Study of NiO-GDC material produced by aqueous tape casting

Wilson Acchar¹, Luana Barbosa Cruz¹, Herval Ramos Paes Junior²

¹Post-Graduation Program of Science and Materials Engineering, Federal University of Rio Grande do Norte (UFRN), Natal, Brazil
²Universidade Estadual Norte-Fluminense-UENF, Rio de Janeiro,Brazil
e-mail: wacchar@gmail.com, cruzluana@gmail.com, hervalpaes@gmail.com

ABSTRACT
Studies have been developed in last decades in order to produce NiO-based material to be used as anode in solid oxide fuel cell (SOFC). Aqueous-based tape casting was used to produce NiO-GDC substrates with smooth and homogeneous surfaces and good flexibility. Physical and mechanical properties were obtained in green tapes sintered at temperatures ranging from 1200 to 1400 °C. The tapes sintered in 1400 °C showed the best density and porosity values and mechanical strength between 7 and 25 MPa. SEM micrographs show a dense material with cracks and pores. The sintered material shows the presence of nickel oxide and gadolinium cerium oxide.

Keywords: NiO-GDC; sintering; tape casting

1. INTRODUCTION
Solid oxide fuel cells (SOFC) are a green and clean energy and have been intensively studied in the last decades. Many studies are developed in order to reduction the operating temperature, fabrication costs and improve the energy efficiency [1-3]. Two basically points were investigated. The first point is to developed new electrolyte material with higher ionic conductivity and the second is to decrease the electrolyte thickness, developing the electrode-supported SOFC [4,5]. GDC electrolyte has an ionic conductivity higher than of yittria stabilized zirconia (YSZ) and a thermal expansion coefficient much closer to that of the Ni-cermet and commercial ferrite stainless interconnects compared to YSZ, making the GDC a very good candidate to electrolyte material [6].

Recently, some works about tape casting and solid-state reaction of NiO-GDC anode substrate have been reported in the literature [6-9]. The mainly result obtained in these studies indicated that is possible to produce a homogeneous anode substrate by tape casting process.
Tape casting has showed to be an excellent good method to obtain thin films and is particularly indicated to produce multilayer ceramic composite and nanostructured material [10-14]. The objective of this work was to obtain a Ni-GDC homogeneous sheet.

In this study, Ni-GDC sheet was produced by an aqueous-based tape casting process and sintered at different temperatures. The physical and mechanical values behavior of sintered material was evaluated.

2. MATERIALS AND METHODS
Ni-GDC anode green tapes were obtained by aqueous tape casting. The slurries were prepared with 50 wt. % NiO-CDG powder. Details about the rheological characterization were reported earlier [9]. The results indicated that the acrylic-based suspensions showed a pseudoplastic behavior and remained stable and homogeneous, which is ideal to tape casting process. Debinding of the green laminates was performed by heating up to 600 °C with the rate of 5 °C min⁻¹. Sintering process was carried out in an electric furnace (Nabertherm, Germany) at temperatures between 1200 °C and 1400 °C during 1 hour. The apparent density and porosity of the sintered tapes were determined by using the Archimedes water displacement method. Mechanical strength at room temperature of the sintered samples (average of three specimens for each value) were measured with a universal testing machine (Zwick-Roell, 2.5 kN) in three-point bending tests at a constant cross-head speed of 0.5 mm/min. The crystalline phases present after sintering were identified by X-ray diffraction (Shimadzu, XRD-60). The microstructures of fractured surfaces were examined by Scanning Electron Microscopy (Shimadzu SSX-550,25KV)
3. RESULTS AND DISCUSSION

Figure 1 shows the X-ray diffraction pattern of the green tape sintered at 1400°C during 1 hour. The sintered material showed the presence of Nickel oxide and gadolinium cerium oxide, as expected. No others phases or new reaction products were identified. Similar crystalline phases were founded at 1200°C. The GDC phases founded in this work are totally in agreement with the reported in the literature [10].

![X-ray diffraction pattern](image)

**Figure 1**: X-ray diffraction of green tape sintered at 1400°C.

Figure 2 shows the NiO-GDC sheet obtained after the tape casting process. The tape shows a smooth and homogeneous surface, showing no visible superficial defects.

![Green tape](image)

**Figure 2**: Green tapes.

Figure 3 shows compares the porosity and density values founded in this work with data reported in the literature. The sintered material shows an improvement of density and porosity values by increasing the sintering temperature, as expected. The best values were founded at 1400°C (P = 30%, D = 6.5 g/cm³). The density obtained in this work show better density values an as compared to the literature [7], regardless the sintering temperature. Figure 4 shows the strength values of the simple tape and laminates. The multilayer ceramic package (laminates) used in this work were prepared by a thermocompression of three simple tapes at 100°C with a pressure of 2 MPa. The tapes and laminates show a flexural strength of approximately 7 and 25 MPa, respectively. The low strength values founded can be related to the processing defects produced in the tape casting technique. The results indicated that the laminates show better strength values as compared to the monolayer tape, demonstrating that the laminates improves the strength of the monolithic layer. Figure 5 shows...
SEM micrographs of the green and sintered tapes. It is possible to see the presence of nickel oxide (gray area) and the gadolinium oxide (white regions), according to the x-ray diffraction (fig. 1).

The sintered material showed a dense structure, but the presence of cracks and pores, which can explain the low strength values of the sheets. Studies are under way in order to improve having a crack free sintered material with better mechanical properties.

**Figure 3:** Porosity and density values of the sintered sheets.

**Figure 4:** Strength values of normal tapes and laminates.
Figure 5: MEV of the sheets (a) green and (b,c,d) sintered.

4. CONCLUSIONS
NiO-GDC anode substrates were successfully obtained by aqueous-based tape casting process and sintering. X-ray diffraction at the sintered tape showed the presence of nickel oxide and gadolinium cerium oxide. No other crystalline phase was detected. The best sintering temperature was 1400°C for 1 h, in which sufficient open porosity of around 30% was obtained. Mechanical bending strength between 7 (normal tape) and 25 MPa (laminates) were obtained, which can be associated to the presence of cracks and pores. The sintered material showed a dense structure, but the presence of cracks and pores.

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6. BIBLIOGRAPHY


