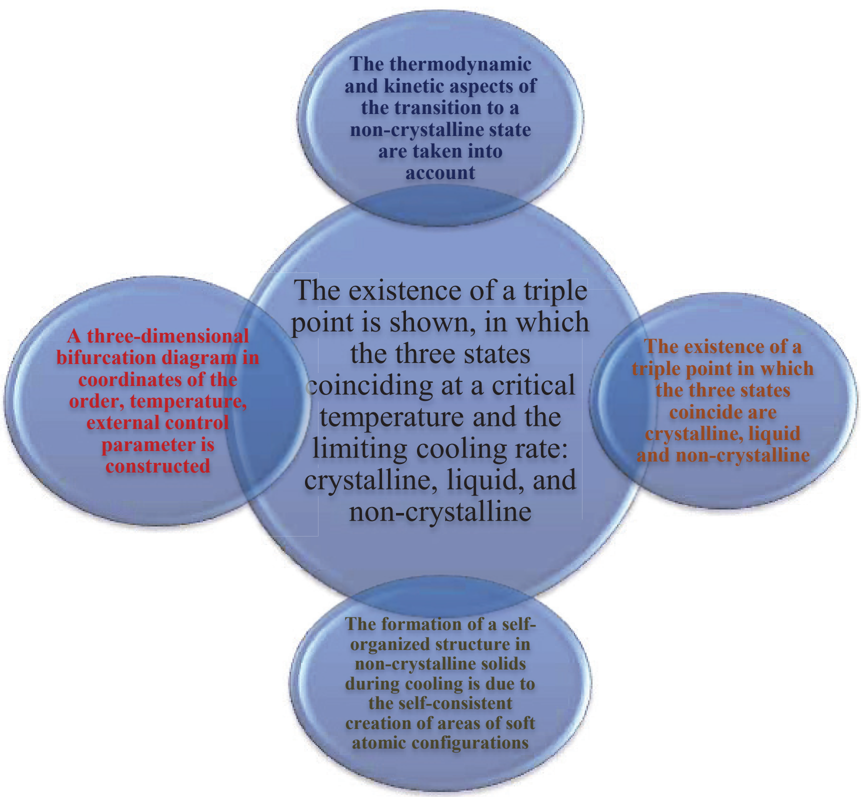


Fig. 4.4. Synergetics of the three-dimensional bifurcation diagram.

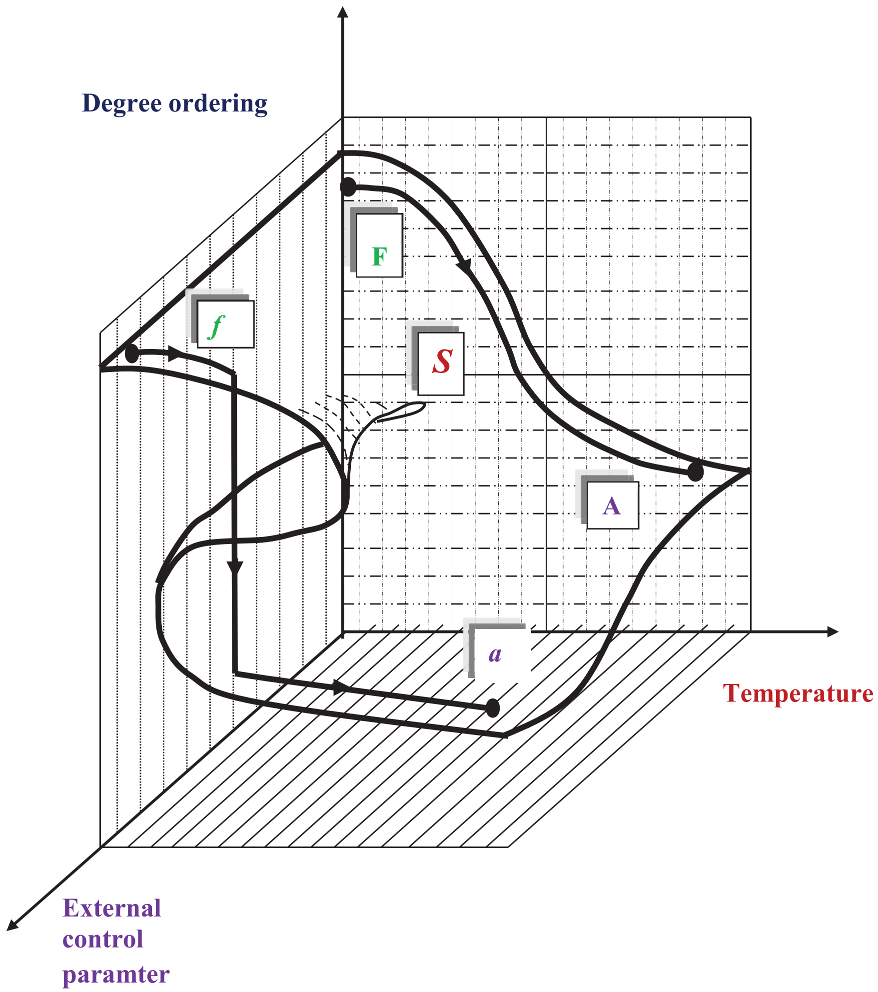


Fig. 4.5. Branching of the degree ordering solutions at different of the external control parameter q (***f*-*a*** is an equilibrium transition, ***F*-*A*** is a non-equilibrium transition to the non-crystalline state, ***S*** is a triple point).

The results of research on the influence of synthesis conditions on dynamic stability and physical and chemical parameters of NCM's materials in the region of high and low temperatures are presented. In the high-temperature approximation $\theta >> k_B T_D$, where T_D is a Debye temperature, simulation of the influence of synthetic conditions on dynamic stability on the example of glassy As_2S_3, synthesized at different temperatures. To assess the degree of ordering of the structure with increasing the temperature of the synthesis, the dependence of the temperature of the loss of dynamic stability on the parameters of the static disordering of the distance and the angles $Q,\ \zeta$ between the links is calculated (Ziman, 1977). Mean square fluctuations of distance and angle between bonds, brought to interatomic distance, for As_2S_3, obtained at a synthesis temperature $T_0 = 870\ K$, make up $Q/r \approx 6.44\%$ and $\varsigma/r \approx 10\%$ respectively (softening temperature $T_g = 448\ K,\ Q^* = \alpha^2 Q^2 = 0.1495,\ \varsigma^* = \varsigma^2 = 0.01, \alpha r \approx 6$). Increase the synthesis temperature to $T_0 = 1370\ K$ leads to an increase $Q,\varsigma\ \left(Q/r \approx 6.91\ \%,\ \varsigma/r \approx 22.3\ \%\right)$ and reducing the softening temperature to $T_g = 435\ K$.

It is shown that the temperature T_s at which the dynamic stability of the NCM's materials is disturbed is determined by the energy of the dissociation of the bond between the molecular fragments V_0 and η_{ang} , their geometry and the degree of disorder of the near and middle orders:

$$T_S = \frac{2V_0 e^{-\alpha^2 Q^2}}{k_B e}\left(1+\Delta_s\right),\quad \Delta_s = \frac{3\eta_{ang}\gamma_{ang}}{4\alpha V_0} e^{1+\alpha^2 Q^2} e^{-2\zeta^2} \qquad (4.4)$$

(the parameter γ_{ang} takes into account the geometry of the fragments and is related to their average size). The contribution of dynamic instability to the NCS' material softening process is analyzed. The temperature behavior of the mean-square displacement of the fragments near the temperature of the loss of dynamic stability is given by the ratio

$$\sqrt{\bar{u}^2} = \frac{r}{6}\left(1 + \frac{\Delta_s}{2} - \left(1 - T/T_s\right)^{1/2}\right)^{1/2} \tag{4.5}$$

and correlates with the ratio obtained for the mean square displacement within the theory of bound modes and experimentally investigated for inelastic neutron scattering (Adam & Zhang, 2014; Svoboda & Malek, 2015). The temperature dependence of the mean square displacement of the NCS fragments contains a linear region $\sqrt{\overline{u^2}} \approx T$ at $T << T_s$ and nonlinear at $T \leq T_s$. Extrapolation of linear dependencies on sites $T << T_s$ and $T \leq T_s$ defines the temperature range of softening, and their intersection - the softening temperature T_g. The dependences of the dynamic characteristics of the NCS are presented, which confirm the significant contribution of the dynamic instability to the processes of self-organization in the range of softening temperatures (Mar'yan & Yurkovych, 2015; Zhu, Liu, Sun, Yin, Tiao & Dai, 2019).

4.2. Fractality of the Non-Crystalline State and Information Technologies

The nature of the bifurcation process of transition to a non-crystalline state in the framework of the theory of neural networks with Hebb and Kohenen algorithms is revealed. Considerable attention is paid to the study of self-organizing models that model themselves, the algorithmic complexity of the self-organized structure. It is shown that the processes of self-organization in non-crystalline materials in the transition to a non-crystalline state, as well as self-consistent allocation through the processes of self-organizing order parameters, can be investigated using the theory of neural networks with back propagation algorithms, Hebb and Kohenen. Structure of states according to experimental structural-sensitive data of non-crystalline solids As_2S_3 was revealed, depending on the cooling rate, which allows determining the spectrum of self-organized structures in the form of a fractal structure. The fractal structure of the bifurcation process of transition to the state NCS and the functional dependence of the structural-sensitive parameters $f(\tilde{q}_m)$ on the reduced cooling rate $\tilde{q}_m$ in the form $f(\tilde{q}_m) \cong \tilde{q}_m^{d_f}$ where the fractal dimension $d_f = 0.631$ is established.

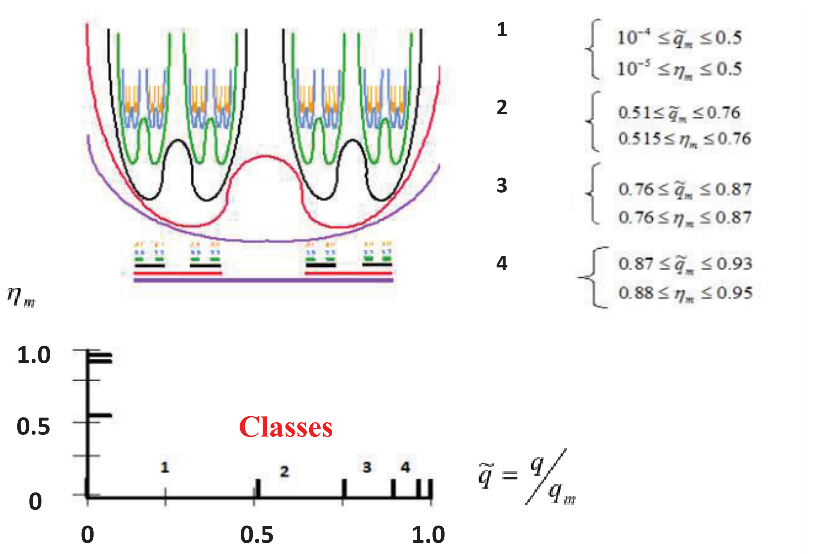


Fig. 4.6. Classes of fractal structuring for the non-crystalline solids.

This is considered as one of the possible variants of the formation of a fractal structure (Fig. 4.6, 4.7). The performed studies show and confirm the formation of the fractal structure of the resulting non-crystalline state. The paradox and peculiarity is that the versatility of the structure and properties of non-crystalline materials is given not statistically, randomly or partially, but, conversely, account is taken of the totality and multiplicity of the fractal structure itself (Mar'yan & Yurkovych, 2018). This is a fundamentally excellent approach to the formation of intelligent non-crystalline materials: the features of structure and parameters are not introduced from the outside, are limited, but are manifested through the formation of a fractal structure, that is, these unique properties are self-sufficiently discovered and provided by the fractal structure itself (Shatalov, Mar'yan & Kikinesy, 1996; Mar 'yan & Yurkovych, 2019).

(Similar approaches and structures are also present in the formation of the Mandelbrot's set, which is determined by the movement of prices on the cotton market during the thirties, that is, in the chaotic, at first glance, price patterns were inherent in a unique pattern (Frame & Mandelbrot, 2002), changes in currency quotations on stock exchanges (Gregory-Williams & Williams, 2008).

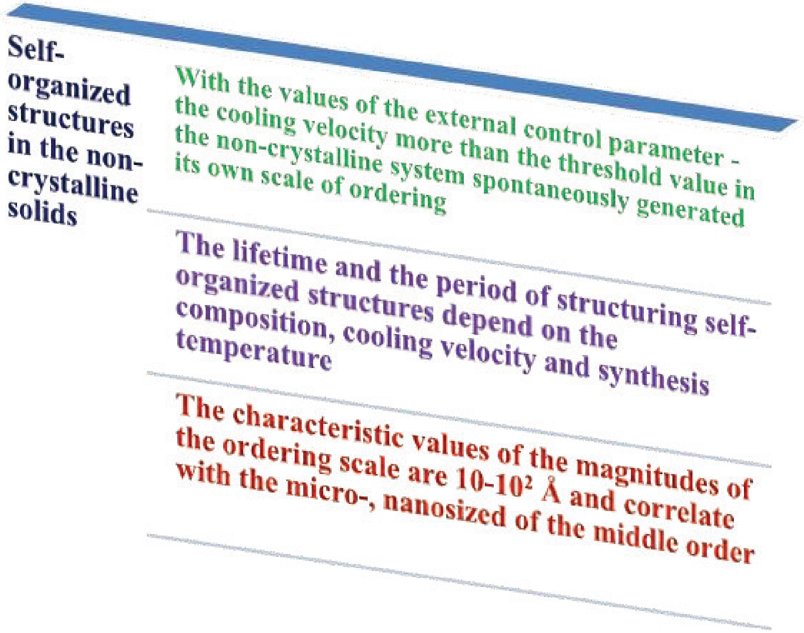


Fig. 4.7. Self-organized structures in the non-crystalline solids.

Thus, in non-crystalline and intelligent materials, the formation of self-organized structures, which possess unique information properties along with predicted physical & chemical parameters, is possible. It is the main emphasis placed on research on the possibilities of developing materials with pre-set parameters for systems of archival memory, touch devices, and so on. The proposed approach involves the possibility of creating an informational self-organized system with a spectrum of fractal structures, signal-code links in non-crystalline solids that have hypersensitivity under certain parameters.

(*We will examine these issues in more detail in the following chapters of the monograph*).

Chapter 5

THE LOW-TEMPERATURE ANOMALIES IN THE NON-CRYSTALLINE SOLIDS: MICRO, NANOSIZED EFFECTS

We do not by chance choose one another ... We meet only those who already exist in our subconscious.

SIGMUND FREUD, Founder of Psychoanalysis

Nata Popova.
The Infinity.

5.1. The Two-Level Anomalies of the Structural-Sensitive Parameters Non-Crystalline Materials: *Formation of the Self-Organized Structures*

In the region of low temperatures $\left(T < 50^{o} K\right)$, the temperature behavior of a number of thermal properties is different from the temperature characteristic of the crystalline compounds: the heat capacity, the coefficient of thermal expansion, the velocity of sound propagation (Mar'yan, Khiminets & Turyanitsa, 1990). The low-temperature anomalies of physical properties for non-crystalline solids are described at present on the basis of representations of two-level tunnel states and soft atomic configurations (SAC) without a single interpretation of their microscopic nature (Klinger, 1999; Holovatch, 2017; Mar'yan & Yurkovych, 2018). An interesting application of such phenomena is also the Bose & Einstein Condensation (BEC), which has been intensively studied over the past decades (Stasyuk, Velychko & Vorobyov, 2015; Quyet, Thu, Tam & Phat, 2019).

(*With the condensation of BEC, there are hopes for the development of quantum computers; processes of self-organization and a synergistic approach to this phenomenon can drastically change the views and methods of implementation without dissipative dissemination of information.*)

In order to explain the nature of the low-temperature phenomena of non-crystalline materials in a wide temperature range, it is necessary to consider the behavior of physical and physical-mechanical properties in conjunction with the features of the structure and factors that determine it. These factors include the conditions for obtaining non-crystalline materials and the effect of external fields (electromagnetic radiation, hydrostatic pressure, external noise). Non-crystalline materials, as shown above, are characterized by the presence of self-organized structures, whose parameters, due to influence on the near and medium order, are largely determined by the conditions of obtaining (Fig. 5.1) (for example, when cooling the system, such factors include the synthesis temperature, cooling rate, annealing regimes, which determine the spatial fluctuations of structural parameters (Mar'yan, Khiminets & Turyanitsa, 1990; Mar'yan, Yurkovych, Seben, 2018)). In addition, the self-consistent consideration of the dynamics of atomic oscillations, the reorganization of local atomic potentials, and the spectrum of low frequency excitations of non-crystalline materials in terms of conditions for their obtaining is of fundamental interest (Stasyuk, Velychko & Vorobyov, 2015) (the nature of the transition to a non-crystalline state and low-temperature anomalies have much in common (Mar'yan & Yurkovych, 2018)).

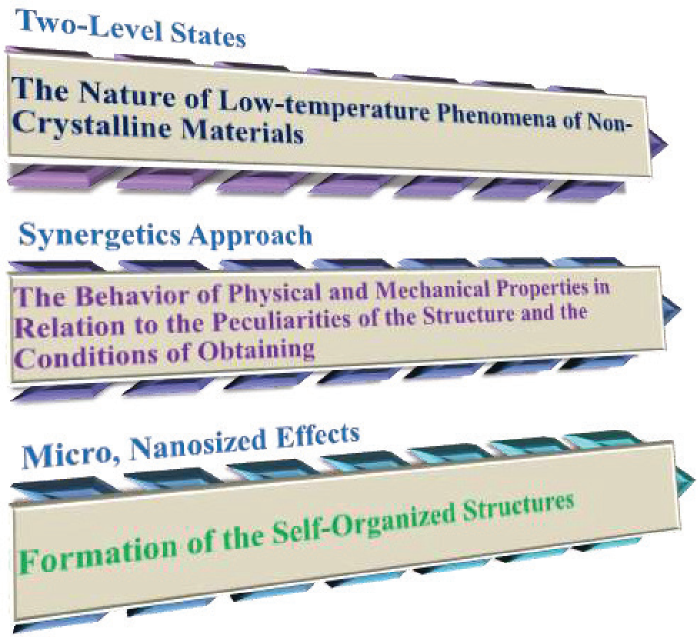


Fig. 6.1. The nature of low-temperature phenomena in the non-crystalline solids.

Let's consider the relationship between the behavior of physical properties (mean-square displacements and frequency of oscillations of atoms, heat capacity and thermal expansion) of non-crystalline solids in the region of low temperatures $T < 100\ K$ with the conditions for their obtaining. The fluctuations of the parameters of the non-crystalline structure, which are described at the near-order level by the dispersion of the interatomic distances and angles between the bonds, cause the local heterogeneity of the matrix and lead to the formation of regions with different levels of ordering. The Hamiltonian of such a system can be given as follows

$$H = \sum_f \sum_l \left(\frac{\left(P_l^f\right)^2}{2m} + U_f\left(\vec{r}_l\right) \right) \sigma_l^f + \frac{1}{2} \sum_{f,f'} \sum_{l,l'} \Phi_{ff'}\left(\vec{r}_l - \vec{r}_{l''}\right) \sigma_l^f \sigma_{l'}^{f''} . \qquad (5.1)$$

Here $U_f(\vec{r}_l) = \sum_{f',l'} \Phi_{ff'}(\vec{r}_l - \vec{r}_{l'})$ is the single-particle potential, $\Phi_{ff'}(\vec{r}_l - \vec{r}_{l'})$ is the paired interaction potential, σ_l^f are the local characteristic functions. Effective Hamiltonian of two-level low-energy states $(f = 1,2)$ the system has the look:

$$\widetilde{H} == \sum_f \widetilde{H}_f ,$$

$$\widetilde{H}_f = \sigma_f \sum_l \left(\frac{\left(\vec{P}_l^f\right)^2}{2m} + U_f\left(\vec{r}_l\right) - \mu \right) + \frac{A_f}{2} \sum_{l,l'} \Phi_f\left(\vec{r}_l - \vec{r}_{l'}\right), \qquad (5.2)$$

where $A_1 = 1 - \sigma_2^2$, $A_2 = \sigma_2^2$, $\sigma_1 + \sigma_2 = 1$.

Configuration entropy $dS_i = -k_B \ln\left[\prod_f \left\{ \frac{g_f!}{N_f!\left(g_f - N_f\right)!} \right\} \right]$, associated with fractal regrouping the areas of SAC's configurations inside the system, is determined for this case by the number of distribution methods N_f atoms in f possible states with degrees of degeneracy g_f. Degree of degeneracy g_f takes into account the splitting of the corresponding energy level due to the influence of neighbors, and $g_f > N_f$. So, $g_2 > N_{2\max}$ ($N_{2\max} = \left(10^{-4} \div 10^{-2}\right) \cdot$ N is the density of possible soft configurations SAC in non-crystalline material, which is determined by its structure and conditions of obtaining) and $g_1 \geq N_{1\max} \cong N$, which gives an estimation $g_2 / g_1 = 10^{-4} \div 10^{-2}$. Since in the non-crystalline material the proportion of atoms contained in SAC's configurations is significant $\left(\sigma_2 \cong 10^{-4} \div 10^{-2}\right)$, and the displacement of the atoms for the system near the order $(10 \div 30)\%$ the interatomic distances, then for the study of the temperature behavior of the non-crystalline system, it is necessary to involve methods that take into account strongly anharmonic effects and structural rearrangements. We use the self-consistent pseudo-harmonic approximation, which enables us to determine the renormalization of the force constant and local potentials as a result of the anharmonicity of atomic oscillations (Mar'yan & Yurkovych, 2018).

The solution of the variational problem

$$\partial F/\partial\sigma_2 = a_e \cdot (\sigma_2 - \sigma_2^e), \qquad (5.3)$$

where is the functional of free energy $F = F_f - T \cdot dS$, $dS \approx dS_i$, $a_e = \left(\partial^2 F / \partial\sigma_2^2\right)_e$, σ_2^e is an equilibrium value σ_2, leads to equations:

$$\sigma_2 = \frac{\widetilde{\Lambda}_1 - \widetilde{\Lambda}_2 - \vartheta \ln \dfrac{g_2/N_2 - 1}{g_1/N_1 - 1} + a_e \cdot (\sigma_2 - \sigma_2^e)}{2(\widetilde{\Phi}_2 - \widetilde{\Phi}_1)}, \widetilde{\Lambda}_f = \left\langle \sum_l \frac{(\vec{P}_l^f)^2}{2m} \right\rangle, \ \widetilde{\Phi}_f = \left\langle \sum_{l,l'} \Phi_f(\vec{r}_l - \vec{r}_{l'}) \right\rangle. \qquad (5.4)$$

The system of equations with respect to renormalized power constants $\widetilde{\upsilon}_f(l)$ and mean square displacements $\widetilde{D}(l) = \left\langle \frac{[\{u(l) - u(0)\}l]^2}{l^2} \right\rangle$ in the approximation of the pair interaction of near neighbors z, it is possible to investigate the temperature behavior of the non-crystalline system and has the form

$$\widetilde{\upsilon}_f(l) = A_f \frac{\partial^2}{\partial r_l^2}\left[\exp\left\{\frac{1}{2}\widetilde{D}_f \frac{\partial^2}{\partial r_l^2}\right\}\Phi_f(r_l - r_{l'})\right], \ z\widetilde{D}_f(l) = \frac{\hbar}{N}\sum_k \frac{\omega(k)}{\widetilde{\upsilon}_f(l)} cth \frac{\hbar\omega(k)}{2\vartheta}. \qquad (5.5)$$

Describing the effective interaction of atoms with the Morse potential, we find for a self-consistent interaction potential:

$$\widetilde{\Psi}_f(l) = A_f V_{0f} \exp\{-Q^*\}[\exp\{-2\alpha(l - a_0)\}\exp\{2y_f\} - 2\exp\{-\alpha(l - a_0)\}\exp\{y_f/2\}], \qquad (5.6)$$

where $a = a_0 + \dfrac{3Q^*}{2\alpha}$ is an averaged interatomic distance taking into account the static disordering of equilibrium positions characterized by a parameter $Q^* = \alpha^2 Q^2$; $y_f = \alpha^2 \widetilde{D}_f(l)$ are given reduced mean-square displacements of atoms; α and V_{0f} are the parameters of the potential. Thus, according to the principle of the local quasi-equilibrium of non-crystalline material in the presence of external applied pressure P, the average interatomic distance is equal

$$l_f = a_0 + \frac{3y_f}{2\alpha} + \delta_f, \quad \delta_f = -P^* \exp(y_l) \Big/ \left(3\alpha\left(1-\xi\sigma_2^2\right)\right), \quad \xi = 1 - \frac{V_{02}\exp\{y_1 - y_2\}}{V_{01}} << 1,$$

$P^* = \dfrac{6P\alpha a_0^2}{zf}$ is the reduced pressure,

$f = 2\alpha V_{0f}\exp\{-Q^*\}$ is the power constant in a harmonic approximation, then the potential energy and force constants in the region of low temperatures ($\theta << k_B T_D$, where T_D is a Debye's temperature) are defined by expressions

$$\widetilde{\Psi}_f(l_f) = -A_f V_{0f}\exp\{-Q^*\}\exp\{-y_f\}, \quad \widetilde{\upsilon}_f(l_f) = A_f f\left(\exp\{-y_f\} + \frac{P^*}{1-\xi\sigma_2^2}\right),$$

$$y_f \cong \frac{\beta_f}{A_f^2\lambda_f}\vartheta^4\left(1 + \frac{5\beta_f}{2A_f^2\lambda_f}\vartheta^4 + \ldots\right), \qquad (5.7)$$

where

$$\lambda_f = \frac{V_{0f}a_0\left(1+P^*\right)\cdot V\cdot\exp\{-Q^*\}}{\pi^2\hbar\nu_{0f}S_{0f}}, \quad \beta_f = \frac{a^4}{60\left(\hbar S_{0f}\right)^4},$$

$S_{of}^2 = zfa_0^2\left(1 + \dfrac{P^*}{1-\xi\sigma_2^2}\right)\Big/2m$ is a sound speed in harmonic approximation, ν_{0f} is a geometric structural factor $(0 < \nu_{0f} < 1)$. The system of equations (5.4) -

(5.7) allows us to investigate the behavior of the mean-square displacements, the atomic fraction in SAC's configurations and a number of other physical properties that are determined through $y_f(T)$ and $\sigma_2(T)$ in the temperature range $T < 100^o K$.

Because

$$A_f \widetilde{\Phi}_f = zN\widetilde{\Psi}_f(l)/2\ ,\ \sigma_f \widetilde{\Lambda}_f = zN\widetilde{\upsilon}_f(l)/\alpha^2$$

then equation (5.4) using the relation (5.7) is rewritten in this way:

$$\sigma_2 = \frac{V_{02} y_2 \sigma_2 \left(\exp\{-y_2\} + \dfrac{P^*}{1-\xi\sigma_2^2} \right) - V_{01} y_1 (1+\sigma_2) \left(\exp\{-y_1\} + \dfrac{P^*}{1-\xi\sigma_2^2} \right) + + \vartheta \ln \dfrac{g_2/\sigma_2 - N}{g_1/(1-\sigma_2) - N} \exp\{Q^*\} + a_e \cdot (\sigma_2 - \sigma_2^e)}{V_{01} \exp\{-y_1\} - V_{02} \exp\{-y_2\}}\ .$$

In particular, taking into account (5.7), for $T < 1^o K$ we get

$$\sigma_2 = \frac{(1+P^*)\vartheta^4}{2\varepsilon} \left(\frac{\beta_2 V_{02}}{\lambda_2 \sigma_2^3} - \frac{\beta_1 V_{01}}{\lambda_1 (1-\sigma_2^2)(1+\sigma_2)} \right). \qquad (5.8)$$

From here we have

$$\sigma_2 \cong \gamma\theta,\ \gamma^4 = \frac{\beta_2 (1+\mathrm{P}^*) V_{02}}{2\lambda_2 \varepsilon} << 1,\ \varepsilon = \mathrm{V}_{01} - V_{02}\,. \qquad (5.9)$$

Solutions of the self-consistent system of equations in the temperature region $T < 100^o K$ calculated numerically using the iterative method (calculation results are given in Fig. 5.2 for characteristic parameters of the NCS' materials: $P^* = 0.1,\ \ \varepsilon = 10^{-4} eV,\ \ \mathrm{f} = 10^5 \mathrm{dyn/cm},\ \ \mathrm{g}_1/\mathrm{g}_2 = 11$).

Linear temperature dependence of the fraction of atoms in SAC's configurations at $T < 1^0 K$, which is approximated by the relation (5.9), and as the temperature rises, it becomes nonlinear $\left(\sigma_2 \approx T^{\kappa},\ \kappa < 1\right)$, saturated $\left(\sigma_{2\max} \approx 10^{-4} \div 10^{-2}\right)$ about $T \approx 10 \div 10^2 \quad K$.

Internal energy

$$\widetilde{E} = \left(1 - \sigma_2^2\right)\widetilde{\Phi}_1 + \sigma_2^2\widetilde{\Phi}_2 + \sigma_2\widetilde{\Lambda}_2 + \left(1 - \sigma_2\right)\widetilde{\Lambda}_1$$

and volume

$$V = N\left(\sigma_1 v_1 + \sigma_2 v_2\right),\ v_f = v_{0f} l_f^3,$$

there are functions σ_2 , $y_{1,2}$ asked this way:

$$\widetilde{E} = \frac{z}{2}\exp\left\{-Q^*\right\}\times$$
$$\times\left[-V_{01}e^{-y_1} + \sigma_2^2\left(V_{01}e^{-y_1} - V_{02}e^{-y_1}\right) + V_{01}y_1\left(1-\sigma_2^2\right)\left(e^{-y_1} + \frac{P^*}{1-\xi\sigma_2^2}\right) + V_{02}y_2\sigma_2^2\left(e^{-y_2} + \frac{P^*}{1-\xi\sigma_2^2}\right)\right],$$

$$\frac{V}{N} = \left(1-\sigma_2\right)v_{01}\left(a + \frac{3\cdot y_1}{2\alpha} - \frac{P^* e^{y_1}}{3\alpha\left(1-\sigma_2^2\right)}\right) + \sigma_2 v_{02}\left(a + \frac{3\cdot y_2}{2\alpha} - \frac{P^* e^{y_2}}{3\alpha\left(1-\xi\sigma_2^2\right)}\right) \quad . (5.10)$$

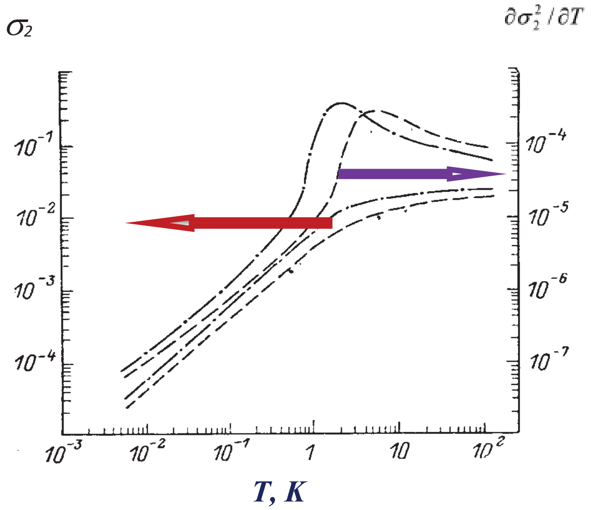


Fig. 5.2. Temperature dependence of the fraction of atoms in SAC's configurations σ_2 and $\partial\sigma_2^2/\partial T$ (– – – $Q^* = 0.15$, –·–·– $Q^* = 0.18$).

Thus, the low-temperature thermal capacity and the coefficient of thermal expansion of the system are described by the relations

$$C_p = \frac{M_a}{m}\cdot\frac{\partial\left((\tilde{E}+PV)/N\right)}{\partial T}\Bigg|_P = \frac{z}{2}\frac{M_a}{m}\cdot e^{-Q^*}\cdot$$

$$\left\{\begin{array}{l}\left[V_{01}e^{-y_1}(1-y_1)-V_{02}e^{-y_2}(1-y_2)-(V_{01}y_1-V_{02}y_2)\right]\dfrac{P^*}{1-\xi\sigma_2^2}\dfrac{\partial(\sigma_2^2)}{\partial T}+\\ V_{01}e^{-y_1}\left(1-\sigma_2^2\right)(2-y_1)\dfrac{\partial y_1}{\partial T}+V_{02}e^{-y_2}\cdot\sigma_2^2\cdot(2-y_2)\dfrac{\partial y_2}{\partial T}+\\ \left[V_{01}\left(1-\sigma_2^2\right)\dfrac{\partial y_1}{\partial T}+V_{02}\sigma_2^2\dfrac{\partial y_2}{\partial T}\right]\dfrac{P^*}{1-\xi\sigma_2^2}+P(v_2-v_1)\dfrac{\partial\sigma_2}{\partial T}+\\ P\dfrac{\partial v_1}{\partial T}+P\sigma_2\dfrac{\partial}{\partial T}(v_2-v_1)\end{array}\right\}, \qquad (5.11)$$

$$\alpha_T = \frac{1}{V}\frac{\partial V}{\partial T}\bigg|_P = \frac{1}{V}\left[(v_2 - v_1)\frac{\partial\sigma_2}{\partial T}+\frac{\partial v_1}{\partial T}+\sigma_2\frac{\partial}{\partial T}(v_2-v_1)\right]. \qquad (5.12)$$

Here M_a is molar mass. Using (5.11), (5.12) for E and V, in the temperature range $T < 1 \quad K$ we will get:

$$\widetilde{E} = \frac{z}{2} e^{-Q^*} \left[-V_{01} + \gamma^2 \vartheta^2 \left(\varepsilon + \frac{\beta_2 V_{02} (2 + P^*)}{\lambda_2 \gamma^4} \right) + \frac{\beta_1 V_{01} \vartheta^4}{\lambda_1 (1 - \gamma^2 \vartheta^2)^2} \left(2 + P^* - \gamma \vartheta (1 + P^*) - \gamma^2 \vartheta^2 \right) \right],$$

$$\frac{V}{N} = a_0^3 \left(1 - \frac{P^*}{3\alpha a_0 (1 - \xi \gamma^2 \vartheta^2)} \right)^3 \times$$

$$\left\{ \begin{aligned} & \nu_{01} (1 - \gamma \vartheta) \left[1 + \frac{\beta_1 \vartheta^4}{6\alpha a_0 \lambda_1 (1 - \gamma^2 \vartheta^2)^2} \left(9 - \frac{2P^*}{1 - \xi \gamma^2 \vartheta^2} \right) \right]^3 + \\ & + \nu_{02} \gamma \vartheta \left[1 + \frac{3\beta_2}{2\alpha a_0 \gamma^4 \lambda_2} - \frac{\beta_1 P^* \vartheta^4}{6\alpha a_0 \lambda_1 (1 - \gamma^2 \vartheta^2)^2 (1 - \xi \gamma^2 \vartheta^2)} \right]^3 \end{aligned} \right\}. \quad (5.13)$$

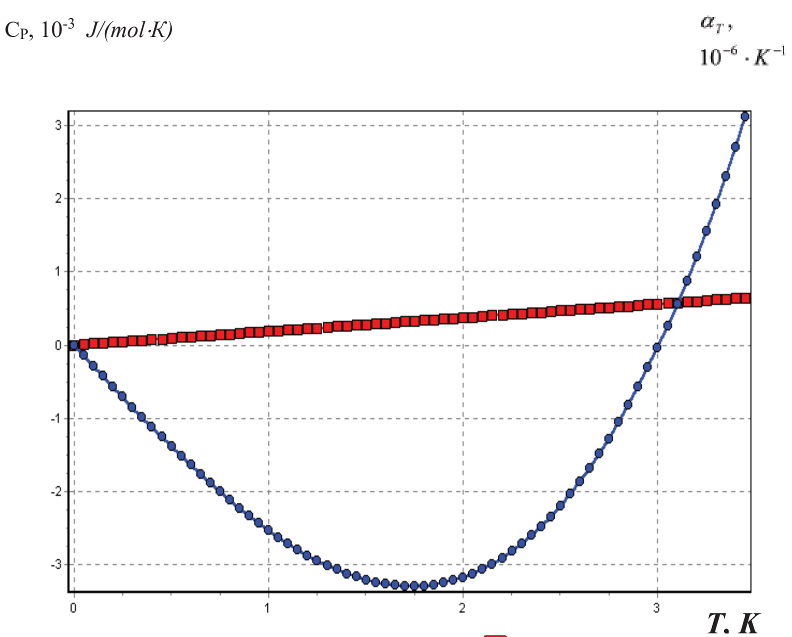


Fig. 5.3. Low-temperature heat capacity C_P (■) and the coefficient of thermal expansion α_T (●) at $Q^* = 0.18$.

The corresponding thermal capacity and thermal expansion coefficient of the system will look like:

$$C_P = a_1 T + a_2 T^2 + a_3 T^3,$$
$$\alpha_T = -b_1 T + b_2 T^3, \qquad (5.14)$$

where

$$a_1 = z\gamma^2 k_B^2 \cdot \frac{M_a}{m}\left\{e^{-Q^*}\left[\varepsilon + \frac{\beta_2 V_{02}\left(2+P^*\right)}{\lambda^2\gamma^4}\right] - \frac{2\xi \nu_{01} V_{01} P^*}{3}\right\},$$

$$a_2 = \frac{M_a}{m}\cdot\frac{zf\left(\nu_{01}-\nu_{02}\right)P^*\gamma^3 k_B^3}{3\alpha^3},\; a_3 = 3z\beta_1 k_B^4 \frac{M_a}{m}\left[\frac{V_{01}\left(2+P^*\right)e^{-Q^*}}{2\lambda_1} + \frac{fP^*}{\alpha^2\lambda_1}\right], \qquad (5.15)$$

$$b_1 = \frac{2P^*\xi\gamma^2 k_B^2}{\alpha a_0},\; b_2 = \frac{18\beta_1 k_B^4}{\alpha a_0 \lambda_1}.$$

Let's consider the comparison of the obtained theoretical dependencies within the synergetic model with the results of other models and experimental data (Adam & Zhang, 2014). In Fig. 5.4 shows the experimental dependence of the thermal capacity of the glass As_2S_3 in the temperature region $T = 1 \div 12 \;\; K << T_D = 161 \;\; K$, where T_D is Debye's temperature (● – experiment (Adam & Zhang, 2014), —— calculation according to (5.14)). Within the synergistic model, the structure of non-crystalline solids can be described as a linear contribution to thermodynamic functions C_P and α_T, caused by fluctuation transitions of atoms or their groups between SAC's configurations, and cubic, due to phonons. Since the coefficient of the linear part of the temperature dependence α_T is negative, then in the low temperature region the volume of the system initially decreases with heating, and then, due to the growth of the contribution of phonons $\left(\approx b_2 T^3\right)$, begins to grow.

The nature of the effect of temperature compression of non-crystalline solids in the region $T \le 1 \quad K$ is as follows. Structural heterogeneity at the level of the middle and near-order (which equates to the micro, nano-levels) accounts for the heterogeneity of the phonon subsystem (the anharmonicity of the atomic oscillations is most pronounced for weak links). Accumulated in the local areas of the non-crystalline system, the volatile energy is stored in the form of elastic deformations for the metastable state with nonlinearity in the selected degrees of freedom (energy

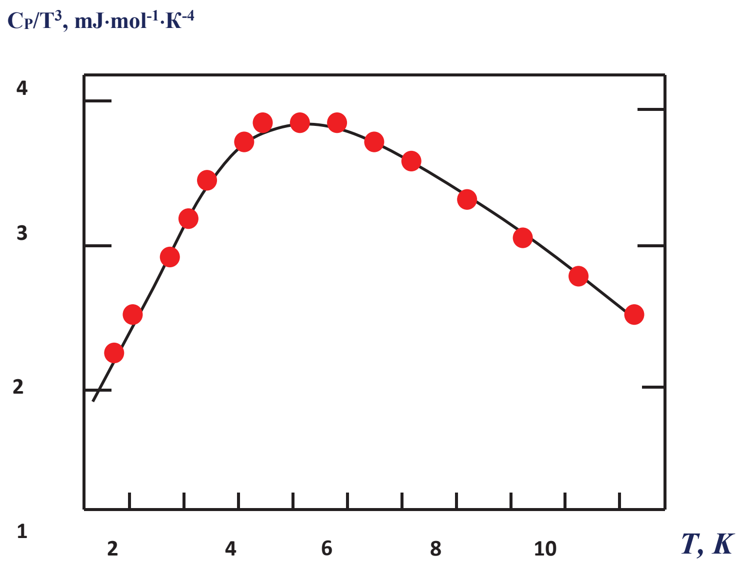


Fig. 5.4. Low temperature dependence of the thermal capacity of the glass As_2S_3 (● - experiment (Adam & Zhang, 2014), — calculation according to (5.14)).

contribution of elastic deformations $\approx P^* \exp(y_2)/(1-\xi\sigma_2^2\ )$). With the growth of the proportion of atoms in soft configurations SAC, elastic deformations will also increase, causing the sample to compress. At higher temperatures $\left(1 \div 10 \quad K\right)$, cubic contribution to α_T becomes decisive. The obtained result is consistent with the experimental data (Holovatch, 2017) on the temperature dependence $(\Gamma = -1)$ for a number of non-crystalline solids in the temperature range $T \leq 10 \quad K$.

This model explains the quasilinear temperature dependence of heat capacity

$$C_p \approx T^{\delta} \quad (\delta = 0.1 \div 0.4),$$

taking into account the self-consistent way, along with the contribution of purely phonon excitations, their renormalization as a result of interaction with low-energy structural states (Fig. 5.5). This contribution, due to the interaction of phonons with two-level low-energy soft configurations, has the order

$$a_2 \cdot T^2$$

and is essential in the temperature range $T \leq 1 \quad K$.

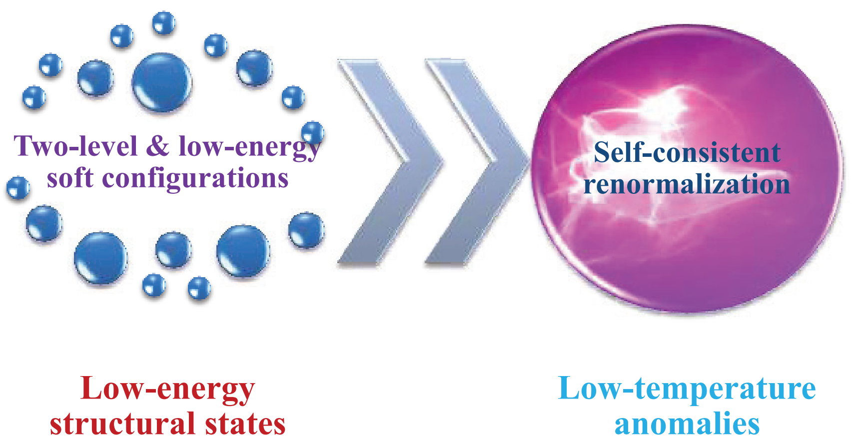


Fig. 5.5. Synergetics of the low-temperature anomalies in the NCS state.

The temperature dependence of the heat capacity, including not very low temperatures and calculated in accordance with (5.14), is presented in Fig. 5.6. For

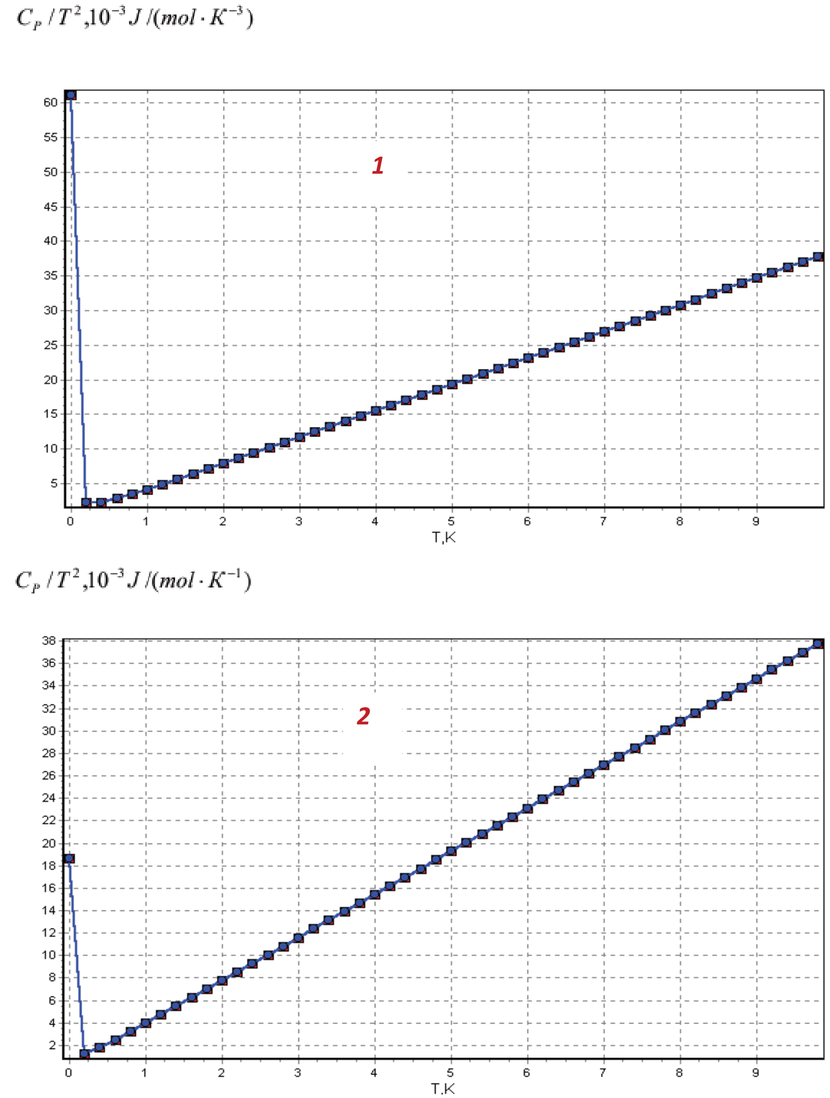


Fig. 5.6. Temperature dependence of heat capacity C_P / T^2 of the non-crystalline As_2S_3 ($1 - Q^* = 0.15$, $2 - Q^* = 0.18$).

$T = 3 \div 10\ K$ dependence C_p / T^3 have a wide maximum ("hump"), which, in the framework of the model under consideration, is due to the interaction of atoms in SAC's configurations with the matrix of the NCS' state, which leads to a self-consistent renormalization of the force constants, the distribution of low-energy states and its nonlinear temperature dependence. We analyze the influence of the conditions of obtaining on the nature of low temperature anomalies of the thermal properties of non-crystalline solids. The influence of external control parameters (technological regimes of reception: changes in the temperature of synthesis T_0) was taken into account as follows: an increase in the synthesis temperature causes an increase in the continuum disorder of the framework Q^*, which is described by the dispersion of distortion of the short order and causes the change in atomic potentials (5.11), the frequency of oscillations of the atoms and thermodynamic functions E, V.

So, for non-crystalline material As_2S_3 obtained by cooling the melt from the synthesis temperatures in the range $T_0 = 870 - 1370\ K$, the boundaries of which are determined by the minimum and maximum temperature of synthesis of this composition at a rate *q=1.8K/s*, there is a change in the dispersion of interatomic distances, which is coordinated in order of magnitude with experimental data (Adam & Zhang, 2014). It should be noted that the variation of the conditions of synthesis does not change the universal nature of low-temperature anomalies C_p and α_T non-crystalline solid, but causes a change in the ratios of different contributions and temperature intervals. As can be seen from Fig. 5.6, the growth of the dispersion of the fluctuations of the interatomic distances of the material obtained at the synthesis temperature $T_0 = 1370\ K$, causes an increase in the atomic share in soft atomic configurations and a shift in the temperature interval of saturation to a region of lower values in comparison with those for a material obtained at a temperature $T_0 = 870\ K$. This result is consistent with the results obtained by the authors (Adam & Zhang, 2014) in studies of the growth of the density of low-energy states with a decrease in the transition temperature to a non-crystalline state (an increase in the synthesis temperature at $q = const$ for As_2S_3 causes a decrease in the temperature interval of softening-glass transition (Mar'yan, Khiminets & Turyanitsa, 1990)). Correspondingly, the change Q^* affects the nature of the dependence C_p/T^3 from T (Fig. 5.6), which qualitatively agrees with the experimental studies on the influence of the conditions of obtaining As_2S_3 to low-temperature heat capacity in the temperature range $2 \div 10$ K.

The influence of technological regimes of synthesis on the coefficient of thermal expansion of non-crystalline materials in the region of low temperatures is described similarly. As the temperature of the synthesis of non-crystalline material increases, an increase in the cubic contribution and the narrowing of the temperature interval of the negative values of the expansion coefficient α_T are observed.

It should be noted that the conducted studies of the correlation of low-temperature anomalies of physical properties (mean-square displacements, heat capacity, and coefficient of thermal expansion) of NCS with the conditions of their obtaining show the common features of transition to state NCS and low-temperature anomalies (Mar'yan, Khiminets & Turyanitsa, 1990; Mar'yan & Yurkovych, 2019). The empirical relations between the softening temperature and the density of soft low-temperature states, the change in the coefficient under the linear temperature dependence of the heat capacity are established. In particular, the authors (Mar'yan, Khiminets & Turyanitsa, 1990) show that the coefficient for the linear part of the temperature dependence of the heat capacity is a function of the softening temperature $a_1 = f(T_g)$. Since the softening temperature depends on the conditions for obtaining a particular synthesis temperature $T_g = f(q, T_0)$, then use (5.15) to rewrite as follows:

$$a_1 = c' + \frac{c''}{\exp(Q^*)} = c' + \frac{c''}{f(q, T_0)} = f(T_g). \qquad (5.16)$$

That is, the ratio (5.16) for the coefficients of thermal dependence of the heat capacity allows us to obtain an empirical relation, which describes the correlation between low-temperature anomalies and the transition to the state NCS (Fig. 5.7).

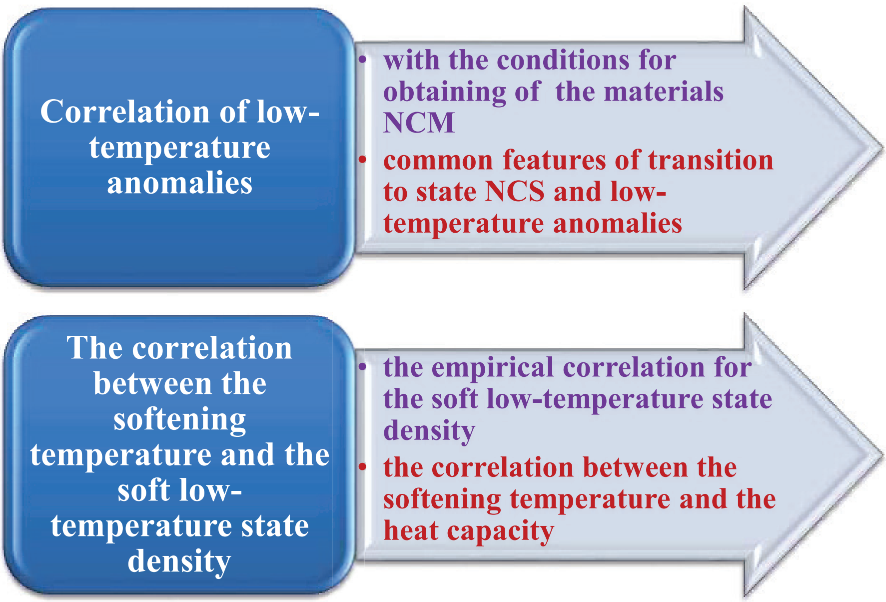


Fig. 5. 7. The correlations of low- temperature anomalies which transition to the state NCS.

5.2. Micro, Nanosized Effects: ***Structuring of Correlation Scales***

According to (5.11) - (5.15), the heat capacity and the coefficient of thermal expansion in the temperature region $T \geq T_D$, $T_D = \hbar\omega_D / k_B$, T_D is a Debye's temperature, are defined in this way:

$$C_P = \frac{M_a}{m}\frac{\partial((E+P\cdot V)/N)}{\partial T}\Big|_P = C_{str} + C_{ph} + C_{\text{int}} \ ,$$

$$\alpha_T = \frac{1}{V}\frac{\partial V}{\partial \tau} = \alpha_{str} + \alpha_{ph} + \alpha_{\text{int}} .$$

Here the deposits are allocated: structural ($\approx \frac{\partial \sigma_2}{\partial \tau}$), oscillating ($\approx \frac{\partial y_l}{\partial \tau}$) and integrated ($\approx \sigma_2 \frac{\partial y_l}{\partial \tau}$, $y_l \frac{\partial \sigma_2}{\partial \tau}$). The behavior analysis C_P, α_T, taking into account temperature dependences $y_l(\tau)$, $\sigma_2(\tau)$, indicates that the heat capacity and the coefficient of thermal expansion have a maximum at a temperature T_s determined by the condition $\left.\frac{\partial^2 \sigma_2}{\partial T^2}\right|_{T=T_s} = 0$. With $T \to T_s$ functions increasing C_P, α_T, which is due to an increase in structural and vibrational contributions.

Self-consistent consideration of oscillatory modes of atoms and transitions between soft configurations SACs allows us to describe the process of their mutual influence: the growth of the atomic particle in configurations SACs with increasing temperature causes an increase in the energy of the phonon subsystem, that is, an increase in the mean-square displacement of the atoms, which reduces the potential barrier and contributes to additional growth σ_2. Consequently, the consideration of soft configurations SACs for non-crystalline solids consists in the renormalization of the force constants and the oscillation frequencies of the atoms, and the change in the energy of the system is due both to atomic transitions in configurations SACs and to the self-consistent effect of this process on the oscillation frequency and the mean-square displacement of atoms.

For obtaining on the basis of expressions (5.17) information on the nature of the change in the structure at the microscopic level in the interval between the temperatures of softening and the determination of the values of the structural and vibrational contributions to the internal energy, depending on the metastability of the system, compare the results of the calculations with the experimental studies of the temperature behavior of the heat capacity and relative elongation of non-crystalline

As_2S_3 in the temperature range $300 \div 550\ K$ (Mar'yan, Khiminets & Turyanitsa, 1990). The samples As_2S_3 are synthesized from the elementary components by the method of vacuum smelting. The critical cooling rate of the melt, which determines the degree of non-equilibrium of the non-crystalline body, was evaluated in a semi-empirical manner on the basis of the kinetic-thermodynamic approach and $q_c = 5 \cdot 10^{-3} K/s$. An increase in the cooling rate of materials when they are produced causes a change in the corresponding temperature dependences C_P, α_T. Typical temperature dependences C_P, α_T of samples As_2S_3, cooled with velocities $q = 5 \cdot 10^{-3} K/s$ and $q = 3\ K/s$ from the synthesis temperature $1020\ K$, show that the abnormal behavior of the investigated properties is observed in the temperature range $430 \div 450\ K$, with the increase q in the height of the jump decreases ΔC_P. On the basis of the conducted object-oriented computer simulations, we can conclude that the variation q stimulates the change in the parameters of the soft interaction potentials, the degree of ordering the structure. This causes a change in the anharmonicity of the oscillations of the atoms, that is, an increase y_l, y_t, which in turn affects the magnitudes of the structural and oscillatory contributions in the anomaly C_P, α_T. Indeed, with less q, there is a narrowing of the temperature interval of the transition of atoms to soft states and an increase in the angle of inclination $\sigma_2(T)$ (Fig. 5.2). Since the structural and vibrational contributions according to (5.17) are determined by the terms, proportional $\approx \frac{\partial \sigma_2}{\partial T}$ and $\approx \frac{\partial y_l}{\partial T}$ accordingly, this leads to the prevalence of the structural contribution to the heat capacity with a decrease in the cooling rate, and a slight decrease in the oscillatory. Thus, at low cooling rates, the jump in heat capacity is mainly due to a change in the distribution of atoms in soft configurations, while for samples obtained at higher cooling rates, the contribution of the oscillatory subsystem can be significant and cannot be neglected.

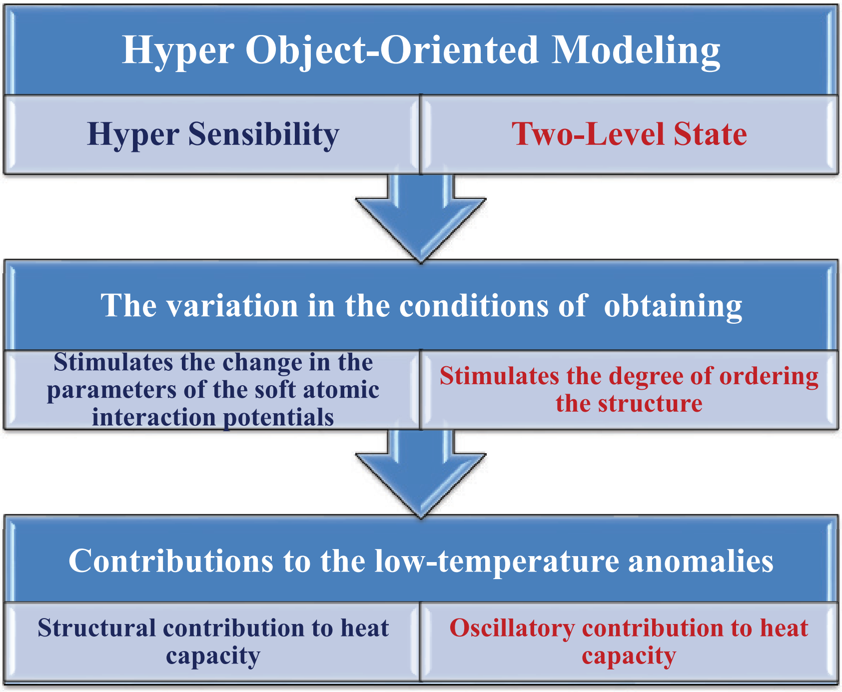


Fig. 5.8. The HOOM's modeling of the low-temperature anomalies.

The analysis of the influence q on the thermal expansion of non-crystalline solids also indicates a significant dependence of the state of the system in the area of softening temperatures on the technological conditions of production. Thus, for As_2S_3, obtained at significant cooling rates, the oscillatory contribution to the coefficient of thermal expansion is predominant, i.e., the expansion is mainly carried out by increasing the anharmonicity of the oscillations of the atoms. The model parameters are fluctuations of the near-order parameters Q/a_0 and ζ/a_0 the strength constant of the central $\Delta\tilde{f}/\tilde{f}$ and non-central interaction $\Delta\tilde{g}/\tilde{g}$ of the non-crystalline As_2S_3, synthesized at the synthesis temperature $T_0 = 1020K$, as shown in Table 5.1.

Table 5.1. Model parameters of non-crystalline As_2S_3, synthesized at the synthesis temperature $T_0 = 1020K$.

Speed cooling	Q/a_0, *relative units*	ζ/a_0, *relative units*	$\Delta\tilde{f}/\tilde{f}$, *relative units*	$\Delta\tilde{g}/\tilde{g}$, *relative units*
$q = 5\cdot10^{-3}\ K/s$	**0.027**	**0.08**	**0.033**	**0.023**
$q = 3\ \ K/s$	**0.068**	**0.22**	**0.185**	**0.158**

Consequently, studies have been conducted on the formation of self-organized structures in non-crystalline materials in the region of low temperatures and softening temperatures, confirming the presence of micro, nano regeneration regions. The common for self-organized structures at different temperature intervals is the presence of self-organization processes, which is essential for the development of intelligent materials of artificial intelligence.

5. 3. Bose & Einstein Condensation and Information

The direction of research, connected with the use of synergetics to study the possibilities of controlling chaotic behavior, changing views on chaos and transition to ordering, is extremely relevant and promising (Stasyuk , Velychko & Vorobyov, 2015; Panochko, Pastukhov & Vakarchuk, 2017; Quyet, Thu,Tam & Phat, 2019). The main focus is on Bose & Einstein condensation (BEC) research, which is directly related to the formation and access to information (Holovatch, 2017).

With the condensation of BEC, there are hopes for the development of quantum computers, direct access to information. The processes of self-organization and the synergetic approach to this phenomenon can drastically change the views and methods of implementation without dissipative dissemination of information (Fig. 5.9). For self-organized systems the condensation BEC is a conductor for an orchestra. He is not appointed, is not selected as the best music professional on a competitive basis, is not imposed externally (external noise); it is formed and manifested spontaneously, without applying energy. In the presence of a self-organized conductor, the information environment and members of the orchestra are reformatted: they play music that is informally present in them, without discipleship, without any effort. Members of the orchestra get the properties of the conductor and themselves become conductors (waves) for themselves and their surroundings. Thus, the uniqueness of each participant (atom) manifests itself through merger, propagation spontaneously in the information environment with the preservation of its individuality. But this personality, the feature is already fundamentally new, spontaneous, unlimited, and infinite.

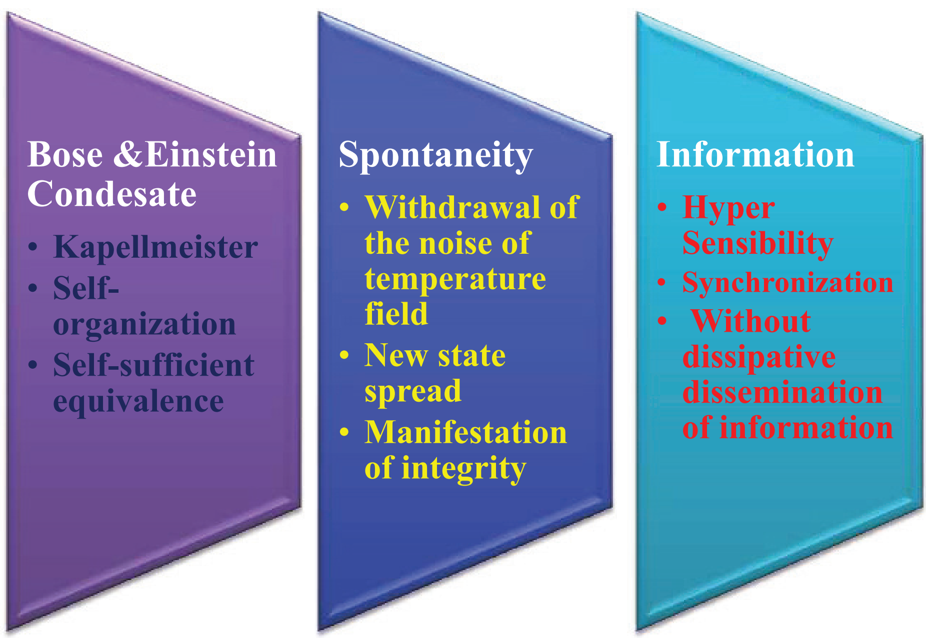


Fig. 5.9. Synergetic approach to the BEC condensate.

(*This is one of the interpretations of the condensation BEC from the point of view of the self-organized systems and fractality.*)

Chapter 6

SYNERGETIC IDEAS ABOUT WATER STRUCTURING: INFORMATION

And at the beginning of the road, few believed in us, was not it?

QUENTIN TARANTINO, Film-Maker

Nata Popova.
The Creation.

6. 1. Synergetic Ideas about Water Structuring

Among a large number of liquids, water is distinguished by a simple, at first glance, structure, but at the same time multifaceted, on this day to the end of the unclear structure that determines its unique physic-chemical and information properties, in particular, the functioning of biological objects of wildlife . The increased interest in this connection arises from the study of the spectrum of possible water states: from the crystalline state of ice to liquids with a different degree of structural order, possessing various not only physical and chemical properties but also information characteristics. In the whole problem information correlates with the general problem of structure, self-organization of non-crystalline systems and intelligent materials of artificial intelligence (non-crystalline materials, glass, amorphous layers). Therefore, taking into account a number of data known today on the study of the properties of non-crystalline materials and water, we develop a synergetic model of water structuring, which can be used to explain the specificity of its properties (Mar'yan, Kurik, Kikineshy, Watson & Szasz, 1999; Mar'yan & Szasz, 2000). We consider the application of the results of a synergetic model developed in relation to the state of NCS, for the study of structured liquids and the possibility of implementing self-organized structures with a different spectrum of life time and hypersensitivity (Mar'yan & Yurkovych, 2018).

In addition, water studies conducted over the past decades have shown that the water structure can surprise scientists around the world (https://ipress.ua/photo/). It turns out that the fluid we use every day has information (Emoto, 2006). Due to a detailed review of water, it has been discovered that water reacts differently to human emotions, music and even the names of historical figures (Emoto, 2006). Scientists from many countries took a huge step when they realized that they did not know anything about water, because they always paid attention to the well-known chemical composition of H_2O.

(The paradox is that this "embarrassment" can be both obvious and present and for many other generally accepted and reasoned at first sight of research, along with

which hidden enormous wealth - information and reality. That is, the change in generally accepted trends does not mean the collapse of development, but rather the transition to a natural way of functioning.)

6.2. Synergetics of Structured Liquids: *Disorderly and Self-Organized Structures*

Let's consider in more detail the structuring of water. Despite the simplicity of the chemical formula, water is a complex substance (Fig.6.1). This, above all, is due to its abnormal properties and the presence of two-level and multi-level states.

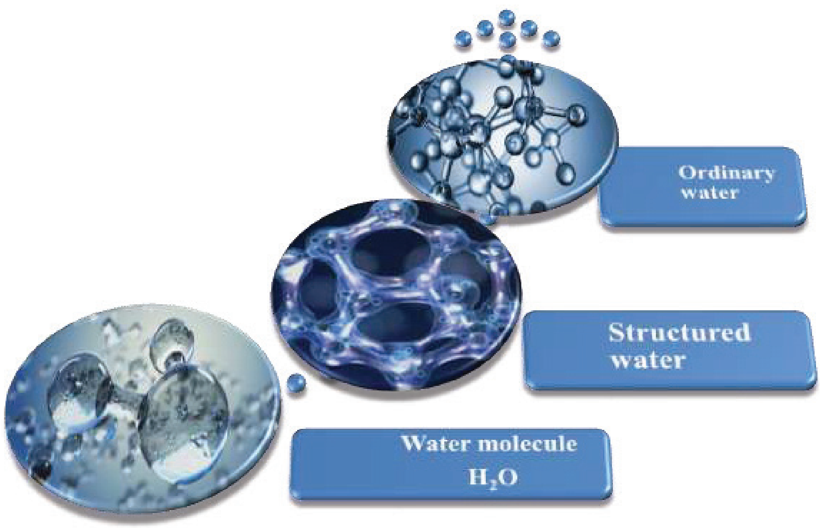


Fig. 6.1. Structures of the water.

Analyzing the works (Mar'yan & Szasz, 2000; Mar'yan & Szasz, 2016) for the study of water properties, one can distinguish the following features. The structure of water is determined by the characteristic hierarchy of time scales: the period of

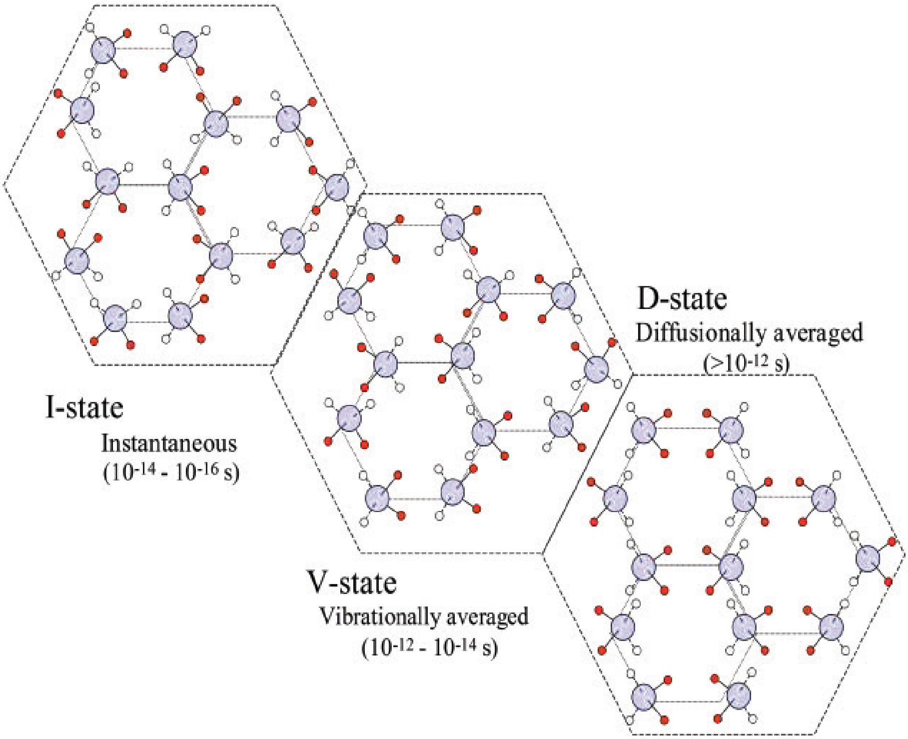


Fig. 6.2. Models of water: ***I-, V-, D-***states (Mar'yan & Szasz, 2000).

oscillations t_v a separate molecule around its equilibrium position (for water, this value is a value $\approx 10^{-12} s$) and the time of "settled life" t_d , that is, the average time of existence of a given local environment of one molecule (for water $t_d \approx 10^{-11} s$). These two parameters split the timeline into three areas, each of which corresponds to its own structure of the liquid (Ziman,1977). If $t \leq t_V$, then chaotic molecules are observed, among which it is difficult to notice of any order. This disordered arrangement of water molecules is called "Instantaneous", or ***I***-structure. At a time interval $t_V \leq t \leq t_d$ the real molecules are no longer noticeable, but the highlighted positions around which they carry out their fluctuations. These positions in water are spaced quite regularly and form a distinct structure, which is called ***V***-structure, or "Vibrationally averaged". ***I***- and ***V***-structures the water is similar to the same ice structures. To see the difference between these structures in water and ice, it is necessary to observe them with characteristic time $t \geq t_d$. Observed in this case, the structure is called ***D***-structure – "Diffusionally averaged". In contrast to the ice, the ***D***-structure of water is completely blurred due to frequent jumps of water molecules at a large distance. The ***D***-structure is determined by a certain orderly environment of the molecule at its chaotic displacement in volume.

Table 6.1. Hierarchy of time scales for the water states.

Period of oscillations of the molecule around the equilibrium position	t_v	$t_v \approx 10^{-12} s$
Time "settled life"	t_d	$t_d \approx 10^{-11} s$
I-state: Instantaneous	t_I	$t_I \approx (10^{-14} \div 10^{-16}) s$
V-state: Vibrational averaged	t_V	$t_V \approx (10^{-12} \div 10^{-14}) s$
D-state: Diffusional averaged	t_D	$t_D \approx (10^{-10} \div 10^{-12}) s$
Lifetime of self-organized structures for the structured water	τ_{life}	$\tau_{life} \approx (10^{-3} \div 10^{-5}) s$
$\tau_{life} \succ t_d \propto t_D, t_V \succ t_I$		

Among the model representations, the water distribution is structurally and disorderly the most common. The first hypothesis is the presence of an ice-like structure: from the elements of a structural grid to a quasicrystal, and the second is formed from the first due to the destruction of the structure during heating, the introduction of impurities with increasing density. Structure in the water structure is analyzed within the framework of the hydrogen bonds model and corresponding clusters, for example, tetramers, oxamers, whose dimensions are estimated within the nanosized dimensions $10 \div 30 \quad A^0$ (Mar'yan & Szsaz, 2016). Hamiltonian system (Mar'yan & Szsaz, 2000):

$$H = \sum_f \sum_l \left(\frac{\left(\vec{P}_l^f\right)^2}{2m} + U_f\left(\vec{r}_l\right) \right) \sigma_l^f + \frac{1}{2} \sum_{f,f'} \sum_{l \neq l'} \Phi_{ff'}\left(\vec{r}_l - \vec{r}_{l'}\right) \sigma_l^f \sigma_{l'}^{f'} , \qquad (6.1)$$

where σ_l^f is a local characteristic function, which is defined as follows (*f=1* corresponds to an ordered state, *f=2* corresponds to a disordered state), $\vec{P}_l^f$ is an impulse operator, *m* is a mass of water molecule, $U_f = \sum_{f',l'} \Phi_{ff'}\left(\vec{r}_l - \vec{r}_{l'}\right)$ is a single-particle potential, $\Phi_{ff'}\left(\vec{r}_l - \vec{r}_{l'}\right)$ is a potential energy of interaction. Effective Hamiltonian system is equal

$$\widetilde{H} = \sum_f H_f \, , \; H_f = \sigma_f \sum_l \left(\frac{\left(\vec{P}_l^f\right)^2}{2m} + U_f \right) + \frac{\sigma_f^2}{2} \sum_{l \neq l'} \widetilde{\Phi}_f\left(\vec{r}_l - \vec{r}_{l'}\right), \qquad (6.2)$$

The solution of the variational problem in the linear approximation of non-equilibrium thermodynamics

$$\delta F / \delta \sigma_2 = -a \cdot \left(\sigma_2 - \sigma_2^e\right), \qquad F = \sum_f F_{0f} - T \cdot S ,$$

$$F_{0f} = \theta \cdot Ln\left[Sp(\exp(-H_f / \theta))\right], \; a = \left(\partial^2 F / \partial \sigma_2^2\right)_e = f(q),$$

leads to the equation relative σ_2 :

$$\widetilde{\Lambda}_2 - \widetilde{\Lambda}_1 + 2\sigma_2(\widetilde{\Phi}_2 - \widetilde{\Phi}_1) - 2\Phi_1 - \theta \cdot N \ln \frac{\left(g_2 / \sigma_2 - 1 \right)}{\left(g_1 / \sigma_2 - 1 \right)} = a \cdot (\sigma_2 - \sigma_2^e). \qquad (6.3)$$

Here are the notation

$$\widetilde{\Lambda}_f = \sum_l \left\langle \frac{\left(\vec{P}_l^f\right)^2}{2m} \right\rangle, \widetilde{\Phi}_f = \left\langle \frac{1}{2} \sum_{l \neq l'} \left(\left\langle \Phi_{ff'}\left(\vec{r}_l - \vec{r}_{l'}\right) \right\rangle_c \right) \right\rangle. \tag{6.4}$$

The system of equations with respect to renormalized power constant $\widetilde{\Phi}_{ll'}^{\alpha\beta}$, mean-square displacements of molecules $\widetilde{D}_{ll'}^{\alpha\beta} = \left\langle \left(u_l^\alpha - u_{l'}^\alpha\right)\left(u_l^\beta - u_{l'}^\beta\right) \right\rangle$ and potentials values $\widetilde{\Lambda}_f, \widetilde{\Phi}_f$, is calculated in the same way as in (Mar'yan & Yurkovych, 2018).

The interaction of molecules can be represented in the form $\Phi(r) = \Phi_1(r) + \Phi_2(r)$, where $\Phi_2(r)$ is a short-range component (approximated by the potential of solid balls), $\Phi_1(r)$ is a long-range component (Mar'yan & Yurkovych, 2018). The intermolecular interaction will be described by means of an effective potential $\Phi_1(r)$ determined by Morse's central potential

$$\Psi(r) = V_0 \left(\exp\left\{ -12 \frac{r - a_0}{a_0} \right\} - 2 \exp\left\{ -6 \frac{r - a_0}{a_0} \right\} \right), \tag{6.5}$$

and non-central potential

$$G(\delta) = -G_0 \exp\left\{ -4 \left(\frac{\delta}{a_0} \right)^2 \right\}. \tag{6.6}$$

Where a_0 is an intermolecular distance in harmonic approximation, δ is the displacement of the molecule in a plane normal to the direction of bond, G_0 and V_0 is the energy of bond dissociation, $\alpha = 6 / a_0$ is the potential parameter, $a = a_0 + \frac{3Q^*}{2\alpha}$ is an averaged intermolecular distance taking into account static disordering of equilibrium positions characterized by a parameter $Q^* = \alpha^2 Q^2$. We calculate the self-consistent potentials of pair interaction $\widetilde{\Psi}(r)$ and $\widetilde{G}(\delta)$:

$$\widetilde{\Psi}(r) = V_0\left[\exp\left\{-12\frac{r-a_0}{a_0}\right\}\exp\{2y_l\} - 2\exp\left\{-6\frac{r-a_0}{a_0}\right\}\exp\left\{\frac{y_l}{2}\right\}\right], \quad (6.7)$$

$$\widetilde{G}(\delta) = -\frac{G_0}{1+2y_t}\exp\left\{\frac{-4\left(\frac{\delta}{a_0}\right)^2}{1+2y_t}\right\} \quad . \quad (6.8)$$

Here $y_l = {36D_l^{\alpha\alpha}}/{a_0^2}$, $y_t = {4D_t^{\alpha\alpha}}/{a_0^2}$ the mean-square displacements of molecule along the bond are given and perpendicular to it, respectively, $\widetilde{Q}_l = 36Q_l^2/a^2$, $\widetilde{Q}_t = 4Q_t^2/a^2$ are fluctuations of the intermolecular distances and the angle between the bonds. The motion of atoms in a self-consistent field is determined by the effective paired potentials of the central and non-central interaction (Fig 6.3, 6.4).

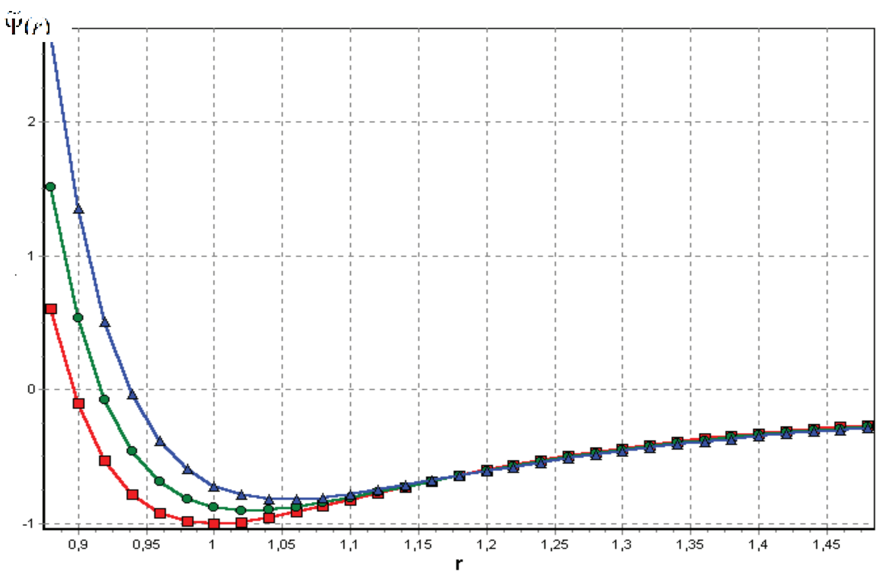


Fig. 6.3. Self-consistent Morse's potential $\widetilde{\Psi}(r)$ at different values of reduced mean-square displacements y_l of molecules (■ – $y_l = 0.3$, ● $y_l = 0.7$, ▲ $y_l = 1.0$).

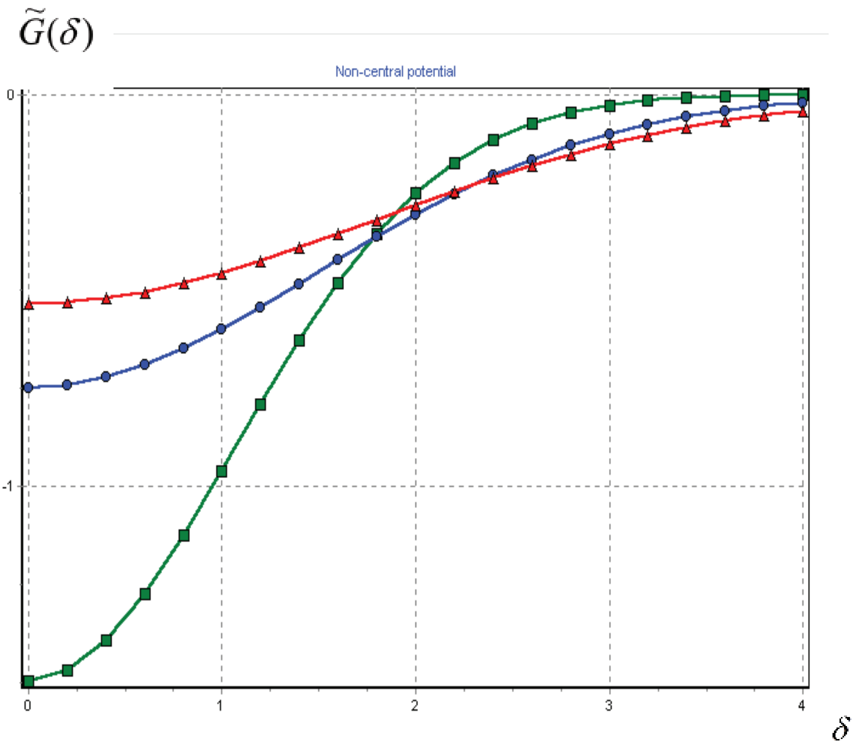


Fig. 6.4. Self-consistent potential of non-central interaction δ at various values of the reduced mean-square displacements y_t of molecules (■ – $y_t = 0$, ● – $y_t = 0.5$, ▲ – $y_t = 0.9$).

Determining self-consistent interaction potentials, we obtain a self-consistent system of equations

$$\frac{2(1-\sigma_2)y_l}{\tau} = \frac{e^{y_l} e^{Q_l}}{B(y_l) + \dfrac{P^*}{6\sigma_1^2 (r/a)^2 e^{y_l}}},$$

$$\frac{0.27 y_t (1-\sigma_2)}{\tau} = \frac{g}{f}\left[\frac{\left(1+2\left(y_t+\widetilde{Q}_t\right)\right)}{\left(\frac{P^*}{12\sigma_1^2}(r/a)^2 + B(y_l)/2e^{-y_l}\right)^{1/2}}\right],$$

(6.9)

$$\sigma_2\xi + \sigma_1 z\left\{\frac{e^{-y_l}e^{\widetilde{Q}_l}}{2}\left[B(y_l) - \frac{P^*}{12\sigma_1^2}\left(\frac{r}{a}\right)^2 e^{y_l}\right]\right\} + \left\{\frac{0.1}{1+2\left(y_t+\widetilde{Q}_t\right)}\exp\left(-\frac{4(z/a)^2}{1+2\left(y_t+\widetilde{Q}_t\right)}\right)\right\} -$$

$$-\tau \ln\left(\frac{(g_2-\sigma_2)\sigma_1}{(g_1-\sigma_1)\sigma_2}\right) = a\left(\sigma_2 - \sigma_2^e\right).$$

Here $\tau = \theta/V_0$ is the reduced temperature, $\xi = \varphi/V_0$, z is the number of neighboring molecules, P^* is the reduced pressure.

Heat capacity C_P and the coefficient of thermal expansion α_T equal

$$C_p = \frac{1}{N}\frac{\partial(E+PV)}{\partial T}\bigg|_p = 3R + \sigma_1^2\frac{\partial\left(\widetilde{\Phi}_1/N\right)}{\partial T} + \sigma_2^2\frac{\partial\left(\widetilde{\Phi}_2/N\right)}{\partial T} +$$

$$+\frac{P}{N}\left(\sigma_1\frac{\partial v_1}{\partial T} + \sigma_2\frac{\partial v_2}{\partial T}\right) +$$

$$+\frac{1}{N}\left\{2\sigma_2\left(\widetilde{\Phi}_1+\widetilde{\Phi}_2\right) - 2\widetilde{\Phi}_1 + P(v_2 - v_1)\right\}\frac{\partial\sigma_2}{\partial T}, \qquad (6.10)$$

$$\alpha_T = \frac{1}{V}\frac{\partial V}{\partial T}\bigg|_p = \frac{N}{V}(v_2 - v_1)\frac{\partial\sigma_2}{\partial T} + \frac{N}{V}\left\{\frac{\partial v_1}{\partial T} + \sigma_2\left(\frac{\partial v_2}{\partial T} - \frac{\partial v_1}{\partial T}\right)\right\}. \qquad (6.11)$$

Where V is a volume of the system, P is a pressure, $v_f = v_{0f} l_f^3$ and v_{0f} is a geometric structural factor. n the liquid water obtained during the melting of ice, the

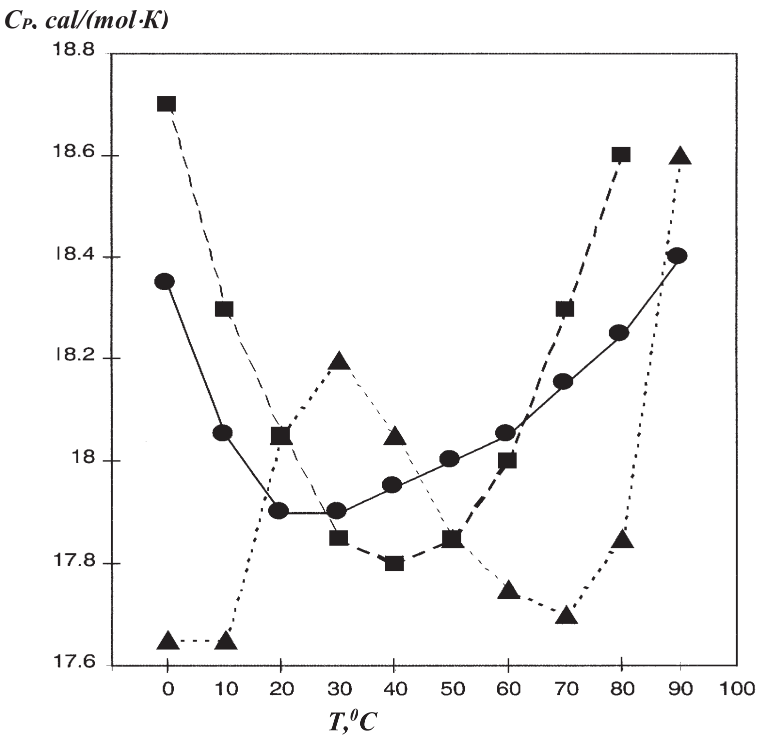


Fig. 6.5. Thermal behavior of heat capacity of structured water (● - experiment, ■ – calculation according to (6.10), ▲ – calculation according to cluster model).

appearance of clusters with highly developed hydrogen bonds alternates with areas where hydrogen bonds are realized partially or completely absent. The alternating regions appear and disappear as a result of local heterophase fluctuations $\sigma_2 > \sigma_2^e$, where σ_2^e corresponds to an equilibrium statistically disordered state.

The results of calculating C_P in accordance with (6.10) are presented in Fig. 6.5 (used parameters (Mar'yan & Szasz, 2000): P^*=0.1, $f=10^5$ *erg ·cm*, $Q_i=0.03\ a$, $a=2.8$ *nm, E=5 kcal/mol*). It is necessary to note the satisfactory coincidence of the experimentally obtained and theoretically calculated thermal temperature dependence of the heat capacity calculated within the framework of the model under study, which

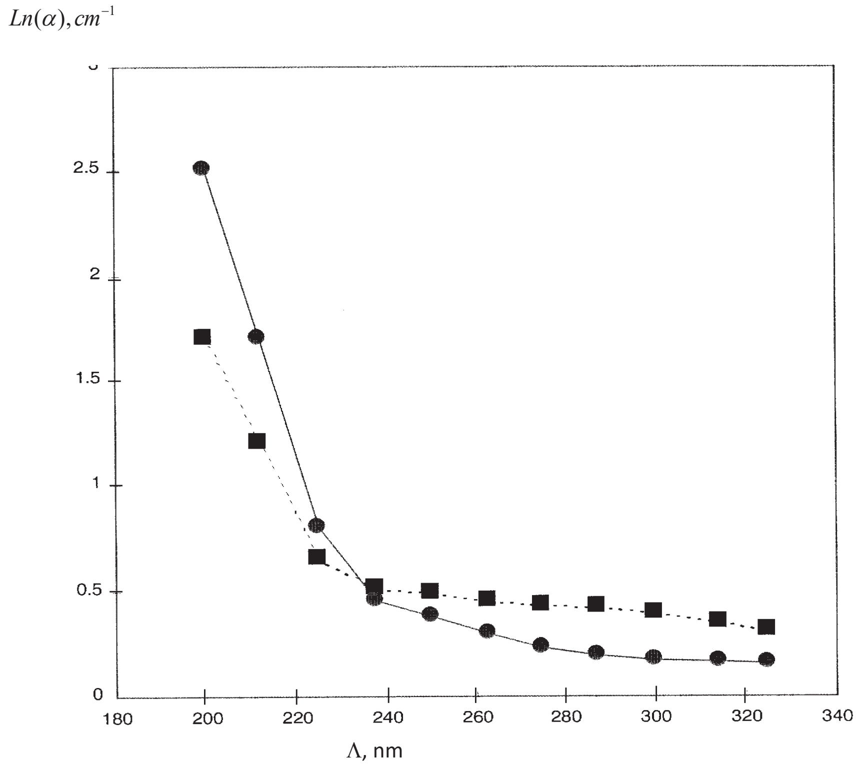


Fig. 6.6. Optical absorption of structured water (room temperature: ● - molten ice → (***type 1***), ■ - after boiling at100^{0}C, followed by cooling to room temperature →(***type 2***).

is obtained within the framework of the cluster concept (Fig. 6.5). Temperature dependence α_T according to the relation (6.11) contains a negative interval of values and agrees with the experimental one.

An experimentally observed structural heterogeneity of water (Fig. 6.6) obtained after melting of ice (***type 1***), and after boiling, followed by cooling to room temperature (***type 2***) along the edge of Urbakh's own absorption in the spectral region

7.5~8.9 eV (***X→D-B** transitions* , dependence *lnα[cm^{-1}]*) from *Λ [nm]* (Mar'yan, Kurik, Kikineshy, Watson & Szasz, 1999). The obtained results confirm the presence of water structuring, that is, the presence of self-organization processes in form self-organized structure. At a fixed temperature $\sigma_2 > \sigma_2^e$, where σ_2^e corresponds to an equilibrium statistically disordered state, there is a relaxation of the ordered state to a thermodynamically equilibrium with a decrease in the structure of water, that is, a decrease in the degree of ordering (Fig. 6.7) (Fig. 6.8 shows the temperature dependence of the difference $\eta_L = \Delta\sigma_2 = \sigma_2 - \sigma_2^e$). This result illustrates the flow of excellent dynamic processes for structured and unstructured water. It should be noted that the most favorable for the processes of self-organization and water structuring is the temperature interval $\approx 15 \div 60\ ^0C$ (Fig. 6.8).

The synergetic approach allows the most adequate description of the structure and phase transformations of structured and non-crystalline solids of inorganic and

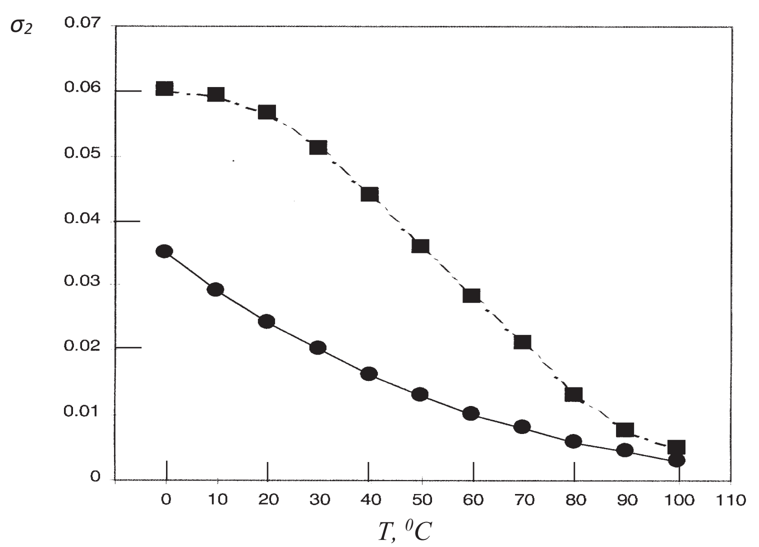


Fig. 6.7. Temperature dependence of the molecular fraction σ_2 : ■ – structured water, ● – unstructured water.

organic origin. This is due in particular to the fact that within the synergistic approach self-consistent and and integral action of all factors, including thermodynamic and kinetic. In the framework of this approach, structured liquids are considered as the

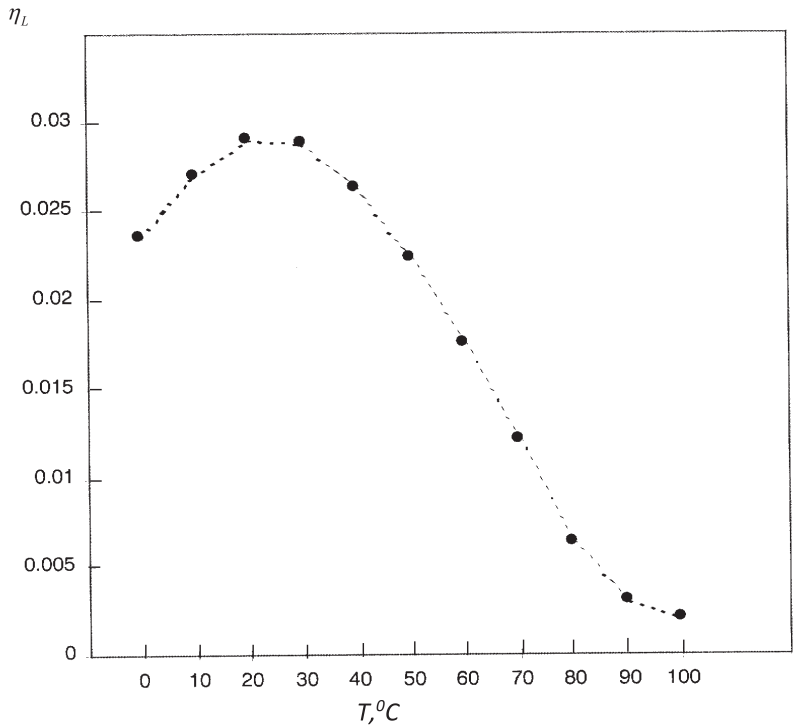


Fig. 6.8. Temperature dependence of the ordering for structuring water.

result of a previous self-organization, during which there is a dissipation of energy and its transformation into other types of energy, in particular, in the way of functional organization of the structure (Mar'yan, Kikineshy, Szendro & Szasz, 2001).

Our study of the structure of water, the processes of sharp climbing and melting of ice, weighing and developing researches carried out in the future in the laboratory Masuro Emoto (Emoto, 2006).

6.3. Structured Water: *Information Characteristics*

The mystery of the water lies in its structure. Water is able to memorize (https://ipress.ua/photo/). Water reacts to human emotions, changing its structure and properties. With the help of special cryogenic chambers in the laboratory of Masuro Emoto (Emoto, 2006), they quickly frozen water, applying to it a certain effect before. The result was all stunned, because photos with water crystals after good and bad words, after calm and heavy music, differed considerably (Fig. 6.9).

Fig. 6.9. Structures of water (Emoto, 2006).

Since scientists hypothesized the existence of memory in water, science has made a huge leap in this area. Today, the structural features of water are used in medicine, biology, physics, chemistry, nanotechnology (Emoto, 2006; Holovatch, 2017; Mar'yan & Yurkovych, 2019). And this is not the limit. Through the study of simple water, humankind opens up new opportunities. Step by step, scientists come to a sensational conclusion: life is a directional information process associated with the unique properties of water.

The special information characteristics of water structuring and the influence of the environment on the processes under consideration are snowflakes. There are at least ***130*** different forms of snowflakes (https://ipress.ua/photo/snizhynky). Such a large number of forms of snow crystals arose due to the complexity and variety of temperature conditions, air and humidity movements in the clouds where they originate, and the change of these conditions in the way of snowflakes to the surface of the earth. During snowfall the shape of snowflakes can change several times; then in the layer of snow of one snowfall it is possible to detect secondary layers associated with changes in falling crystals (Fig. 6.10).

Fig.6.10. Forms of the snowflakes.

Let's return to the synergetic approach of structuring water. Let's analyze hyper sensibility of the self-organized structures in water and self-organizing processes. Under the action of cooling processes at different speeds on the water, under the influence of external noise, processes of self-organization and formation of self-organized structures are possible. Self-organized structures have a hyper sensibility that is related to their informational nature and can be applied to the development of sensory devices and diagnostics, memory effect (Mar'yan, Seben & Yurkovych, 2018; Mar'yan, Yurkovych & Seben, 2019;) (Fig. 6.11).

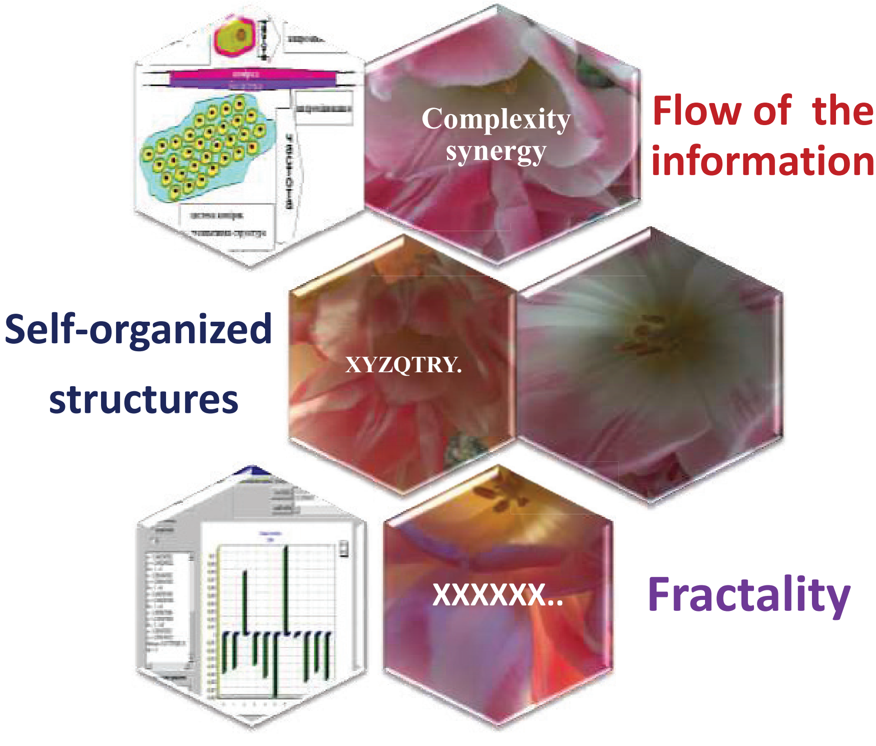


Fig. 6.11. Algorithmic complexity of the information systems for structured water.

Stability of solutions by Lyapunov (Mar'yan & Szasz, 2016)

$$Y_j = Y_{js} + \delta Y_j, \quad \delta Y_j = A_j(t) \cdot e^{ikx + \int_0^t \lambda dt},$$

$$\frac{d}{dq} \lambda(q) \bigg|_{q = q_{\substack{structured \\ water}}} \neq 0$$

λ is the increment of development of self-organized structure.

A condition of transversality and the results of the research of the information component of self-organized structure show that the time of life has a fractal nature. This phenomenon defines and forms an extremely unique feature of self-organized structures. This is hyper sensibility (Fig. 6.12). The table 6.1 shows a time scale hierarchy for a variety of physical processes and processes implemented on the principles of self-organization and integrity.

It is interesting to study the nature of the dependence of the biological effect on the density of the power and frequency of the wave. The dependence of the period of self-organizing structures on the intensity of the irradiation determines the change in the order of magnitude without changing the nature of the structure itself, that is, the energy effect (Fig. 6.9, 6.10). (*This effect can be extremely relevant in the consideration of so-called smart environments, the development of materials of artificial intelligence (Mar'yan & Yurkovych, 2018).*)

The irradiation of bioobjects at certain frequencies of the sound and electromagnetic fields makes it possible to determine the type of functional ordering with given external control parameters. The sound and electromagnetic radiation of a certain frequency $P > P_{\min}$ defines the nature of the self-organizing structure that is formed, and is capable of transferring the open system to the region of structural stability and thus eliminates the generated functioning impairment. Consider functional rearrangement in bioobjects as typical self-organized structures under the action of irradiation of a certain frequency in terms of synergetics (Mar'yan & Yurkovych, 2018). The change in the entropy of the system is determined by the change in entropy within the system $(dS)_i$ and the entropy flow from the external environment $dS)_e$, i.e.

$$dS = (dS)_i + (dS)_e . \tag{6.12}$$

At a certain frequency $\nu < \nu_0$, the stability condition for the system under consideration is performed throughout the range of values of frequencies, and the case corresponds to the absence of a biological effect of influence $P < P_{\min}$, i.e., the formation of a self-organized structure is not observed:

$$\nu = \frac{1}{T} < \nu_0 = \frac{1}{T_0} . \tag{6.13}$$

In $\nu \geq \nu_0$ addition $P > P_{\min}$, there is a transition to a non-uniform regime, which is given by the flow of negative entropy through radiation from the environment and is determined by the spatial domains of ordering L_c and the period in time $T \leq T_0$, conjugate with the lifetime of the self-organized structure.

For

$$\nu \geq \nu_1 = \frac{1}{T_1} > \nu_0 , \tag{6.14}$$

it is possible to perform the inequality $T_1 < T_0$, where the period of time T_1 is connected with the lifetime τ_{life} of the self-organized structure on the basis of clusters of SAC's configurations (Fig. 6.9, 6.10).

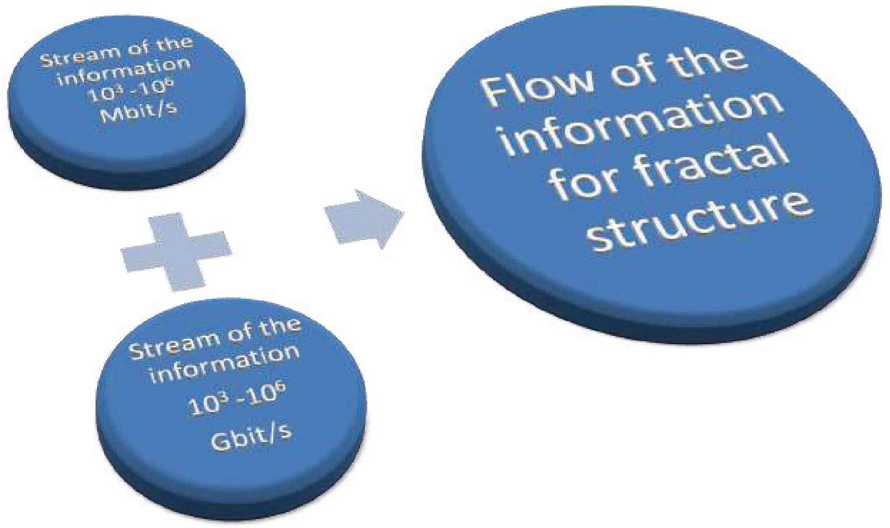


Fig. 6.12. The information flows of fractal structures in structured water.

For comparison, we give the following characteristics. The real data rates and connections used in Wi-Fi technologies are ***150-300 Mbit/s***. This is the maximum speed at the physical level to date. In addition to the quantitative differences, the integrity of the information that directly forms the fractional self-sufficiency of SOISs is extremely important: all that is necessary for functioning is available and provides the same self-sufficient development and distribution in the appropriate space and time. This is a sign of hyper sensibility for the structured water.

Chapter 7

MICRO, NANOLEVELS OF THE STRUCTURING IN NON-CRYSTALLINE SOLIDS: EFFECT OF ELECTROMAGNETIC RADIATION

Everything you can imagine is real.

PABLO PICASSO,
Painter

Nata Popova.
A Complementarity.

7.1. Levels of the Structuring in Non-Crystalline Solids: *Effect of Electromagnetic Radiation*

The model of influence of electromagnetic radiation in the visible spectrum (wavelength irradiation $\Lambda = 0.63 \ mkm$, laser power density $P \le 1 \ W/cm^2$) on the formation of self-organized structures in layers of the non-crystalline materials $As - S(Se)$ systems and its analysis on the basis of experimental research is presented.

In the absence of illumination, separate SAC's configurations N_{20} are statistically uniformly distributed over the sample volume. The case of an electromagnetic field $E(r,t)$ incident normally to the surface of a NCS' layer along the wave axis Z, for which a direction is singled out on the surface $r(x,y)$ of the layer, and the case of an axially symmetric field with a Gaussian distribution along the beam section is considered. The dynamics of the change in the number of atoms in SAC's configurations N_2 and the temperature T under the action of radiation is given by a system of equations (Mar'yan, Seben & Yurkovych, 2018):

$$\frac{\partial N_2}{\partial t} = G - \frac{N_2 - N_{20}}{\tau_{rel}} + D \cdot \nabla^2 N_2 , \qquad (7.1)$$

$$\rho C \frac{\partial T}{\partial t} = div\left(\chi \cdot grad(T)\right) + W(T) - Q(T) , \qquad (7.2)$$

where $G = \gamma P \beta V / \hbar\omega$ is the rate of atoms generation in SAC's configurations (β is a quantum yield; V is a volum of system; $I = I_0 \exp(-\gamma \cdot z)$ is the intensity of the electromagnetic wave; γ is an absorption coefficient; $P = E^2/(s_0 t_p)$ is a density of intensity irradiation ($s_0 = \pi \cdot r_0^2$ is an effective beam cross section, r_0 is an effective beam radius irradiation, t_p is a duration of irradiation); τ_{rel} is a relaxation time to a metastable state; D is a coefficient of diffusion; ρ, C and χ are density, heat capacity and coefficient of thermal conductivity of the material, respectively; $W(T)=\gamma\cdot P$ is the power of the laser heat source; $Q(T)$ is a heat exchange with the surrounding environment.

The spatial variation of the number of atoms in SAC's configurations and the temperature of the system under the influence of radiation affects inversely the width of the quasi-blocked zone E_g and the absorption coefficient of radiation γ. The photoinduced gain of the absorption coefficient $\Delta\gamma$ at the laser absorption frequency ω in the linear approximation is calculated according to the ratio $\gamma(\omega)=\gamma_0+\Delta\gamma$ where γ_0 is an absorption coefficient to irradiation, and is determined by the power of radiation P and structurally sensitive parameters of the NCS' material due to the change N_2, T:

$$\Delta\gamma=\frac{1}{\hbar}\left(\frac{\partial\gamma}{\partial\omega}\right)_s\cdot(\beta_{N_2}(N_2-N_{20})+\beta_T(T-T_0)).$$

Here the coefficients β_{N_2} and β_T take into account the change in the absorption coefficient when the atoms are transferred to the soft configuration and when heated. In the case of significant optical absorption (for chalcogenide glass-like semiconductors of systems $As-S(Se)$ in the visible region of the spectrum $\gamma_0\approx(10^2\div10^3)\ cm^{-1}$) there is an area of values of the wave vector

$$k^2\le k_c^2=\frac{(G_0-G_{\min})}{D\tau_{rel}G_{\min}},\quad G_{\min}=\frac{\gamma_0\hbar}{\tau_{rel}\beta_{N_2}\left(\frac{\partial\gamma}{\partial\omega}\right)_s}\left(1-\frac{\beta_T}{a_T\beta_{N_2}}\right),\quad a_T=\frac{\chi}{\rho C},\qquad(7.3)$$

in which increment of attenuation

$$\lambda(k)=D(k_c^2-k^2)\ge0.$$

This indicates a loss of stability of a homogeneous distribution of atoms in SAC's configurations. As a result, at $G_0 \geq G_{\min}$ a uniform spatial structure of the distribution of atoms in soft configurations in the case of a linear irradiation field or an inhomogeneous radial-ring structure with a number of rays m is formed and becomes stable

$$m = \frac{k_c^2 r_0^2}{4} - 1 = \frac{G_0 - G_{\min}}{4D\tau_{rel} G_{\min}} \cdot r_0^2 - 1$$

in the case of axial symmetry of the field.

The period L_c and time of life τ_{life} of the formed inhomogeneous structure are determined by the relations

$$L_c = 2\pi / k_c = \frac{2\pi}{\sqrt{\frac{(G_0 - G_{\min})}{D\tau_{rel} G_{\min}}}}, \quad \tau_{life} = \left(\frac{(G_0 - G_{\min})}{\tau_{rel} G_{\min}} - D \cdot k^2 \right)^{-1} \qquad (7.4)$$

and depend on the power density of the radiation.

Also, studies on the interaction of electromagnetic radiation with NCS' layers obtained in highly non-equilibrium conditions have been carried out, and the possibility of forming clusters of SAC's configurations has been taken into account. The dynamics of the change in the number of atoms in SAC's configurations and the function of distribution by size x of clusters of soft configurations $g(x,r,t)$ under the action of radiation in this case are given by equations:

$$\frac{\partial N_2}{\partial t} = G - \frac{N_2 - N_{20}}{\tau_{rel}} - 4\pi \int_0^\infty x^2 V(x) g(x,r,t) dx + D \cdot \nabla^2 N_2, \qquad (7.5)$$

$$\frac{\partial g(x,r,t)}{\partial t} = -\frac{\partial}{\partial x}\left[V(x) g(x,r,t)\right] + D(x) \nabla^2 g(x,r,t). \qquad (7.6)$$

Here $D(x)$ is a cluster diffusion coefficient, which is approximated by expression $D(x) = \beta_0 / x^2$, β_0 is the diffusion constant; the growth rate of clusters under the action of electromagnetic radiation is determined by the increase in the number of atoms in soft configurations and is given by the ratio $V(x) = D(N_2 - N_{20})/x$. The dynamics of temperature variation T under the influence of electromagnetic radiation is described by the relation (7.2). It is established at $G_0 \geq G_{\min}$ that where $G_{\min} = \frac{(4\pi N_d \bar{x})^2 \beta_0}{3\tilde{\alpha}_1}$, in a system of randomly distributed clusters of soft configurations under the influence of radiation, a transition to a nonuniform state with the formation of a dissipative structure of the distribution of clusters of soft configurations with a period is possible L_c:

$$L_c = L_0 \sqrt{\frac{G_{\min}}{G_0 - G_{\min}}}, \; L_0 = \frac{2\pi\tilde{\alpha}_1}{N_d \bar{x}\left[1 + \frac{4\pi N_d \bar{x} \beta_0 \beta_T \omega (\partial\gamma/\partial\omega)_s}{3\tilde{\alpha}_1 \gamma_0 \rho C}\right]}, \qquad (7.7)$$

where N_d is the density of defective centers, $\bar{x}$ is the average size of the cluster, $\tilde{\alpha}_0$ and $\tilde{\alpha}_1$ are the coefficients, $\nu = D \cdot (N_{2s} - N_{20})$. A typical time of existence of a self-organized structure

$$\tau_{life} = \left(\frac{\left(3\nu\tilde{\alpha}_1 - (4\pi N_d \bar{x} + \tilde{\alpha}_0)\beta_0\right)^2 + 12\nu\beta_0\tilde{\alpha}_0\tilde{\alpha}_1}{16\pi N_d \bar{x}^3 \beta_0 \tilde{\alpha}_1} \right)^{-1}. \quad (7.8)$$

We analysis of the solution bifurcation and its stability at $G_0 \geq G_{\min}$. The processes of self-organization of the structure induced by electromagnetic radiation induced by the loss of stability of a homogeneous spatial distribution of atoms in soft configurations at an order of magnitude higher than the average order are revealed. At characteristic values of parameters of electromagnetic radiation $He-Ne$-laser (power density of radiation $P = 1 \; mW/cm^2 \div 1 \; W/cm^2$, frequency of radiation $\omega = 3 \cdot 10^{15} \; s^{-1}$, effective radius of the beam $r_0 \approx 0.11 cm$) and parameters of non-crystalline materials of systems $As - S(Se)$ for density of radiation power $G_0 > G_{\min}$, where $G_{\min} \approx 10^{17} \div 10^{18}$ quantum $/(cm^2 \cdot s)$, period of the self-organized structure $L_c \approx (10^{-2} \div 5)mkm$, the lifetime of a self-organized structure, which is formed on the basis of the distribution of soft atomic configurations $\tau_{life} >> 1\ \ s$, but for a self-organized structure based on the distribution of clusters of soft configurations $\tau_{life} \approx (10^{-5} \div 10^{-1})s$ (Fig. 7.1).

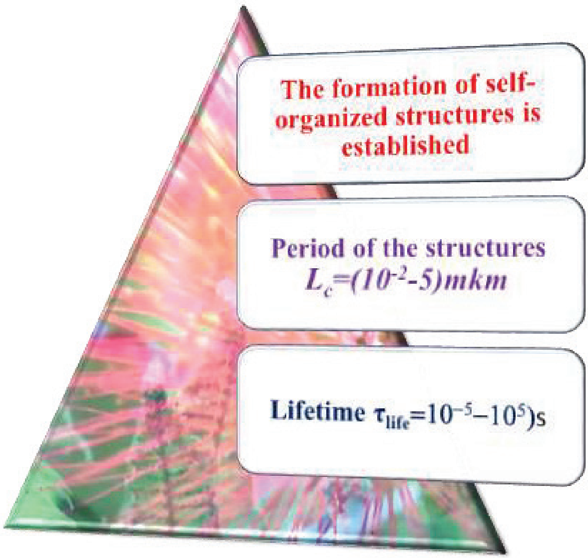


Fig. 7.1. Parameters of the self-organized structures for non-crystalline materials of $As - S(Se)$ system.

The manifestation of the self-organized structures and processes of self-organization in the peculiarities of the behavior of optical and structural-sensitive parameters As_2S_3 was first established. The possibility of a controlled change in the parameters of dissipative structures as a chemical composition and conditions of synthesis, as well as electromagnetic radiation parameters is shown. In particular, photo induced growth of the absorption coefficient in the development of instability has an order $\delta\gamma/\gamma_0 \approx 10^{-3} \div 4\cdot 10^{-2}$. Electron microscopic images of structures that are formed in As_2S_3 under the action of electromagnetic radiation $\lambda = 0.63\ mkm,\ P \leq 1.5\ mW/cm^2$, testify to the presence of heterogeneous structures on spatial scales $(0.5 \div 2.5)\,mkm$. Calculations for the case of axial symmetry of radiation with power density $P = 1.5\ mW/cm^2$ on the layers As_2S_3 determine the number of rays of the radial-ring structure $m = 34$ period of structure $L_c \approx 1.2\ mkm$ which correlates with the experimental data.

7.2. Temperature Instability and Formation of Self-Organized Structures

Analyze the model of thermal instability and the formation of NCS' self-organized structures under the action of continuous infrared radiation (wavelength $\Lambda = 10.6\ mkm$, power $\mathrm{P} = (3 \div 5)\ \mathrm{W/cm^2}$, exposure duration $t_p = (1 \div 30)\ s$) on amorphous condensates of the system $Ge - As - Te$ and its comparison with experimental data.

Radiation with Gaussian distribution along the beam section falls normally to the surface of the layer along the axis z and is completely absorbed in the volume of the substrate. The dynamics of temperature change T on the surface with an amorphous layer and in a substrate, which is described by a system of nonlinear differential equations taking into account the processes of heat generation, its propagation and heat transfer for the substrate and thin film amorphous layer, is considered.:

$$\rho C \frac{\partial T}{\partial t} = div(\chi gradT) + W(T) - Q(T), \tag{7.9}$$

$$\rho_a C_a \frac{\partial T}{\partial t} = div(\chi_a gradT) + Q(T) - Q_a(T).$$

Here c, ρ and χ are heat capacity, density and conductivity of the substrate, respectively; $W(T)=\gamma UP\exp(-\gamma z)f(t)$ is a laser heat source; $\gamma=\gamma_0\exp\{-\alpha_a T_a/T\}$ is an absorption coefficient, α_a and T_a are parameters of the absorption capacity of the substrate; U is optical transmission of the amorphous layer at the wavelength $\Lambda=10.6mkm$; $f(t)=1$ for $t\le t_p$ and $f(t)=0$ for $t>t_p$; $Q(T)=\int_{T_0}^{T}\eta_h(T)\frac{s_0}{V}dT=\eta_h(T-T_0)/d_\gamma$ is the heat exchange with amorphous layer (η_h is a heat transfer constant, T_0 is a temperature before irradiation, $V=s_0 d_\gamma$ is an effective volume of absorption radiation, d_γ is an effective depth of radiation penetration in the substrate); C_a, ρ_a and χ_a are heat capacity, density and thermal conductivity of the amorphous layer, respectively; $Q_a(T)=L_a\rho_a f_a$ is the amount of heat absorbed by the crystallization of the amorphous layer, L_a is is the caloric of crystallization, $f_a=\upsilon\exp(-\upsilon\cdot t_p)$ is the proportion of crystallized volume per unit of time, which is determined by the Johnson-Mel-Abraham equation, $\upsilon=\upsilon_0\exp(E_a/k_BT)$, E_a is the activation energy of crystallization.

The depth of radiation penetration d_γ into the quartz or mica substrate at the wavelength $\Lambda=10.6\ mkm$ is a magnitude $d_\gamma\le 1\ mkm$, while the thermal front extends over the entire depth of the substrate $d\approx 10^3 mkm >> d_\gamma$ and through heat transfer to an amorphous layer. It is shown that the uniform distribution of the temperature field along the beam cross section at the power density of the radiation

$$P>P_c\ ,\ P_c=\frac{U\tilde{p}_c}{\eta_h T_a},\quad \tilde{p}_c=\frac{\Phi_s^2}{\alpha_a}\exp\{\alpha_a/\Phi_s\},\ \Phi_s=\frac{T_s}{T_a} \qquad (7.10)$$

becomes unstable and forms a structure with a spatially inhomogeneous profile of the temperature field. The characteristic spatial scale of heterogeneity L_c and the number of rays, which is determined by the dissipative structure formed, are equal

$$L_c / r_0 = 2\pi / k_c = 2\pi \big/ \sqrt{\varepsilon / \widetilde{k}}\ , \ m = (k_c^2 r_0^2 - 1)/4 \tag{7.11}$$

and depend on $\widetilde{p}$

$$\varepsilon = \left(\widetilde{p} - \widetilde{p}_c\right) / \widetilde{p}_c\ , \qquad \widetilde{k} = \frac{\chi \cdot d_\gamma}{\eta_h r_0^2}\ . \tag{7.12}$$

The structural changes in the layer that occur during irradiation are recorded due to a change in the optical density D in the visible region of the spectrum $\Lambda = 0.63\ mkm$. For a given radiation power at minor exposures, there is a repetition of the spatial profile of a beam with a continuous increase D in the center. With growth t_p, the optical density begins to decrease D, and then grows again, going to saturation. It was found that stabilization of thermal instability is carried out at the expense of self-regulating mechanisms, which lead to saturation of non-linear absorption and equalization of the growth rate of the absorbed energy and heat dissipation. The bifurcation diagram of the temperature dependence of the material on the radiation power is considered, which explains the nonmonotonic behavior of the optical density of amorphous condensates $Ge - As - Te$ and allows us to determine the threshold of laser radiation exposure. At $P > P_c = (7.6 \div 8.5) W / cm^2$ (intensity $I = 0.3\ W$, effective radius of the beam $r_0 = 0.11\ cm$), threshold duration of irradiation, at which develops instability, order $(0.35 \div 0.4)\ s$, which corresponds to exposures in the range of nonmonotonic behavior D. Characteristic values of the spatial scale of the heterogeneity of the temperature profile $L_c \approx (0.3 \div 0.5) \cdot r_0$, the lifetime of the self-organized structure $\tau_{life} \approx (10^{-2} \div 10^{-1}) s$, which is consistent with the experimental data. The radial-ring structure with the number of rays $m \geq 3$ is formed at the density of IR radiation power $P \geq 18.6\ W / cm^2$.

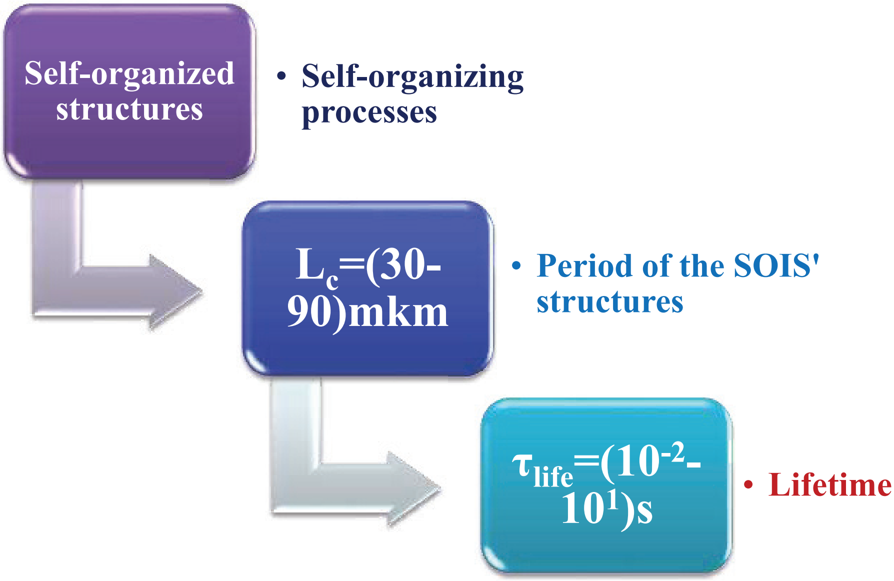


Fig. 7.2. Parameters of the self-organized structures for non-crystalline materials of the $Ge-As-Te$ system.

7.3. Photo Induced Transformations of the Non-Crystalline Materials and Information Technology

The results obtained are used (Fig. 7.3):

- *for obtaining and interpreting the physical properties of non-crystalline solids of systems* $As-S(Se)$, $Ge-As-Te(Se)$, $Ge-S(Se)$ *obtained by cooling from a melt with different temperatures of synthesis and cooling rates;*
- *to create devices for optical recording and information processing based on non-crystalline materials systems As-S(Se), Ge-S(Se,Te), Ge-As-Te(Se);*
- *investigations of photo induced transformations and the formation of one-dimensional and radial-ring heterogeneous structures can be applied for the*

development of environments for recording information, touch devices with the time of switching order $(10^{-6} \div 10^{-9})s$ *;*

- *Development of recording environments based on amorphous condensates of Ge-As-Te, Ge-Te, As-S systems, has an applied interest in connection with the problems of laser radiation diagnostics, the ability to create archival memory and video discs based on them (Fig. 7.3).*

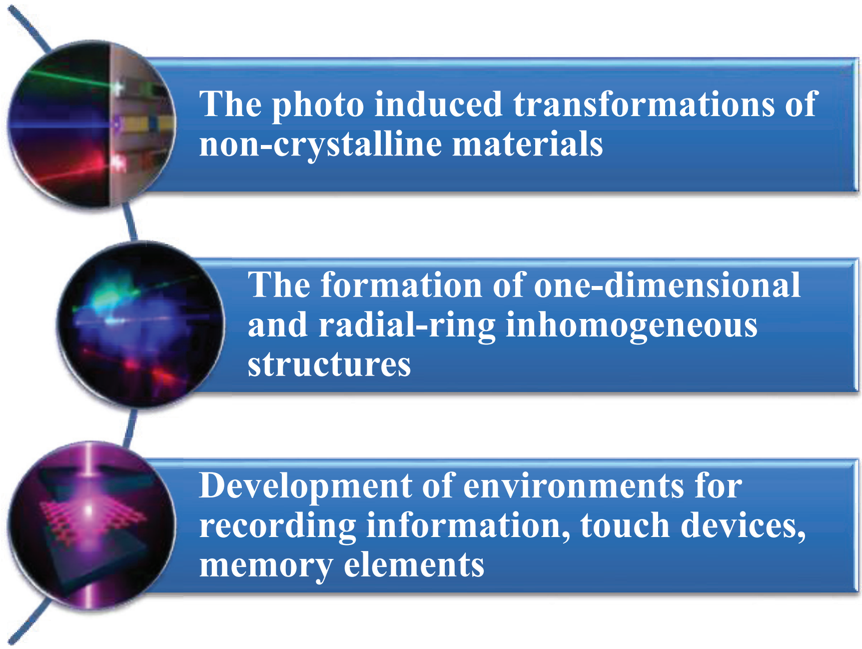


Fig. 7.3. The practical application of photo induced transformations and the formation of self-organized structures in NCS' materials.

The correlation of the frequency of electromagnetic radiation with the lifetime of self-organized structures has been established (Fig. 7.4), the existence of bifurcation at selected frequencies has practical significance in the study of radiation action on bioobjects (Mar'yan & Yurkovych, 2019).

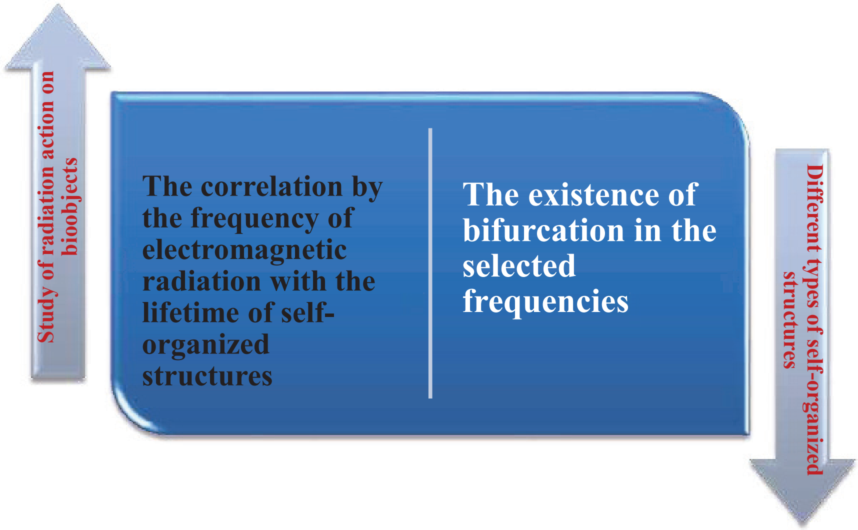


Fig. 7.4. Investigation of the radiation action on biobjects.

The vast majority of the processes of ordering in bioobjects are extremely complex and varied, which results in the absence of a universal theory that would be fair in all areas of their functioning (Mar'yan & Szasz, 2000; Mar'yan & Szasz, 2016). In such a situation, it turned out to be effective to use the results obtained from the consideration of less complex processes in adjacent areas, in particular, in the study of physico-chemical processes in non-crystalline systems, followed by their application in biological objects. An example can be obtained from the results of the study of the interaction of laser irradiation with non-crystalline materials and structures on their basis.

The irradiation of bioobjects at certain frequencies makes it possible to determine the type of functional ordering with given external control parameters. Electromagnetic radiation of a certain frequency $P > P_{\min}$ defines the nature of the self-organizing structure that is formed, and is capable of transferring the open system to the region of structural stability and thus eliminates the generated functioning impairment (Mar’yan & Yurkovych, 2019).

Chapter 8

SYNERGETICS RANDOMNESS & INSTABILITY: PATH TO INFORMATION

The flight of ideas is the same reality as the wind, like the flight of a bird.

RICHARD D. BACH, Writer

Nata Popova. The Labyrinth.

8.1. Effect of White Noise: *Bifurcation and Attractors*

The study of the influence of cooling velocity fluctuations in the approximation of white noise on the formation of self-organized structures in non-crystalline solids of the system are given $As-S$. The external random temperature field is given by changing the cooling rate

$$q_t = q + \sigma_{\xi}\xi_t, \tag{8.1}$$

where q is an average value of the cooling rate (corresponds to the deterministic case), ξ_t is a random external fluctuating field, σ_{ξ} is the intensity of the external noise. As a parameter of order $\eta_{\sigma}(r,t)$ the system uses a relative change in the temperature of loss of dynamic stability

$$\eta_{\sigma} = {(T_m - T_{sg})}/{T_m}, \quad 0 \le \eta_{\sigma} \le 1, \tag{8.2}$$

which is directly determined experimentally: for the crystals $T_{sg} = T_m$, for the non-crystalline materials $T_{sg} = T_{sg}(q)$ and decreases with growth q. The stochastic differential equation (SDE) in the Stratonovich's interpretation when taking into account the external noise is presented in the form (Shuster, 2016; Mar'yan & Yurkovych, 2019):

$$d\eta_{\sigma}(t) = \left(\lambda\eta_{\sigma} + \gamma\eta_{\sigma}^{2} - \beta\eta_{\sigma}^{3}\right)dt + \tilde{\sigma}_{\xi}\eta_{\sigma}dW_t. \tag{8.3}$$

Here $dW_t = \xi_t dt$ is an increment of random of magnitude ξ_t, $\tilde{\sigma}_{\xi} = \sigma_{\xi}/q_c$ is a reduced the intensity of the external noise,

$$\lambda = a\tilde{q}, \quad \tilde{q} = {(q - q_c)}/{q_c}, \tag{8.4}$$

γ, β are parameters of system. The threshold values $\sigma_{\xi c}$ for the intensity of the white noise of the cooling rate $\sigma_{\xi} < \sigma_{\xi c} = 3 \cdot 10^{-3}(K/s)$, under which the structural characteristics of the non-crystalline materials are insensitive to the change in the conditions for their obtaining are determined and the formation of self-organized structures induced by noise at certain noise intensities $\sigma_{\xi} \geq \sigma_{\xi c}$ is provided (Fig. 8.1). From the nature of the density distribution function $\Re_s(\eta_\sigma)$ of the relative change in the temperature of the loss of dynamic stability, it was found that the transition in the state NCS can be called, maintaining a constant cooling rate, but increasing the intensity of the fluctuations of the external temperature field more than the threshold value $\sigma_{\xi} \geq \sigma_{\xi c}$.

The extremes of stationary densities $\Re_s(\eta_\sigma)$ correspond to macroscopic stationary states of the system (crystalline and non-crystalline states), and qualitative change of the species $\Re_s(\eta_\sigma)$, depending on the cooling rate and the intensity of noise, acts as a transition indicator. External noise causes expansion and spill δ-like distortion peaks of distribution functions $\Re(\eta_\sigma, t)$ that are characteristic of the crystalline state. The presence of noise-induced transition is shown, which is the shift of the deterministic bifurcation diagram of the dependence of the relative change in the temperature of the loss of dynamic resistance from the cooling rate.

The results of the study of the influence of the random temperature field upon cooling As_2S_3 in the air on the structural-sensitive parameters are presented (the random field was determined by the change in the airflow intensity during cooling (Mar'yan & Yurkovych, 2019)). So, when cooling at a speed

$$q = 1.5 \cdot 10^{-2} K/s \text{ at } q_c = 5 \cdot 10^{-3} \ K/s, \ \tilde{q} = {(q - q_c)}/{q_c} = 2$$

threshold noise intensity order $\sigma_{\xi c} = 3 \cdot 10^{-3} (K/s)$; in the absence of external noise, the softening temperature $T_g = 447 \ K$ and in the presence of noise with intensity $\sigma_{\xi} = 8 \cdot 10^{-3} K/s$ – $\Delta T_g = {(T_g - T_{g\xi})}/{T_g} \approx 1.5 \ \%$ which is consistent with the theoretical calculations of the influence of the random temperature field on the dynamic stability.

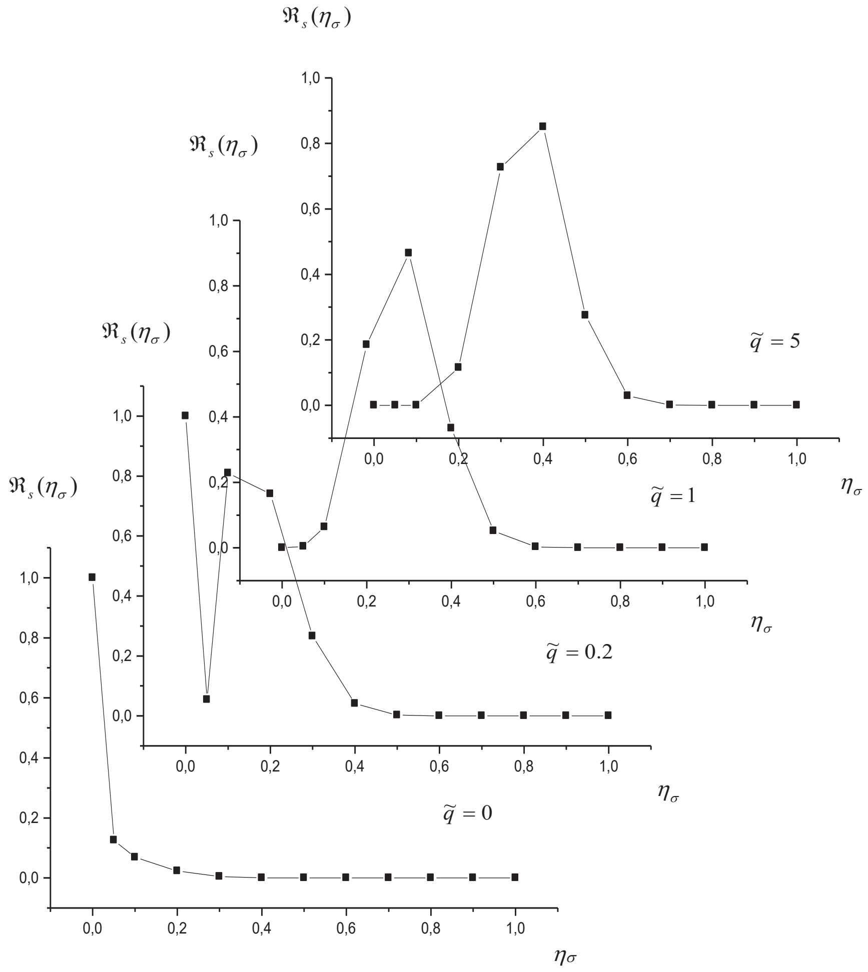


Fig. 8.1. Dependence of the stationary density of the distribution function $\Re_s(\eta_\sigma)$ from the relative change in the temperature of loss of dynamic stability η_σ at various reduced cooling speeds $\widetilde{q}$ ($\sigma_\xi = 0.5 \cdot 10^{-2} (K/s)$).

8.2. Randomness & Instability: *Synergetic of Path to Information*

The critical values of the fluctuations of parameters are determined, in which the structural characteristics of non-crystalline materials when cooled in a random temperature field are insensitive to changing the conditions for their obtaining, which identifies their use as stable materials for optical elements, memory elements, and recording media (Adam & Zhang, 2014; Mar'yan & Yurkovych, 2019).

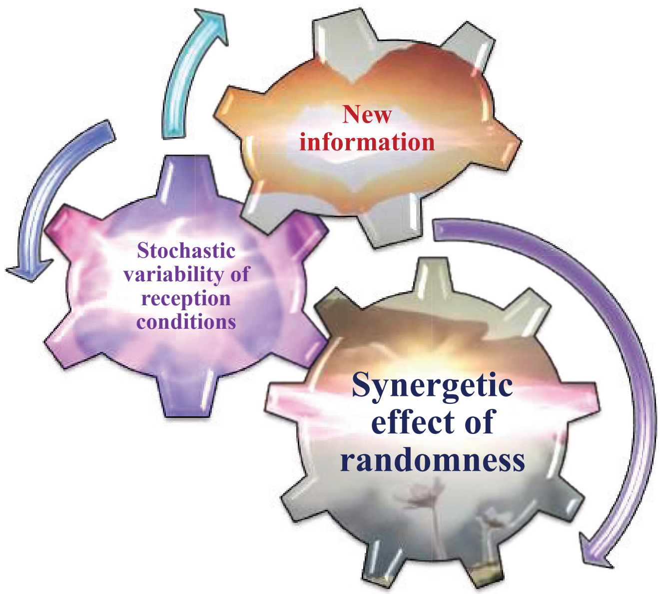


Fig. 8.2. Synergetic effect of the instabilities and randomness.

Synergetics considers randomness as a manifestation of the absence or blocking of information flows, the imperfection of information & communication systems, the use of inadequate interpretations. That is, at restoring of information streams the chance and randomness can be transformed, and manifest themselves in a new context for a coherent structure (Fig. 8.2). This, as in the well-known fairy tale of Gans Khristian Andersen "The Ugly Duckling", a nasty duckling resets of imposed on the outside of the interpretation, restores main nature and turns into an amazing swan.

Instability and randomness for the information & communication systems can play and play a constructive role by the presence of processes of self-organization. Here it becomes important to use the movement to self-sufficiency and integrity as control of the intensity and character of the randomness of external influence. That is, it is not destructive, chaotic processes, but rather a much higher level of structuring is realized. It is self-sufficiency and integrity that is the new product, the manifestation of information that is being formed (Fig. 8.2). This is the only unique and phenomenal property of information that the synergetics of instability and randomness manifests the common nature of the formation of self-organized structures for non-crystalline solids and information & communication systems.

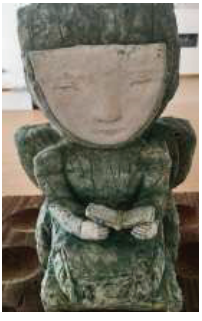
A famous quote by John W. O. Lennon, founder of the British rock band “The Beatles” and one of the most influential musicians of the 20th century - "*Life is what side by side when you make plans*". That is, an integrated information environment that contains and realizes all the possibilities (mostly fundamentally different from plan making) is right next door. It can become one whole and integrated with life, plans, projects. But for this it is necessary to restore the integrity of life and to be informationally united with it.

Chapter 9

SYNERGETICS OF INFORMATION & COMMUNICATION SYSTEMS

Education is what remains after one has forgotten what one has learned in school.

ALBERT EINSTEIN,
Nobel Prize Laureate



Nata Popova.
The Education.

9.1. Intellectualization of Multimedia Information & Self-Organizing Systems

Intellectualization of information & communication systems involves and determines the integral presence of information at all levels; information is creative and capable of transformation (Fig. 9.1).

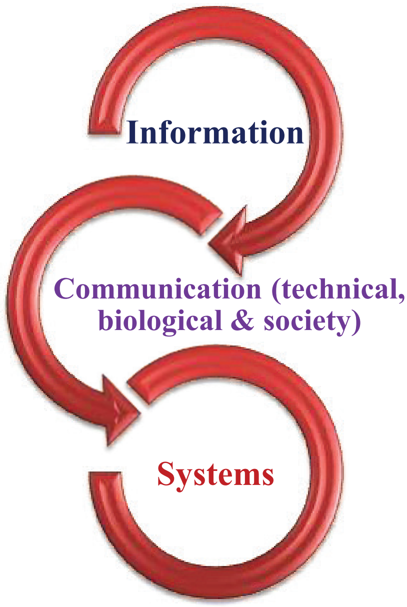


Fig. 9.1. Intellectualization of the information & communication systems.

The reader (student, professor) is able to seamlessly, without dissipative see himself. It is a kind of reflection of what is real (like it or not, it is the ability to perceive outside the emotionally imposed, grounded, but still unrealistic). It is a way of opportunities and changes. To see the content, the essence of this reflection is already positive. How will the reflection be realized? Everyone will see himself (or a part of himself) that can become whole (and is whole, real). Where exactly and what you see - it's unique, original, intimate. In this, the main content of the book - not to impose (neither myself nor the other). Develop yourself through reflection (without discussion, through awareness). This path also applies to the formation of financial flows, the restoration of the environment, the restoration of the nature of information and energy.

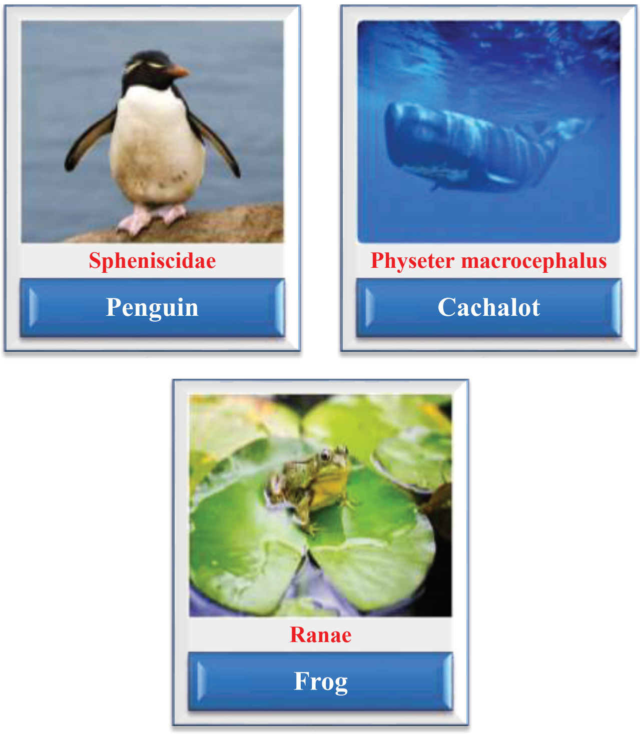


Fig. 9.2. Examples of the self-organized structures: ***Penguin, Cachalot,*** and ***Frog***.

What is common to the self-organized structures presented on Fig. 9.2? Shared is information. The information has changed its structure and surrounding the information environment. How to perceive the surrounding information environment ***Penguin, Cachalot,*** and ***Frog*** ? What is given in the course of biology, this is only "imprint" of information. However, ***Penguin, Cachalot,*** and ***Frog*** have an unique information structure.

Penguins is the family of non-flying seabirds living in the open sea of the southern hemisphere. The imperial penguin survives in the harsh conditions of the long Antarctic winter, when the temperature drops to -60 ° C, and the wind speed can reach 200 km / h. The heart rate is the slowest of all animals - during immersion it is only 4-8 beats per minute.

Known unique ability of ***Cachalot*** to super-deep dives. He dives deeper than any other animal breathing air. Depth of cachalot is 400 to 2000 m. The whale's body is well adapted for such dives due to a number of features. The colossal pressure of water at the bottom does not damage the whale, because its body to a large extent consists of fat and other liquids, not compressive pressure. In the body of the cachalot does not accumulate an excess of nitrogen that occurs in all other living creatures when immersed at a great depth. In addition, the blood plasma of sperm whale has an increased ability to dissolve nitrogen, not allowing this gas to form microbubbles.

Frogs, living in a cold climate, have an interesting feature - they can freeze in water bodies, in fact completely freezing in the ice. When the ice melts, the frog comes to life and is a normal way of life (https://ozro.ru/uk/animal).

The ***Cachalot*** whale does not need to create a bathyscaphe or similar submersible chambers at depths of 1500-2000 m. It owns and operates using an information structure that enables it to be easily and without dissipative used not only by means of immersion in the depths of the ocean (which are fundamentally different from those created by man), but also to be one with the ocean, with nature. So does the frog - 100% recovery of the body after 100% freezing. This is only due to the availability of information. Nano, pico effects “to see” are possible not only with the use of paramagnetic electron resonance, infrared spectroscopy or other equipment. It is capable of "making" a direct and without dissipative the self-organized structure that has a corresponding informational nature and really perceives nano, pico, femto effects as itself - information.

A person is able to change and develop his informational structure in the modern information society, which is extremely important, to change the surrounding information & communication environment, bringing and restoring full and integral functioning. Copying and mechanically creating prototypes of behavior and functioning (as, for example, mastering the dance rhythms of frogs and penguins, studying the effect of cooling on the state of cells, the effect of the depth of immersion on nitrogen disease, etc.) without changing the information structure is the way to lose its own information structure. As quoted by film-maker Quentin Tarantino, *"And at the beginning of the road, few believed in us, was not it?"* (Chapter 6). Faith, confidence is information, awareness, a new level of functioning of a modern person. This is followed for movement and development processes by B. Gates' (Gates, 2008), R. Kiyosaki's (Kiyosaki, 2013), B. Williams' (Gregory-Williams & Williams, 2008), and many others. As also cited in the quote by Nobel Prize Laureate Albert Einstein "*Education is what remains after one has forgotten what one has learned in school"* (Chapter 9). That is, real education is possible, which is restored and based on information (Fig. 9.3).

There are classical types of computer simulation - mathematical, physical, analog, conceptual, cybernetic, and so on. The following types of simulation highlight certain aspects of abstraction and indirect operation of the object. Combined use of a mixture of types of modeling brings both the detail of an object and, at the same time, the distortion of real information due to the lack of integrity.

We have proposed and tested a fractal approach to the teaching of natural sciences using object-oriented modeling. This approach is illustrated by an example of the Archimedes' law (Fig. 9.3). The teaching of the classical Archimedes' law in physics lectures is based on the assertion that the body, immersed in water, has a pushing force directed vertically upwards and equal to the force of the weight of the displaced water. One can cite the historical facts of the invention of this law (which is precisely the confirmation of the genius and spontaneity of the functioning of information reality).

Archimedes' force is generated, manifested historically by the lack of trust in sellers of gold products (or, that identical, by the lack of information, no knowledge, facts, circumstance about gold products, as usually interpret information, namely **information**). The use of the level of "facts, circumstance" and their interpretation indicates a lack of access to information and the involvement of a probabilistic approach to the study of the environment and the formation of an appropriate information space-time continuum. That is, it does not mean that information is absent at all and is only provided through interpretation (which actually removes access to information). This is just one of the most commonly used and distributed in this information environment of the society of options for "development".

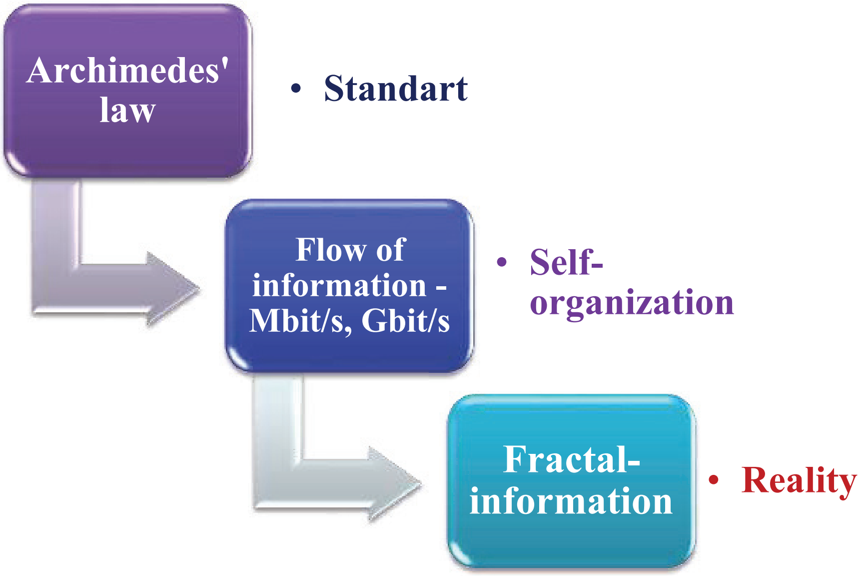


Fig. 9.3. Changing of the information reality.

As for Archimedes' force, it is realized in a variety of structured environments (that differing not only by mass but by the degree of inertia). But in the presence of information (integrity and absence of separation), this force (like other forces that, strangely enough, are created from primary sources by the information itself) is transformed and becomes what it really is - information. That is, information is force, power, and vice versa, force is information. (As in Hans Christian Anderson's famous tale, "The Ugly Duckling" - the ugly duckling is transformed into a wonderful swan.

But at the same time, both the "duckling" and the world (reality) around it, and the principles of functioning are transformed). Therefore, probabilistic environments (regular and substantiated at the "contemporary" stage of society's development) are more likely an exception rather than regularity - information. In information environments, force (information) loses its attachment to the name of Archimedes, while maintaining its uniqueness and originality (origin) and simply is, maintaining and exhibiting self-sufficiency and integrity.

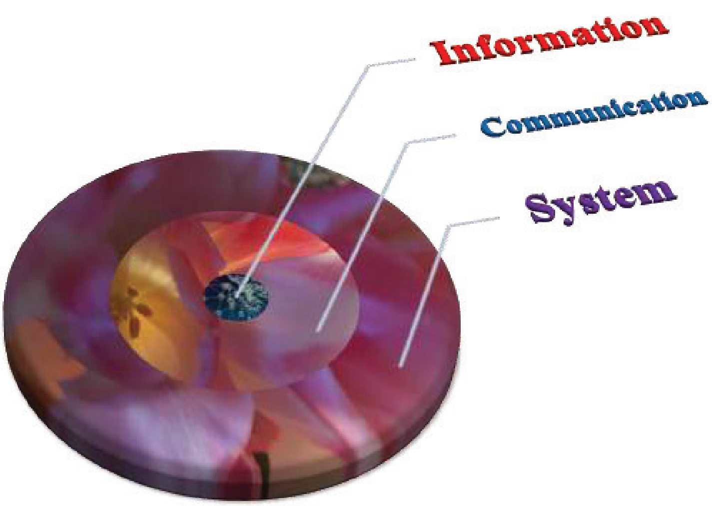


Fig. 9. 4. Transformation by the information & communication system.

All the beauty lies in the fact that the standard perception and teaching of this and other laws, their mathematical abstraction is only the possibility of access to real information that is present in the immediate vicinity (Fig. 9.3, 9.4). Within the framework of the OOM, the use of the principles of encapsulation, inheritance and polymorphism makes it possible to combine description and action (encapsulation), create a hierarchy and a network of new information objects (inheritance) and environments (polymorphisms). That is, the new information media of the functioning of this law are possible (pushing out, attraction in social networks, societies, conferences, communities, and so on). Here, similar common informational laws are manifested (the body of inertia acts as a body weight - the mass, stereotypes of behavior, the directions of the applied force are also modified and more diverse). These are already other reflexive streams of information that can be controlled, adapted, and engaging for the information development of society. (To some extent it is used in advertising, shows, cinematograph, and the like). That is, when the tandem - "student & teacher" - will see the real power of laws directly in the environment surrounding their information environment (not tomorrow or somewhere spatially remotely, but directly, at lectures at a university or a laboratory at a computer), and a real opportunity to influence, determine their functioning - it will already be access and the ability to form a new intelligent ecology, a new intelligent education, a new intelligent economy. This is already a step towards fractal perception of information - reality.

9.2. Synergetics of Science, Information Technology and Society: *New Concepts of Development*

For information & communication systems, information flows are formed, adapted, synchronized at the level of the subconscious. Here there are systems of processing and transmission of information, selection, protection, storage. Visual, textual, tactile, audio, mental processing of information is carried out. These systems are structured, have a certain time of life (resistance to changes in the environment of information environment), the ability to develop. The integrity of the perception of information is formed through awareness and transformation of the subconscious. It is in this that there is a colossal reserve of development and restoration of information reality. As stated in a well-known quote from one of the founders of psychoanalysis Sigmund Freud *"We do not by chance choose one another ... We meet only those who already exist in our subconscious"* (Chapter 5). The distribution of this monograph in the Internet and other information systems is also associated with the influence on the collective subconscious and the ability to develop the concepts and methods set out in it through conscious perception of readers, **IT**, **SF**'s fractality, and so on. This is a journey of awareness, which contains "known", acceptable in the information environment, and radically new; at first glance, excluding the present, but the previous one and creating an unexpected, but logical one. In fact, this is a step towards rebuilding and the ability to create a new level of information perception - the qubit, fractal level. As well as stressed in the quote by writer Agatha Christie "*Being part of what you do not understand is the most amazing feature of this life*" (Preface).

This approach is also present in the teaching of natural sciences (Yurkovych, Seben & Mar'yan, 2017; Mar'yan & Yurkovych, 2019) (Fig. 9.5).

Fig. 9.5. The development of the fractal structure in the education.

There is an analogy with the rapidly developing telecommunication technologies and means of disseminating information. The transition of the ***3G, 4G, 5G, ...*** is not a mechanical increase in the volume of information flows (which is also significant), but also the implementation of fundamentally new concepts, approaches at each stage (Fig. 9.6). At the same time, it is high-quality and spontaneously manifested in the impossibility of reproduction and realization of the new through mechanical appeal to the previous one: an ancestor is already present in a descendant who has implemented a completely new property or action (this is one of the basic principles of the OOP's programming).

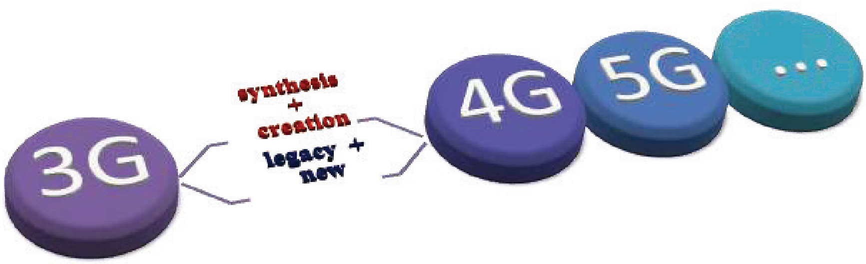


Fig. 9.6. Features from the telecommunication means of information dissemination.

The transition of ***3G, 4G***, ***5G***… is not only an increase in the speed and volume of information transfer, a radical reformat and ways of presenting the information itself, but above all, a change in the interaction between the operator (source of information) and the client (user), the teacher and the student. In doing so, the distance (separation) and all the accumulated valid attributes that serve it are leveled. Everything becomes one whole - the user (student) receives the properties and functions of the information source, information (source) fills the entire space-time continuum. (The same applies to the dissemination of information in structured liquids (chapter 6), in quantized information systems - information integrity, causation, Bose-Einstein condensation (chapter 5)).

As part of the fractal approach to education, this is also primarily a mechanical combination of disciplines, historical facts, static volumes of information, and the restoration of natural harmony and correlation, reproduction of a coherent picture (Fig. 9.5). Again, if you look at the quote from Albert Einstein, "*Education is what is left after one has forgotten what one has learned in school*". Modern telecommunication means is a symbiosis of science, education and information technologies (similar to the phenomenon of the Silicon Valley that is developing and spreading to the present day).

The formation of a holistic structure for perception of information from the use of the computer OOM and HOOM is achieved not only by the study of the laws of nature, the preparation of tests and examinations, but and above all the release of slags, prints, stereotypes, that is, cleansing the subconscious, access to the intuitive level (Fig. 9.5, 9.7) and a conscious perception of reality, motivation for the needs of society without their being substantiated by forced tyranny. It is the formation of a self-organized fractal structure that has an individual character, manifested through the directions of distribution and development, the attraction of the environment and its enormity, and the ability to transform. Everything that constrains and creates problems for a "closed" system here is fractal and spontaneously disclosed in the new interface and wonder. Ecology, education, science, information technology is first and foremost the ability to directly see, perceive the information, and the next step - to move, to create new levels of structuring in accordance with the information received without destroying its informational nature.

The basis of self-organized structures is information. The minimum of energy dissipation, openness of the system, periods of structuring, lifetime (which is mostly emphasized by scientists) is a product, a manifestation of information. In the presence of information integrity (and information can be and is only integral), it forms the same integral structure without dissipative, unique, capable of filling and creating a new continuum of space-time - the flow of energy and information.

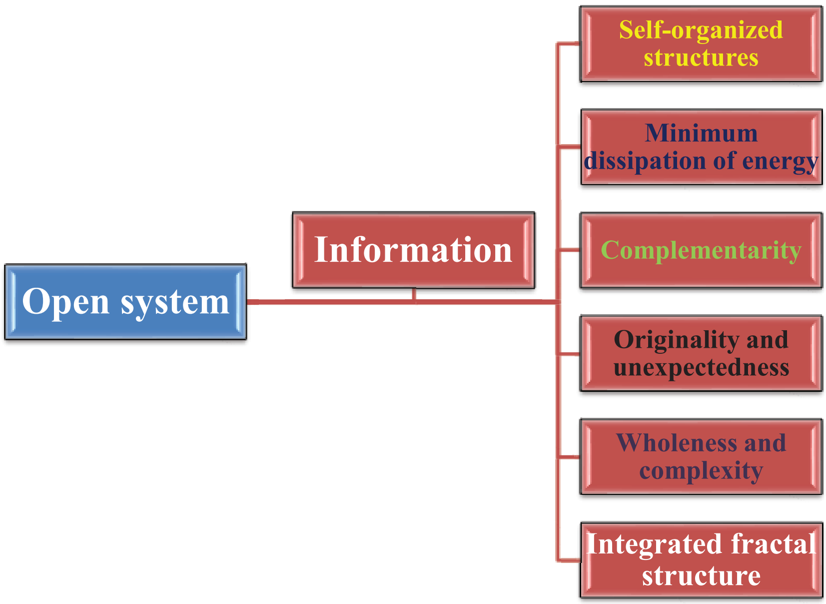


Fig. 9.7. Formation of the integrated fractal structure in education.

Chapter 10

MICRO, NANO, PICO, FEMTO: LEVELS OF THE STRUCTURING IN THE INFORMATION SYSTEMS

If you have an idea and I have an idea and we are sharing these ideas, then everyone will have two ideas.

BERNARD SHOW,
Writer

Nata Popova.
The Singleness.

10.1. The Ordering Levels of Self-Organized Structures: *the Non-Crystalline and Intelligent Systems*

What information do we get from research? What structures and corresponding spatio-temporal measurements are capable of identifying these scientific researches? Classical among modern scientific researches are the nuclear magnetic resonance spectroscopy, paramagnetic electron resonance, infrared spectroscopy (Fig. 10.1, Table 10.1). The following scientific directions determine the unique hierarchy of time scales and their corresponding processes. This is usually a breakthrough in obtaining information about the environment and the person who can perceive this information. But this information, reduced to ***bit, Mbit, Gbit***-information, still does not have integrity, that is, it is only a reflection of real information.

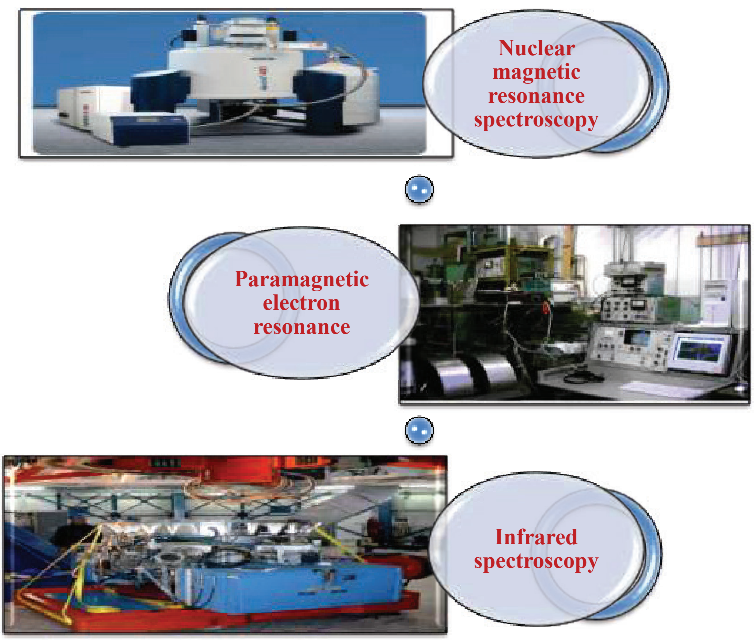


Fig.10.1. The modern scientific researches: nuclear magnetic resonance spectroscopy, paramagnetic electron resonance, infrared spectroscopy.

Table 10.1. Hierarchy of the time-based.

Time of the experiment	$t_{exp} = n_{int} \cdot t_{int}$
The number of interactions for the measurement	$n_{int} \approx 10^3 \div 10^6$
Characteristic time of interactions for different effects	t_{int}
Nuclear magnetic resonance spectroscopy	$t_{int} \approx 10^{-1} \div 10^{-5} s$
Paramagnetic electron resonance, Ultrasound absorption	$t_{int} \approx 10^{-4} \div 10^{-8} s$
Combination light scattering, Infrared spectroscopy	$t_{int} \approx 10^{-10} \div 10^{-11} s$
Hyper Sensibility of the Self-Organized Structures	
Sensibility of the self-organized systems to initial conditions	$t_{tr} \approx 10^{-10} \div 10^{27} s$
Integrity, Completeness, Self-Sufficiency	$t_{tr} \approx 10^{-10} \div 10^{-27} s$
Coherence, Synchronization on different time intervals – FRACTALITY	$t_{tr} \approx 10^{10} \div 10^{-27} s$

As can be seen, the time scales of structuring self-organization processes not only cover well-known physical systems, but also provide the opportunity to implement radically new areas and directions of structuring. This is achieved through the principles of the functioning of information systems (Fig. 10.2).

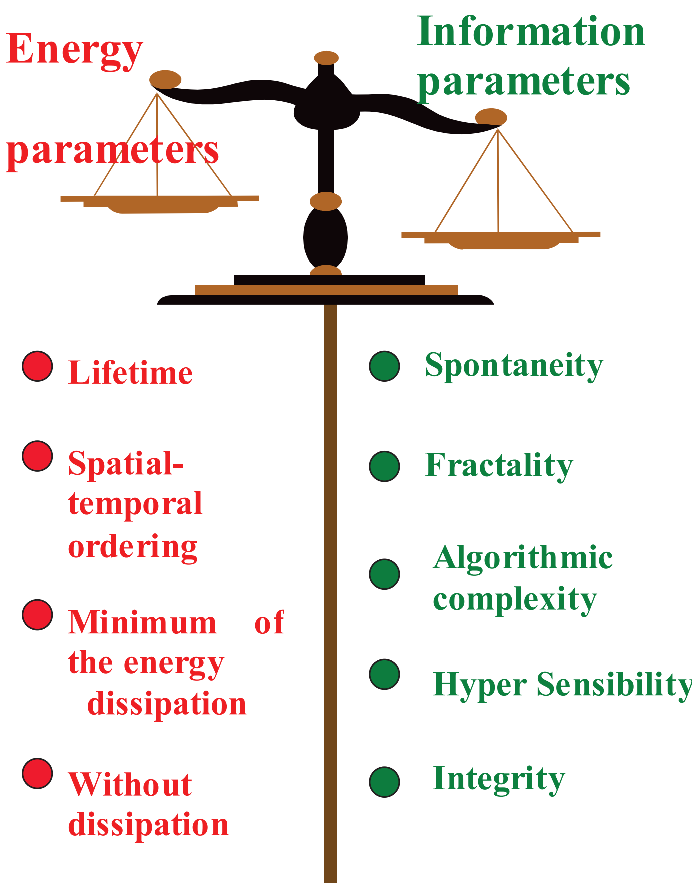


Fig. 10.2. Energy and information parameters of the information systems.

Integrity and, accordingly, Hyper Sensibility, can be obtained only by self-organized structures and a person who changes his self-organization - energy-information structure, fractality (Table 10.1, Fig. 10.2).

10.2. Micro, Nano, Pico, Femto: *New Ways to Control and Analyze of Structuring Levels for Information Systems*

Self-organized structures can be formed in systems of diverse nature (Fig. 3.5). In particular, we considered the formation of self-organized structures in non-crystalline and intelligent materials (Mar'yan & Yurkovych, 2015; Mar'yan & Yurkovych, 2018), education - the teaching of natural sciences and the use of computer simulation (Yurkovych, Seben & Mar'yan, 2017; Mar'yan & Yurkovych, 2019), water structuring (Mar'yan, Kurik, Kikineshy, Watson & Szasz, 1999; Mar'yan & Szasz, 2000; Mar'yan & Szasz, 2016).

Especially, there has been increasing interest in the study of the synchronization of complex systems. Synchronization and structuring of complex systems has great potential in physics, chemical and biological systems, secure communications, development of intelligent materials, and so on (Table 10.1).

We considered the formation of self-organized structures in non-crystalline and intelligent materials at various external control parameters and over a wide temperature range of the *0..1500 K*. It can be stated that the external control parameters (melt cooling rate, synthesis temperature, electromagnetic radiation power, external noise intensity) influence on self-organization processes and structurally-sensitive parameters of the received materials. At the same time, they are not the reason for the existence and formation of self-organized processes; self-organization processes and self-organized structures are formed without energy expenditure due to the influx of synentropy - information that determines levels without dissipative structural ordering. This is the surprising and uniqueness of this phenomenon, which can be realized at low and high temperatures, have a common informational nature in different temperature regions, although the manifestation of the micro, nanolevel at the same time will be radically different. Thus, external factors (temperature, noise, irradiation) are mostly conjugated and determine the structure of the existing dissipative environment, leaving the informational nature under the direct "influence and supervision" of information. Global warming, food shortages, and so on - is a manifestation of the influence of external factors, adjustments which only slightly "decorate" the artificially created problem. Change and reorganization is possible only when transitioning to the information level of the perception information with the corresponding levels of structuring.

The next aspect of **self-organized information structures** (**SOIS**) is the fractality of lifetime and spatial ordering (Table 10.1). Fractalities lay the foundations without dissipative functioning, in which ***Micro, Nano, Pico, Femto, ...*** levels of structuring act as a manifestation of one whole. That is, the listed levels of structuring reflect the "imprint-iteration" fractal structure. It is not necessary to bring fractal information to bit-information. This does not mean the rejection, the lack of use of bit-information. It is just important to see the limited involvement of it in moving to a holistic structure. ***Micro, Nano, Pico, Femto***, **…** structuring levels are like invitations to reality, but not the reality itself - information.

Another aspect of SOIS's information structures is the common nature and organization in intelligent materials, systems of artificial intelligence, information & communication systems. Thus, they act as one of the ways of mediators of recovery and access to a holistic reality.

In the presence of information integrity (an information can be and is only integrity), it forms the same integrity without dissipative structure, capable of filling and creating a new continuum of space-time - the energy and information. Bringing separation, disharmony, and loss of integrity and access to information leads to dissipative processes; accordingly, the implemented "product, object, system" only partially exhibits the properties and attributes of information - minimum energy dissipation, system openness, structuring periods, lifetime. Information (integrity) can be “near” (only access to it is closed due to the separation, creation and dissemination of “restricted”, “pseudo semantic” objects). Information does not disappear (scattered, transformed and so on); because it is not its attribute, not its principles of functioning (disappear, transformations of interpretations, "prints" of information).

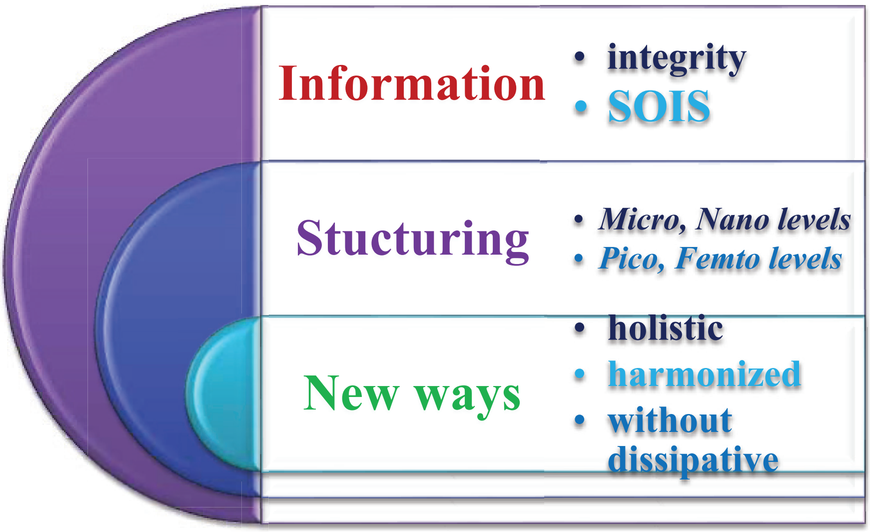


Fig. 10.3 . Information: new ways to control and analyze of structuring levels.

That is, possible (and is!) without dissipative information reality, filled with self-sufficiency and self-similarity. A dissipative, structured system can only sense the presence of information (though it does not "see" it because it lacks integrity). Therefore, it has a certain period of functioning in space and time as the dominant is still disharmony, dissipation. Expanding and spreading in space and time in the presence of dissipation, reproduction of a variety of "limited" objects is only an attempt to overcome the loss of integrity. The "diversity" of bounded quasi-objects (they are still quasi-objects because they are artificially isolated in the environment), their absorption and inter-conversion with energy dissipation is also an attempt to cover up the lack of information (integrity). Information reality is holistic, harmonized and without dissipative.

Methods for realizing bits of information (0 and 1) - whether or not electrical current is flowing, percolation processes are available or absent, and several others contain much more information. According to these methods of implementation of bits are processes, energy flows (bits of information - there is an energy flow or no energy flow), which are associated with fractals of information through attractors (in this case, for bits of information - point attractors). At the quantum level, qubits of information are realized through states of photons, polarization of molecular orbits, and more. All this has and manifests a common informational nature due to the change in the level of perception, the awareness - from limited (divided) to unlimited (whole) on nano, pico, femtoscale. And the transition is through the exit from the "restriction", the imposition of interpretations now, at this moment. It is an opportunity to change reality and yourself - an observer, participant, creator.

Chapter 11

INFORMATION AND PROGRAMMING: INTEGRATED PROGRAMMING ENVIRONMENTS

It is better to take and invent tomorrow than to experience that yesterday was so-so.

STEVE JOBS,
Founder of the Apple Corporation

Nata Popova.
The Original Algorithm.

Information and **Programming** can be self-organized and complementary. Programming implements an algorithm (sequence of actions) according to a given project (program) - information. The integrated programming environment (IPE) is complete information and communication system and a means of implementing the algorithm (Fig. 11.1). Programming concepts - encapsulation, inheritance, and polymorphism - restore the principles of information integrity, that is, available, present directly in information.

Fig. 11.1. Correlated functioning of the information and programming.

Two interconnected and synchronized components of information systems (both technical, biological, and social) are software and hardware. Among the information systems are technical information systems, namely artificial intelligence, i.e. systems created by man using information technologies. The natural question is how technical information can collect, process, use or create information or at least "understand" teams of people? The answer is that these systems are programmed by humans, that is, they contain a software component or software. Therefore, a person must first "explain" to the system how to behave in certain situations - to set for it a program of action - an algorithm; only then will the system be able to function in a social environment.

*Software is first and foremost **information** that determines the behavior, direction of movement of an information system. Software are the programs and other operating information used by a computer. Any information system - technical, biological or social*; *for any information system, there is "software" and information everywhere.*

Where are the programs recorded and by what means does the system execute the program instructions? To do this, there must be special devices in the system called hardware component or hardware information system.

*Hardware is also **information** that defines a set of technical means necessary for the functioning of an information system. Most emit hardware as tools, machinery, and other durable equipment.* But it is information defines this complex, that is, it is creative. Information itself defines and shapes technical means, their development and functioning.

Artificial Intelligence is usually interpreted as the theory and development of computer systems capable of performing tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages, and the like. At the same time, artificial intelligence is realized and formed, for example, along with the "introduction" of steam locomotives, cars, conveyors (mechanized structures, machine tools, etc.), development of computer and computer systems, and others. (Prior to implementation in the form of technical information systems, they were present as information in biological, social systems). That is, carrying out movements, transportation of goods, performing labor-consuming operations is all that facilitates the physical functioning of a person. The paradox is that the information structure of the person - thoughts, emotions, desires - must change together; to restore the spiritual information structure. Translating physical effort and engaging "artificial" intelligence is a positive step, but it is not yet an exemption from the dissipative way of functioning, restoring and returning to its holistic information structure. This is first and foremost a positive step in the intelligent vision of oneself. "Movement", interaction and communication, continuum of space-time in general must be synergetic transformed, reformatted only on the basis of information and energy. Ultimately, everything is realized through the availability of information - which determines their meaning and need, use and place of artificial intelligence.

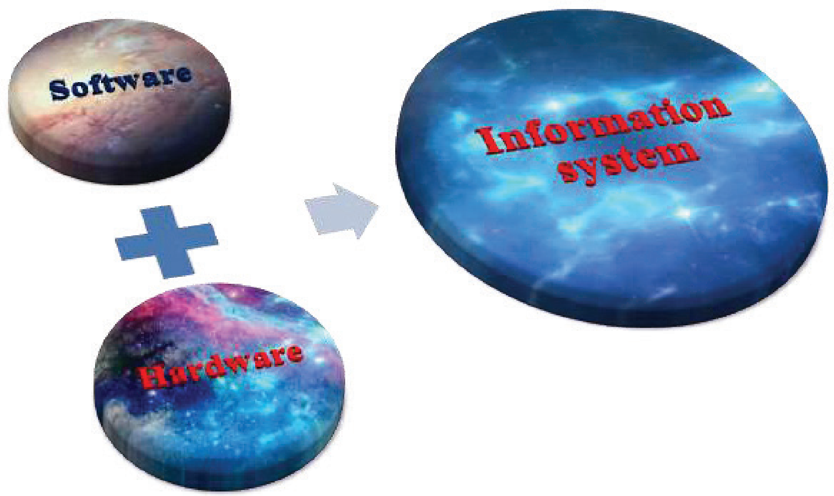


Fig. 11. 2. Synergetics of an information component in the software & hardware.

Modern concepts of abstract programming - encapsulation, inheritance, polymorphism are as attributes of information as through it the basis of modern algorithmic languages of programming and development of artificial intelligence (Fig.11.3). Encapsulation is integration, synthesis of description and action (methods). This is a sign that description and action become inseparable, which creates a new reality. It actually returns and restores the qubit of information (word and action integrity). That is, what it really is - is the ability to create, distribute encapsulatively, that is, non-dissipative. Inheritance and polymorphism are the "development" of the information qubit (integrity); the creation of new beyond the bits of information, which is impossible in terms of bits information, and becomes valid after the creation. It is like movement from a point attractor through creation of a ***cardinally new*** (really new, born, without copying, cloning, "standard closed distribution"), non-dissipative way of functioning and obtaining similarly without dissipative properties of a cyclic attractor and attractor of torus, with subsequent transformation, birth into a strange attractors. This is embedded in information, deeply in the concepts of encapsulation, inheritance, polymorphism.

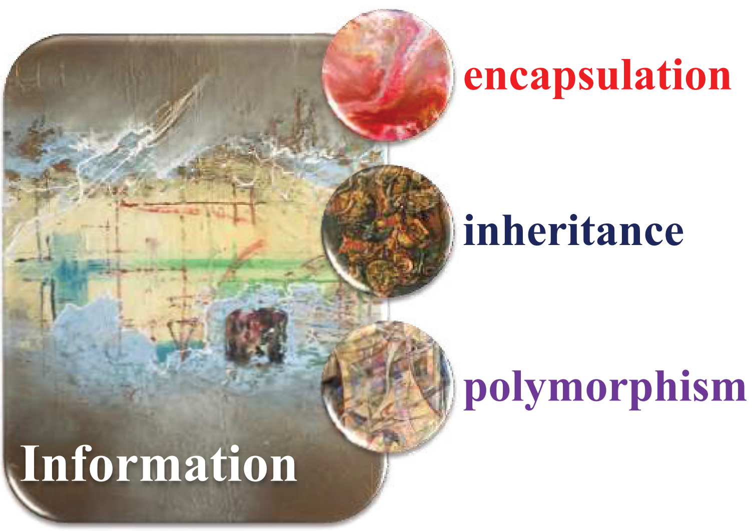


Fig. 11.3. Functioning of information in integrated programming environments.

Terms *Transport, Transformer, Translate, Passport, Prospect, Norway, Telephone, Television, Smart Home, Teleportation* and others, have information nature, which defines the further process, formation and structuring of information system, development opportunities. For example, *Transport, Transformer* contain not only the standard, familiar ways of moving, reforming, but also all possible, not yet revealed, not adapted, not implemented steps of development, software with the subsequent formation of the relevant information environment. The disharmony, the overlapping interpretations obscures this structuring. But the force (informational nature) of the word is decisive and determines the "not expected" at first glance, but at the same time the natural path and possibilities of without dissipative development beyond the functioning of conservative systems. Integrated programming environments have a certainty, a compilation of the algorithm implementation. Information objects - *Transport, Transformer, Point*,… and others function radically differently from "diffusion, percolation, stochastic" functioning in conservative (social) systems. Words are one way to set and implement an algorithm (Fig.11.4).

Fig. 11.4. Synergetics of algorithm & information: without dissipation.

The fractal functionality of implementing algorithms, when they exhibit their dynamism, the ability to self-organize (this is primarily for object-oriented programming through encapsulation, inheritance and polymorphism), provides an opportunity for non-dissipative or with a minimum of energy dissipation to form an adequate information and programming environment for project implementation (see also chapter 2). In this context, the self-organized algorithm becomes an integral part of the system. It seems to dissolve in it, lifting the system and itself to a new level of structuring, self-sufficiency and synergy.

Chapter 12

SYNERGETICS: NEW WAYS OF CORRELATION AND COHERENCE

A person has two lives, and the second begins when we realize that life is only one.

THOMAS W. HIDDLSTON, English Actor

Nata Popova. The Excellence.

12.1. Paths by Self-Sufficiency, Integrity and Coherence

The fractality of information systems lays the foundations, paths without dissipative functioning, at which the levels of structuring act as a manifestation of one whole - information. The levels of structuring reflect the "imprint-iteration" of fractal structure. ***Macro, Micro, Nano, Pico, Femto, ...*** structured levels are like invitations to reality, but not reality itself.

Another attribute of SOIS' structures is a common nature and organization in intelligent materials, systems of artificial intelligence, information & communication systems. Thus, they act as one of the ways for recovery mediators and access to a holistic information reality. Significant is the self-consistent and coherent change in the level of laws perception, patterns of nature through the transformation of the information structure for the "observer" himself. That is, the "observer" has the complementarity - the function of contemplation, the ability to accept the environment, and be open to transformations, the restructuring of information systems. It is also essential to adjust the level of abstraction objects in the direction of approximation, merging with the information environment and moving to a new level of abstraction, on which they are leveled as the "imprint-iteration". This is not a substitute, a rejection of the laws and principles of the functioning of information systems. On the contrary, it is an opportunity to see the laws as they really are - without interpretations and interpreters, and see the possibility of their full, without dissipative functioning (Fig. 12.1).

The peculiarity of the monograph is connected with the presented researches of the self-organization processes and fractality for various informational complementary systems such as non-crystalline and intelligent materials, low-temperature anomalies, structured liquids, ecological and education systems. The main emphasis is placed on the common nature of the formation processes, the influence of external factors (cooling velocity, irradiation, random noise, temperature intervals) on micro, nanoscale effects and structuring. The fractality of the lifetime for SOIS' structures is established and investigated, which is essential for the implementation of hypersensibility in information processing systems on their basis. Shown is the possibility of the implementation and development obtained results on the study of physical processes in the structuring and integrity of the information systems.

Fig. 12.1. The ways of the self-sufficiency and coherence.

12.2. The Most Beautiful and the Most Amazing: *Perspectives and Outlook*

One of Mandelbrot's most famous quotations (Frame & Mandelbrot, 2002) is the following: "The most beautiful and surprising thing that is created by nature, along with a woman, is a fractal. However, this is the most mysterious, obscure phenomenon of nature". In the context of this monograph, all the beauty, miracle and wonder of fractals opens and restores information (as well as women, but this will be a completely different perception, a completely different woman) (Fig. 12.2).

Fig.12.2. Beauty of the Information: **Fractality** & **Synergetics**.

Advertising, music, films and other multimedia information and communication tools are also programming and application of integrated human information environments at the subconscious level. Namely, neuro-linguistic programming. Reflexes, signal-code communication, perception of the environment, all this has and forms an information nature that can be restored. Synergetic programming can be created consciously and capable of meeting the real needs of society and human beings without dissipating energy, disharmony, viruses, false programming, and zombies. The laws of physics, mathematics, economics, and other sciences have a grand hidden potential that can be consciously realized in integrated information environments, to become truly part of human functioning and development. Similarly, a fundamentally new fractal approach (view, consideration) can be implemented with respect to the standard perception of the Snails', Newton's, Einstein's laws, Euler's, Chapman-Kolmogorov's mathematical relations, biological neurons and cells, as well as a whole set of others (Fig. 9.3). This is first of all a change, a restructuring of the information environment, a new manifestation of the realization and restoration of the nature laws, when man (his information structure) becomes an immediate part of this environment. This is first of all information & mind ecology (Fig. 12.3).

Science, education is an "unlimited" by language of communication, gestures, and emotions - that is, the subconscious. Science should be "simple" - understandable. That is, understandability, awareness is synonymous with "simplicity". Everything is stored (integrity, completeness) in the presence of awareness, understanding. This is the way to restore integrity. Equally understandable and really meaningful can be "a sheet of formulas, symbols", "a scrap of code", “visual representation of the process” if they are synchronized with information.

This confirms the algorithm of the word ***Education*** in different languages of communication:

Education (in English) – doctrine, creation;

Educatio (in Latin) - instruction, knowledge, creation;

Освіта (in Ukrainian) – light, lighting, enlightenment;

Образование (in Russian) – formation, generation, background;

教育 (in Japanese) – Kyōiku, creation;

Vzdelanie (in Slovak) - formation, construction, creation;

Εκπαίδευση (in Greek) – Ekpaidefsi, formation.

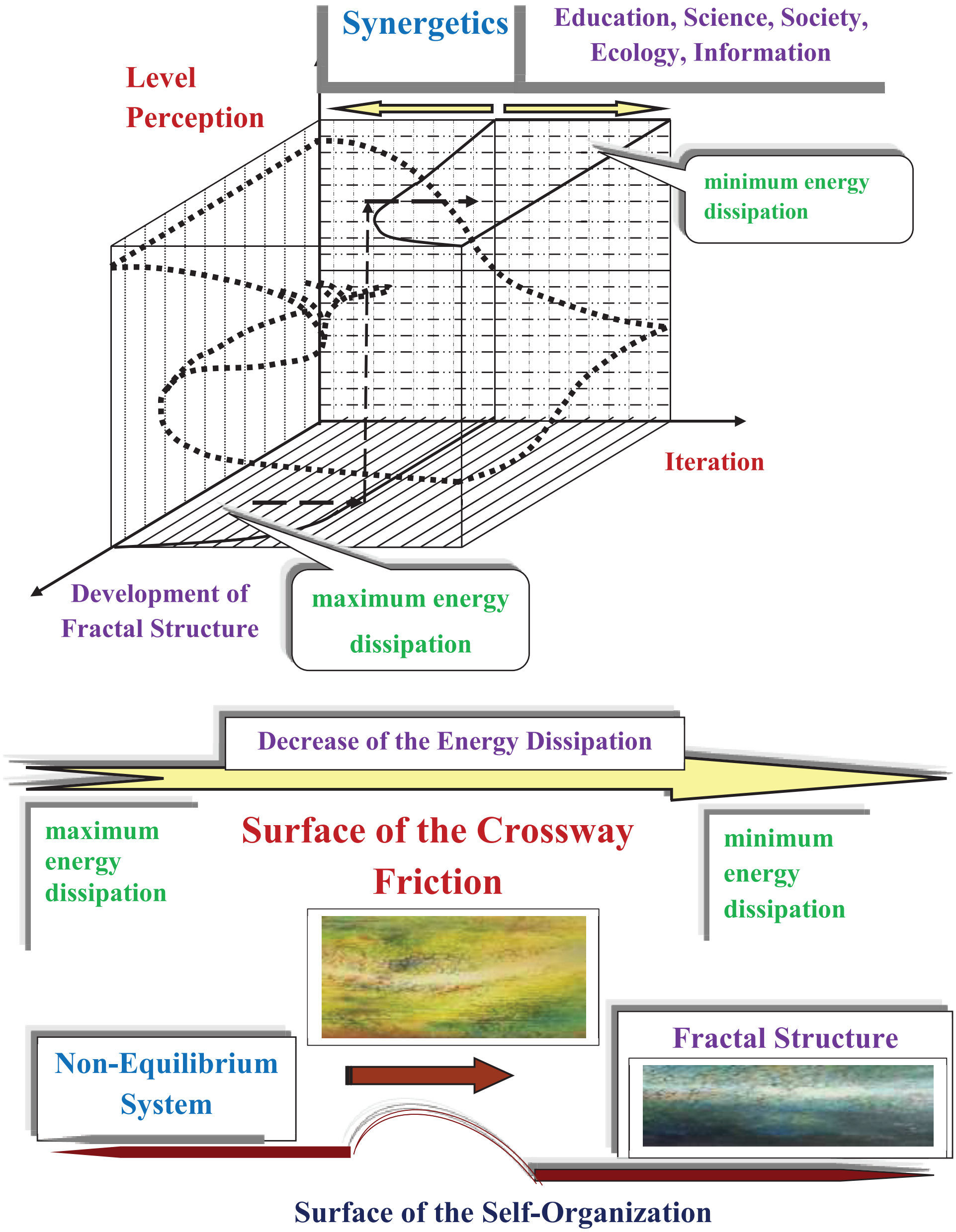


Fig. 12.3. Formation of the fractal structure for systems different nature.

Self-organized information structures (SOISs), regardless of the environments in which they are formed (non-crystalline and intelligent materials, structured fluids, photo, thermoinduced instabilities (Mar'yan & Yurkovych, 2019)) have unique properties and methods for their implementation. This is first and foremost a **superfluidity, superconductivity, hypersensibility, ...** that are based and implemented on an informative basis. It is also a butterfly effect, cybernetic, transistor, and other effects - which are just the first steps in approaching SOIS's capabilities and resources. Fractality is one of the self-sufficient algorithms for implementing SOIS. Programming, processing and transmission systems are as fundamentally different in SOIS, and directly related to the above properties as well-organized methods for implementing algorithms (Fig.12.4).

Fig. 12.4. Properties & methods of the SOIS' structures.

Information does not disappear because it is not its principles of functioning: only interpretations, "prints" of information disappear, transform, reformat. That is, a non-dissipative information reality filled with self-sufficiency and self-similarity is possible. A structured self-organized system can only sense the availability of information. Therefore, accordingly, has a certain period of hers functioning in space and time. But at the same time, it also gets the opportunity to self-improve, self-develop, approach to an "**excellence & completeness**" (Fig. 12.1-12.2). The information reality created in this way and the relevant information structures are exactly **holistic, harmonized** and **without dissipative**. This is the most **Beautiful** and **Most Amazing** in nature.

No problems. They arise only when imposed externally inadequate into the present moment the program technologies, approaches, interpretations of development personality, essence society, education, ecology, and information technology. This is the point of view and reality for the authors of this monograph. Alongside is a friendly, creative information reality, open to collaboration and synergy.

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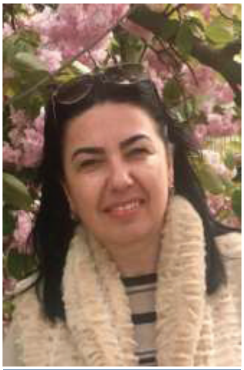

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FOR NOTES AND REVIEWS

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