PROYECTO INICIACION N°11060302

INVESTIGADOR RESPONSABLE: MANGALARAJA RAMALINGA VISWANATHAN

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INFORME FINAL
PROYECTO FONDECYT INICIACION

N° PROYECTO: 11060302  DURACIÓN: 3 años  AÑO ETAPA: 2008
TÍTULO PROYECTO: DEVELOPMENT OF PROCESSING AND CHARACTERIZATION OF CERIA BASED MATERIALS FOR SOLID OXIDE FUEL CELL APPLICATIONS: SYNTHESIS OF NANOPOWDERS AND ITS SINTERING CHARACTERIZATION

DISCIPLINA PRINCIPAL: INGENIERIA DE MATERIALES
GRUPO DE ESTUDIO: INGENIERIA 1
INVESTIGADOR(A) RESPONSABLE: MANGALARAJA RAMALINGA VISWANATHAN
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COMUNA: Concepcion
CIUDAD: CONCEPCION
REGIÓN: VIII REGION
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INFORME

OBJETIVOS
Cumplimiento de los Objetivos planteados en el Proyecto. Recuerde que los objetivos del proyecto no se refieren a listar actividades desarrolladas sino a los objetivos desarrollados

<table>
<thead>
<tr>
<th>N°</th>
<th>OBJETIVOS</th>
<th>CUMPLIMIENTO</th>
<th>FUNDAMENTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phase analysis and structural studies; study on the particle size and morphology; calcination of nanopowders; publication.</td>
<td>TOTAL</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Calcination and fabrication; sintering; study on the physical properties.</td>
<td>TOTAL</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sintering; electrical properties; mechanical properties studies; Publication.</td>
<td>TOTAL</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Sintering property and microstructural studies; mechanical, electrical and thermal properties; Publication.</td>
<td>TOTAL</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Electrical Properties; Publication and 3rd year report to the FONDECYT.</td>
<td>TOTAL</td>
<td></td>
</tr>
</tbody>
</table>

Otro(s) aspecto(s) que Ud. considere importante(s) en la evaluación del cumplimiento de objetivos planteados en la propuesta original o en las modificaciones autorizadas por los Consejos.

The research work of this FONDECYT (N°:11060302) Project went on well as per the activities mentioned in the original proposal. The results are published and communicated in 11 International Journals. A Chapter (Capitulo) is got accepted to publish in the forth coming E-book on Combustion Synthesis to be Published (end of 2009) by Bentham Publishers.

The second graduate thesis of this FONDECYT Project is being carried out by graduate student Srl. Andrea Ortiz, and is on the completion stage. She has completed all the experimental work and writing her thesis to defend on December 2009.
En el tercero año del proyecto, los principales resultados obtenidos son:

1. Phase analysis and structural studies:

Crystalline nature and phase purity were examined using powder X-ray diffraction technique (X’Pert Pro, Philips X-ray diffractometer). The X-ray diffraction was recorded using CuKα radiation. The crystallite sizes were determined using Scherrer’s equation. As prepared ceria powders were characterized by thermal analysis (TG/DTA) with a constant heating rate of 10°C/min (up to 1300°C) in He atmosphere using Netzsch-STA 409 PC/PG analyzer equipped with a mass spectrometer (Balzers MID) for identifying the evolved gases.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Weight Loss (%)</th>
<th>Weight Gain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-Ce0.9Gd0.1O1.95 - as prepared</td>
<td>15</td>
<td>0.3 (from 1240°C)</td>
</tr>
<tr>
<td>C-Ce0.9Gd0.1O1.95 -700°C</td>
<td>10</td>
<td>2.3</td>
</tr>
<tr>
<td>C-Ce0.9Sm0.1O1.95 - as prepared</td>
<td>15.8</td>
<td>2.8</td>
</tr>
<tr>
<td>C-Ce0.9Sm0.1O1.95 -700°C</td>
<td>5</td>
<td>2.9</td>
</tr>
<tr>
<td>10% SO4-C-Ce0.9Gd0.1O1.95 - as prepared</td>
<td>13.4</td>
<td>2.7</td>
</tr>
<tr>
<td>10% SO4-C-Ce0.9Gd0.1O1.95 -700°C</td>
<td>11</td>
<td>2.2</td>
</tr>
<tr>
<td>20% SO4-C-Ce0.9Gd0.1O1.95 - as prepared</td>
<td>20.4</td>
<td>0.8</td>
</tr>
<tr>
<td>20% SO4-C-Ce0.9Gd0.1O1.95 -700°C</td>
<td>18.4</td>
<td>2.0</td>
</tr>
</tbody>
</table>

The powder X-ray diffraction patterns of the as combusted (using different fuels urea, citric acid, glycine and polyethylene glycol) GDC; SDC; NDC; YDC; 10 and 20 mol% ammonium sulphate added and 700°C calcined GDC and SDC powders are characterized for their structure and phase analyses. In all the cases single-phase cubic fluorite structure of ceria is noticed [JCPDS No. 34-394]. Since there were no peaks representing free Gd, Sm, Nd and Y dopants, we can confirm that the Gd3+, Sm3+, Nd3+, Y3+ dopant ions get substituted in the CeO2 lattice. The crystallinity is also identical for the powders derived through sulphated combustion. The in-situ addition of ammonium sulphate acts as secondary fuel and enhances the combustion efficiency. It produced comparatively reactive ceria precursors that can be transformed into fully crystalline ceria at 700°C.
XRD analysis of rare earth (Gd^{3+}, Sm^{3+}, Nd^{3+}, Y^{3+}) doped ceria powders prepared using different organic fuel such as urea, citric acid, glycine and polyethylene glycol
(a) Gd and Sm doped with different fuels (b) Nd and Y doped ceria with different fuels (b) sulphate doped ceria (d-e) as-prepared and calcined (Gd doped and Sm doped ceria)
2. Particle Size Analysis:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Surface Area (m²/g)</th>
<th>Primary Particle Size (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-Ce0.9Gd0.1O1.95 - as prepared</td>
<td>68.1</td>
<td>12.3</td>
</tr>
<tr>
<td>C-Ce0.9Gd0.1O1.95 - 700°C</td>
<td>25.7</td>
<td>32.6</td>
</tr>
<tr>
<td>C-Ce0.9Sm0.1O1.95 - as prepared</td>
<td>50.9</td>
<td>16.4</td>
</tr>
<tr>
<td>C-Ce0.9Sm0.1O1.95 - 700°C</td>
<td>36.5</td>
<td>22.9</td>
</tr>
<tr>
<td>C-Ce0.9Nd0.1O1.95 - as prepared</td>
<td>35.2</td>
<td>19.6</td>
</tr>
<tr>
<td>C-Ce0.9Nd0.1O1.95 - 700°C</td>
<td>18.6</td>
<td>26.4</td>
</tr>
<tr>
<td>C-Ce0.9Y0.1O1.95 - as prepared</td>
<td>40.3</td>
<td>20.4</td>
</tr>
<tr>
<td>C-Ce0.9Y0.1O1.95 - 700°C</td>
<td>19.6</td>
<td>28.7</td>
</tr>
<tr>
<td>10% SO4-C-Ce0.9Gd0.1O1.95 - as prepared</td>
<td>55.0</td>
<td>15.2</td>
</tr>
<tr>
<td>10% SO4-C-Ce0.9Gd0.1O1.95 - 700°C</td>
<td>22.0</td>
<td>38.1</td>
</tr>
<tr>
<td>20% SO4-C-Ce0.9Gd0.1O1.95 - as prepared</td>
<td>50.0</td>
<td>16.8</td>
</tr>
<tr>
<td>20% SO4-C-Ce0.9Gd0.1O1.95 - 700°C</td>
<td>18.0</td>
<td>46.6</td>
</tr>
</tbody>
</table>

The specific surface areas and primary crystallite sizes were measured by Brunauer-Emmett-Teller (BET) measurement. As expected the powders received after combustion showed high surface areas and lower crystallite sizes compared to the calcined powders. Upon calcination approximately 50% decrease is seen in the specific surface area values and at the same time the crystallite size is increased to double. Specific surface area values indirectly indicating the porous and agglomerate nature of the as combusted foams and its reactivity. The precursor foams appear to be soft agglomerates containing mixture of amorphous and semi crystalline doped ceria crystallites.

Morphology, particle size and distribution of the powders were analysed by both scanning electron microscope (SEM-JEOL 6460 LV) and transmission electron microscope (TEM-JEOL JEM 2000 EX). TEM samples were prepared by dispersing the powder in dilute ethanol medium under ultrasonic agitation. A drop of suspension was placed on a carbon coated fine mesh copper grid. Once ethanol was evaporated, images were seen under TEM.
TEM micrographs of Gd and Sm doped ceria powders prepared using different organic fuels and calcined at 700°C.

3. Physical and microstructural studies:

The powders calcined at 700°C for 2h were uni-axially pressed into cylindrical pellets (thickness, t = 3mm and diameter, D = 10mm) and sintered at different sintering temperatures. The sintered densities of the specimens were measured by water immersion technique.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Morphology of as-prepared powders</th>
<th>Morphology of powders calcined at 700°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-Ce₀.₉Gd₀.₁O₁.₉₅</td>
<td>Platelets</td>
<td>Spherical grains</td>
</tr>
<tr>
<td>C-Ce₀.₉Gd₀.₁O₁.₉₅</td>
<td>Sponge thin flakes</td>
<td>Spherical grains</td>
</tr>
<tr>
<td>G-Ce₀.₉Gd₀.₁O₁.₉₅</td>
<td>Sponge thin platelets</td>
<td>Spherical grains</td>
</tr>
<tr>
<td>P-Ce₀.₉Gd₀.₁O₁.₉₅</td>
<td>Flakes</td>
<td>Spherical grains</td>
</tr>
<tr>
<td>U-Ce₀.₉Sm₀.₁O₁.₉₅</td>
<td>Platelets</td>
<td>Spherical grains</td>
</tr>
<tr>
<td>C-Ce₀.₉Sm₀.₁O₁.₉₅</td>
<td>Sponge thin flakes</td>
<td>Spherical grains</td>
</tr>
<tr>
<td>G-Ce₀.₉Sm₀.₁O₁.₉₅</td>
<td>Sponge thin platelets</td>
<td>Spherical grains</td>
</tr>
<tr>
<td>P-Ce₀.₉Sm₀.₁O₁.₉₅</td>
<td>Flakes</td>
<td>Spherical grains</td>
</tr>
<tr>
<td>Sample</td>
<td>Sintered Density (gm/cc)</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td>U-Ce&lt;sub&gt;0.9&lt;/sub&gt;Gd&lt;sub&gt;0.1&lt;/sub&gt;O&lt;sub&gt;1.95&lt;/sub&gt;</td>
<td>95.3</td>
<td></td>
</tr>
<tr>
<td>C-Ce&lt;sub&gt;0.9&lt;/sub&gt;Gd&lt;sub&gt;0.1&lt;/sub&gt;O&lt;sub&gt;1.95&lt;/sub&gt;</td>
<td>97.5</td>
<td></td>
</tr>
<tr>
<td>G-Ce&lt;sub&gt;0.9&lt;/sub&gt;Gd&lt;sub&gt;0.1&lt;/sub&gt;O&lt;sub&gt;1.95&lt;/sub&gt;</td>
<td>97.7</td>
<td></td>
</tr>
<tr>
<td>P-Ce&lt;sub&gt;0.9&lt;/sub&gt;Gd&lt;sub&gt;0.1&lt;/sub&gt;O&lt;sub&gt;1.95&lt;/sub&gt;</td>
<td>91.8</td>
<td></td>
</tr>
</tbody>
</table>

Sintered density with respect to fuel.

<table>
<thead>
<tr>
<th>Samples</th>
<th>% of Theoretical Density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sintered at 1200°C</td>
</tr>
<tr>
<td></td>
<td>2h</td>
</tr>
<tr>
<td>U- Ce&lt;sub&gt;0.9&lt;/sub&gt;Sm&lt;sub&gt;0.1&lt;/sub&gt;O&lt;sub&gt;1.95&lt;/sub&gt;</td>
<td>93.3±0.2</td>
</tr>
<tr>
<td>C- Ce&lt;sub&gt;0.9&lt;/sub&gt;Sm&lt;sub&gt;0.1&lt;/sub&gt;O&lt;sub&gt;1.95&lt;/sub&gt;</td>
<td>96.8±0.2</td>
</tr>
<tr>
<td>G- Ce&lt;sub&gt;0.9&lt;/sub&gt;Sm&lt;sub&gt;0.1&lt;/sub&gt;O&lt;sub&gt;1.95&lt;/sub&gt;</td>
<td>97.1±0.2</td>
</tr>
<tr>
<td>P- Ce&lt;sub&gt;0.9&lt;/sub&gt;Sm&lt;sub&gt;0.1&lt;/sub&gt;O&lt;sub&gt;1.95&lt;/sub&gt;</td>
<td>90.3±0.2</td>
</tr>
</tbody>
</table>

Sintered density variation with respect to soaking time.

5. Mechanical hardness and fracture toughness:

The sintered samples were carefully diamond polished to produce optical finish. The room temperature Vickers hardness was measured on the polished surfaces by Struers hardness tester. The hardness was determined by the ratio of the applied load via a geometrically defined indenter to the contact (projected) area of the resultant impression using the relation:

$$H_v = \frac{1854.4 \ P}{d^2} \text{ (GPa)}$$

where $H_v$ is the Vickers hardness (GPa), $P$ is the applied load (kg) and $d$ is the indentation diagonal length (mm). In a typical indentation test, load was varied from 1N to 20N. The indentation time was 10 seconds. Six to eight indentations were made for each load on all the samples. The sintered Ce<sub>0.9</sub>Sm<sub>0.1</sub>O<sub>1.95</sub> samples were also subjected to indentation fracture toughness measurements at a load varied from 1N to 20N. Fracture toughness is a measure of the crack and damage resistance offered by the material against mechanical stress and hence the diagonal lengths of the damaged indented images were measured and the fracture toughness ($K_{ic}$) values were calculated from the formula

$$K_{ic} = 0.16 \ H_v \ a^{3/2} [\text{MPa} \ m^{1/2}]$$
where $H_v$ is the Vickers hardness, ‘$a$’ and ‘$c$’ are the diagonal and crack lengths generated out of the indentation.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Microhardness, $H_v$ (GPa)</th>
<th>Fracture Toughness, $K_{IC}$ (MPa $m^{1/2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-Ce$_0.9$Gd$<em>0.1$O$</em>{1.95}$</td>
<td>5.87 ±0.2</td>
<td>1.94 ±0.3</td>
</tr>
<tr>
<td>C-Ce$_0.9$Gd$<em>0.1$O$</em>{1.95}$</td>
<td>8.72 ±0.2</td>
<td>1.75 ±0.3</td>
</tr>
<tr>
<td>G-Ce$_0.9$Gd$<em>0.1$O$</em>{1.95}$</td>
<td>8.82 ±0.2</td>
<td>1.68 ±0.3</td>
</tr>
<tr>
<td>P-Ce$_0.9$Gd$<em>0.1$O$</em>{1.95}$</td>
<td>2.45 ±0.2</td>
<td>1.99 ±0.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample</th>
<th>Microhardness, $H_v$ (GPa)</th>
<th>Fracture Toughness, $K_{IC}$ (MPa $m^{1/2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-Ce$_0.9$Sm$<em>0.1$O$</em>{1.95}$</td>
<td>4.89± 0.2</td>
<td>5.37± 0.2</td>
</tr>
<tr>
<td>C- Ce$_0.9$Sm$<em>0.1$O$</em>{1.95}$</td>
<td>6.27± 0.2</td>
<td>6.89± 0.2</td>
</tr>
<tr>
<td>G- Ce$_0.9$Sm$<em>0.1$O$</em>{1.95}$</td>
<td>6.82± 0.2</td>
<td>7.15± 0.2</td>
</tr>
<tr>
<td>P- Ce$_0.9$Sm$<em>0.1$O$</em>{1.95}$</td>
<td>1.85± 0.2</td>
<td>1.90± 0.2</td>
</tr>
</tbody>
</table>

6. Electrical conductivity:

The transport property of the rare earth doped ceria samples was analysed by impedance spectroscopy in air. In order to separate grain and grain boundary conductivity, ac impedance spectra is often a useful tool. In a typical ac impedance measurement, the complex impedance of the sample as a function of frequency is measured. Generally polycrystalline
specimen, independent semicircular arcs from high frequency to low frequency correspond to the conduction across the grains, grain boundaries, and the electrode specimen interface, respectively. As the temperature increases, the arcs are shifted into higher frequencies, which lead to the successive disappearance of grain and grain boundary arc and finally the electrode contribution will be seen at higher temperature. Therefore, the grain and grain boundary resistance can not be separated at higher measured temperature. The corresponding resistance values were converted to conductivity using sample dimensions. Accordingly, the grain conductivity, grain boundary conductivity, and the total conductivity were calculated at different temperatures.

Impedance plots of Ce$_{0.9}$Sm$_{0.1}$O$_{1.95}$ ceramics sintered at 1200°C for 6h, measured at (a) 88, (b) 203, (c) 328 and (d) 450°C.

![Impedance plots](image_url)
The Arrhenius plot of (a) ac and (b) dc-conductivities for \( \text{Ce}_{0.9}\text{Sm}_{0.1}\text{O}_{1.95} \) sintered at 1200°C for 6h.

Variation of DC-electrical conductivity with respect to temperature for samples \( \text{Ce}_{0.9}\text{Gd}_{0.1}\text{O}_{1.95} \) sintered at 1400 and 1500°C for different soaking time

7. Thermal diffusivity and thermal conductivity:

<table>
<thead>
<tr>
<th>Sintering Temperature (°C)</th>
<th>Sintered Density (g cm(^{-3}))</th>
<th>Thermal Diffusivity ( \left(10^{-6} \text{ m}^2\text{s}^{-1}\right) )</th>
<th>Thermal Conductivity (W m(^{-1})K(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200°C/6h</td>
<td>6.56±0.7</td>
<td>0.57</td>
<td>1.31</td>
</tr>
<tr>
<td>1400°C/6h</td>
<td>6.89±0.05</td>
<td>1.04</td>
<td>2.52</td>
</tr>
<tr>
<td>1500°C/6h</td>
<td>7.09±0.05</td>
<td>1.12</td>
<td>2.79</td>
</tr>
</tbody>
</table>

The room temperature (298.15K) thermal diffusivity values were evaluated by photo-acoustic technique and the thermal conductivities were calculated also for \( \text{Ce}_{0.9}\text{Sm}_{0.1}\text{O}_{1.95} \) sample sintered at 1200°C for 6h. The thermal diffusivity and thermal conductivity values were found to be \( 0.5 \times 10^{-6} \text{ m}^2\text{s}^{-1} \) and \( 1.2 \text{ W m}^{-1}\text{K}^{-1} \), respectively, obtained for the samarium doped ceria sintered at 1200°C for 6h.
LOGROS:

1. Established a laboratory named, “Laboratorio de Cerámicos Avanzados y Nanotecnología”, at the Department of Materials Engineering, University of Concepción, with the help of funding from FONDECYT 11060302 and University of Concepción, during the first year of this FONDECYT Project.

2. 11 (Eleven) publications have been published in the International Journals.


4. 15 (Fifteen) research papers have been presented in the International and National Conferences held in different countries like CHILE, USA, JAPAN, INDIA, BRAZIL and Argentina. Three of them were invited talks.

5. Two graduate thesis (Memoria de Título):

   2. Srta. Andrea Ortiz (to be completed on December 2009, She completed the experimental work and writing the thesis to submit on December 2009).

6. Received an Exchange Student, Ms. Anke Schachtsiek, from the Department of Materials Science, Technical University of Darmstadt, GERMANY to work on her summer training programme during the third year of this FONDECYT. She worked under this FONDECYT project for three months.
Resumen:

Solid Oxide Fuel Cell (SOFC) is regarded as a highly efficient power-generation system for future application. The research in the field of SOFC is concentrated nowadays on the development of the new generation of cell component materials to allow operation at low temperatures even at 200°C as well as on the development of the low cost technologies for their production. Exploring new type of electrolyte and electrode and their synthesis method is very important for developing the low temperature SOFC.

Ceria based electrolyte ceramic materials are noteworthy as candidates for electrolyte materials because they possess higher ionic conductivities at lower temperature. The particle size and distribution in a ceramic powder will affect the microstructure and so affect the electric performance of the ceramic strongly. Also it is well known that the sintering temperature decreases when nanosized powders are used and the conductivity in the nanocrystalline grain boundary regions is higher than for large grains. In this respect it is important, as a first step to develop powders of high quality with particle size in the nanometer range. In this work, the development of processing and characterization of ceria based electrolyte materials for SOFC applications was studied to improve the conductive properties and thus will improve the performance of the SOFC. The synthesis of ceria nanopowders doped with rare earth oxides such as Y2O3, Gd2O3, Sm2O3, Nd2O3 using organic various fuels such as urea, citric acid, glycine, ethylene glycol, and oxalic acid were prepared. The wet chemical self-sustaining combustion technique was adopted to prepare the ceria based nanopowders. The influence of organic fuels during combustion and the effect of dopants on the characteristics of the precursor powder as well as calcined powders were studied and reported.

Based on the preliminary results, the project was focused to study of the powder characteristics, fabrication and sintering properties of electrolyte materials were sintered at different temperatures of 1200, 1400 and 1500°C with a soaking period of 2, 4 and 6h, esp. for Gd2O3 and Sm2O3 doped ceria in all the cases. The powders prepared using organic fuels citric acid and glycine were considered in most of the cases to study the powder and sintering characteristics of the electrolyte materials. Thermal analysis like TG/DT techniques and DSC analysis was studied with respect to temperature and dopants; Structural and phase analyses with XRD powder diffraction and particle size and powder morphology by TEM were studied with respect to dopant and organic fuel used. The sintering properties were also studied with calcinations temperature, dopant and organic fuels used to prepare the nanopowders. Importantly, the electrical and mechanical properties were studied with respect to the microstructure, temperature and rare earth dopants, which gave significant results to improve the performance of SOFC electrolytes at operating temperature. The effect of dopants on the grain size and morphology of the sintered materials were also be studied and reported. It was found that the citric acid and glycine fuels used prepared powders showed better powder, phase and structural characteristics than the other organic fuels urea and polyethylene glycol. With respect to rare earth dopants, Gd2O3 and Sm2O3 were effectively provides the better properties on sintering properties, esp. mechanical and electrical properties.

Finally, it was concluded that the rare earth doped nanopowders prepared using citric acid and glycine showed better powder and structural characteristics among the various organic fuels. In case of sintered, microstructural, electrical and mechanical properties, Gd2O3 and Sm2O3 doped on ceria showed better results and significantly improved the electrical and mechanical characteristics of the SOFC electrolytes. Especially, the electrical conductivity measurements with respect to temperatures showed that the Gd2O3 and Sm2O3 doped on ceria samples showed a high conductivity on the order of 10² and 10³ S cm⁻¹ at 500 and 700°C, respectively. The thermal diffusivity and thermal conductivity values observed at room temperature were 0.5 to 1.0 x 10⁴ m²s⁻¹ and 1.0 to 2.0 W m⁻³K⁻¹, respectively. Ceria electrolytes derived from the glycine and citric acid fuels have maximum micro hardness of 7.0-8.0 ±0.2 and 7.5-8.5 ±0.2 GPa. Dense nanocrystalline ceria electrolyte membranes having theoretical sintered densities of 98% and the sintered grain sizes less than 500nm were successfully achieved at 1200°C. The study significantly contributes to select the fuels appropriately so that the advantages of low temperature densification and mechanically durability can be achieved in ceria electrolyte membranes for IT-SOFC applications.
COOPERACIÓN INTERNACIONAL

N° Proyecto: 7080176
Nombre Colaborador (a) Extranjero (a): ANANTHAKUMAR SOLAIAPPAN
Afiliación Institucional Actual: COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

Fechas de estadía

Describa las actividades realizadas y resultados obtenidos. Destaque su contribución al logro de los objetivos del proyecto. Si es pertinente, indique las publicaciones conjuntas generadas, haciendo referencia a lo informado en la etapa Productos. Agregue en la etapa anexos la información necesaria.

The hard copy of the report already has been sent to FONDECYT:
The activities carried out during the stay of Dr.S.Ananthakumar as follows:

1. The mechanical characterization and the correlation with the sintered microstructures (microstructure-mechanical property relationship) were studied for rare earth doped ceria electrolytes used for solid oxide fuel cells. This work was carried out in our Advanced Ceramics and Nanotechnology Laboratory at Department of Materials Engineering, University of Concepcion. The possibility of enhancement of hardness and fracture toughness was also discussed.

2. A postgraduate course (Code Number: 4206028, one credit) titled, “RECENT TRENDS IN ADVANCED CERAMIC PROCESSING” was conducted at Department of Materials Engineering for postgraduate students of all engineering disciplines. There were six students from Materials, Aeronautical, Mechanical and Chemical Engineering were attended and it was included in their curriculum. Also, this course was opened for final year undergraduate students of our Department of Materials Engineering. A certificate was issued for Fourteen undergraduate students who attended the course. The details of the course, copy of Acta de Notas and copy of certificate for undergraduate students were enclosed. The course event and research activities were published in our University of Concepcion (UdeC) Panorama and Faculty of Engineering (Fl) Notice.

3. A research manuscript titled, “Microhardness and fracture toughness of Ce0.9Gd0.1O1.95 for manufacturing solid oxide electrolytes” submitted to the journal of Materials Engineering A, was revised and finalized to submit the revised version during Dr.S.Ananthakumar’s stay. (Materials Science and Engineering A, 2009, 517 (1-2) 91-96.

4. Scientific discussions and interactions with Professors and Students in our Department of Materials Engineering were went on separately during the stay of Dr.S.Ananthakumar. Especially, future collaboration and research work were also discussed in connection with FONDECYT initiation project (NO: 11060302).

PRODUCTOS

ARTÍCULOS
Para trabajos en Prensa/ Aceptados/Enviados adjunte copia de carta de aceptación o de recepción.

N°: 1
Autor (a)(es/as): R.V.Mangalaraja, J.Mouzon, P.Hedström, I.Kero, K.V.S.Ramam, Carlos P. Camurri, M.Odén
Nombre Completo de la Revista: Journal Materials Processing Technology
Indexación: ISI
ISSN:
Año: 2008
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<th>Indexación</th>
<th>ISSN</th>
<th>Año</th>
<th>Vol.</th>
<th>N°</th>
<th>Páginas</th>
<th>Estado de la publicación a la fecha</th>
<th>Otras Fuentes de financiamiento, si las hay</th>
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<td>Microhardness and fracture toughness of Ce0.9Gd0.1O1.95 for manufacturing solid oxide electrolytes,</td>
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<td></td>
<td>2009</td>
<td>517</td>
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<td>91-96</td>
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<td>Electrical and thermal properties of 10 mol% Gd3+ doped ceria electrolytes synthesized through combustion technique</td>
<td>ISI</td>
<td></td>
<td>2009</td>
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<td></td>
<td>137-143</td>
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<td>Synthesis and characterization of Gd3+ and Sm3+ ions doped ceria electrolytes through in-situ sulphated combustion technique</td>
<td>ISI</td>
<td></td>
<td>2009</td>
<td>10</td>
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Enviando documento en papel: sí
Archivo Asociado al artículo: Publication-6_-_MSE_A.pdf

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Archivo Asociado al artículo: Publication-7_-_PAC.pdf

Enviando documento en papel: sí
Archivo Asociado al artículo: Publication-8_-_PAC.pdf
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<th>Autor (a)(es/as):</th>
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<td>9</td>
<td>R.V. Mangalaraja, S. Ananthakumar, Anke Schachtsiek, Marta López, Carlos P. Camurri, Ricardo E. Avila</td>
<td>Materials Science and Engineering A</td>
<td>Synthesis and mechanical properties of low temperature sintered Sm3+ doped nano ceria electrolyte membrane for IT-SOFC applications</td>
<td>ISI</td>
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<td>10</td>
<td>R.V. Mangalaraja, S. Ananthakumar, Anke Schachtsiek, Marta López, Carlos P. Camurri, Ricardo E. Avila</td>
<td>Journal of Materials Science</td>
<td>Synthesis and electrical characterization of Sm3+ doped ceria electrolytes</td>
<td>ISI</td>
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Thermal diffusivity and thermal conductivity of ytterbium doped yttria measured by photoacoustic technique

ISA

Otras Fuentes de financiamiento, si las hay :

Enviar documento en papel : sí
Archivo Asociado al artículo : Publication-11_-_JMSCL.pdf

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Microwave assisted combustion synthesis of mixed oxide electro-ceramic nanopowders

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CONGRESOS
1. R.V. Mangalaraja, Kasimayan Uma, Romel M. Jiménez, Marta López, Carlos P. Camurri, S. Ananthakumar
   Título (Idioma original): Ceramic nanostructures for electronic applications - An overview of the synthesis approaches
   Nombre del Congreso: International Conference on Functional Materials for Advanced Technology (ICFMAT-2009)
   País: INDIA
   Ciudad: CHENNAI
   Fecha Inicio: 29/01/2009
   Fecha Término: 30/01/2009
   Nombre Publicación: Conference Proceedings

2. R.V. Mangalaraja, Kasimayan Uma, Romel M. Jiménez, Marta López, Carlos P. Camurri, S. Ananthakumar
   Título (Idioma original): Synthesis strategies for nanostructured rare earth doped ceria SOFC electrolytes to operate at reduced temperature
   Nombre del Congreso: 1er Congreso de Nanotecnología
   País: CHILE
   Ciudad: Valparaíso
   Fecha Inicio: 25/05/2009
   Fecha Término: 28/05/2009
   Nombre Publicación: Conference Abstracts Proceedings

3. R.V. Mangalaraja, S. Ananthakumar, Marta López, Carlos P. Camurri, Ricardo E. Avila
   Título (Idioma original): Synthesis and electrical characterization of Sm3+ doped electrolytes
   Nombre del Congreso: 11th International Conference on Advanced Materials (ICAM-2009)
   País: BRASIL
   Ciudad: Rio de Janeiro
   Fecha Inicio: 20/09/2009
Nº: 4
Autor (a)(es/as): R.V.Mangalaraja, S.Ananthakumar, Marta López, Carlos P.Camurri, Ricardo E. Avila
Título (Idioma original): Electrical characteristics of Gd3+ doped ceria electrolytes processed through thermal decomposition of organic fuels
Nombre del Congreso: 9th International Conference on Metallurgy and Materials (SAM-CONAMET 2009)
País: CHILE
Ciudad: Buenos Aires
Fecha Inicio: 19/10/2009
Fecha Término: 23/10/2009
Nombre Publicación: Abstracts Proceedings
Año: 2009
Vol.: 4
Nº: 0
Páginas: no
Envía documento en papel: no
Archivo Asociado: Abstract_-_ICAM_2009.pdf

TESIS/MEMORIAS

Nº: 1
Título de Tesis: STUDIES ON THE EFFECT OF RARE EARTH DOPANTS (Gd2O3, Sm2O3, Nd2O3, Y2O3) ON THE STRUCTURAL, ELECTRICAL AND THERMAL PROPERTIES OF CERIA (CeO2) BASED ELECTROLYTES FOR SOLID OXIDE FUEL CELLS.

Nombre y Apellidos del(de la) Alumno(a): Andrea
Nombre y Apellidos del(de la) Tutor(a): Ortiz Iribarren
Título Grado: Pregrado
Institución: Departamento de Ingeniería de Materiales, Universidad de Concepción
País: CHILE
Ciudad: Concepción
Estado de Tesis: En Ejecución
Fecha Inicio: 01/05/2009
Fecha Término: 30/12/2010
Envía documento en papel: no
Archivo Asociado: Abstract_-_Memoria_de_Titulo_-_Srta._Andrea_Ortiz.pdf
A continuación se detallan los anexos físicos/papel que no se incluyen en el informe en formato PDF.
COMPROBANTE DE RECEPCIÓN DE INFORME FINAL

N° PROYECTO: 11060302
INVESTIGADOR(A) RESPONSABLE: MANGALARAJA RAMALINGA VISWANATHAN
RUT: 22.060.403-9
TÍTULO PROYECTO: DEVELOPMENT OF PROCESSING AND CHARACTERIZATION OF CERIA BASED MATERIALS FOR SOLID OXIDE FUEL CELL APPLICATIONS: SYNTHESIS OF NANOPowDERS AND ITS SINTERING CHARACTERIZATION

DISCIPLINA PRINCIPAL: INGENIERIA DE MATERIALES
CÓDIGO DE TRANSACCIÓN: C5SB5ABFEFE6787C6E666135EB2165C1

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