

13th International Ceramics Congress

Part A

Edited by
Pietro Vincenzini

13th International Ceramics Congress

Part A

Edited by
Pietro Vincenzini

13th International Ceramics Congress

Proceedings of the 13th International Ceramics Congress,
part of CIMTEC 2014-13th International Ceramics Congress
and 6th Forum on New Materials,
June 8-13, 2014, Montecatini Terme, Italy

PART A *including:*

*Symposium CA – Ceramic Powders:
Advances in Synthesis, Processing and Manufacturing*

Edited by

Pietro Vincenzini

World Academy of Ceramics and
National Research Council, Italy

Co-edited by

Masahiro Yoshimura

National Cheng Kung University, Taiwan



**on behalf of TECHNA GROUP
Faenza • Italy**

Copyright © 2014 Trans Tech Publications Ltd, Switzerland

Published by Trans Tech Publications Ltd., on behalf of Techna Group Srl, Italy

All rights reserved. No part of this book may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, recording, photocopying or otherwise, without the prior written permission of the Publisher.

No responsibility is assumed by the publisher for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions or ideas contained in the material herein.

Trans Tech Publications Ltd

Churerstrasse 20

CH-8808 Pfaffikon

Switzerland

<http://www.ttp.net>

Volume 87 of

Advances in Science and Technology

ISSN print 1662-8969

ISSN cd 1661-819X

ISSN web 1662-0356

Full text available online at <http://www.scientific.net>

The listing of the other Volumes of the Series "Advances in Science and Technology" are available at TECHNAGROUP website: <http://www.technagroup.it>

Distributed worldwide by

Trans Tech Publications Ltd

Churerstrasse 20

CH-8808 Pfaffikon

Switzerland

Fax: +41 (44) 922 10 33

e-mail: sales@ttp.net

and in the Americas by

Trans Tech Publications Inc.

PO Box 699, May Street

Enfield, NH 03748

USA

Phone: +1 (603) 632-7377

Fax: +1 (603) 632-5611

e-mail: sales-usa@ttp.net

PREFACE

CIMTEC 2014 was held in Montecatini Terme, Italy on June 8-19, 2014 under the auspices of the Italian Government, the Italian National Research Council (CNR) and the Italian National Agency for New Technologies, Energy and the Environment (ENEA). This high qualitative and comprehensive congressional event, similarly to the previous editions, has been designed to encompass and derive synergism from a broad interdisciplinarity network capable of offering opportunities for identifying and exploring new directions for research and production. The above based on the view that ongoing and future innovations require at an ever increasing extent a complex array of interconnections among scientific research, innovating technology and industrial infrastructure.

CIMTEC 2014 consisted of two major events: the 13th INTERNATIONAL CERAMICS CONGRESS (June 8-13, 2014) and the 6th FORUM ON NEW MATERIALS (June 15-19, 2014). The World Academy of Ceramics and the International Ceramic Federation (ICF) acted as principal endorsers for the first one, and the International Union of Materials Research Societies (IUMRS) for the FORUM.

The 13th INTERNATIONAL CERAMICS CONGRESS included 15 International Symposia, two Special Sessions and the Serial International Conference “Advanced Inorganic Fibre Composites for Structural and Thermal Management Applications” which covered recent progress in almost all relevant fields of ceramics science and technology. The 6th FORUM ON NEW MATERIALS consisted of 10 International Symposia primarily concerned with energy technologies, three Special Session and five Serial International Conferences (“Novel Functional Carbon Nanomaterials”, “Mass, Charge and Spin Transport in Inorganic Materials: Fundamentals to Devices”, “Novel Non-volatile Inorganic Memory Devices: materials, concepts and applications”, “Science and Engineering of Novel Superconductors” and “Medical Applications of Novel Biomaterials and Nano-biotechnology”).

A balanced, high quality programme of invited and contributed papers resulted from the over one thousand and seven hundred scientific and technical contributions effectively presented during the working days to a large international audience coming from sixty countries throughout the world.

The 10 volumes which constitute the Official Proceedings of CIMTEC 2014 (6 for the Ceramics Congress, 4 for the Forum) include a selection of the papers presented. Having most of them been written by authors whose mother tongue is not English, considerable revision of the original texts was often required. Even so, in order to allow the scientific and technical community to have access to the proceedings volumes within a reasonable length of time, compromise was necessary in regard to the quality of writing, and papers containing language imperfections were considered acceptable provided that their technical content was adequate and easily understandable.

The six volumes that constitutes the Proceedings of the 12th International Ceramics Congress include selections of papers of the following Symposia and Conferences:

Part A

Symposium CA - Ceramic Powders: Advances in Synthesis, Processing and Manufacturing

Part B

Symposium CB - Progress in Non Conventional and Novel Manufacturing Routes to Ceramics

Symposium CD - Joining Inorganic Materials at Different Length Scales

Part C

Symposium CC - Materials Solutions for Highly Demanding Tribological Applications

Symposium CF - High and Ultra High Temperature Ceramics for Extreme Environments

Symposium CG - Progress in Nano-laminated Ternary Carbides and Nitrides (MAX Phases) and Derivatives Thereof (MXenes)

Conference CP - Advanced Inorganic Fibre Composites for Structural and Thermal Management Applications

Part D

Symposium CJ - Advances in Electroceramics

Symposium CK - Functional Magnetic Oxides

Symposium CL - Inorganic Materials Systems for Optical and Photonic Applications

Part E

Symposium CE - Innovative Synthesis and Processing of Nanostructured, Nanocomposite and Hybrid Functional Materials for Energy and Sustainability

Symposium CH - Porous Ceramics for Environmental Protection, Energy-related Technologies and Advanced Industrial Cycles

Symposium CI - Ceramic Thin Films and Coatings for Protective, Tribological and Multifunctional Applications

Part F

Symposium CM - Inorganic Polymers (Geopolymers) and Geocements: Environmentally Friendly Ceramic Materials for Low-Technology and High-Technology Applications

Symposium CN - Science and Technology for Silicate Ceramics

Symposium CO - Refractories: Developments in Raw Material, Production and Installation, Modelling, and Testing/Performance

The Editor, who also acted as the Chairman of CIMTEC 2014, would like to express his sincere appreciation to all the Institutions and Professional Organizations involved in the congress, to the members of the International Advisory Committees, the Co-Chairs Prof. Gary Messing (USA) for the INTERNATIONAL CERAMICS CONGRESS and Prof. Robert P.H. Chang (USA) for the FORUM ON NEW MATERIALS, the Programme Chairs, the Lecturers, the technical staff of Techna Group, and to the many others who directly or indirectly contributed to the organization. It was mainly through the involvement of the above bodies and individuals, and the active participation of most internationally qualified experts from major academic and government research institutes and industrial R&D centers that a very valuable scientific programme could be arranged.

It is therefore expected for the Proceedings of CIMTEC 2014-13th INTERNATIONAL CERAMICS CONGRESS & 6th FORUM ON NEW MATERIALS to constitute a further valuable contribution to the literature in the field.

P. VINCENZINI

World Academy of Ceramics

Emeritus Research Manager

National Research Council of Italy

Table of Contents

Preface

Chapter 1: Powder Synthesis and Characterization

Preparation of Protonic Conductor $\text{BaZr}_{0.5}\text{Ce}_{0.3}\text{Ln}_{0.2}\text{O}_{3-\delta}$ (Ln=Y, Sm, Gd, Dy) by Using a Solid State Reactive Sintering Method J.F. Bu, P.G. Jönsson and Z. Zhao	1
High Energy Milling of Zirconia: A Systematic Critical Review on the Phase Transformation N. Gorodylova, Ž. Dohnalová and P. Šulcová	6
Structural and Electrical Properties of $(1-x)\text{Pb}(\text{Zr}_y\text{Ti}_{1-y})\text{O}_3-x\text{Sm}(\text{Fe}^{3+}_{0.5}, \text{Nb}^{5+}_{0.5})\text{O}_3$ Ceramics Prepared by Conventional Solid State Synthesis and Sintered at Low Temperature F. Kahoul, L. Hamzioui and A. Boutarfaia	12
Structural and Electrical Properties of Ca^{2+} Substituted $\text{Pb}[(\text{Zr}_{0.52}\text{Ti}_{0.48})_{0.98}(\text{Cr}^{3+}_{0.5}, \text{Ta}^{5+}_{0.5})_{0.02}\text{I}_{0.96}\text{P}_{0.04}\text{O}_3]$ Ceramics L. Hamzioui, F. Kahoul and A. Boutarfaia	18
Soft Synthesis of FAU Nanozeolites and Microporous Membranes T.F. Mastropietro, E. Drioli and T. Poerio	24
Characteristic and Sinterability of Alumina-Zirconia-Yttria Nanoparticles Prepared by Different Chemical Methods J. Grabis, D. Jankovica, I. Steins, K. Smits and I. Sipola	30
Ultradispersed Powdery Y_2O_3-Bi_2O_3-ZnO Composition with High Chemical Homogeneity for Fine-Grained Ceramics E.A. Trusova, K.V. Vokhmintcev and A.N. Kirichenko	36
Preparation of Highly-Dispersed Powders of Cobalt, Nickel, Molybdenum and Tungsten Oxides by Modified Sol-Gel Technique E.A. Trusova and K.V. Kotsareva	42
Development of Highly Dispersed Hybrid Nanoalumina with the Sol-Gel Method F. Petrakli, D. Sioulas and A. Tsetsekou	48
Study of Gamma Alumina Synthesis – Analysis of the Specific Surface Area A.H. Munhoz, H. de Paiva, L. Figueiredo de Miranda, E.C. de Oliveira, R. Cons Andrades and R.R. Ribeiro	54
Synthesis and Characterization of Nanocomposite $\text{HA}/\alpha\text{-Al}_2\text{O}_3$ Sol-Gel Powders for Biomedical Applications N.H.A. Camargo, P. Corrêa, P.F. Franczak and E. Gemelli	61
Effect of Ammonium Sulfate on Morphology of Y_2O_3 Nanopowders Obtained by Precipitation and its Impact on the Transparency of YAG Ceramics H. Tomaszewski, A. Wajler, H. Weglarz, A. Sidorowicz, U. Brykała and K. Jach	67
Segregation and Color Change on (Cr,Ca) Codoped Nanocrystalline Tin Dioxide D. Gouvêa, D. Ucha Rocha and L. Batista Caliman	73
Microstructural Characterization of Activated Carbon Obtained from Waste Tires F. Mazzanti, G. Magnani, S. Grilli, A. Brillante, T. Salzillo, A. Brentari, E. Buresi, C. Mingazzini and P. Fabbri	79

Chapter 2: Colloidal Processing, Shape Forming and Compaction Mechanisms

Transparent Tetragonal Zirconia Ceramics by Colloidal Processing of Nanoparticle Suspension M. Trunec and O. Bera	85
Composition – Property Relations in Shear Thickening Fluids Ł. Wierzbicki and M. Leonowicz	91
Thick Film Processing Challenges in the Realisation of a Co-Fired Solid Oxide Fuel Cell Roll M. Cassidy, P. Connor, M. Etches, Y. Kalecheff, M. MacHado, J. Nairn and J. Irvine	98

A Mixed SVD-Neural Network Approach to Optimal Control of Ceramic Mould Manufacturing in Lost Wax Cast Processes	
C. Caramiello, S. Iannuzzi, A. Acernese and D.M. D'Addona	105
Manufacturing of Porous Ceramic Spheres Using Calcium Phosphates, by a Mechanical Method without Additives or Binders	
K.B. Violin, T.S. Goia, K. Ishikawa, J.C. Bressiani and A.H. de Almeida Bressiani	113
 Chapter 3: Sintering and Related Phenomena	
<i>In Situ</i> Platelet Reinforcement of Alumina and Zirconia Matrix Nanocomposites – One Concept, Different Reinforcement Mechanisms	
F. Kern and R. Gadow	118
Sol-Gel Derived Mullite-Gahnite Composite	
S. Kurajica, E. Tkalčec, V. Mandić, I. Lozić and J. Schmauch	126
3D Phase-Field Simulation and Characterization of Microstructure Evolution during Liquid Phase Sintering	
H. Ravash, E. Specht, J. Vleugels and N. Moelans	132
Influence of Alumina Addition on Low Temperature Degradation of Y₂O₃-Coated Powder Based Y-TZP Ceramics	
F. Zhang, K. Vanmeensel, M. Inokoshi, B. van Meerbeek, I. Naert and J. Vleugels	139
Effect of Different Sintering Processes on Microstructure of Alumina Ceramics	
A.S.A. Chinelatto, C. Lago Ojaime, M.V. Gelfuso, D. Thomazini and A.L. Chinelatto	145
Mechanical Characterization of Conventional and Non-Conventional Sintering Methods of Commercial and Lab-Synthesized Y-TZP Zirconia for Dental Applications	
A. Presenda, M.D. Salvador, F. Peñaranda-Foix, J.M. Catalá and A. Borrell	151
Sintering of Al₂O₃-TiO₂ Mixtures Obtained by High-Energy Ball Milling	
A.S. Ramos, M.A. de Souza, R. de Oliveira Magnago, C. dos Santos, C.A.A. da Silva and B. de Almeida Fortes	157
Effect of Particle Size of ZrO₂(Y₂O₃) Powders on the Shrinkage of the Sintered Substrate with Coloring Gradient	
P.C. da Silva, R. de Oliveira Magnago, C.A.A. da Silva, B. de Almeida Fortes and C. dos Santos	162

Preparation of Protonic Conductor $\text{BaZr}_{0.5}\text{Ce}_{0.3}\text{Ln}_{0.2}\text{O}_{3-\delta}$ (Ln=Y, Sm, Gd, Dy) by using a Solid State Reactive Sintering Method

Junfu Bu^{1, a*}, Pär G. Jönsson^{1, b} and Zhe Zhao^{1, 2, c*}

¹Department of Materials Science and Engineering, KTH Royal Institute of Technology, SE-10044 Stockholm, Sweden

²Department of Materials Science and Engineering, Shanghai Institute of Technology, 201418, Shanghai, China

^ajunfu@kth.se, ^bparj@kth.se, ^czhezha@kth.se

Keywords: Solid oxide fuel cell, barium cerate, barium zirconate, protonic conductor, solid state reactive sintering.

Abstract. Protonic conductors of $\text{BaZr}_{0.5}\text{Ce}_{0.3}\text{Ln}_{0.2}\text{O}_{3-\delta}$ (BZCLn532, Ln=Y, Sm, Gd, Dy) were successfully synthesized by using a cost-effective solid state reactive sintering (SSRS) method with 1 wt.% NiO as a sintering aid. The pellets of the BZCLn532 were obtained at sintering temperatures between 1300 - 1600 °C. The results show that the morphologies and the final relative densities of the obtained BZCLn532 pellets are influenced significantly when different sintering temperatures were applied. Dense pellets of the BZCLn532 can be obtained at sintering temperatures of 1600 °C for $\text{BaZr}_{0.5}\text{Ce}_{0.3}\text{Y}_{0.2}\text{O}_{3-\delta}$ and 1400 °C for $\text{BaZr}_{0.5}\text{Ce}_{0.3}\text{Sm}_{0.2}\text{O}_{3-\delta}$, $\text{BaZr}_{0.5}\text{Ce}_{0.3}\text{Gd}_{0.2}\text{O}_{3-\delta}$ and $\text{BaZr}_{0.5}\text{Ce}_{0.3}\text{Dy}_{0.2}\text{O}_{3-\delta}$. The ionic conductivity results show that the $\text{BaZr}_{0.5}\text{Ce}_{0.3}\text{Y}_{0.2}\text{O}_{3-\delta}$ (BZCY532) and $\text{BaZr}_{0.5}\text{Ce}_{0.3}\text{Dy}_{0.2}\text{O}_{3-\delta}$ (BZCD532) ceramics are demonstrated to be good candidates of oxygen ion conductor and proton conductor materials for intermediate temperature solid oxide fuel cells (IT-SOFCs) applications.

Introduction

Protonic conductor based electrolytes are good candidates for solid oxide fuel cells (SOFCs) applications, due to their promising protonic conductivity at lower operating temperatures. Since Iwahara et al. [1, 2] first reported the proton conduction phenomenon in the ABO_3 perovskite compounds of doped strontium cerates and doped barium cerates, many doped perovskite-type cerates and zirconates compounds have been investigated intensively, especially during the recent years [3-19]. However, high sintering temperatures (normally higher than 1600 °C) and long sintering times (more than 24 h) are always needed for BaCeO_3 - and BaZrO_3 -based ceramic materials to obtain dense bulk materials. But this will lead to very large grain sizes, and eventually result in a low mechanical strength. Thus, this will limit their application for electrolyte-support cell structure designs. Therefore, many wet chemistry methods have been introduced to prepare high quality nanocrystalline powders to decrease the sintering temperatures and sintering times of Barium zirconate and Barium cerate based materials [20]. In addition, various transition metal oxides, such as NiO, CoO, MnO, FeO, ZnO [8, 9, 16-18, 20-26], have been added into the pre-synthesized powder, to improve the sintering behaviour and to achieve a reduced sintering temperature.

Among these alternative methods, the solid state reactive sintering (SSRS) method was improve by Tong et al. [23-25] for $\text{BaZr}_{0.8}\text{Y}_{0.2}\text{O}_{3-\delta}$, by Coors et al.[26] for $\text{BaZr}_{0.6}\text{Ce}_{0.2}\text{Y}_{0.2}\text{O}_{3-\delta}$ and by Ricote et al. [18] for $\text{BaCe}_x\text{Zr}_{0.9-x}\text{Y}_{0.1}\text{O}_{3-\delta}$ by using NiO as a sintering aid. Therefore, the normal two separate steps solid-state reaction method for synthesize the powder and the sintering of pellets can be combined into one cost-effective single sintering step. Also, as one of the most promising protonic conductor candidates, $\text{BaCe}_{0.5}\text{Zr}_{0.3}\text{Y}_{0.2}\text{O}_{3-\delta}$ have attracted more and more attention during the recent years [27, 28]. This is due to that it can maintain a good chemical and mechanical stability as well as that it possesses a very good electrical conductivity. Thus, dense ceramic pellets of lanthanides doped barium zirconate-cerate with the formula of $\text{BaCe}_{0.5}\text{Zr}_{0.3}\text{Ln}_{0.2}\text{O}_{3-\delta}$ (BZCLn532, Ln=Y, Sm, Gd, Dy) were prepared by the solid state reactive sintering method in this study. The obtained pellets were characterized by XRD and SEM. In addition, the relative densities of the BZCLn532 pellets, which were sintered at different sintering temperatures, were also studied.