Phosphate-based Geopolymer a review of recent literature

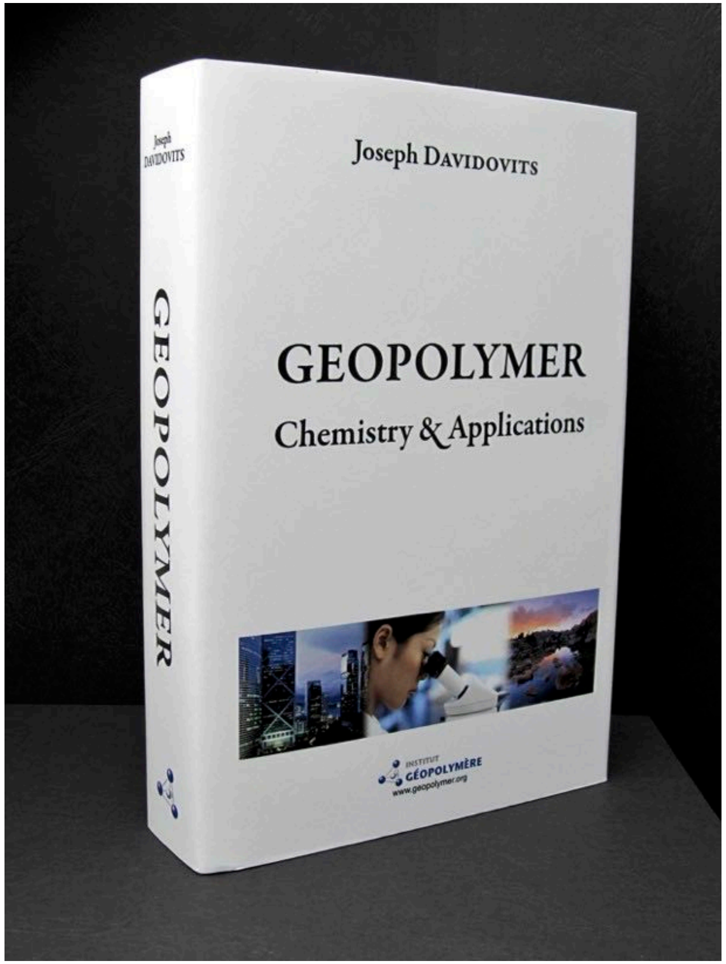
2018
GEOPOLYMERCAMP

Joseph Davidovits

#8 Phosphate-based geopolymer

In acidic medium

phosphoric acid H_3PO_4



Chapter 13

$$Al_2O_3 + 2H_3PO_4 \Longrightarrow 2AlPO_4 + 3H_2O$$

$$(MK)\ Si_2O_5Al_2O_2 + 2H_3PO_4 = \Longrightarrow 2AlPO_4 + 2SiO_2 + 3H_2O$$

Geopolymer Book: Section 13.6 AlPO4-based geopolymers

… $AlPO_4$ species: variscite $AlPO_4 \cdot 2H_2O$, metavariscite $AlPO_4 \cdot 2H_2O$ and berlinite $AlPO_4$.

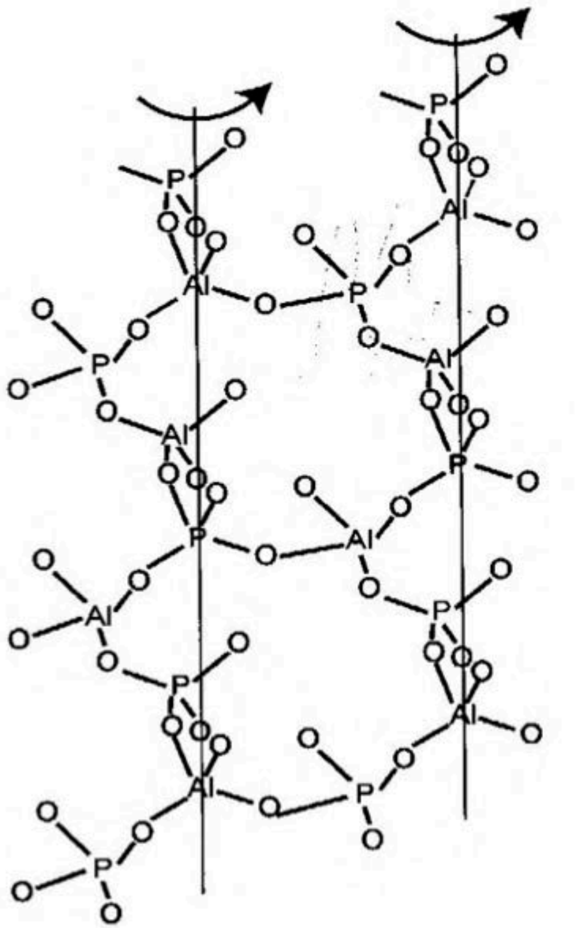
100–300°C, variscite / metavariscite lose their water molecules to form α-berlinite (trigonal $AlPO_4$) stable phase up to 540°C, and > 550°C onwards tetragonal β-berlinite.

$AlPO_4$-berlinite is **isostructural** with quartz SiO_2 , i.e. same molecular structure. Upon heating, same transitions as quartz, into tridymite and cristobalite equivalent molecular structures.

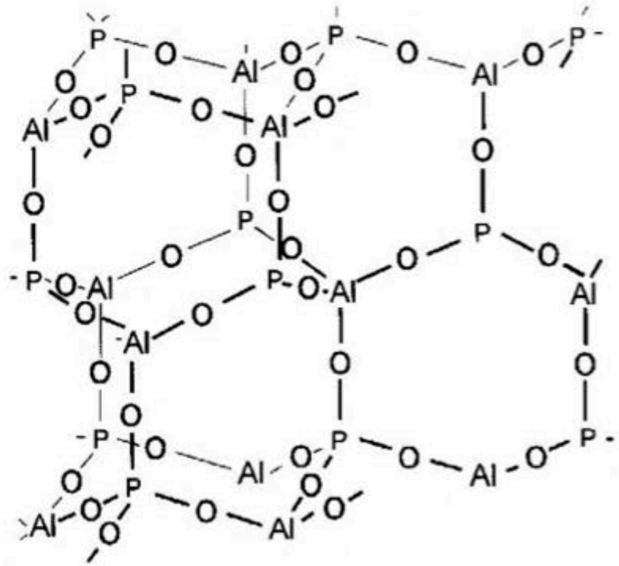
Transition from one form to the other is readily followed by X-Ray powder diffraction analysis.

Polymeric structures of AlPO4-Geopolymers

⇒ Cross-linked (P-O-Al-O)n poly(alumino-phospho) chains



AlPO$_4$-berlinite (isostructural to quartz)



AlPO$_4$-tridymite/cristobalite

Journal of the Chinese Ceramic Society
Volume 33, Issue 11, November 2005, Pages 1385-1389

2005

Synthesis and structure characterization of geopolymeric material based on metakaolinite and phosphoric acid

Cao, D., Su, D., Lu, B., Yang, Y.

[a]School of Chemistry and Chemical Engineering, Guangxi University, Nanning 530004, China

[b]Institute of Materials, South China University of Technology, Guangzhou 510641, China

Abstract

A geopolymer material based on MK and phosphoric acid was synthesized from metakaolinite **at room temperature**. The product of the geopolymerization has a polymeric Si-O-Al-O-P three-dimensional structure.

Material structure and geopolymerization mechanism were investigated using X-ray diffraction (XRD), infrared (FTIR) spectroscopy, and ^{29}Si and ^{27}Al magic angle spinning nuclear magnetic resonance (NMR). The XRD pattern of the obtained polymers is essentially amorphous.

J Mater Sci (2008) 43:6562–6566
DOI 10.1007/s10853-008-2913-6

2008

LETTER

Relative strengths of phosphoric acid-reacted and alkali-reacted metakaolin materials

Dan S. Perera, John V. Hanna, Joel Davis, Mark G. Blackford, Bruno A. Latella, Yosuke Sasaki, Eric R. Vance.
ANSTO, Australian Nuclear Science and Technology Organisation, Menai, NSW 2234, Australia

	Si/Al	Na/Al	P/Al
MK / Na-PSS	2	1	-
MK / Phospho	1	-	1

Cast in sealed molds, kept at RT for 2 hours, 60°C for 24 hours.
Removing the seals and kept at RT: Na-PSS demolded after 4 days, MK/Phospho after 14 days.

After *Perera et al. (2008)*

Table 2 Physical and mechanical properties of the materials

	MKGP	MKSGP	MKP	MKSP
BD (g/cm^3)	1.46	1.60	1.82	1.89
OP (%)	20	20	0.0	0.0
CCS (MPa)	72 (5)	70 (6)	146 (17)	96 (10)
Shrinkage[a] (%)	+0.7	+0.6	4.0	3.9

One standard deviation listed within brackets

[a] Diametral shrinkage wet to dry on a wet basis, + indicates expansion

Applied Clay Science 50 (2010) 600–603 **2010**

ELSEVIER

Contents lists available at ScienceDirect

Applied Clay Science

journal homepage: www.elsevier.com/locate/clay

Note

Preparation of phosphoric acid-based porous geopolymers

Liu Le-ping, Cui Xue-min *, Qiu Shu-heng, Yu Jun-li, Zhang Lin

School of Chemistry and Chemical Engineering, Guangxi University, Nanning 530004, PR China

MK + H_3PO_4 85% + Al powder for expansion and Al_2O_3 powder;

5 h at 80°C in sealed mold.

Excellent thermal stability up to 1400°C, porosity 85%, compressive strength ca. 7 MPa.

Contents lists available at ScienceDirect

2011

Materials Chemistry and Physics

journal homepage: www.elsevier.com/locate/matchemphys

Materials science communication

A novel aluminosilicate geopolymer material with low dielectric loss

Xue-min Cui [a,*], Le-ping Liu [a], Yan He [a], Jin-yu Chen [a], Ji Zhou [b]

[a] *School of Chemistry and Chemical Engineering and Guangxi Key Lab of Petrochemical Resource Processing and Process Intensification Technology, Guangxi University, Nanning, 530004, PR China*
[b] *State Key Laboratory of New Ceramics and Fine Processing, Tsinghua University, Beijing, 100084, PR China*

Phosphate-based geopolymers, with very low dielectric loss could be used as an insulated encapsulating material (for electronic devices): heat treatment at 300°C is lower than the usual temperatures for common packaging of ceramic materials.

The 2.4H3PO4–Al2O3–2SiO2 geopolymers are heat-resistant to approximately 1500°C. Therefore, the phosphoric acid geopolymers might serve as potential high-temperature packaging or encapsulating materials.

Applied Clay Science 101 (2014) 60–67 2014

Contents lists available at ScienceDirect

Applied Clay Science

journal homepage: www.elsevier.com/locate/clay

Research paper

Structure and properties of new eco-material obtained by phosphoric acid attack of natural Tunisian clay

S. Louati [a], W. Hajjaji [b], S. Baklouti [a], B. Samet [a,*]

[a] *Laboratoire de Chimie Industrielle, Ecole Nationale d'Ingénieurs de Sfax, Université de Sfax, BP 1173, 3038 Sfax, Tunisia*
[b] *Geobiotec, Geosciences Dept, University of Aveiro, 3810-193 Aveiro, Portugal*

sealed container, 2 hours room t° before 60°C 24 hours,

calcined clay + H_3PO_4 85% with varying Si/P ratio. Best is Si/P = 2.25, equiv. to P/Al=1.

Materials Letters 190 (2017) 209–212

2017

Contents lists available at ScienceDirect

Materials Letters

journal homepage: www.elsevier.com/locate/mlblue

Phosphate-based geopolymer: Formation mechanism and thermal stability

Yan-Shuai Wang [a], Jian-Guo Dai [a,*], Zhu Ding [b], Wei-Ting Xu [a]

[a] Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong, China
[b] School of Civil Engineering, Shenzhen University, 518060, China

MK reaction with monoaluminum phosphate (MAP): $Al(H_2PO_4)_3$, powder in fact mixture of [$Al(H_2PO_4)_3$, $AlPO_4$] and $Al_2(HPO_4)_3$.

Applied Clay Science 147 (2017) 184–194

2017

Contents lists available at ScienceDirect

Applied Clay Science

journal homepage: www.elsevier.com/locate/clay

Research paper

Influence of the molar concentration of phosphoric acid solution on the properties of metakaolin-phosphate-based geopolymer cements

Hervé K. Tchakouté[a,b,*], Claus H. Rüscher[b], Elie Kamseu[c,d], Fernanda Andreola[d], Cristina Leonelli[d]

[a] Laboratory of Applied Inorganic Chemistry, University of Yaounde I, Faculty of Science, Department of Inorganic Chemistry, PO Box 812, Yaounde, Cameroon
[b] Institut für Mineralogie, Leibniz Universität Hannover, Callinstrasse 3, D-30167 Hannover, Germany
[c] Local Materials Promotion Authority, PO Box: 2396, Nkolbikok, Yaoundé, Cameroon
[d] Department of Engineering Enzo Ferrari, University of Modena and Reggio Emilia, Via Vivarelli 10, 41125 Modena, Italy

24 hours room t° before 60°C 24 hours,

MK + H_3PO_4 of different concentration: molar 2 to 12 M good results, strength varying from 36 MPa to 93 MPa, whereas with 14 M = 0 MPa

Applied Clay Science 140 (2017) 81–87 **2017**

Contents lists available at ScienceDirect

Applied Clay Science

journal homepage: www.elsevier.com/locate/clay

Research paper

Mechanical and microstructural properties of metakaolin-based geopolymer cements from sodium waterglass and phosphoric acid solution as hardeners: A comparative study

Hervé Kouamo Tchakouté [a,b,*], Claus Henning Rüscher [b]

[a] Laboratory of Applied Inorganic Chemistry, University of Yaounde I, Faculty of Science, Department of Inorganic Chemistry, PO. Box 812, Yaounde, Cameroon
[b] Institut für Mineralogie, Leibniz Universität Hannover, Callinstrasse 3, D-30167 Hannover, Germany

Like Perera's paper (2008), ageing 24 h at room T° and cure at 60°C, 24 h

- Na-poly(sialate) geopolymer: 63 MPa
- Phosphate-based geopolymer: 94 MPa

Applied Surface Science 416 (2017) 200–212 2017

Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

Full Length Article

Surface decoration of polyimide fiber with carbon nanotubes and its application for mechanical enhancement of phosphoric acid-based geopolymers

Tao Yang[a], Enlin Han[b], Xiaodong Wang[a,*], Dezhen Wu[a,*]

[a] State Key Laboratory of Organic–Inorganic Composites, Beijing University of Chemical Technology, Beijing 100029, China
[b] Changzhou Institute of Advanced Materials, Beijing University of Chemical Technology, Changzhou, Jiangsu Province 213164, China

Polyimide fiber is not alkali resistant, yet acid-resistant. Good candidate for PH-based geopolymer composite.

Addition of 1.5% weight increase the Flexural strength from 10 MPa to 40 MPa.

Ceramics International 44 (2018) 2578–2583

2018

Contents lists available at ScienceDirect

Ceramics International

journal homepage: www.elsevier.com/locate/ceramint

Superhigh strength of geopolymer with the addition of polyphosphate

Yan-Guang Wu[a], Sui-Sui Xie[a], Yun-Fei Zhang[a,*], Fei-Peng Du[a,*], Chun Cheng[b]

[a] School of Materials Science and Engineering, Wuhan Institute of Technology, Wuhan 430205, China
[b] Department of Materials Science and Engineering, Southern University of Science and Technology, Shenzhen 518055, China

Method to enhance the compressive strength of GP Na-poly(sialate) by addition of aluminum dihydrogen triphosphate (ATP).

Compressive strength reaches 160 MPa with an optimum 1.0 wt% ATP, i.e. 108% increase.

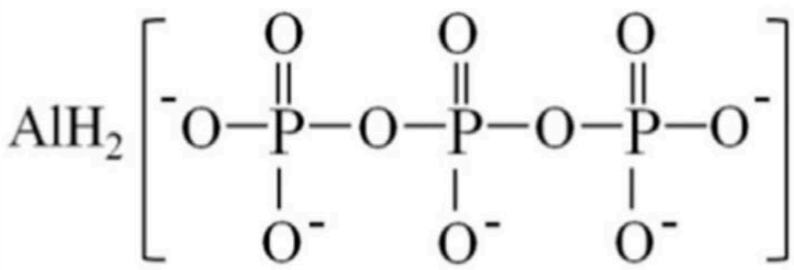


Fig. 1. Chemical structure of ATP.