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Challenges in the investigation of SOFC materials

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Abstract:
The increase in energy demand and the concerns regarding the environmental pollution led to the development of green energy sources. Solid oxide fuel cells (SOFCs) are electrochemical conversion devices operating at high temperatures (about 1000 °C) characterized by high efficiency, low emissions, fuel flexibility. With the aim to decrease the operation temperature down to 700 °C and below, new materials and processing technologies are currently under investigation. Several issues regarding material synthesis, characterization and testing will be addressed in this study.

Keywords: solid oxides, fuel cells, titanates, sol-gel

1. INTRODUCTION

Currently, the increase in energy demand of our modern society and the concerns regarding the environmental pollution led to the development of new energy sources [1]. Even if renewable energy sources such as solar and wind energy, as well as hydropower are plentiful, their availability is intermittent. Thus, efficient and inexpensive energy-conversion and storage systems are required [2].

Solid oxide fuel cells (SOFCs) are electrochemical conversion devices operating at high temperatures (about 1000 °C) characterized by high efficiency, low emissions, fuel flexibility [3].

However, long term operation at high temperatures puts drastic requirements on the SOFC components. Therefore, the research in the field of SOFC research is focused on the decrease of the operation temperature down to the intermediate-temperature region (500-700 °C), the focus being set on the development of new materials and processing technologies.

Our goal was to prepare new solid oxides with mixed ionic-electronic conductivity, with improved performances.

2. MATERIALS AND METHODS

Titanate nanocrystalline powders with pyrochlore and cuspidine structure have been synthesized using a modified Pechini method. X-ray diffraction (XRD), Raman spectroscopy, scanning-electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDXS) were used to evidenced the crystalline structure, composition, and morphology of the samples.

The sintering behavior of the powders was investigated using dilatometry measurements. After sintering, the electrical conductivity was determined by electrochemical impedance spectrometry (EIS).

3. RESULTS AND DISCUSSION

Powders based on $M_2Ti_2O_7$ (with M= Gd, Y, Sm) and $La_4Ti_2O_{10}$ have been synthesized by a Pechini method. The pyrochlore and cuspidine structures of these two sets of compounds have great compositional flexibility due to the presence of two cation sublattices, with multiple doping possibilities.

In order to obtain solid solutions, the synthesis procedure was modified to maintain the precursor cations in solution by adjusting the pH (to avoid precipitation). The solid resins obtained after gel drying were calcined in a tube furnace, under air, at 550 °C.

XRD measurements evidenced the nanocrystalline nature of the as-synthesized powders, due to the presence of broaden characteristic peaks. In this case, Raman spectroscopy proved to be a powerful tool for the identification of crystalline phases. EDXS analysis revealed that the proposed stoichiometry was reached in the investigated samples.

The nanocrystalline oxide powders have been shaped into pellets and sintered at high temperatures. The sintering temperatures were determined using dilatometry measurements. However, the duration of thermal treatment was established in order to achieve a relative density (the ratio between practical density and theoretical density) higher than 96%. Such high densification is required for electrochemical evaluation of electrical conductivity in solid oxides.

As the electrochemical testing set-up is equipped with gold electrodes, a thin gold layer was deposited onto both sides of the sintered pellets by sputtering to allow a good electrical contact between the investigated samples and gold electrodes. The investigated temperature range was 300-800 °C, and the EIS measurements were performed under air and under reducing atmosphere (2% H_2 in Ar). Activation energies of conduction were calculated from Arrhenius plots of conductivity.

4. CONCLUSION

- The high structural flexibility of pyrochlores and cuspidines may lead to many interesting technological applications.
- A or B site cation dopind is a good strategy for tuning their electrical conductivity.
- After exposure to highly reducing atmosphere, a strong increase in conductivity was usually noticed, along with a change in activation energy of conduction.

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