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Sensing properties of perovskite oxide $\text{La}_{1-x}\text{Sr}_x\text{CoO}_{3-\delta}$ ($x=0.5$) obtained by using pulsed laser deposition

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Summary: $\text{La}_{1-x}\text{Sr}_x\text{CoO}_{3-\delta}$ belongs to the group of perovskite oxides of the ABO_3 structure, with a trivalent rare earth in the A position (La) and a trivalent metal ion in the B position (Co). Doping with divalent Sr-ions at the trivalent La-positions creates oxygen vacancies which give the oxide catalytic properties to H_2O_2 . However, the conventional techniques which are used to prepare this oxide such as chemical methods, are not suitable for making a thin film. In this paper, a thin layer of $\text{La}_{1-x}\text{Sr}_x\text{CoO}_{3-\delta}$ ($x=0.5$) perovskite oxide is deposited on a Pt electrode by using the Pulsed Laser Deposition technique. The catalytic properties of this perovskite oxide to hydrogen peroxide due to the presence of the oxygen vacancies will be discussed. The results show the possibility to use this perovskite oxide as a sensing material for potentiometric hydrogen peroxide sensors.

Keywords: perovskite oxide, $\text{La}_{1-x}\text{Sr}_x\text{CoO}_{3-\delta}$ pulsed laser deposition, hydrogen peroxide
Category: 2 (Materials and technology) or 5 (Chemical sensors).

1 Introduction

$\text{La}_{1-x}\text{Sr}_x\text{CoO}_{3-\delta}$ belongs to a group of perovskite oxides of the ABO_3 structure with a trivalent rare earth in the A position (La) and a trivalent metal ion in the B position (Co). The structure of the LaCoO_3 perovskite oxide consists of CoO_6 octahedra and the La^{3+} ions, which are inserted between the CoO_6 octahedra. When the trivalent La^{3+} ions in LaCoO_3 are replaced by divalent earth alkaline ions Sr^{2+} to form $\text{La}_{1-x}\text{Sr}_x\text{CoO}_{3-\delta}$, a positive charge is generated. Because the Co^{2+} ions can have a different oxidation state, the charge neutrality is maintained by the formation of oxygen vacancies and a change in the valence state of the Co^{2+} ions. Therefore, the oxide has an oxygen deficiency, δ , due to the high oxygen vacancy concentration.

This type of perovskite oxides is a promising candidate for solid oxide fuel cells, oxygen separation membranes and sensor material [1]. Different types of the perovskite oxides, which are synthesized by chemical methods, have been used as a material for hydrogen peroxide sensing. However, the response time of the sensor is quite low due to the long time it takes for the hydrogen peroxide to diffuse into the thick layer of the perovskite oxide. Among the existing deposition methods, the Pulsed Laser Deposition (PLD) is a suitable technique for the fabrication of a perovskite oxide thin film. This technique allows the stoichiometric transference of the deposited material from target to substrate [2]. In this paper, we show the possibility to obtain a thin $\text{La}_{1-x}\text{Sr}_x\text{CoO}_{3-\delta}$ ($x=0.5$) perovskite oxide film by using

the PLD technique and its sensing properties to hydrogen peroxide.

2 Experiments

The $\text{La}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$ thin film is deposited on platinum electrodes which were sputtered on a $\text{Ta}_2\text{O}_5/\text{SiO}_2/\text{Si}$ wafer, using the setup as shown in Fig. 1. During the deposition process, a metallic shadow mask was placed on top of the substrate to shield the platinum electrical contacts from undesired deposition of the $\text{La}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$. The ablation process of $\text{La}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$ is realized by a spatial uniform 248 nm excimer laser beam. The deposition time was varied from 5 to 7 min depending on the required thickness of the film. The thickness of the film was estimated to be about 75 nm after 5 min of deposition. After deposition, the sample was cooled down to room temperature in an O_2 flow. The annealing in the oxygen environment is necessary to obtain a stable composition and to create the oxygen vacancies in the perovskite oxide film. Finally, the wafer was diced in separated devices and encapsulated with Hysol[®].

The sensing properties of the $\text{La}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$ thin film to hydrogen peroxide is characterized in a phosphate buffer (pH = 7.1) containing 0.1M KCl. All chemicals used (Merk, Fluka) were of analytical reagent grade.

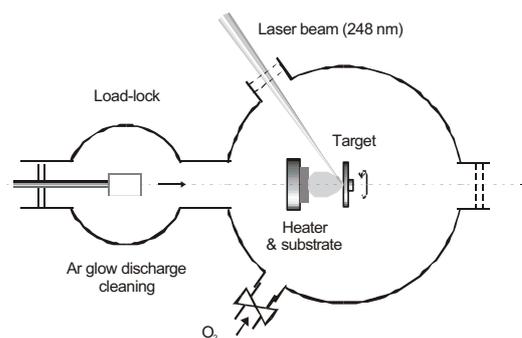
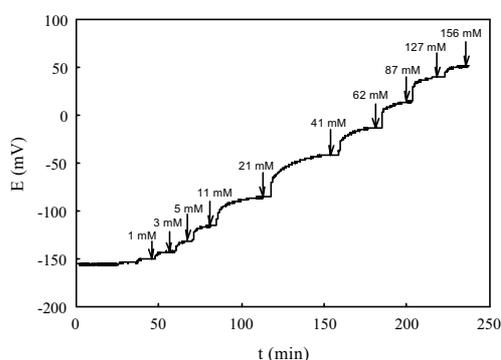


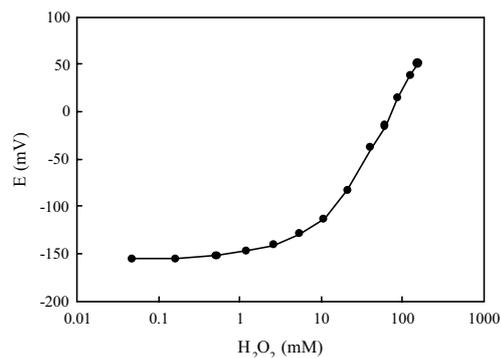
Fig. 1: Pulsed Laser Deposition system.

3 Results and discussions

Fig. 2: Potential of the $\text{La}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$ electrode depends on the hydrogen peroxide concentration.

The $\text{La}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$ thin film shows catalytic properties to hydrogen peroxide. The potential response of the $\text{La}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$ electrode to a change in the hydrogen peroxide concentration has been measured with respect to a saturated calomel electrode (SCE) and is shown in Fig. 2.

The response time of the electrode potential to hydrogen peroxide is estimated to be about 10 min. The electrode potential response depends on the

Fig. 3: Potential of the $\text{La}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$ electrode as a function of the hydrogen peroxide concentration.

logarithm of the hydrogen peroxide concentration with a slope of 130 mV/dec (see Fig. 3). The high sensitivity of $\text{La}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$ to hydrogen peroxide is suggested to be caused by a change in the oxygen vacancy concentration in $\text{La}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$ during its reaction with hydrogen peroxide. The investigation of the oxide oxygen vacancy concentration by means of the corresponding work function measurement will be discussed.

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