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Interdependence of Fundamental and Applied Research in Material Science

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Abstract:
Development of materials with desirable properties essentially depends on realization of interdependence: natural science ⇔ technical sciences. Taking this into account, in order to develop of new advanced materials it is essential to determine principles that characterize this interdependency.

Therefore, in this article the principles of fundamental research and the importance of obtained results are considered and implemented in the field of technical realizations.
Keywords: *Fundamental and applied sciences; Materials science; Advanced materials.*

1. Causal Relationship Between Fundamental and Applied Research in Material Science

Theoretical achievements of fundamental research are the basis of experimental applied research. Basically, the applied research is focused on solving the practical problems or on investigations of scientifically founded solutions which represent the foundation for engineering achievements.

The explosive development of material science in second half of the last century was the result of fundamental research in physics, chemistry and mathematics. Consequently, such multidisciplinary science became the basis for various new technologies without which there wouldn't be development of modern electronics, machinery construction and space technology as we know it.

There is a causal relationship among individual science disciplines as shown on diagram 1.

This kind of relationship between fundamental and applied natural sciences, as well as technical sciences, obviously proves that those are only links of one unique chain of science without which there is no and there could not be any development.

Regardless of this, very often the applied research is unjustifiably being opposed to fundamental research. However, the fact is that the fundamental sciences are focused on search for truth, while applied ones are intended to offer the answer on how to organize results of fundamental sciences.

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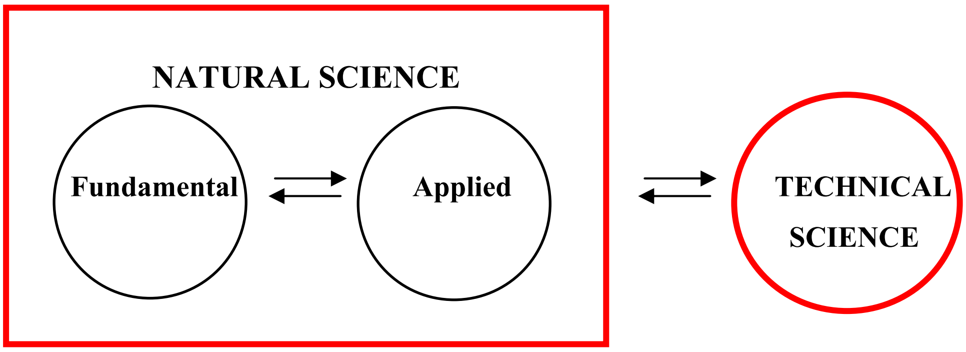

Fig. 1. Relationship between natural and technical science

Applied research, in general, focuses on comprehensive study of new phenomena with respect to certain possible applications as well as from the standpoint of an appropriate interpretation. This is the starting point of a certain engineering achievement. In fact, the applied research contributes to the exploration for technical solutions, while realizing the connection between the natural and technical sciences.

To determine the linking mechanism between fundamental and applied research it is essential to accurately determine a causal function that defines the interaction of natural sciences and engineering sector.

Finally, with respect to the mutual relations between technical and natural sciences it is undeniable that the technical science is firmly linked to the applied sciences, since they have the same task - the practical application of the results of fundamental research.

2. Affiliation of Natural and Technical Sciences

The modern approach of interpreting the importance of science and attempt to turn the science into a significant force of production and driving force of development is very often too simplified, so all efforts made in this direction contribute to the negation of the basic effort. It is impossible to imagine any kind of scientific progress without achieving the causal coherency of natural and technical sciences, which however, must not in any case to be of a formal character.

If we start from the fact that today's technical progress is achieved through the chain which consists of three links:

- Fundamental (basic) research,
- Applied research and
- Practical application of results of applied research along with further personal developmental research then, the interconnection of these links could be shown with sharply curved logistical graph whose basic properties are derived from the analysis of growth in the organic world, economics and science.

The relationship of science and industrial realization is shown in Fig. 2.

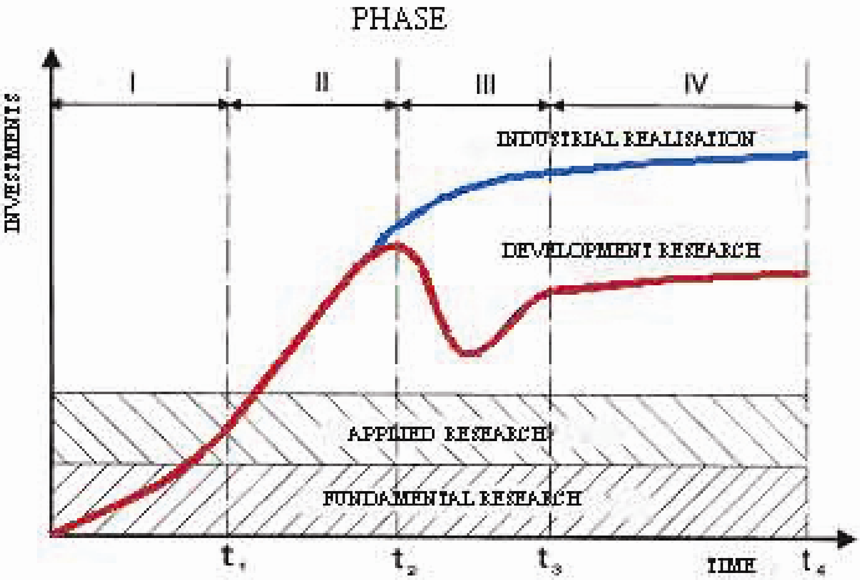

Fig. 2. The relationship of science and industrial realization

Given this the characteristics of particular phases are as follows:

Stage I – the phase of basic research (0-t_1) can be very different time-wise, depending on the scientific level and investment in this research. In general, fundamental research must be ongoing, because only in this way necessary conditions of realization of phase II-IV could be established. In the phase I the ongoing development of staff who will work in all fields of research is being carried out, including the industrial implementation. This, in fact, establishes necessary conditions for causal connections between all research and industrial implementation.

Stage II (t_1-t_2) begins with a jump caused by the knowledge of the potential value of the relevant discovery. This is the phase of maximal activity. Characteristics of the phase II is the occurrence of a specific project and increase of the number of researchers involved in orientated and applied research. During the phase II the economic prospects have the main role. The results achieved in fundamental research are used in applied research, which results continue to serve the realization of concrete production program.

Stage III (t_2-t_3) is characterized by separation of the disposition of scientific and professional experts. At this point a significant increase in activity is achieved by enforced involvement of engineers, designers, administrators, technicians, etc.

At the same time a reduction in number of scientists involved in developmental research is taking place. This causes reduction of financial costs for targeted research, so that at the end of the phase III of investment the cost of research is minimal.

Stage IV (T3-T4) is characterized by the simultaneous independence, but also a causal connection between the realization of industrial research and generated development of research from inflow of funds from industrial implementation. This is conditioned by the necessity of further production development, because maintenance of achieved level, or continued modernization, requires new scientific results. It is quite obvious that optimal solution for development of scientific-research activities has to be seen in light of these principles of connection between science and industrial realization. The analysis of contemporary development of science consequently shows that it is necessary to do everything to achieve multi-disciplinary programs.

3. Modeling and Simulation in Material Science

Modeling and simulation are of the great significance for material science [1]. The concepts of modeling should be based the principles of self- organization and on a complex relationship between individual sequences from the ground state of matter (via the synthesis of materials) and properties of final components (Fig. 3).

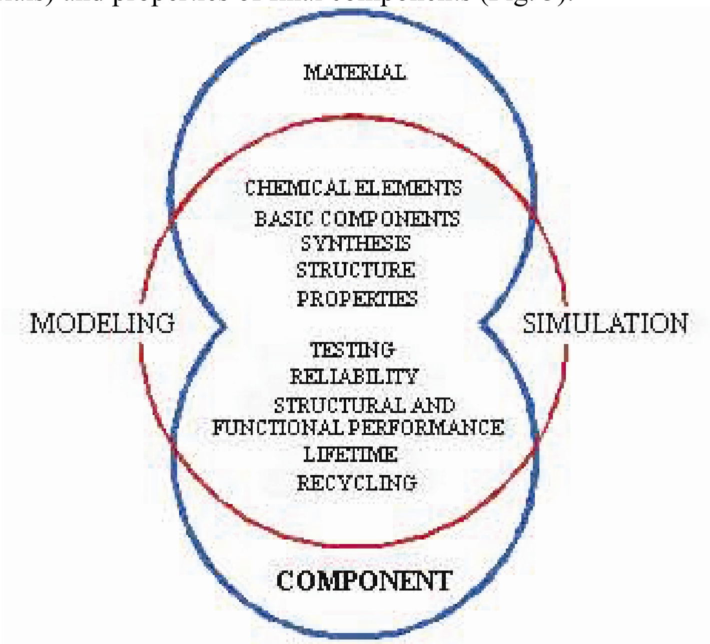

Fig 3. Modeling and simulation in material science

The properties of materials obtained by that way are much better, then those obtained by traditional methods (non-homogenous structure and chemical composition) [2]. Detailed study of the problems of obtaining a new materials show that the period from the beginning of research in lab conditions up to the commencement of sustainable commercial production is around 10 years (Fig 4) [3].

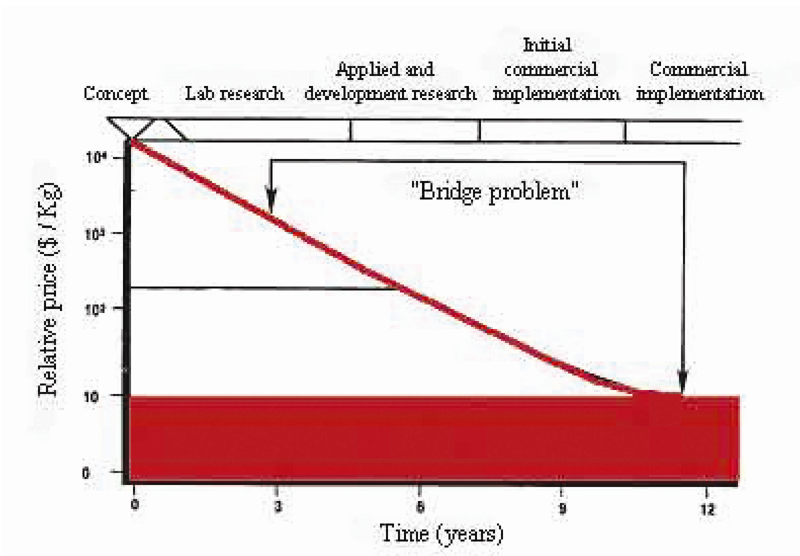

Fig. 4. A typical curve of development of new materials

In accordance with this, for example, is a realistic scheme of developing functional materials (Fig. 5) based on principles of configuration model of G.V. Samsonov [4-7].

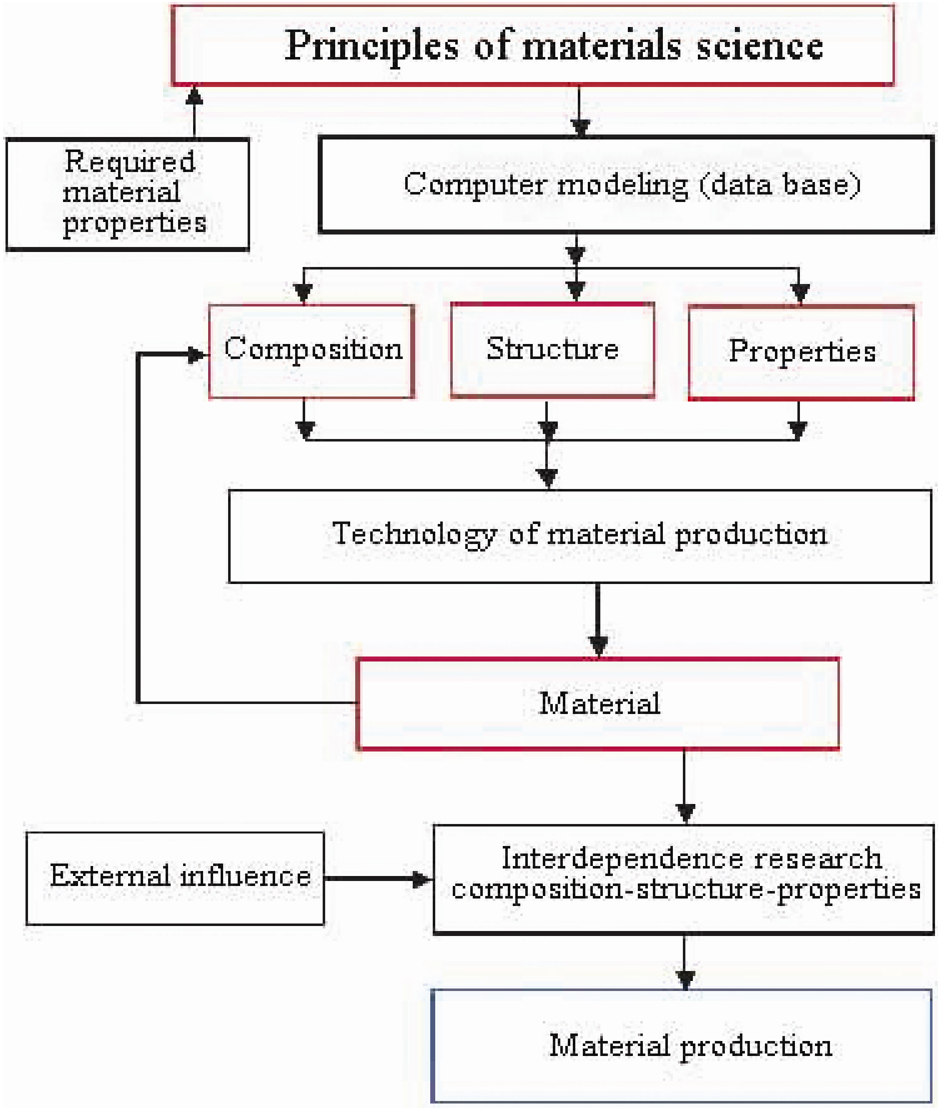

Fig. 5. The scheme of obtaining of functional materials

Starting from the principle of this model it is possible to set the scheme "composition-structure-properties-technology", based on which the principles of material application are being defined.

Fig. 6 shows the number of possible phase diagrams in function of the number of elements. Today there are 86 simple systems (elements), 3655 binary systems, more than a 100.000 ternary systems, although it is theoretically possible that there is $6{,}6 \cdot 10^{24}$ phase diagrams with only 43 elements.

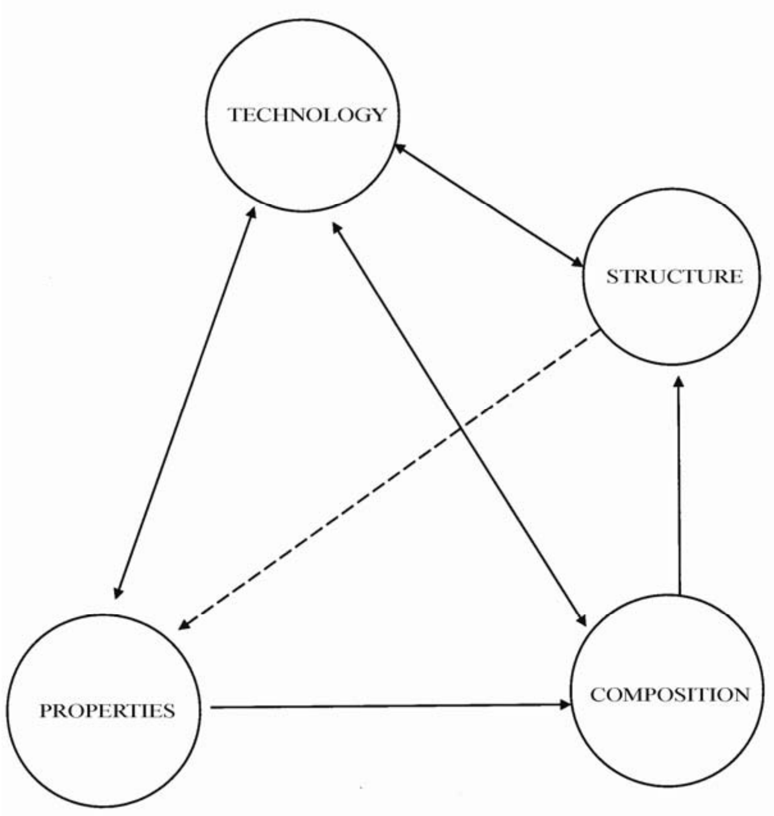

Fig. 6. Tetrads "Composition-Structure-Properties-Technology"

The number of phase diagrams so far investigated is about 10,000. This is shown in Fig. 7 ("mountain" of materials) with a small dark-hatched area. This surface [8] represents all known materials.

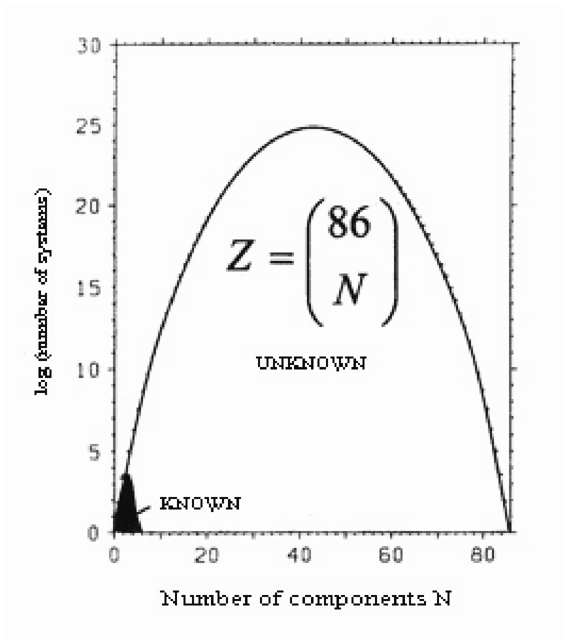

Fig. 7. ''Mountain'' of materials

The ratio of known-unknown materials based on possible phase diagrams is less than

10^{-22}. However, many possible combinations of elements would not be of any practical significance, but a combination of many elements will inevitably lead to the appearance of completely new materials.

At the same time, we must bear in mind that the traditional technologies of obtaining materials are based mainly on quasi-balanced processes which ensure the formation of structure in terms of aspirations of the system state characterized by the minimum value of free energy.

This greatly limits the possibility of the targeted structure and material property management and, as a rule, does not allow obtaining a materials of homogeneous and uniform structure. In open systems, characterized by an intense external impact which ensures that with introduction of the thermodynamic forces and/or fluxes of critical values corresponding to bifurcation points, self-organization of dissipative structures with new properties of symmetry is going on, which again characterizes the way the organization of individual elements and connections between them. Therefore, under the organization here the processes generating more complex and more elaborate structures are implied. This provides a decrease of entropy and energy production in the system, while those structures will objectively represent the characteristics of brand new materials [9].

Such an approach to natural science is considered as entirely logical worldwide, particularly when funding is done by organizations that are basically responsible for the implementation of applied programs. Exposed principles of fundamental and technical sciences, as well as those of production, are the basis for the formation of unique academic programs in which the natural laws are studied, and all of that within boundaries where directed and applied research is performed, being an objective foundation of overall research and development program. Accordingly, technical sciences have become a specific system of knowledge that enables transformation of results of fundamental and applied research into technological processes, the discovery and development of new methods of constructional-technical activities, in a word - the materialization of knowledge.

Acknowledgements

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Садржај: *Добијање материјала задатих својстава условљен је суштински остваривањем међузависности: ПРИРОДНЕ НАУКЕ* $\Leftrightarrow$ *ТЕХНИЧКЕ НАУКЕ. С обзиром на то, када се ради о добијању нових материјала, неопходно је утврдити законистости које карактеришу ову међузависност.*

Сагласно овоме у овој публикацији разматрани су принципи фундаменталних истраживања и значај добијених резултата за примену у области техничких реализација.

Кључне речи*: фундаменталне и примењене науке; наука о материјалима; напредни материјали*