

DOI: 10.17725/rensit.2022.14.341

Triad matter - substance - material

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Received April 01, 2022, peer-reviewed April 08, 2022, accepted April 15, 2022

Abstract: An essay on the philosophical aspects of materials science in the absence of a modern philosophical category "material" is presented. The features of the categories "substance" and "material" are considered, which express the distinctive properties of the corresponding objects of nature - the formlessness of the substance and the proper form of the material, the size of the particles of the substance and the structural form of the material. Substance-material mutual transformations, their energy aspects, a certain conditionality of the substance-material boundary, and adequate filling of the corresponding categories are analyzed. Also noted is the virtual reality of the elements of the structure of matter and material, its dependence on the distorting influence of experimental tools. The prospects of translating the regularities of matter-material transformation to extraterrestrial objects are noted.

Keywords: materials science, material shape, substance particle size, substance-material transformation

UDC 1:001; 001.8; 02.31.31; 620.22: 81.09.01

For citation: Sergey P. Gubin. Triad matter–substance–material. *RENSIT: Radioelectronics. Nanosystems. Information Technologies*, 2022, 14(3):341-348. DOI: 10.17725/rensit.2022.14.341.

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1. INTRODUCTION

A person, having once been on the planet Earth, was forced, in order to ensure his existence, first of all to establish interaction with the surrounding material world. This interaction, the development of the surrounding world proceeded empirically, by the method of "trial and error". And it turned out that the surrounding world, perceived by Man, with all its diversity, consists of objects of two types – having their own FORM and FORMLESS media – gaseous, liquid, dispersed (loose), etc.

Being himself an integral part of the material world, from the first steps of his formation, Man began not only to "master" the surrounding material world, but also to adapt (remake) it to his

needs. Since then, this process has not stopped even for a minute.

However, since ancient times, it has turned out that in the philosophical understanding of the surrounding world, the categories of *spirit* and *matter* (*primary substance, substance*) turned out to be not equivalent from the point of view of Man: "mundane" matter somehow attracted his attention less than everything connected with the spiritual side his life. Somehow, there was an idea behind the scenes that the material world is something "simple" that does not require special attention. Philosophy of nature, ancient and medieval – natural philosophy from the pre-Socratics and Aristotle [1] to Thomas Aquinas [2] was richly kneaded in the "expression of will" of spiritual forces, mystical within the existing level of scientific knowledge.

REMARK

It should be noted that and at the present time both *matter* as a whole and its categories such as *substance* and, in particular, *material*, do not often appear as a basis (subject) for discussion on the pages of philosophical publications [3,4]. There

is a section of the science – materials science, but there is no definition of what a material is. There is no material classification. At the same time, any Person always deals with materials, is immersed in the material world.

There is an urgent need for a modern philosophical interpretation of such forms of reason as the categories of *substance* and *material*, which interpret the corresponding states of matter, their mutual transformations and place among other types of matter. While Man in everyday life and activity deals with objects of precisely these two categories of both mineral and biological origin, their modern philosophical interpretation leaves much to be desired. Therefore, the concentration on these issues of the attention of specialists from different areas within the framework of anthropocentric perception of the material world does not seem superfluous. In this paper, an attempt is made to place accents in the interpretation of the categories matter – substance – material.

2. MATTER

The world around us in the Human consciousness (perception) is divided into material – given to us in direct sensations by our senses, and "non-material" – created by us in our consciousness on the basis of the field attributes of matter, including information, and their analysis and synthesis. Although there is often no sharp boundary between the two worlds in the mind, such a habitual dichotomy allows a Human to navigate in the environment, trying to use the objects of the material world not only to ensure his own existence, but also to cognize the "non-material" world with their help.

Usually, both specialists working in the field of natural science and technology and ordinary people deal with matter in three types – either with compact objects in the form of subjects, products, samples, pieces of rock, etc. (we will call them materials), or with shapeless objects in the form of powders of varying degrees of dispersion, liquids or gases (let's classify them as

substances), or, finally, with field attributes of the surrounding world given to us in sensations. Both that, and another, and the third are parts of a more general philosophical category of *matter*, which thus represents to Man three types of existing objects – objectively rigid, or completely formless, as well as field.

Of all the types (kinds, varieties) of matter, we will here consider only substances and materials with which Man constantly deals and voluntarily or involuntarily studies (feels, observes, classifies, etc.) directly (real, not speculative), with using his senses: sight, touch, hearing. Staying at the same time in the fields of the surrounding world (gravitational, electromagnetic) and using them as far as possible and necessary.

REMARK

Having set foot on another Celestial body, the first thing a Man will not be interested in is whether he has many electrons, bosons, etc. under his feet. First of all, he will be interested in what kind (state) the matter is under his feet and whether it is possible from it and how to create a material world around him that is close to the Earthly one. That it is a free-flowing shapeless powder in which a heavy object sinks without finding support, or is it a solid compact object that you can lean on. At the same time, the composition, structure, electronic structure, etc. will be of interest to him later. On Earth, Man answered these questions a long time ago (hundreds of thousands of years ago) using the "trial and error" method. On other Celestial bodies, he will never have such a reserve of time. It is necessary to know more deeply the properties of matter in various states, the possible variants of its morphological transformations.

3. SUBSTANCE

At the anthropocentric approach, substance is one of the types of matter perceived by Man as such and at the same time as what the entire material world perceived by him on Earth consists of.

To the category of *substance*, we will refer objects of the surrounding world that do not have their own FORM under normal conditions – gases, liquids, loose powders and other dispersions. Being left to themselves, these objects, under the influence of the Earth's force field, spread (scatter) over the surface in a thin layer. The constituent parts (powders, flakes, drops, etc.) of a substance are too loosely interconnected to resist the action of the Earth's force field, which, when freely poured out (pouring out), usually leads to uniform distribution (spreading) over the surface so that individual parts experienced the same force of Earth's gravity. Such objects (substances) usually take the form of the that volume (vessel, can, box, etc.) in which they are located.

The key parameter of a substance is the SIZE of its constituent macro- and microparticles (crystallites, molecules, clusters, atoms, elementary particles) and their interaction. And although the category – *substance* appeared in philosophy quite a long time ago, its current definition is completely (without any participation of philosophy) formulated in terms of modern physics.

3.1. NANO-CONDITION OF SUBSTANCE

The dispersion (and dispersibility) of a substance (including spontaneous) is determined, depends on the ratio of the energies of intra- and interparticle interaction. At the same time, large material objects (large crystals, large ingots, etc.) do not differ in properties from smaller samples. In contrast, when materials (and substances) are crushed to sizes nano-, there comes a moment when the properties change, moreover sharply. Such a nano-condition of substance can be preserved not only in dispersed media, but also in compact materials. Similar discreteness is due to energy factors.

Nanosized particles of substance – nanoparticles – one of the forms of existence of matter. A person cannot fix the nano-condition of matter without instruments

and equipment, but special properties of nanoobjects are detected in some cases.

REMARK

A nanoparticle (NP) is a part of the whole, having dimensions of several nanometers; "whole" is a substance in the form of a gas, liquid or solid body (material). Having the same composition, NPs differ in properties (often significantly, sometimes radically) from the "parent" material (gas, liquid, solid). In other words, without changing the composition of the sample, it is possible to transform it by grinding into a substance (material) with fundamentally different properties. This feature requires the separation of NPs into a separate class of objects that differ from atoms, ions, molecules, or clusters, on the one hand, and micropowders, granules, crystallites, etc. – with another.

Thus, from the point of view of Man, the category – *substance*, denoting the corresponding condition of matter, has an ubiquitous character on Earth, but is perceived by Man rather abstractly. The category *substance* is broader than what is usually called material.

4. MATERIAL

Category *material* has long been considered as part of a more general philosophical category of *matter*, while materials (of which there are a great many in the environment of Man) remained out of discussion, as well as their mutual transformations.

In classical philosophy, this category is absent.

A material is a kind of matter that has its own FORM under the Earth's p, T conditions – the key parameter of the material. In other words, a material is a substance in which the individual components interact with each other strongly enough to resist gravity and not crumble.

When the FORM is lost (during crushing, melting, etc.), the material turns into a substance, as a rule, of the same

composition. This process is reversible, there are a significant number of techniques and methods for giving the substance its own form, i.e. transformation it into material. Material objects can take various forms, the role of which is to distinguish this material object from the environment. If the material is in the form of one or another object, then the Person identifies it primarily by its shape, structural features and weight (mass).

Unlike a substance, a material, being in the form of pieces, products, etc. objects, usually has one or another form of its own, which is able to resist the action of the Earth's force field and keeps the substance contained in its composition in the form of various three-dimensional objects – from kilometer-long mountains to thin films. Individual components in the material are linked into a single whole.

A person has long learned to give a free-flowing formless substance one or another form he needs, turning it into a material object. The substance turned into a material begins to show new qualities (properties) that are not characteristic of a shapeless mass. For example, quartz single crystals (*material*) are used in spectral experiments, but are unsuitable for polish, while fine quartz powder (*substance*) is excellent for polish, but it is unsuitable for using in spectral devices. In other words, the shape of a material can change his properties when transformed from a substance and vice versa; when a material is created from a substance, the latter often acquires new properties. That is Man in his practical activity has long learned to turn substance into material and back material into substance.

As a result, a Man at any given moment can have matter at hand in the form that is convenient for his practical tasks (goals). The ability to transform the surrounding matter into the necessary state is the greatest achievement of Mankind.

REMARK

Herewith we are talking ONLY about inanimate nature, biotransformations of matter are beyond the scope of this consideration.

4.1. FORM

The substance has a composition and an structure, but does not have its own form, while any material reality cannot remain formless for a long time. The form limits the place in space that a given material object occupies. The form allocates (isolates, separates) the object in the general flow of matter.

What is new in a substance when it takes on a form? Being in a dispersed state, all parts of matter interact equally (equally) both with the force field of the Earth and with the components of the environment – radiation, gases, liquids. Giving shape to a formless substance is a "fight against entropy", the material has better organization and less chaos than in the original substance. As soon as the transformation of substance into material has taken place, the differentiation of substance into internal and external immediately appears. These two parts of the same substance begin to differ not only in morphology and structure, but often also in composition. The transformation of a completely homogeneous substance into a material is always accompanied by the appearance of a certain amount of heterogeneity (differentiation) in it. The original homogeneous substance is transformed into a more complex, non-single-component object. At the same time, one of the essential components of the material is a special structure – the shell.

4.2. SHELL

Any material object exists in the environment. Between the material and the environment, by definition, there is a border divide where the objects in contact interact with each other. So, any surface to some extent sorbs the components of the environment. In addition, parts of the material that are on its surface are in an asymmetric environment

due to energy differences inside the material and outside it. At the same time, individual structural elements do not stick out on the surface as fragments of broken bonds, but find opportunities to interact with each other, which leads to the emergence of a new substance – SHELL, covering the surface of a material object.

POSTULATE

The shell that separates the material from the environment is an integral his component, which has its own structure and properties.

Since the shell is an self-dependent component of the system, it is counterproductive to neglect its existence. The shell of the material always exists, although it may be atomically thin and hardly noticeable, or it may be quite perceptible.

The material is in the shell as in a cocoon, often it supports it, protects it, determines the connection with the outside world. The composition and structure of the shell (interface) always differs to a greater or lesser extent both from what is inside and, of course, from the environment in which the object is located. The shell is always the result (product) of the interaction of internal and external. And the contribution of each of these two parts of the material can vary from almost 0 to almost 100%, but both of these components are always present in any sample.

The shell, being atomically thin, is such that it is usually considered that it does not exist, but it certainly exists and will manifest itself under certain conditions. The shell-core ratio of the material can be arbitrarily small, but there will always be a situation in which the influence of the shell will be noticeable.

Friction, corrosion, absorption or reflection of energy, and many other processes begin (and often are realized) precisely in the surface layer (shell) of material. Thus, the shell is an integral part of the material.

5. SUBSTANCE-MATERIAL INTERCONVERSIONS

Within the framework of Kant's empirical realism taken as a basis in this work, matter in any form on Earth is a reality given to us in direct sensations. This is the first, "SURFACE" level of Man interaction with the material world. There is no place for electrons, atoms, ions, clusters, nanoparticles, etc. – that is, elements with the use of which they usually distinguish, classify, build the structure of substances and materials. This second level is no already based on the results of Man direct observations.

The reality of the above elements of the structure of substance and material is usually based on the data of devices and the results of calculations. A Man cannot directly receive information about these structural elements. For a Man, this is another, virtual reality, the fruit of our consciousness. Their perception is due to the presence of the necessary instrumental base and computer technology in the Man. Without them, the presence of these structural elements in substances and materials remains speculative.

A person was forced to place between matter and himself a certain device (let's call it a device in a broad sense), with the help of which it became possible to look inside a substance or material. Over time, such "devices" appeared a great many.

But any devices to some extent distort information about the object. A Man is forced to constantly recheck the information received in this way in order to confidently navigate in the surrounding material world.

From the frequent use of these virtual concepts (nothing more), they are often operated on as if they had become quite real, tangible; they are drawn, molded, models are built, etc. But it's still a typical virtual reality. The boundary between the virtual and real worlds in the Man consciousness is gradually blurred.

The internal structure of substances and materials is outside the scope of our anthropocentric research – since the Human senses cannot directly and reliably identify objects smaller than 10 microns, and even more so – their internal structure.

5.1. MUTUAL TRANSFORMATIONS SUBSTANCE - MATERIAL

Nature knows how to turn materials into substances and substances into materials. A person has mastered (created new ones) many techniques (technologies) that allow such transformations to be carried out.

The conditionality of the substance–material boundary is illustrated by the following example: a finely crystalline powder of table salt is a typical substance, and a cubic single crystal grown from it is a material. Plates are cut out of it and used in spectral studies. At the same time, the composition and structure remain unchanged. This is a typical transformation of substance into material.

On the other hand, you can take a microcrystal of salt from a salt shaker and print an electronic circuit of nanoscale on it. In this case, the microcrystal, remaining a substance, turns into a substrate for the circuit – a typical material, while the composition and internal structure remain unchanged. This example illustrates the conventionality of the boundaries between the categories *substance* and *material*. Any material is a substance, but not all substance is a material.

With such reasoning, it is necessary to introduce one or another coordinate system. Such transformations are constantly taking place in the material world surrounding Man. They are divided into natural and artificial. The first occur without the participation of Man. Materials once created by Nature in the form of massive ridges, mountains, plates and other similar material objects over time (billions of years) spontaneously transform from shaped materials into shapeless fine dispersions of various types – sands, water dispersions, solutions, etc.

But Nature is able not only to transform materials into substances, but also to transform substances into materials. Most often these are thermal processes under pressure, etc.

From the moment of his formation, man has existed in the environment of substances and materials created by Nature, but gradually their "range" ceases to satisfy him. Man began to master techniques that allowed him to give the substance the shape and functionality he needed, and to mold various material objects from loose substances. A person has mastered (created) many techniques (technologies) that allow such transformations to be carried out.

Such transformations occur only under certain conditions: for example, a liquid substance – water (a typical formless substance) turns into a material – ice below 0°C, CO₂ gas (substance) below minus 80°C turns into a fairly strong material, the so-called dry ice. These typical materials with increasing temperature (changing p, T conditions) pass from materials to matter. These are phase transitions of the first kind. Many other types of such transformations are known.

Thus, the matter surrounding Man on Earth appears to him in the form of two categories of substance and/or material, which are in constant mutual transformations.

5.2. ENERGY

Matter in the form of a dispersed substance has a large reserve of internal energy compared to that which has a compact material of the same mass and composition. The transformation of a compact material into a dispersed substance (chaotization of matter) is accompanied by an increase in the internal energy of the system, while when an object is ordered (for example, when a substance is transformed into a crystalline monolith), excess energy is released in one form or another.

When solving the problems that arise before it, Nature makes extensive use of this regularity in the processes of conservation and reconversion of energy not only on a local,

but also on a planetary scale. A person is still (thank God!) too weak technically to effectively participate in these processes.

Note, however, that as the Earth ages, the processes of dispersion of materials on its surface gradually begin to prevail over compaction: in other words, there is more and more matter in the dispersed state on the surface of the Earth; perhaps this is a temporary phenomenon.

Man, together with the matter surrounding him, being on the surface of the Earth, is exposed to the environment of the force and magnetic field of the Earth, thermal radiation of the Earth and the Sun, cosmic rays, atmosphere, pressure, aggressiveness of the environment, etc. The types of matter surrounding Man – substances and materials – react differently to the action of these environmental factors. In a compact material, the main "impact" is taken by the surface layer (shell). Under the influence of the factors listed above, the shell can change not only the structure, but also the composition, continuity, etc. The change in the phase state of matter (melting, dissolution, evaporation), which is in the form of a substance or material, occurs differently, the boundaries of phase stability depend on the degree of dispersion of the object. Since matter in the form of a substance has a much larger surface area per unit mass than that of a compact material, the results of external influences are manifested more intensely, distinctly, brightly.

5.3. ABOUT SIZES AND DISPERSION

Human interaction with the material world is limited by the capabilities of his senses. Most of the micro- and the entire nano-world remain outside the limits of direct perception by Man.

The properties of the material do not change when the dimensions of the sample are changed up to certain limits. A giant (weighing tens of kilograms) sample of quartz in the form of a single crystal and a small quartz plate have the same set of properties. On the other hand, the material in the form of one or another

three-dimensional object loses its shape during grinding and turns into a powder (substance), as a rule, without changing its composition (in this case, into quartz powder). But in the usual sense, the object ceases to be a material and passes from a real quartz to a virtual state, when a Person is no longer able to directly (without any auxiliary devices) identify it as quartz, and not table salt. In other words, it is difficult for a person to distinguish fine quartz powder from other equally dispersed powders. The sample loses its individuality.

Changing the size of an object first of all changes the ratio of the surface layer (shell) to the total mass of the object. For the majority of real material objects surrounding Man, these changes are insignificant and, as a rule, they are neglected. The size of objects from 100 to 10 microns is the limit where the possibilities of direct (only using touch and vision) interaction between a Human and the outside world end. Deeper – only with the help of auxiliary devices (devices, etc.).

AXIOM

All auxiliary research devices to some extent distort information about the object under study. Therefore, when creating a picture of an object less than 10 microns close to reality, a combination of instruments and methods and a cross-analysis of the results are used.

Based on the above, the following definition can be given.

Materials science is a branch of science about a substance that is in the form of compact materials of various shapes, and about the relationship between their structure, physical and chemical properties and performance characteristics.

REMARK

The term "materials science" is widely represented in educational, scientific and technical literature. As usual, each author gives his own definition; their diversity reflects the versatility of the topic and the relative youth of this branch of science.

6. CONCLUSION

Being in the Earth conditions, a Man from all types of matter primarily interacts (communicates) with substances and materials that ensure his existence not only as a person (subject), but also allow him to claim the role of a global player in the UNIVERSE, while still not far from the Earth, but in the future this role is quite definite. In this regard, it can be assumed that having ever been on another celestial body, where other chemical (composition of the surface and gaseous shell) and physical (p, T , gravitational and electromagnetic fields) conditions on the surface, Man, as well as on Earth, first of all, will meet matter in the form of a formless mass of substance and various compact material objects of various shapes and hardness. It will be necessary to know in what form the matter is on the surface of a given celestial body (substance-material ratio) and how these types of matter will interact with Man. Later, it will be necessary to know how the conditions of substance-material interconversions on a given celestial body differ from those on Earth. Without this, it will hardly be possible to gain a foothold in the new territory. Transporting matter (substances and materials) from the Earth is counterproductive. Matter is everywhere – Man needs to learn how to turn it into substances, materials and vital objects that he needs at a given point in the Universe.

If we figure out how such transformations take place on Earth, the translation of these regularities to extraterrestrial objects will become more reliable.

It can be assumed that the two types of matter discussed above will, just as on Earth, constitute the main environment of Man. And he will need not only to understand, but also to manage the processes of their mutual transformations in conditions different from those on Earth. It is quite possible that matter exists on other celestial bodies in other forms than on Earth,

but the essence of their primary anthropocentric perception is unlikely to be different.

The quite natural desire of Man to understand the internal structure of material objects diverted attention from the "lying on the surface" properties of matter. It can be seen that even before "looking inside" it is possible to investigate the interaction between Man and matter.

REMARK

Biological materials and, in general, issues of materials science of biological systems are not considered here. The main attention here is paid to the issues of compatibility of "ordinary" materials with biological (including living) systems. Solid parts of living organisms such as bones, shells, shells, corals, etc. are not usually the subject of materials science research, although their role in the formation of the earth's crust can hardly be overestimated. When considering these phenomena, one would inevitably have to touch upon the philosophical aspects of the "living-non-living" problem, which is beyond the scope of this essay.

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