Novel Concept for New Materials and Technology Developments

Zoltan Kish, *Ph.D.*
Quasar ScienceTech
Burlington, Ontario, Canada
Email: kishz@quasarsciencetech.com

February 2016

Progress in the development of advanced material applications and technologies is an essential pillar for viable economic growth. The global market continually requires new materials processes and materials with desirable properties. This need is compounded by pressures to stay competitive by keeping costs reasonable while continuing to make new materials and technologies available for rapid technological advances being made by industry. Advanced materials are the basis for modern science and technology and play an important role in the technology innovation for a variety of industries. Achieving this goal requires new approaches in the rapid development of new material processes and exceptional materials.

In response to the market requirements for new technologies and advanced materials applications, a new research and development concept [1] can be used for optimization of the new materials and technology development by analyzing and changing the materials system to obtain new materials with required properties (Fig. 1).

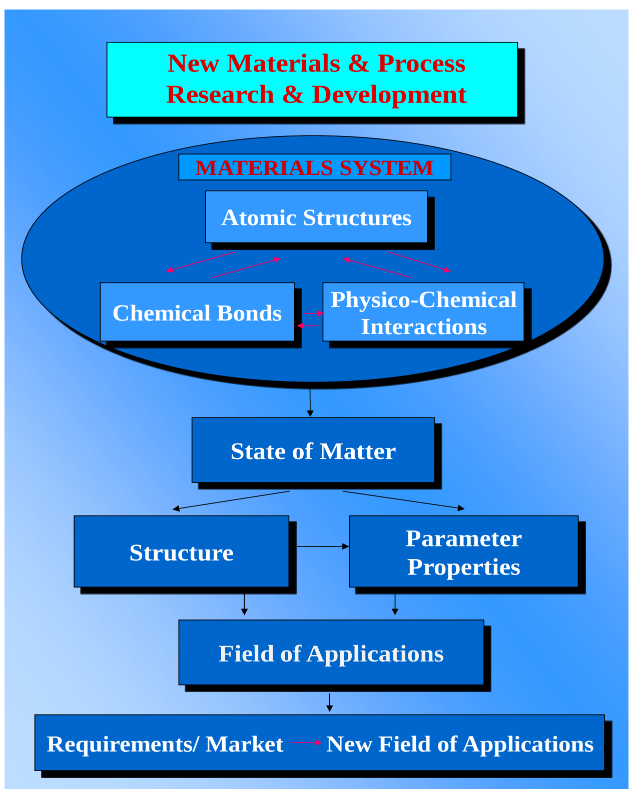

Fig. 1. A novel research and development concept for new materials and technology developments.

The materials properties and processes depend on the state of the materials system. If the market requires a new application, the state of the materials system should be analyzed and changed to produce a new material or process and determine an optimal development of the new application. The state of the material system depends upon the interconnections among the different chemical and physical factors, such as type and structure of the particles, chemical bonds, and physical-chemical interactions. The physico-chemical interactions are determined as interactions among the particles of the material system by the substance and energy that can be modified by different forms of energy (e.g. thermal, compression, radiation, magnetic, mechanical, gravitational, etc.) and time duration of applied energy. Accordingly, the equilibrium of these interconnections determines the state of matter, i.e. the state of the substance, which means the kind of substance and its form of existence: solid (polycrystalline, single crystal, glass, etc.), liquid, gas, and plasma states [2]. Every state of substance has corresponding structure (or space location) of the particles (e.g. atoms, ions, molecules, etc.) and parameter properties. Finally, the material structure and parameter properties determine the field of practical applications.

The new state of the materials system can be produced by changing chemical composition, the physico-chemical interaction and producing new bonds among the particles, for example:

- Biomass and waste (carbonaceous matter) can be converted to syngas (mostly hydrogen and carbon monoxide) by reacting with steam (H_2O) at ~900 °C, which can be utilized for clean power generation and liquid bio-fuel production.
- Silicon Nitride ceramic is produced by the reaction of nitrogen gas molecules with silicon at the appropriate high temperature (~1400 °C) and pressure.
- Evaluation of phase diagrams for corresponding materials system is very important to produce new materials in variety forms (e.g. polycrystalline, single crystal and glass).
- The state of semiconductors can be changed by adding very small amount of doping substances, for example, germanium significantly changes its electrical properties by phosphorus or gallium addition.

On the other hand, the new state of matter can be just achieved by the physico-chemical interaction and without changing the chemical composition of the materials system, for example~~s~~:

Transition using high energy of the physico-chemical interaction:

- Non-metallic hydrogen to metallic hydrogen at ~3 800 000 bar
- Graphite to Diamond (~60 000 bar, ~1300 °C)

Transition using medium energy of the physico-chemical interaction:

- Biomass and waste (carbonaceous matter) can be converted to syngas, pyrolytic oils and char by pyrolysis at ~550 °C without adding any reactant.
- Regular polycrystalline materials (1-100 µm) to nanomaterials (0.001 - 0.1 µm or 1 - 100 nm)
- Congruently melting semiconducting polycrystalline materials to single crystals for new electronic and optical applications

Transition by low energy of the physico-chemical interaction:

- Transition of dielectric ceramic to superconductor at low temperature (~90 K), for example: $YBa_2Cu_3O_{7-X}$
- Isomer transitions. Isomers are substances that have the same number and kind of atoms, arranged differently. For example, there are two compounds with the molecular formula C_2H_6O. One is ethanol (also called ethyl alcohol), CH_3CH_2OH, a colorless liquid alcohol; the other is dimethyl ether, CH_3OCH_3, a colorless gaseous ether. Among their different properties, ethanol has a boiling point of 78.5 °C and a freezing point of –117 °C; dimethyl ether has a boiling point of -25 °C and a freezing point of -138 °C. Ethanol and dimethyl ether are isomers because they differ in the way the atoms are joined together in their molecules. Isomers play a significant role in the new drug development.

As above examples reveal, new materials can be obtained by applying the appropriate energy type to the materials system without adding additional substances or by minimal energy and chemical composition changes. The understanding of the Material – Process – Property – Application Relationships, as interconnections among the type and structure of the atoms, chemical bonds, and physical-chemical interactions in the material systems and resulting materials properties, is very important in the development of new processes and new materials with enhanced properties for new fields of applications. In accordance with this research and development approach, it is much easier to obtain a required material with corresponding properties for a specific practical application and determine the optimum technological treatment in order to obtain the material in corresponding forms. Based on this research and development approach, the optimum technological treatment conditions can be determined in order to get materials in corresponding forms and produced required materials at lower cost with appropriate properties for corresponding industrial applications. The analyses of the Material – Process – Property – Application Relations using a new model of interactions in material systems provides opportunities to gain further understanding into the phenomena created by new materials processes.

This proposed concept of the research and development can be used for any materials process and product development to accelerate the innovation implementation in corresponding industrial sectors, which need new materials and technologies for a variety of applications, such as clean energy, transportation, electronics and other fields. If the market requires a new material or process (technology) for a specific application, the interaction in the material system should be analyzed in order to determine appropriate materials compositions, state, properties, design, and processes. A new material and/or process (technology) can be developed according to the new market and application requirements by optimization of materials composition, changing chemical bonds, and the physico-chemical interactions in the materials systems. This concept can accelerate the materials development for new applications in a variety of industrial sectors.

References

1. V.B. Lazarev, Z.Z. Kish, E.Yu. Peresh, and E.E. Semrad, "Complex Chalcogenides in the A^{I} - B^{III} - C^{VI} Systems", Publisher - Metallurgiya, Moscow, pp.240, (1993).
2. Z.Z. Kish, "Forms of the State of Matter", Uzhgorod State University, Uzhgorod, (1989), p. 21, Fig.1, Ref.5, (Monograph, Dep. in UkrNIINTI), No.2278-Uk.89, 25.10.1989.