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Characterization of Layered Material Properties in Solid Oxide Fuel Cells using a Laser Ultrasound Technique

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1. Abstract

This paper is focused on nondestructive characterization of material and geometrical properties of ceramic layers in a solid oxide fuel cell (SOFC). More specifically, elastic properties and thickness for the electrolyte layer are measured using a nondestructive procedure. The procedure employs a laser ultrasound technique to generate and detect guided acoustic waves to propagate in the layer, followed by an inversion algorithm to extract properties from the acoustic signal. The results indicate that the thickness can be determined with high accuracy remotely, and the elastic moduli are also determined with good agreement with those in some rare literature obtained with a contact manor.

2. Introduction

Solid oxide fuel cell (SOFC) has the advantage of high efficiency in converting the chemical energy to electricity. The mechanical properties of materials for use in SOFC are becoming increasingly important, as many stack concepts are now being scaled up and evaluated for their long-term reliability. Some of the mechanical properties of yttria-stabilized zirconia (YSZ) electrolytes have been studied and reported in the literature [1]. The mechanical properties of the individual layers in the SOFC structure will dependent on defects and impurities introduced during processing; for example it is well established that the Young's modulus (E) of ceramic materials changes with porosity and impurity content [2, 3, 4]. The ceramic structure also suffers from the difficulties in the control of geometrical and mechanical properties in the manufacturing process. This research is aimed at the characterization of layer properties in a nondestructive way. Plate-shape electrolyte samples are tested. A procedure employing a laser ultrasound technique (LUT) together with a simplex inversion algorism is used to characterize the ceramic SOFC layer properties.

3. Methodology

This research uses a novel procedure to characterize the material properties of the electrolyte layer in the SOFC. The procedure employs a laser ultrasound technique to generate and detect guided acoustic waves to propagate in the layer, followed by an inversion algorithm to extract properties from the acoustic signal. The theoretical model with its configuration shown in **Fig.1**. is a matrix-based method for the modeling of dispersion relations of guided acoustic waves propagating in layered structures [5, 6].

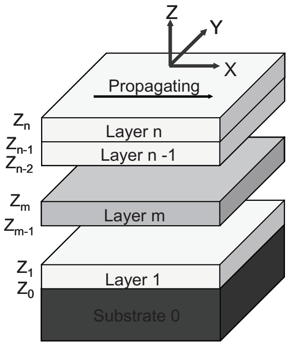

Fig. 1: Schematic guided wave propagating in multilayer structures.

An inversion procedure based on simplex algorithm is used to extract the desired material and geometrical properties form the acoustic data. Fig. 2 shows the experimental configuration consisting of a pulsed laser for the generation of ultrasonic waves and a laser-based optical detector for the detection of acoustic waves. The investigated samples are layers of 0.34 mm thick electrolyte from institute of nuclear energy research (INER).

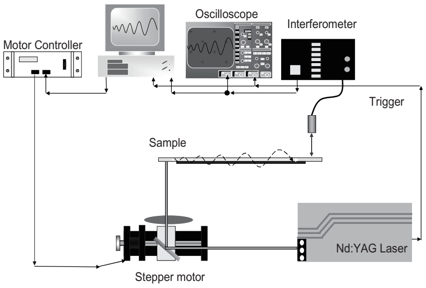

Fig. 2: A schematic for the experimental setup

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4. Results and discussions

Fig. 3 shows the measured dispersion curves for the guided acoustic waves propagating in the electrolyte layer of the SOFC. After LUT measurements the dispersion relations, it was still necessary to use them to determine values for the physical properties. The properties serve as input parameters to a wave propagation model that predicts the dispersion relation. Predictions are compared to measurements and the input parameters adjusted iteratively to obtain optimum agreement. The inversion method was done on all three parameters Young’s modulus (E), Poisson’s ratio (ν) and thickness (h).

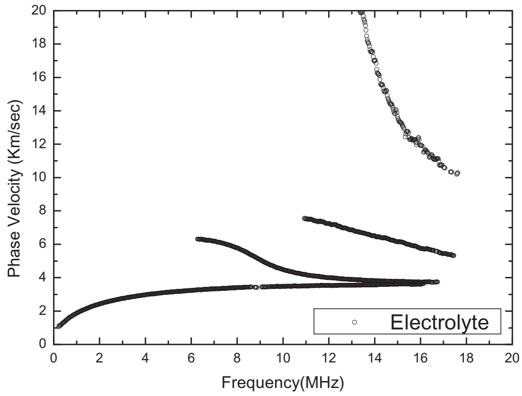

Fig. 3: LUT measured dispersion spectra for the electrolyte

After inversion process the electrolyte properties are determined as: h =0.34 mm, E= 207.96 GPa, and ν=0.30. **Fig. 4** shows electrolyte a comparison between the measured dispersion spectra and those from calculations using the inversion-determined properties. In Fig. 4 the measured data of the dispersion curves and the calculations curve; agreement is seen to be excellent. While independent measurement using an optical microscope is used as a reference, the inversion-determined thicknesses are 0.34 mm for the electrolyte layers, respectively. The inverted thickness shows an accuracy of better than 1%. Also, the obtained material properties are compared with those in the literature where destructive methods are employed [1], where E=212GPa, ν=0.32 for the electrolyte. The determined Young's modulus shows errors of 1.9% for the electrolyte.

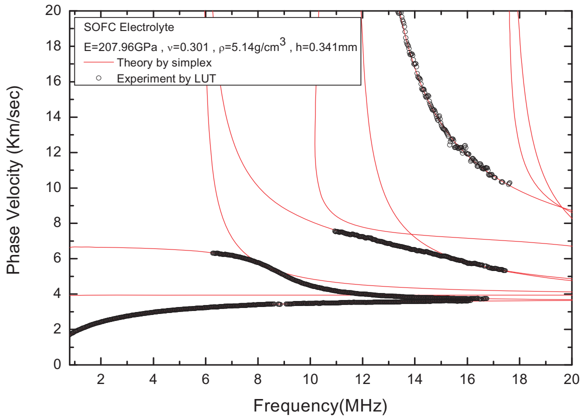

Fig. 4: LUT measured and calculations dispersion spectra for the electrolyte

5. Conclusions

A procedure employing a laser ultrasound technique and an inversion algorism is introduced for nondestructive characterization of material properties and thickness of individual layer in solid oxide fuel cell (SOFC). Good accuracy for the procedure is demonstrated. Currently this technique is being developed towards an online characterization tool for the manufacturing process.

Acknowledgment

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