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EVOLUTION AND PRESENT STATE OF THE ENGLISH NANOTECHNOLOGY TECHNICAL TERMS

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Abstract

The article considers the peculiarities of development and the present state of the English nanotechnology sublanguage. Special attention is paid to the morphological and semantic structure of nanotechnology technical terms and some of their derivational models, as well as their frame modelling. The authors prove the fact that the English nanotechnology terminology is quite young due to a large number of neologisms and complex (multi-component) technical terms, as well as abbreviations. Three-and four-component structure predominates in abbreviated technical terms of nanotechnology. It is significant to note that in the English terminology of nanotechnology such word-formation models as back derivation and conversion are quite rare, though they are rather widespread in the English language as a whole. The frame model of nanotechnology sublanguage consists of eleven subframes, and each subframe can be further segmented into from two to seven slots. Some subframes have more slots, for example, 'Nanodevices', 'Nanomaterials', than others, such as 'Nanotechnology Instruments' and 'Nanoeducation'.

Keywords: technical term, terminological system, structure, derivation, picture of the world

1. Introduction

Human mental activity is inevitably reflected in the language that by means of its elements segments the reality and to some extent determines the perception of it [1]. The scientific and technological advance is intended for the benefit of people and new technologies help mankind to develop and evolve. Nowadays there is an increasing interest and significant investments in development of nanotechnology [2], which is a whole branch of knowledge, which deals with the systems of extremely small dimensions (10^{-9} m) and incorporates the latest achievements in Physics, Chemistry, Biology, technology,

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Medicine, etc. Scientists, politicians, investors, etc. pin their big hopes on the breakthrough in nanotechnology in future. In general, taking into account the prospects of development of the nanotechnological science, this field of knowledge can be regarded as a new paradigm of the global (scientific-technical, economic, etc.) advancement.

The prospects of nanotechnology development and corresponding dangers are kept very much in the news in newspapers, magazines, the Internet, on the radio and TV. The XXIst century has already got a name of the 'century of nanotechnology' [2], along with the 'century of water vapour' (the XIXth century) and the 'century of atom and computer' (the XXth century) [3, 4].

Nanotechnology is one of the most promising developing fields of modern science and technology greatly changing and transforming our world view. The prefix nano- (from Greek nanos – 'dwarf') signifies one billionth part of a quantity (10^{-9}), i.e. the expression 'nanoscale object' means that the object has at least one dimension (out of three – length, width or height) of one billionth part of a metre.

According to professor G.G. Yelenin, doctor of Physics and Mathematics in Moscow State University: "nanotechnology is an interdisciplinary branch of science which studies the regularities of physical and chemical processes in the nanoscale space domains with the aim of managing separate atoms, molecules, molecular systems for creating new molecules, nanostructures, nanodevices and materials with special physical, chemical and biological properties" [5]. From the linguistic point of view, we should add to this definition that nanotechnology is characterized by a special still forming, developing and enriching terminology (a body of technical terms) that expresses the concepts of this certain fragment of the academic picture of the world.

It should be noted that in modern linguistics the interest to analyzing peculiarities of formation and development of different branches of the language of science is only increasing. There is no doubt that the rapidly developing terminology of nanotechnology is not left untouched by linguists. The body of nanotechnology technical terms is still forming and these language units have not yet been studied from the point of view of both syntagmatic and paradigmatic relations which are present within the framework of the corresponding sublanguage.

Owing to its specificity, the nanotechnological picture of the world does not include the oldest naïve world image, but only modern scientific world picture that can be found in the lexical subsystem of the English language, served for the sphere of nanotechnologies, nanomaterials, nanostructures, etc. Thus the primary objective of this paper is to analyze and describe some peculiarities in formation, structure and evolution of nanotechnology technical terms.

2. Methods and tools

Throughout the study of this developing body of new technical terms different instruments of data collection and analysis were applied that reflect both general approaches and those within linguistics. At the first stage, the corpus of texts devoted to research in nanotechnology was collected, the technical terms were singled out to build a data base of nanotechnology technical terms. As the analysis of their definition was carried out the etymological analysis was considered an important tool. Both the component analysis of term semantic structure and the method of contextual analysis were also important in this respect. These are the methodological instruments that shed light on how the semantic structure forms oppositions and manifests in communication process. As a result the semantic and structural peculiarities of nanotechnology technical terms were described, as well as some mechanisms of new terms creation. The study of the technical terms evolution demanded the application of comparative analysis. Statistics is based on the use of mathematical tools and the qualitative method. The method of frame modelling is also applied in the research.

3. Results

By the notion ‘sublanguage’ is understood the totality of terminological units with the explicit professional orientation and regularities of their functioning in special texts. The primary nanotechnology sublanguage, in our opinion, is a system of linguistic means of the English national language, representing the structures of nanotechnological knowledge, which have emerged during the recent 40-50 years and reflecting the level of the latest socially necessary scientific achievements in this sphere. The concepts of nanotechnological, highly specialized and hierarchically arranged, are objectified in the nanotechnology sublanguage, and due to this fact the communication between experts in nanotechnology is possible [6-10].

It is not a secret that Nanotechnology, being a cross-disciplinary sphere, has got a status of an independent scientific discipline [11]. The terminological system of Nanotechnology appeared as a result of the interaction of such disciplines as Physics, Chemistry, Biology, Microelectronics, etc. The interdisciplinary character of the terminology of Nanotechnology can be proved by the following examples: the following technical terms were borrowed **dielectric, waveguide, semiconductor, biosemiconductor**, etc. from Physics; **adhesion, active catalytic component, active catalytic phase, biosensor, capillary force, carbon fibres, catalysis, clathrate, tunneling**, etc. from Chemistry; **biomimetics, biomembrane, biopolymer, lipid bilayer**, etc. from Biology and Microbiology; **actuator, anodizing (anodising), bipolarjunction transistor, single-electron transistor**, etc. from terminology of Electronics and Microelectronics [http://www.nanodic.com, http://thesaurus.rusnano.com].

Having analyzed the specificity of interaction between the English nanotechnology sublanguage and the sublanguages of other fields of knowledge we have revealed the following gradation (max. -> min.): Material sciences -> Engineering -> Chemistry -> Biology -> Physics -> Medicine -> Mathematics -> Geosciences -> Economics -> Computer sciences -> Ecology -> Linguistics -> Politics -> Philosophy -> Education -> History -> Religion.

The nanotechnology terminology system can be represented as a nanotechnology frame model with an intricate structure, consisting of eleven subframes.

4. Discussion

The interdisciplinary character of Nanotechnology can also be proved by the existence of different branches of Nanotechnology: **Nanobiology, Nanobiotechnology, Nanoelectronics, Nanomaterials, Nanoengineering, Nanoenergetics, Nanochemistry, Nanomedicine, Nanopharmaceutics, EHS nanotechnology, Nanoeducation, Nanometrology**, etc. [http://www.nanodic.com, http://portalnano.ru] each with its own body of technical terms that belong to the terminology of Nanotechnology.

The analysis of the selection of about 6000 technical terms has shown that the corpus of the special nanotechnology lexis is not homogeneous in its mechanisms of formation. It can be explained by the fact that, as opposed to the so-called 'old' terminologies (Military science, Astronomy, Medicine, etc.), nanotechnological terminology from the very beginning of its appearance is being based on the terminological borrowings from the sublanguages of Physics, Chemistry, Biology, etc. In this case, in our opinion, the primary nanotechnology terms are the terminological units that appeared exclusively within the English nanotechnology sublanguage from the introduction of the term 'nanotechnology' (1974) to the time of their penetration to other languages (1980-1990's). These primary terms are mainly single-component nouns with a prefix nano-, for instance, nanotechnology, nanorobot, nanocrystal, nanomaterial, etc. We have come to the conclusion that the terminology of nanotechnology is, in general, secondary in its character because it consists of derivatives and technical terms with borrowed elements the semantics of which was reconsidered.

Let us consider in detail the structural and semantic mechanisms of coining nanotechnology technical terms. First of all, it should be noted that the process of creation of the technical terms of the nanotechnological sphere, as well as other spheres of human knowledge, may rely upon native (English) language units or the borrowings from other (non-native) languages.

About 42.5% of the selected and analyzed terms from the English nanotechnology sublanguage are the technical terms consisting of, at least, two terminological elements, unequal in their sense load, combined by their semantics and syntactical compatibility, in which can be clearly marked the semantic nucleus and periphery [12].

Abbreviation is another structural and semantic mechanism of technical term formation (about 34,3% out of 6000 analyzed terminological units), for example, **AES** (Auger Electron Spectroscopy), **AI** (Artificial Intelligence), **ALD** (Atomic Layer Deposition), **CAN** (Computer-Aided Nanotechnology), **nm** (nanometer, nanometre), **XANES** (X-Ray Absorption near-edge fine structure), **CNT** (Carbon Nanotube), etc. (http://www.nanodic.com).

Such stem shortenings as **nano** from nanotechnology; **nanotech** from nanotechnology or nanotechnological, etc., in our opinion, can not be regarded as separate terminological units because they are just structural variations expressing the same notions. If we change the morphological structure of a word without changing its meaning, we will not have a new word (or lexeme). The given above examples are units of professional jargon that can be proved by their high degree of expressiveness.

Along with abbreviation, there is another mechanism of coining new technical terms based on the transfer of meaning by similarity and full or partial reconsideration of the primary meaning of the whole term or its constituent parts (terminological elements). We have found out that about 16,5% of the analyzed technical terms are based on the metaphorical transferring of meaning, for example, **cap, insulator, scooter mechanism, nanoflower, blue goo, nanotube, nanopillar, ball mill**, etc. [http://www.nanodic.com, http://thesaurus.rusnano.com].

One should also say a few words about compounding (about 19% of the analyzed technical terms). About 13.4% of the terms are formed by stem combining, for example, **atomic-vacancy, core-shell (particle)**, **donor-acceptor (interaction), Ehrlich–Schwoebel (barrier), field-effect (transistor)**, etc. [http://thesaurus.rusnano.com].

About 46% of the analyzed nanotechnological terms are formed by affixation (about 27% – by prefixation and about 19% – by suffixation), for example, **nano-robot, nano-technology, nano-technolog-ist, homo-polymer, nano-biolog-ist**, etc. Due to the fact that the majority of the analyzed nanotechnological terms are formed by affixation, we can say that this method of term formation is highly productive for the nanotechnological terminology.

Some technical terms of other terminologies are onomatopoeic Among the analyzed English terms of nanotechnology this mechanism of coining technical terms has not been revealed. We think that it can be explained by the scale of nanotechnological processes and phenomena. We do not hear nanotechnology, our ears are not able to do it, nanotechnology ‘sounds’ can be registered only by special equipment that is why this method of term formation is not actual for the corresponding terminology.

Borrowing occurs on both morphological (transcription and transliteration) and semantic (translation) levels. It is well known that there are two main types of borrowing – direct (terminological elements come from one language to another) and indirect (terminological elements come from one language to another through the third one). According to our estimates, the portion of the full borrowings in the English sublanguage of nanotechnology is

very low (about 3-5%) because English is the original language of nanotechnological terminology. Nanotechnological terminology has appeared and mainly continues to develop in the English language. However, if we take into account the presence of loan term elements – prefixes, for example, nano- (borrowed from Greek) or other formants (**nano-bot, nano-medicine, nano-electronics, nano-tube, nano-scale, supra-molecular**, etc.), the proportion will rise up to 19% of the selected terms of the nanotechnological sphere.

The terminology of nanotechnology is developing; some terms become archaic and are gradually replaced by other terms. The process of the development of certain technical terms, in our opinion, can be illustrated and analyzed with the help of the 'etymological scale' [12, p. 82]. The etymological scale for the technical terms expressing the notion '**nanorobot**' is exemplified in Table 1.

Table 1. The etymological scale of the technical term 'nanorobot'.

1974	1986	1990-2000
nanotechnological machines nanomachines	engines of creation nanotechnological robot nanorobot	nanobot nanoid nanite nanomite nanorobot

The development of nanotechnologies began in 1974, a new technical term – **nanomachine** – expressing the idea of a nanotechnological machine (robot) appeared. In 1986, thanks to K. Eric Drexler and his book 'Engines of Creation…', the term 'nanorobot' appeared [13]. Now (from about 2000) this term has got a shorter form (**nanobot**) and a few synonyms (Table 1).

Thus, in general, the etymological scale allows to explain the history of development of technical terms in their systematic interaction, consider paradigmatic (hyponymic and hyperonimic, synonymic, etc.) relations existing between these lexical units, determine more accurately the mechanisms of coining new terms and point out the motivational basis in those cases when it is impossible to do without etymological analysis, explain why some terms are replaced by others or continue to co-exist during a certain period of time.

The terminology of nanotechnology is interesting in its dynamics: from the moment of its appearance the main methods of terms formation are changing, and this fact does influence on its current structure and prospects of development. On the one hand, for example, from the initial period of nanotechnology terms formation, the amount of simple terms reduced from 53.2% to 21.1%. In most cases complex multicomponent terms has been gradually reduced and/or abbreviated (about 34.3% of the analyzed terms). The proportion between the amount of simple terms and terms – word combinations is about 21.2% (before) and 45.3% (nowadays).

On the other hand, the amount of borrowings has increased by 1-2% due to the development of the nanotechnological sphere in both English-speaking

and other countries. The majority of the terms – word combinations is formed by the following model: 'derivative term element + simple term element'. According to our calculations, the amount of terms with metaphorical transferring of meaning is 16.5%, at the same time about one quarter (25%) of the whole amount of the term elements in the structure of the multicomponent terms is a result of metaphorization. We have come to the conclusion that such changes in the English nanotechnology sublanguage are related to the development of nanotechnologies in the English-speaking and other countries, the tendency of forming new terms on the basis of the English national language through the formation of terms – word combinations and metaphorization, as well as the intention to resort to the linguistic economy, shortening and, to some extent, – to the information encoding (abbreviation).

A certain body of nanotechnology technical terms is based on eponyms that in 97% refer to the scientists that have made discoveries in the field, for example, **Schottky barrier, Abrikosov vortex**, **Ehrlich-Schwoebel effect, van der Waals forces, Josephson junction, Fresnel lens, Vol(l)mer-Weber growth mode, Stranski-Krastanov growth mode, Frank-van der Merve growth mode, Mössbauer spectroscopy, Fourier-transformed spectroscopy, Iwasawa-Taniguchi effect**, etc. [http://www.nanodic.com, http://thesaurus.rusnano.com]. Thus, the structure of such technical terms consists of two elements with professional and non-professional semantics. The analysis has proved that the studied body of nanotechnology technical terms has approximately 370 eponyms which is quite a lot for a developing sublanguage. The names of some scientists have become very productive in coining technical terms of this field, for example, **Ehrlich-Schwoebel barrier, effect, instability; van der Waals radius, volume, surface, equation, forces; Schottky rectifiers, effect, barrier; Fresnel zone plate, lens, number, reflection, zone, prism; Langmuir-Blodgett film, trough, apparatus; Casimir forces, effect**, etc. [http://thesaurus.rusnano.com, http://www.nanodic.com]. Such eponyms well illustrate the influence of anthropocentrism principles on the development of the language of science. The most numerous productive elements that are common nouns in the structure of these technical terms are **growth mode** (35 technical terms), **method** (29 technical terms), **effect** (28 technical terms), **technology** (26 technical terms), **law** (24 technical terms), **force** (20 technical terms), **spectroscopy** (18 technical terms). Less frequent are technical terms with the following elements: **diode** (9 technical terms), **index** (8 technical terms), **barrier** (5 technical terms), **lens**, **transistor** (2-3 technical terms), etc.

Such technical terms have a complex structure and are compounds or word combinations. It is important to note that there are also terms with two and three personal names in their structure. Such technical terms have synonyms that are not eponyms, for example, **Vol(l)mer-Weber growth mode – island growth mode; Stranski-Krastanov growth mode – layer-by-layer and island growth mode; Frank-van der Merve growth mode – layer-by-layer growth mode; Pechini method – polymerizable complex method, liquid mix technique; Rutherford backscattering spectroscopy – fast-ion-scattering**

spectroscopy; Mössbauer spectroscopy – nuclear gamma-resonance method, gamma-resonance spectroscopy; Hall-Petch relationship (strengthening) – grain boundary hardening, etc. [http://thesaurus.rusnano.com].

We have constructed the frame model of nanotechnology sublanguage [14-18]. The top of the model in question is the cell with the frame name 'NANOTECHNOLOGY'. Due to the fact that Nanotechnology is a complicated and multifaceted sphere, the frame itself has a rather complicated structure. Its second level consists of eleven subframes, such as 'Nanofabrication', 'Nanodevices', 'Nanotechnology Instruments', 'Nanostructures', 'Nanotechnology Facilities', 'Nanomaterials', 'Nanomeasuring Instruments', 'Nanobiotechnologies', 'Nanoeducation', 'Nanomedicine & Nanopharmaceutics' and 'EHS Nanotechnology'. The frame of the English nanotechnology sublanguage is constructed on the principle of 'Russian dolls' vertically and as a 'tree-like branching' structure horizontally. This form of representing professional knowledge about the world allows showing all the detailed and concrete subframes included. It gives an opportunity to show the general facts about nanotechnology, to give the image of this subject's segmentation, its basic concepts and gather all the knowledge and technical terms together. As our analysis shows, in each subframe of the frame model of the English nanotechnology sublanguage there is a possibility of further segmentation within the boundaries from two to seven slots. Some subframes have more slots, for example, 'Nanodevices', 'Nanomaterials', than others, such as 'Nanotechnology Instruments' and 'Nanoeducation'.

Due to the fact that it is impossible to describe all the details of the frame model of the English nanotechnology sublanguage in one short article, we will examine here only one of its main subframes. In the subframe 'Nanomaterials' we can point out at least three slots: 'Functional nanomaterials', 'Composite nanomaterials' and 'Construction nanomaterials', reflecting the main groups of nanomaterials according to their purpose: functional, composite & construction [http://portalnano.ru]. Functional nanomaterials (slot 'Functional nanomaterials'), can be of high purity, have special physical properties (subslots 'High-clean, high-purity', 'With special physical properties'), and can be used in energy and space equipment production (subslots 'For energetics', 'For space equipment').

All construction nanomaterials (slot 'Construction nanomaterials') can be divided into two groups according to their chemical composition: slots 'Carbon nanomaterials (Fullerenes)' and 'Non-carbon nanomaterials'. In the first group of carbon construction materials there are at least three subslots: 'Buckyballs' (Buckminsterfullerene, Boron buckyball, Other buckyballs), 'Carbon nanotubes' and 'Fullerite'. Among non-carbon construction nanomaterials (slot 'Non-carbon nanomaterials') we distinguish subslots of the second level: 'Nanometals & Nanoalloys', 'Nanoglasses', 'Nanopolymers & Nanodendrimers', 'Nanofibers', 'Nanoceramics', 'Nanopowders', 'Nanofluids'.

The branch 'Nanomaterials' of the nanotechnology frame has a rather intricate structure, which means that there is a considerable quantity of terms-verbalizators in it, that, by our calculations, amounts to 2115 (42.3 % from the sample of 6000 lexical units). From the structural view-point, the most interesting slot is 'Construction materials', realized by the following most frequently used terms: **carbon nanomaterial, carbon nanotube (CNT), fullerite, buckyball, buckminsterfullerene, buckytube, nanometal, nanostructured carbons, nanoalloy, nanopolymer, nanodendrimer, nanoparticle, nanofabric, nanofiber, nanoceramics, nanopowder, nanofluid, nanoliquid**, etc. [http://www.nanodic.com, http://thesaurus.rusnano.com, http://portalnano.ru]. The number of verbalizators for the slot 'Composite nanomaterials' is less (463 technical terms) than for the slot 'Construction nanomaterials' (1138 terms), which is visible from its less intricate structure and can be explained by the great importance of construction materials for people. The most frequent technical terms in the area of composite materials are as follows: **nanocomposite, metal nanocomposite, polymer nanocomposite, nanofilled polymer composite, genuine nanocomposite** etc. [http://www.nanodic.com, http://thesaurus.rusnano.com, http://portalnano.ru].

According to the structure, terms verbalizing the subframe 'Nanomaterials', are unicomponent (consisting of one word), for example, **nanomaterial, nanotube, nanopolymer, nanocolloid**, etc., and multicomponent units (consisting of at least two words), constructed according to the models '**N+N**', '**Adj.+N**', '**Adj.+Adj.+N**', for example, **polymer nanocomposite, carbon nanotube, multilayer nanomaterials, multi-walled carbon nanotube**, etc. The percentage of terms-verbalizators in the first group is about 35%, whereas in the second group the number almost doubles – 65%.

5. Conclusions

As it has been illustrated, the described terminology of Nanotechnology is characterized by certain structural characteristics. Thus, one of the evidence that the English nanotechnology terminology is quite young is a large number of neologisms predominate. The analysis of the structure and composition of the considered terminology showed that about 81.1% of the technical terms are multi-component, and 18.9% - one-component. The terminology of Nanotechnology is characterized by the extensive use of abbreviations and a variety of their types. Three-and four-component structure predominates in abbreviated technical terms of Nanotechnology. It is significant to note that in the English terminology of Nanotechnology such word-formation models as back derivation and conversion are quite rare. The terminology of Nanotechnology also includes eponyms that make specific lexical group within the investigated body of technical terms. The basic result of the frame modelling of the English nanotechnology sublanguage is its frame model consisting of eleven subframes. The prospects of the research are the further analysis of the discursive realization of Nanotechnology technical terms, gender peculiarities of

their use in the men's and women's speech, pseudoterms and pseudodiscourse of Nanotechnology.

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Nanotechnology is a part of science and technology about the control of matter on the atomic and molecular scale - this means things that are about 100 nanometres across. Nanotechnology includes making products that use parts this small, such as electronic devices, catalysts, sensors, etc. To give you an idea of how small that is, there are more nanometres in an inch than there are inches in 400 miles. Previous: history of nanotechnology. III. The Present State of Nanotechnology. Previously, we've investigated the history of nanotechnology. Now, let's look at the present state (2008). The principal teachers appear to be Eric Drexler and Ralph Merkle. a. Eric Drexler. In an article "The Incredible Shrinking Man" (Wired Magazine, Issue 12.10, October 2004) we read: "Kim Eric Drexler was born on April 25, 1955, in Oakland, California, to a mother who was a mathematician and a father who was a speech Nanotechnology is a very broad term and encompasses a very broad set of sciences. This is because any technology where at least one dimension of the critical component is less than 100 nm, and where this fact is important to the properties of said technology, is defined as being nanotechnology. It encompasses everything from gene sequencing to the idea of quantum computing. Generally, nanotechnology is divided into 3 distinct fields, although there is significant overlapÂ All in all, nanotechnology is present and in the near future more fancy things will come . 131 views Â·. View upvotes.