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The Development of Phosphate Materials with High added value: a Researcher Viewpoint.

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Abstract

High value material including phosphates can result from: (i) major efforts to maintain and possible improve the quality of education, (ii) cross disciplinary approach (Chemistry, Physics, Geology, Biology etc.), (iii) implementation of new concepts which are able to push back the technological frontiers. In this context four examples of high value phosphate materials are analyzed in detail in this publication:

- $LaPO_4$ composites used at high temperatures and in oxygenated environment.
- Cement for cold areas,
- Phosphate Materials for inertial confinement fusion,
- Photonic component for permanent storage of information.

In all the previous examples the creation of new materials results from an overlapping between the basic functions of the phosphate groups and the new concepts related to various scientific fields e.g. electrochemistry, optics, mechanics, etc., and / or the use of new technologies to the elaboration of materials. The result is a representation of phosphate materials completely new compared to traditional views.

Keywords: High value phosphates, cements , photonic materials.

1. Introduction

The exploitation of phosphates is fundamentally centered on the production of fertilizer and phosphoric acid which represents the most important economic targets. A priori the production of phosphate with high added value is not yet an activity sector which can seem strategically interesting in terms of exploitation, processing and consequently valuation. However, in the second part of the XXth century and even more at the beginning of the XXIst century, the developments of the chemistry, physics medicine and biology revealed in numerous domains the potentialities of phosphates. Two "general public" examples illustrates this tendency: (i) at the frontier of the biological and inorganic worlds, biomaterials such calcium phosphates for evident medical reasons which require sophisticated method of elaboration, (ii) the remarkable scientific and industrial breakthrough of lithium phosphates $LiMPO_4$(M = Iron, Manganese, Cobalt, Nickel) as positive electrodes in the batteries of type " Lithium ion " used specifically in electric motor cars and in many other systems. These two examples, connected respectively with the fields of medicine and energy, are typical of the potential contribution of

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phosphates with high added value for new major economic objects.

Clearly any strategy leading to new technological frontiers based primarily on the quality of training of the actors of this development. This training must take place within a multidisciplinary context that is becoming increasingly necessary: for example the development of biomaterials requires the meeting of competences in chemistry, biology, medicine and mechanics.

Such formation leads to consider progressively scientific concepts which are constantly updated for the development of new techniques or new materials. By focusing on innovation in solid materials - including phosphate-, several of these new approaches can be emphasized:

- the notion of composite which a combination of several phases needed to create a specific property in a material,,
- the role of the final size of the particles obtained in a preparation process (aggregates, nano, micro), and also the influence of their porosity and their surface on the property of the final product,
- the new methods of synthesis may involve either low temperatures – e.g. soft chemistry methods - either high temperatures or high pressures or reactions in a supercritical fluid,
- the fact that the desired property can involve either volume of the particle or its surface,
- the systematic study of aging processes of materials in their operating conditions.

Table 1 summarizes a number of phosphate materials at different stages of development by introducing the competences required to their creation.

Table 1: Examples of phosphate materials at different stages of development

High Value Phosphates	***Required Competences***
Composites for high temperature uses with $LaPO_4$	Geology, Chemistry, Mechanics , High Temperature, Aging process
Chemical bonded phosphate ceramics : cement for low temperature environments and radioactive waste storage	Chemistry, Mechanics, Aging process
Positive electrodes for batteries ($LiFePO_4$)	Composite, Chemistry, Electrochemistry, Surface reaction, Nano
Phosphate glass laser for fusion energy	Physics and Chemistry of Glasses, Optics, Mechanics
Phosphates for second harmonic generation	Chemistry, Crystal growth, Nonlinear optics
Photonic components for information storage	Chemistry: Redox process, Materials laser processing, Optics
Biomaterials	Chemistry, Biology, Mechanics, Medicine, Ceramics
Waste storage	Chemistry, Geology, Mechanics , Aging process

This list is not exhaustive: it does not include all current research on zeolites (heterogeneous catalysis, membranes), the zero expanding ceramics, solid electrolytes, sensors etc..

2. $LaPO_4$ composites used at high temperature and in oxygenated environment.

2.1. What is a composite ?

A composite may be defined as a material with at least two components whose respective characteristics form a new system with improved overall performance or even with a new property. The concept of a composite needs a synergy between the properties of the constituents: this concept is therefore beyond the simple addition of mixture of these constituents.

The notion of composite was first imposed for structural and thermostructural materials in relation to their mechanical properties. They generally consist of **a matrix** (carbon, polymer, ceramic, metal) and a reinforcement (*fiber*: carbon, silicon carbide etc..; *particle*: silicon carbide, oxide, etc..). Between the reinforcement and the matrix, the connecting region (interface) will play a key role in the mechanical and thermomechanical properties.

2.2. Composites Alumina-Lanthanum Phosphate (Fig.1)

One of the parameters governing the mechanical properties of a composite is the interaction between the different phases (e.g. matrix – reinforcement) which can be more or less strong. This interaction may be altered by the presence of one (or