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Electrochemical gas sensor with $LaFeO_3$ sensing electrode for exhaust gas analysis

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Abstract :

The sensors are in the configuration $LaFeO_3$/YSZ/Pt and will be used for the detection of NOx gases. The resistance variation of $LaFeO_3$ layers under NO_2 was also tested. The influence of the deposition temperature and of nature of the substrate on the morphology of the sensing electrodes (thin $LaFeO_3$ layers) was investigated by Transmission Electron Microscopy (TEM) X Ray Diffraction (XRD) Scanning Electron Microscopy (SEM). Sensors were exposed to various concentration of NO_2 in the temperature range 500 - 800 °C and the sensing properties related to the morphology of the sensing electrodes.

Key words: electrochemical gas sensor, perovskite, YSZ, PLD, TEM.

Introduction

Electrochemical sensors with perovskite $LaMO_3$ sensing electrodes deposited on Yttrium Stabilized Zirconia (YSZ) were recently investigated for applications in harsh environment such as car exhaust gases [1-2]. YSZ is a well-known ionic conductive ceramic, and thus a suitable electrolyte material whereas perovskites - based material are already used as catalytists [3]. Both YSZ and perovskite layers are characterized by a high chemical stability at high temperature. Perovskite layers such as In_2O_3 on YSZ showed high sensitivity to NO_2 , as well as long term stability at 700°C [4].The sensors built with screen printed $NdCoO_3$ layers on YSZ, showed high sensitivity to the presence of NOx gases [5]. Sensors for gas detection have two basic tasks: detecting gases or chemical compounds in the ambient air and converting a chemical signal in to an electrical signal. They must meet several requirements: high sensitivity, high selectivity, short response time and stability. The gas sensing mechanism in electrochemical sensors relies on the electrochemical catalytic reaction at the interface between the solid electrolyte and the sensing electrode. The microstructure of the sensing electrode (surface, porosity, thickness) and the interface can have a significant effect on the sensor response. The aim of this work is to elaborate sensing $LaFeO_3$ layers by Pulsed Laser Deposition, to characterize their microstructure, and to relate them to the sensing performance.

Methodology

$LaFeO_3$ layers were deposited on YSZ (9,5 % mol and 3,5 % mol) as well as on Si substrates by Pulsed Laser Deposition (PLD) at 750 °C, 850 °C and 1000 °C in presence of oxygen. The laser ablation system was equipped with the Nd-YAG laser Continuum Powerlite DLS (Digital Laser Source) (λ=266 mm) and a chamber Neocera. The deposition conditions were: laser pulse frequency 10 Hz, energy density on the target 7,8 J/cm^2, laser pulse duration 4 ns, deposition time 2,5 hours. The influence of the deposition temperature and of nature of the substrate on the morphology and chemical composition of the sensing electrodes (thin $LaFeO_3$ layers) was investigated by Transmission Electron Microscopy (TEM) X Ray Diffraction (XRD) Scanning Electron Microscopy (SEM).

The sensing layers were tested under NO_2 at different temperatures around 400°C. The sensors in the configuration $LaFeO_3$/YSZ/Pt were tested in presence of different NOx in the temperature range T = 500-800 °C as a function of time.

Results and discussions

The first studies of $LaFeO_3$ on Si and YSZ 9.5% layers focused on the effect of process temperature and microstructure analysis. The SEM imaged revealed the nanostructuration of the surface (Fig. 1). The morphology of the layers is also affected by the nature of the substrate. At 850°C, droplets were created during the PLD. These droplets do not occur on the surface of layers formed at higher temperatures. Temperature also affects the shape of grains (Fig. 1a - 1c, Fig1b-1d). As the temperature rises, we can also observe grain growth. Layers produced at 850°C have elongated and round grains, they disappear as the temperature increases and mainly grains are extended in one direction. LaFeO3/YSZ layers produced at 850°C were already tested under 50 and 10 ppm of NO_2 (Fig2) and showed high sensibility (100%) at 400°C.

These layers were also tested in the electrochemical LaFeO3/YSZ/Pt configuration.

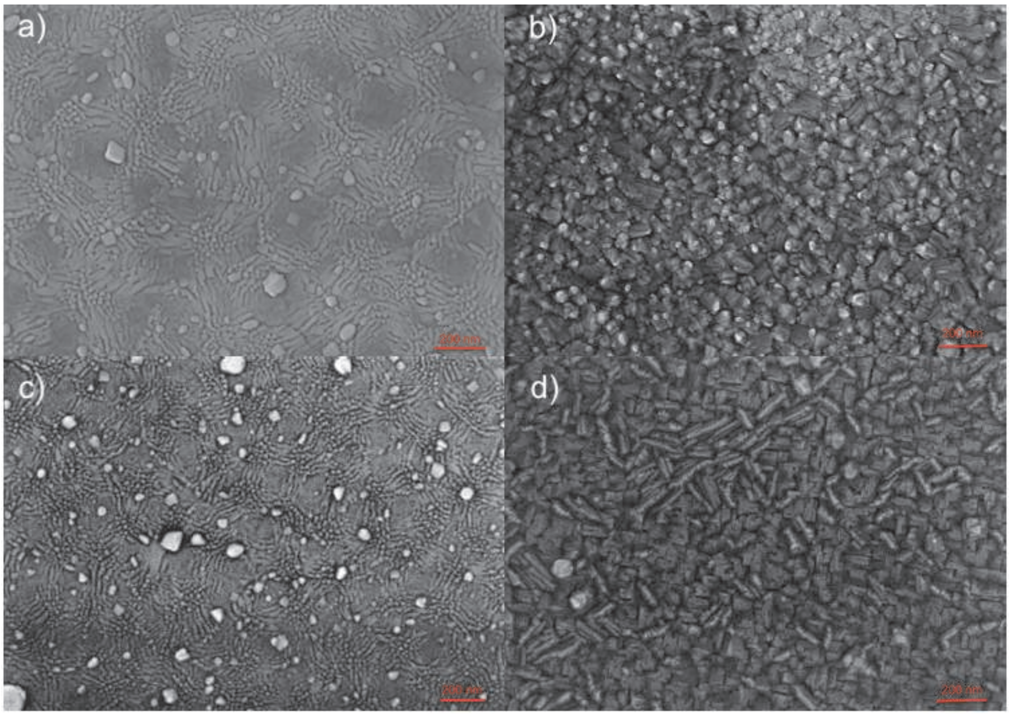

Fig.1. SEM images of thin films surface a) LaFeO3_850_Si; b) LaFeO3_850_YSZ; c) LaFeO3_1000_Si; d) LaFeO3_1000_YSZ.

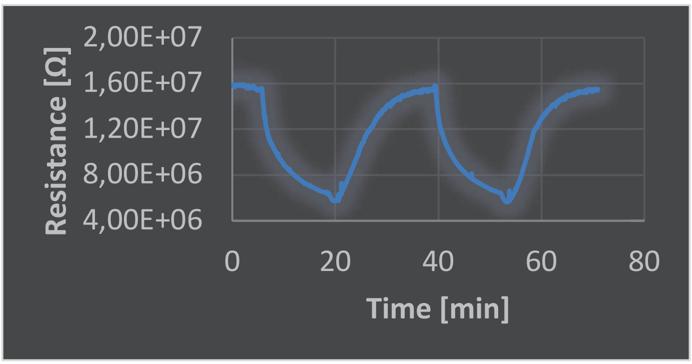

Fig.2. Resistance measurements under 50 ppm NO_2 at 400 °C

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