Lexical analysis of technical terms in the field of materials science

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Abstract. The article presents lexico-morphological analysis of terminology in the research articles on materials science. The article considers lexical features distinguished in scientific texts. The main purpose of the paper is to reveal the most frequent and productive types of word formation used in making specialized words and terms in technical English. For carrying out the linguistic study the analysis of the immediate constituents has been applied. Special attention is given to affixation, composition and contraction as the means of forming new words in the materials science engineering. Compounding or composition has been regarded as an important source of forming new words. Compound adjectives functioning as attributes are found to be primarily used for describing materials physical and chemical properties, conditions and stages of the experiments. Derivational units include borrowed and native productive or non-productive frequent affixes connected with different scientific notions. The study has been carried out on the technical terms and vocabulary from the journals “Advanced engineering materials” and “Advanced composite materials”.

1. Introduction

Language used in science describes and interprets the world, projecting the objective character of scientific knowledge. Scientific and technical communication can be defined as a process of gathering, organizing, presenting and refining information. It is also a process inevitably shaped by its contexts, and which is improved when it recognizes its contexts.

The language of science is governed by the aim of the functional style of scientific prose. The main aims of any scientific work are to prove a hypothesis, to create new concepts, to disclose the internal laws of existence, development, relations between different phenomena. The language means used in science tend to be objective, precise, unemotional, and impersonal.

Any scientific text employs a special technical vocabulary which consists of two main groups: words associated with professional communication and a less exclusive group of so-called learned words.

Scientific English generally includes terms and specialized vocabulary. Terminology may refer to three concepts: terminology as the study of terms, terminology as the practical aspect of doing terminographical work, and terminology as a set of specialized terms. In this article we consider terminology as a set of specialized terms [1]. Terminologies as the lexical components of specialized languages emerge from theoretical and technological innovation: new scientific insights and novel tools enrich the conceptual and practical environment of the specialists, and in the process expand
A term is a dynamic phenomenon that is born, formulated and delves into the process of cognition, the transition from a concept (mental category) to a verbalised concept associated with some theory to conceptualise a particular field of knowledge or activity [2]. This understanding of the term is inextricably linked with explaining connections between the structures of language and knowledge structures.

The written form of scientific discourse is characterized by the following lexical features:

a. lexicalization of -ing and -ed verb forms and their transition into adjectives and nouns;
b. a great number of words derived from one radical stem. The word-terms of the one root are quite abundant even within one given article;
c. the use of contracted or shortened words and acronyms connected with some specific experimental processes or names of an element;
d. the usage of compound words related to the properties of materials, characteristics, physical conditions of reactions and experiments.

Morphologically, the terms are mainly nouns or verbs semantically correlated with nouns and adjectives derived from nouns: absorption (n) — absorb (v), activation (n) — activate (v); anion (n) — anionic (adj), corrosion (n) — corrosive (adj), circle (n) — circular (adj). It should be noted that rows of the same root word-terms function in scientific discourse: adsorb — adsorption — adsorbent — adsorptive, corrode — corrosion — corrosive, diffuse — diffusion — diffused — diffusible [3].

So, lexical and morphological analysis of terminology in scientific articles presents special interest because they contain a great number of specialized terms which are characterized by the different types of word-formation.

2. Word-building types

We consider only those productive word-building types that are of importance for lexical analysis of terms from research articles, that is affixation, composition and contraction.

2.1. Affixation

Affixation is the process of making new when one or more affixes are added to a root. Affix is a derivational morpheme added to the stem and forming a new derivative belonging to a different part of speech or different word class. The meanings of affixes refer to the concept conveyed by the whole word to a certain category.

Affixation is generally divided into prefixation and suffixation depending if the morpheme precedes or follows the root.

There exists an essential difference between suffixal and prefixal derivatives. In the English language suffixation is a characteristic of noun and adjective formation, while prefixation is typical for verb formation. The other difference lies in the semantic structure of the suffix and the prefix [4]. The part-of-speech meaning has a much greater significance in suffixes compared to prefixes. Due to this, a prefix may be confined to one part of speech as or may function in more than one part of speech. Suffixes, on the contrary, function in one part of speech and often form a derived stem of a different part of speech as compared with that of the base.

2.1.1. Prefixation

Prefixation is the formation of words with the help of prefixes.

Prefixes may be classified on different principles. Diachronically there is a division into native and borrowed prefixes. Synchronically prefixes may be classified into:

a) the type of lexical-grammatical character of the base: de-verbal, de-nominal, de-adjectival.
b) the generic denotational meaning prefixes
   — negative (un-, non-, in-, dis-)
Prefix of repetition re- is observed in the research papers in hyphenated way in order to distinguish the meaning. One of the lexical features of scientific writing is the abundance of words composed of Greek prefixes.

These derived lexical units are mainly adjectives and nouns and their semantics is directly connected with materials names that are used in conducting research or experiments. Consider some examples: bioceramics, biocompatibility, biomaterial. All these words are the prefixal nouns. Prefix bio- is a borrowed one of Greek origin. The derived nouns, therefore, possess the meaning connected with living things or someone’s life or as in the case with bioceramics — the material with natural properties and that is not hazardous.

The other prefixes that are frequent in the articles are -micro and -nano. There are numerous examples of nouns formed with them: microstructure, microlevel, microscale, micro-tomography, micro-hardness, macrostructure, macro-architectural, macroscale, macro-level. The borrowed prefix of Greek origin macro- refers to the meaning of size (“large”), and words with the prefix of opposite meaning micro-, meaning “small in size” or “extremely small”.

It should be noted that above-mentioned prefixes usually form so-called neoclassical compounds because of their connection with Greek or Latin. The only difference between the neoclassical forms and native compounds is that the non-native elements are obligatorily bound. They use the so-called combining forms, which are bound morphemes that in principle differ from bound roots and affixes, however, this distinction is difficult to draw in many cases [5]. Scholars consider these neoclassical formations as compounds and do not treat them as cases of affixation.

Other examples of widespread use of borrowed prefixes are post-processing, post-sintering, post-fabrication. The prefix post- has a temporal meaning of “after”. In all the words it emphasizes sequence or consequence of processes expressed by the verb bases.

The non-native prefix of Latin origin inter- is found to show the relations inside or between processes or elements: intermetallic, interdistance, interchangeable, interconnected.

More examples of derivational units having non-native word-building elements in their form are words with prefix nano-: nanoporous, nanoindentation, nano-interface. The meaning of the prefix refers to connection with science and technology, describing the newest achievements in the particular field of study. It is also associated with measurements and has been coined to define a one billionth part of the whole unit.

As for negative prefixes some examples of non- have been observed: non-oxide-based, non-dimensional, non-commensurate, non-homogeneity, nonionic, non-monotonic. In contrast to un- and in-, negation with this prefix does not carry evaluative force. Furthermore, contradictory and complementary opposites of the concepts are formed via this morpheme.

2.1.2. Suffixation

Suffixation is the process of creating words with the help of suffixes. Suffixes usually modify the lexical meaning of the base and transfer words to a different part of speech. They can be classified variously using the word class of their base or using the word class newly formed, or both:

a) noun-forming suffixes: -er, -dom, -ness, -ation, -ing.

b) adjective-forming suffixes: -able, -less, -ful, -ic, -ous;

c) verb-forming suffixes: -en, -fy, -ise (-ize);

d) adverb-forming suffixes: -ly [6].

In the analyzed research articles the most common suffix added to the base is noun-forming frequent suffix of Latin origin -(t)ion: characterization, tension, compression, nucleation, dispersion, iteration, solution, reduction, discretization, elongation, delamination, galvanization.
Noun-forming suffix -ty is mainly applied for describing the properties of a given material or element in the articles under analysis: resistivity, porosity, conductivity, dispersability, diffusivity. In the given examples one can see that the derived noun form is made up of verb bases mainly (resist, conduct, disperse, fuse).

There are some examples of adjectives derived with a borrowed suffix of Latin origin -al: quadrilateral, computational, microscopic, multidirectional, colloidal, sacrificial, topological.

To describe properties or states of the materials derivational adjectives are formed with the help of the productive frequent suffix -ed added to the verb or noun bases: required, solidified, scaled, dealloyed, structured, boronized, prefabricated, infrared, heated, processed.

According to the lexico-grammatical character of the radical suffixes are classified into the following types:
- de-verbal suffixes (added to the verbal base): -er, -ing, -ment, -able,
- de-nominal suffixes (added to the noun base): -less, -ish, -ful, -ist, -some
- de-adjectival suffixes (affixed to the adjective base): -en, -ly, -ish, -ness.

In the research articles under analysis there is a considerable number of de-verbal suffixes which make nouns. The derived nouns with productive -ing suffix possess the meaning of process implied in the verb base: sintering, handling, leaching, cutting, grinding, processing, acidizing, strengthening, backtracking.

There are also semi-affixes, which can either be attached to the base to form a word or can function as independent lexemes.

3. Composition
Composition is a process of word-formation where two or more lexemes combine into a single new word. Compound words may be represented by one word or by two words joined together with a hyphen. The syntactic relation between the words can be traced and shown. Compounds are made up of two immediate constituents (according to morphological analysis) which are called derivational bases. Compound words are inseparable vocabulary units.

Structurally compound words are characterized by the specific order and arrangement of the bases following one another. The order in which the two bases are placed within a compound is rigidly fixed in Modern English and it is the second immediate constituent that makes the head-member of the word, in other words, forms its structural and semantic centre [7]. The term head is generally used to refer to the most important unit in complex linguistic structures.

The classifications of compounds are based upon the type of composition, the linking element, the part of speech and upon the structural pattern.

As for presence or absence of connecting elements, compounds are divided into those without connecting elements or hyphenated, compounds with a vowel or consonant as a linking element and composed words with linking elements represented by preposition or conjunction stems.

According to the structure, compounds can be neutral (without linking elements). There are three subtypes of neutral compounds depending on the structure of the constituent stems: simple or simplexes consisting of simple affixless stems; derivational compounds or complexes having affixes in their structure; contracted compounds which have a shortened (contracted) stem in their structure.

The structural type of compound words and the word-building type of composition have certain advantages for communication purposes. The structural meaning of the derivational pattern of compounds may be abstracted and described through the interrelation of its immediate constituents.

Compound words usually belong to adjectives as a part of speech. Lexical analysis of technical vocabulary from the research papers revealed the following types of compounds. The first largest group are presented by hyphenated derivational or simple compounds formed to the pattern Adj + Adj (adjective+adjective), Adj+N (adjective + noun), N+N (noun+noun), N+Adj (noun+adjective):

Adj+Adj: hexagonal-prismatic, linear-elastic, electro-active, hot-extruded, electrically-actuated, electroless-deposited, multi-layered, electro-deposition, mixed-made, inter-tube;
Adj+N: cohesive-zone, high-purity low-voltage high-ductility high-strength, hot-pressing, reduced-weight;
N+Adj: load-transfer load-carrying, center-notched, node-release, size-dependent, element-based, energy-efficient, size-dependent, bulk-nanostructured, load-applied;
N+N: stress-strain, displacement-delamination, traction-separation, shape-memory, scale-removal, core-shell, liquid-phase.

Adjectival compounds formed by the structural pattern N+Adj can have nouns or other adjectives as non-heads. The interpretation of noun-adjective compounds follows the principles that the non-head element can function either as a modifier as an argument of the head.

Within the structural pattern N+Adj in some cases we can observe with the derivational suffix -ed, whose derivatives can be paraphrased as “having some quality” or “provided with some quality or feature”. Besides, compounds with adjectival heads that are based on past participles also can imply a passive interpretation.

The above-written compound words have the meanings connected with materials processing, the inner structure of element and its properties or for the description of physical and chemical conditions during the experimental studies.

The next group of hyphenated compounds are implied in technical writing to define the mixture of substances or elements under analysis: graphene-oxide, ceramic-polymer, alumina-polymer, polymer — only, boride-based, single-crystal, ceramic-metal.

Morphological compounds are quite few in number: thermoelectric, hydrofluoric, morphometric, thermodynamics, lithiographic, electrochemical, flexographic, petrochemical.

Compounds of different structural types are numerous in the articles under investigation. A very common type of compounds is syntactic ones. It can be illustrated by the following examples: push-to-pull, length-to-diameter, coupling-to-tubing, thermal-to-electrical strength-to-density, roll-to-roll, smaller-is-stronger.

All these composed lexical units have linking elements represented by preposition stems. These derivational adjectives are based on the semantic relations of sequence or consequence or manner. They are usually formed according to the pattern N+to+N or Adj+to+Adj.

We have divided composed words from the articles into several groups according to the pattern they are built upon.

4. Shortening (Contraction)
Contracted or curtailed words are produced in two different ways. The first is to make a new word from a syllable or two of the original word. The second way of shortening is to make a new word from the initial letters of a word group. This type is called initial shortenings. The new form acquires some linguistic value of its own.

Abbreviation refers to any shortened form of a word or a phrase. An acronym is an abbreviation of a special type that abounds in technical and scientific writing. Acronyms imply forming new elements not by combining existing morphemes and proceeding from sound forms to their graphic representation but coining new words from the initial letters of phrasal terms originating in texts.

Abbreviations can be a useful way to make writing and speaking more concise, less repetitive, and more accessible to nonscientists [8].

Abbreviation does not change the part-of-speech meaning - it produces words belonging to the same part of speech as the primary word. Initial abbreviation in which the first element is a letter and the second a complete word. Shortening may be regarded as a type of root creation because the resulting new morphemes are capable of being used as free forms and combine with bound forms.

There are few classifications of shortened words. The generally accepted division is based on the position of the clipped part. According to whether it is the final, initial or middle part of the word that is cut off we distinguish: 1) final clipping (or apocope) 2) initial clipping (apheresis) 3) medial (or syncope) [9].
Graphical abbreviations are the result of shortening of words and word-groups only in written speech while in spoken language full forms are used [10].

In technical writing abbreviations are used to make long names of experimental processes and long technical terms easier to remember and less tedious to refer to repeatedly in a scientific article. In such contexts the long name or technical term first is often given in full form with the abbreviation in brackets after it. After it has been mentioned, just the abbreviation is used. There are a lot of examples of this kind in scientific papers on materials science:

- additive manufacturing — AM
- computer-aided design — CAM
- selective laser sintering - SLS
- dielectric elastomer actuator - DEA
- electroactive hydraulic sar - EAHS
- lamellar dislocation substructured - LDS
- electron channeling contrast imagine - ECCI
- electron backscatter diffraction - EBSD
- misorientation histograms - MDH
- surface mechanical grinding treatment - SMGT
- stream-assisted gravity drainage - SAGD
- thermal and cyclic steam stimulation - TSS and CSS
- physical vapor deposition —PVD
- chemical vapor deposition - CVD
- carbon nanotube - CNT
- resistance pressure sintering- RPS
- SEM - scanning electron microscopy.

They are primarily used for the economy of space and effort in writing.

5. Conclusion

Scientists and researches make use of different terms and vocabulary units to convey the results of their research. Technical writing has its own lexical features, such as nominalization, acronyms, usage of Greek and Latin derivational word-building elements, affixation and composition as the main productive ways of word building [11]. The aim of the article was to define the most productive ways of creating new words in the field of materials science. It has been stated that composition is the primary source of word formations for creating new adjectives. It can be explained by the domain of research articles [12]. Materials science deals with new ways and technologies of improving materials properties and performance as well as with creation of new materials types. Therefore, compound adjectives of different structural patterns serve to describe all the core concepts and describe physical and chemical properties, conditions and stages of the experiment. The study of technical vocabulary shows that the hyphenated simple or derived compounds of structural patterns like N+Adj, Adj+N, Adj+Adj, Adj+N are the most common ones. More complex terms are sometimes expressed by noun phrases consisting of three or more words. These nominal groups are contracted to abbreviations in scientific writing. It saves the space and makes the long term shorter and clearer to the reader. Another type of word formation - affixation - is also proved to be a productive way of forming technical words in the field of materials science. The study has revealed the most frequent adjective-forming, noun-forming and adverb-forming suffixes. Prefixes that are mainly of Greek origin connected with concepts of size and nature (micro-, macro-, bio-). They are used to make derivational compounds like microstructure, biomaterial. Moreover, words derived with these combining initial forms are called neoclassical compounds and they present an active source of vocabulary extension in the English language. Other derivational affixes observed in the articles are negative prefix non-, locative prefix inter-, adjectival suffix -al, noun-forming suffix -ion and adjectival suffix -ed and

The above-mentioned features tend to cluster together as lexical characteristic of scientific writing. The result of the current study will be immensely useful for the researchers who regularly present their
findings because it can help them to understand the technical vocabulary implied and to create new words which are connected with materials, their chemical and physical properties, procedures and stages of the experiments involved. Moreover, being aware of lexical features in scientific articles it is of great importance to scientists who are not native English speakers, as it helps them to get the main point of the article and to understand the text more clearly.

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