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Sensors and Actuators A 132 (2006) 52–55
SENSORS AND ACTUATORS A PHYSICAL
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On–off magnetoresistive sensor based on screen-printed $La_{2/3}Sr_{1/3}MnO_3$ manganite

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Received 14 September 2005; received in revised form 23 May 2006; accepted 27 May 2006
Available online 10 July 2006

Abstract

Half-metallic ferromagnetic oxides present a remarkable potential for the development of magnetoresistive sensors. We report on the design, construction and test of a contact-less on–off position sensor based on thick $La_{2/3}Sr_{1/3}MnO_3$ films. Films were fabricated on polycrystalline Al_2O_3 substrates by means of the standard screen-printing technique. The temperature dependence of the output signal of the sensor has been monitored from room temperature up to 120 °C.

Keywords: Manganites; Thick films; Sensors

1. Introduction

Manganese perovskites, usually called "manganites", show a substantial reduction of their resistivity when a relatively low magnetic field, of the order of a few kOe, is applied [1]. This phenomenon is known as "low field magnetoresistance". Manganites have been intensively investigated in the past years in order to obtain an accurate description of their underlying physics, as well as to develop possible applications. In particular, the manganite $La_{2/3}Sr_{1/3}MnO_3$ (LSMO, presenting a Curie temperature (T_C) of about 360 K) has been successfully used to build analogic magnetoresistive sensors operative at room temperature [2,3].

This work describes the design and test of a new one: a digital (on–off switch) position sensor, based on LSMO thick films prepared by standard screen-printing technique. It is found that the sensor is operative from room temperature up to 100 °C, which is slightly above the Curie temperature of LSMO. This work provides further evidence of the potential of this kind of materials in the construction of low-cost magnetic devices.

2. Fabrication and characterization of LSMO thick films

LSMO powders were prepared by a water-soluble polymer combustion method, starting from electronic grade raw materials [4]. The process avoids the use of extensive milling, as it produces an homogeneous, fine free-flowing powder.

The ceramic grains were suspended in an organic vehicle (56.5/43.5% w/w) [5], and screen printed onto commercial Al_2O_3 (0.65 mm thick). The mask used to define the sensor geometry is a screen made of 200 mesh stainless-steel fabric, having an open area (defined as the ratio between the screen aperture and the string thickness) of 48%. For the final socked application, the sensor will be composed by two magnetoresistive elements (A and B, with dimensions 6 mm × 1 mm, as seen in Fig. 1(a)), which can be operated at the same time and independently from each other. The duplicity of the output signal is intended to accomplish the redundance requirements of the designed sensor.

After screen-printing the LSMO based ink, the films were dried in a conveyor furnace for 12′ in air, at 200 °C [5]. Films were sinterized at 1100 °C, in air, for 8 h. After sintering, the films resulted well adhered, mechanically stable and with a sur-

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doi:10.1016/j.sna.2006.05.034

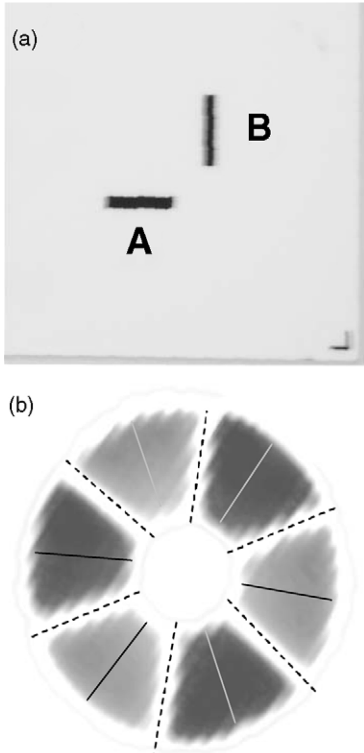

Fig. 1. (a) Photograph of the screen printed sensor. The two LSMO tracks are labelled as A and B. (b) Hall map of the axial component of the hexapolar Sm–Co magnet. The contrast between magnetic poles with opposite polarities can be clearly appreciated. Full lines indicate the maximum field zones, while dotted lines show the minimum field areas.

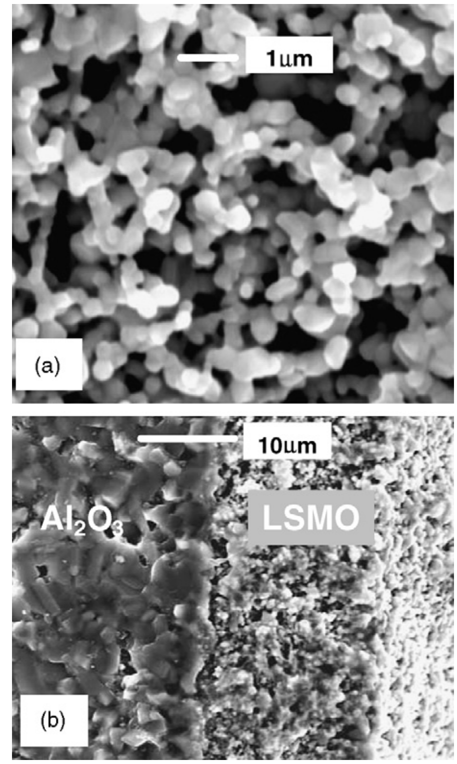

Fig. 2. (a) SEM micrograph showing the microstructure of a LSMO thick film. (b) Cross-section image of the same film.

face free of fissures or visible cracks. Their microstructure can be seen in the scanning electron microscopy – SEM – of Fig. 2(a). It is found the presence of a porous network of well connected submicrometric grains. The SEM cross-section image of Fig. 2(b) shows that films are ∼15 μm thick.

In order to perform the transport characterization, contacts have been made by using commercial silver paste. The room temperature 4-point resistance was found to be of about 40 Ω. This value leads to a resistivity of 0.01 Ω cm, which is in good agreement with reported values in ceramic LSMO samples with similar grain size that our films [3].

Fig. 3 shows the magnetoresistance (defined as $MR = R(H) - R(H=0)/R(H=0)$) of one of the tracks as a function of the applied field. The resistance was measured by means of the standard 4-probe technique, while the magnetic field was provided by a conventional electro-magnet.

The magnetoresistance at the highest applied field ($H = 5.5$ kOe) is of about 1.5%. This value is smaller than that previously reported in thick LSMO films sinterized at the same temperature (2.6% at 5.5 kOe [2]), relying this difference on the higher sintering time – which enhances the grain connectivity and lowers the magnetoresistance – used for films reported here.

3. Testing the sensor response

The magnetic field in the final socked sensor is provided by an hexapolar Sm–Co permanent magnet, with a diameter of 18 mm. Fig. 1(b) shows a Hall map of the axial component of the used magnet, where dark and clear zones correspond to the two possible polarities of the magnetic field. The mean magnetic field acting on each track at a given angle is obtained by integrating the local magnetic field (established from the Hall map) on a surface similar to that of an LSMO film. The maximum mean magnetic field (zones centred around the full lines showed in Fig. 1(a)), at a distance of 1 mm from the magnet surface, is expected to be of about $\langle B \rangle_{MAX} \sim 2.6$ kOe, while the minimum mean field (zones around the dashed lines in Fig. 1(a)) is of about $\langle B \rangle_{MIN} \sim 0.2 \langle B \rangle_{MAX}$. Notice that due to the finite size of the sensing elements, the average minimum

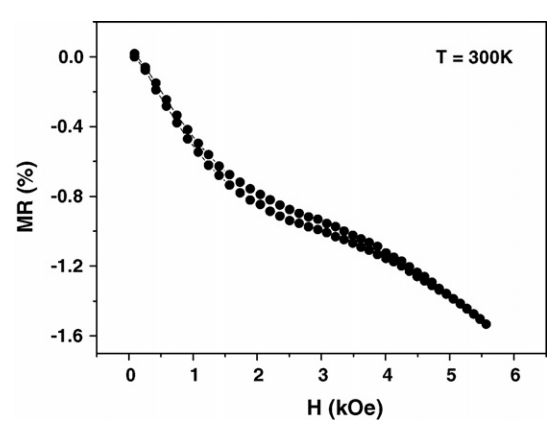

Fig. 3. Room temperature magnetoresistance (MR) as a function of the applied field for a LSMO thick film.