13th International Ceramics Congress

Part A

Edited by

Pietro Vincenzini

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13th International Ceramics Congress

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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

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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.

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Chapter 3: Sintering and Related Phenomena

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Preparation of Protonic Conductor $BaZr_{0.5}Ce_{0.3}Ln_{0.2}O_{3-\delta}$ (Ln=Y, Sm, Gd, Dy) by using a Solid State Reactive Sintering Method

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

Abstract. Protonic conductors of $BaZr_{0.5}Ce_{0.3}Ln_{0.2}O_{3-\delta}$ (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 ℃. 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 ℃ for $BaZr_{0.5}Ce_{0.3}Y_{0.2}O_{3-\delta}$ and 1400 ℃ for $BaZr_{0.5}Ce_{0.3}Sm_{0.2}O_{3-\delta}$, $BaZr_{0.5}Ce_{0.3}Gd_{0.2}O_{3-\delta}$ and $BaZr_{0.5}Ce_{0.3}Dy_{0.2}O_{3-\delta}$. The ionic conductivity results show that the $BaZr_{0.5}Ce_{0.3}Y_{0.2}O_{3-\delta}$ (BZCY532) and $BaZr_{0.5}Ce_{0.3}Dy_{0.2}O_{3-\delta}$ (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 ℃) 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 $BaZr_{0.8}Y_{0.2}O_{3-\delta}$, by Coors et al.[26] for $BaZr_{0.6}Ce_{0.2}Y_{0.2}O_{3-\delta}$ and by Ricote et al. [18] for $BaCe_xZr_{0.9-x}Y_{0.1}O_{3-\delta}$ 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, $BaCe_{0.5}Zr_{0.3}Y_{0.2}O_{3-\delta}$ 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 $BaCe_{0.5}Zr_{0.3}Ln_{0.2}O_{3-\delta}$ (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.