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Nanotechnologies in a New Technological Paradigm

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INTRODUCTION

A new technological paradigm can be defined as a sphere of intelligent creative human activity based on the harmonized integration of natural and artificial intelligence without losing the cultural, social and personal uniqueness of a person. In the system of the generation and transfer of new knowledge for innovative scientific and technological development and staffing of Russia's global competitiveness in the new technological paradigm, taking into account predicted global trends in the formation of the future noosphere harmonized with humans, nanotechnology undoubtedly dominates as a systemic transdisciplinary area.

The aim of this article is to analyze the areas for the concentration of intellectual and infrastructural resources, which determines the creation of new materials and substances with previously unknown, but predictable and sought-after properties.

NANOTECHNOLOGIES AS A NATURAL-SCIENCE BASIS

Nanotechnology in the modern sense is an interdisciplinary "pass-through" technology, which is based on the atomic-molecular design of supramolecular compositions in integration with the physical-chemical processes of structure formation and shaping, including materials and their compositions with previously unknown, but predictable and, of course, sought-after properties. The aim of the ambiguously perceived concept of nanoscience is to describe, provide and predict the properties of these synthesized material objects with the manifestation of nanoscale factors.

Within the analysis of basic trends that characterize the appearance of the sixth technological paradigm, the following should be singled out as dominant backbone technologies: atomic and molecular engineering; bioengineering and robotics; infocognitive and genomic technologies; quantum-wave technologies and bioenergetics.

The main systemic strategic area of research in the field of the natural-science basis of the sixth technological paradigm, of course, is the use of previously unknown properties of materials and compositions that arise during the transition to objects:

(i) the properties of which depend on dimensional and conformational factors;

(ii) representing the integration of artificially and naturally ordered systems;

(iii) integrating the materials-science basis of inorganic and organic natures;

(iv) the structural organization basis of which is nonequilibrium processes;

(v) the functioning basis of which is a complex of cooperative synergetic processes and phenomena.

The most characteristic manifestations of the nanoworld include:

(i) the emergence of nontraditional types of symmetry and special types of conjugation of interfaces, conformations (clusters, particles, complexes) with a dynamically tunable structure;

(ii) dominance over the processes of artificial ordering of the phenomena of self-ordering and self-organization, reflecting the manifestation of the effects of matrix copying and synthesis features under conditions far from equilibrium;

(iii) the high "field" (electrical, magnetic) activity and "catalytic" (chemical) selectivity of surfaces of ensembles based on nanoparticles, including integrated compositions of inorganic and organic natures;

(iv) a special nature of the occurrence of processes of energy and charge transfer, and conformational changes, characterized by low energy consumption, a high speed and bearing signs of a cooperative synergistic process.

As part of solving the problems on the synthesis and practical use of objects with the above properties, it is also necessary to identify possible priority areas of **research studies** to provide an intellectual basis for innovation in the new technological paradigm:

(i) dependence of the properties of materials and systems on their characteristic dimensions;

(ii) nontraditional types of symmetry and conformation with a dynamically tunable structure;

(iii) transfer of energy, charge and information based on cooperative synergistic processes;

(iv) molecular recognition as a basis for selectivity and specificity of processes;

(v) processes of self-formation, self-ordering and self-organization;

(vi) convergent systems: integration of man-made artificial inorganic systems and objects of bio-organic nature.

As the main areas of **applied research** that determine the product model for the development of nanoengineering, we can single out:

(i) distributed self-organizing reflective information networks;

(ii) multifunctional adaptive human-machine interface;

(iii) artificial organs and nonpharmacological correction of the condition of biological objects;

(iv) robotic bioreplacement systems;

(v) biomimetic functional analogs and design principles;

(vi) bionic, including cognitive, algorithms and principles of functioning;

(vii) artificial modification at the genetic, cellular and organ levels;

(viii) artificial modification at the psychophysiological level.

BIONANOINTERFACE

The practice of creating knowledge intensive innovative systems quite widely includes a new terminological basis: convergent systems, and bionic and cognitive technologies.

Attention should be paid to the fact that, evaluating the constructive and functional, energy and informational merits of objects of organic nature, developers are trying to endow artificially created technical systems with the individual properties of biosystems.

In this case, it is precisely the "interface" between animate and inanimate nature that acquires a special role. The current state of the issue in the field of the development and creation of devices based on biological media and their analogs is characterized by the following areas:

(i) the use of biological media in traditional devices, for example, as gate materials of a field-effect transistor or an optical waveguide;

(ii) the use of biological media in the implementation of a precision technological operation, for example, biolithography with nanomolecular resolution;

(iii) creation of biosensors and actuators of invasive and noninvasive types for diagnostics and biocorrection of the condition of the body;

(iv) creation of functional bioprostheses that provide the replacement of lost organs or functions (hearing, vision and even smell);

(v) an attempt to create super-powerful artificial-intelligence systems based on bioneurochips and environments with a neuron-like structure.

When considering biological media as one of the elements of the basis for creating convergent artificially intelligent and sensory nanosystems of the future, first of all, one should pay attention to the functional and technological features determined by the structural conformational properties of biomolecules and compositions based on them.

However, a number of the most significant factors for the emergence of **new threats under conditions of the nanoworld** should also be noted:

(i) the small characteristic sizes of particles and the special nature of their ordering, which ensure the energy and spatial availability of the transport charge, energy, and conformational changes;

(ii) energy, field and "material" nonequilibrium of the surface, covering significant volumes of nanoparticles and nanocompositions;

(iii) intensification of the role of various types of size effects due to the large area of the interfaces under the conditions of nanocomposites;

(iv) manifestation of energetically active nanoparticles and nontraditional mechanisms of ordering, energy and charge transfer under conditions of large groups.

When evaluating the safety of nanomaterials, first of all, one should take into account their impact on such important biological characteristics as the permeability of biomembranes, genotoxicity, the activity of redox processes, including lipid peroxidation, biotransformation, and elimination.

Many factors indicate that nanomaterials can have completely different physical-chemical properties and biological (including toxic) effects than substances in the normal state, and therefore they should be classified as new types of materials, and also products, and the characterization of the potential risk to health and the state of the environment becomes mandatory.

The variety of technological trajectories in various fields of research and production, while maintaining a unified systematic natural-science approach to the processes of atomic and molecular design of structure formation and shaping of supramolecular compositions of inorganic and organic nature, including their hybridization, characterizes modern nanotechnology as a pass-through technology for creating new materials and substances with previously unknown, but predictable and sought-after properties.

Within the formation of a new technological paradigm, the following will be priority areas of innovation for the development of nanotechnology:

(i) design and synthesis of artificial nature-like materials of inorganic and organic natures and their hybrid compositions for intelligent, bionic systems and bioreplacement;

(ii) technologies of atomic and molecular assembly and the formation of an organic-inorganic interface for the purposes of biosensorics and neural interfaces;

(iii) technologies for additive super precision 2D and 3D shaping, including organ printing for the bioreplacement of sensory and structural-and-functional elements of biological media;

(iv) the atomic and molecular synthesis of artificial composite materials with a critical mission for extreme and special operating conditions;

(v) quantum-wave technologies of the interaction with biological objects at the atomic-molecular and organic-physiological levels for the purpose of the noninvasive diagnostics of nonpharmacological correction and control.

The above set of innovative transdisciplinary areas in the nanotechnological field allows us to state the fact that the target functions in the formation of a new technological paradigm can be defined as achieving a new quality of life in the context of the digital transformation of society with communication skills, cyber and biosecurity ensured while maintaining the social, cultural and personal uniqueness of the human.

CONFLICT OF INTEREST

We declare that we have no conflict of interest.

Translated by D. Novikova

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