Measurement 82 (2016) 151–154

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Technical note

Layered $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$ for humidity sensor

Jian-Guang Wang [a], Le-Xi Zhang [a,c], Jing Yin [b], Li-Xin Zhao [b], Li-Jian Bie [a,c,*]

[a] School of Materials Science and Engineering, Tianjin University of Technology, Tianjin 300384, China
[b] School of Environmental Science and Safety Engineering, Tianjin University of Technology, Tianjin 300384, China
[c] Tianjin Key Laboratory for Photoelectric Materials and Devices, Tianjin University of Technology, Tianjin 300384, China

ARTICLE INFO

Article history:
Received 4 June 2015
Received in revised form 29 September 2015
Accepted 4 January 2016
Available online 7 January 2016

Keywords:
Layered perovskite
Humidity sensor
Response
Humidity hysteresis

ABSTRACT

Dion–Jacobson structure layered perovskite $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$ was synthesized using a traditional solid-state reaction. A humidity sensor made from the obtained $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$ reveals that the sensitivity exhibits good linear response, and the response and recovery time is only about 6 s and 2 s at 85% RH respectively, showing fast response and recovery characteristics. Furthermore, the humidity hysteresis is only 7% RH. All these results indicate that $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$ can be utilized in high-performance humidity sensors.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Humidity sensor is widely used in environment detection and control, product quality management and household appliances manufacturing, etc. [1]. Up to now, humidity sensitive materials can be categorized into electrolyte, polymer and ceramic. LiCl electrolyte exhibits slow response and poor stability [2]. Although polymer humidity sensitive material has the advantage of detecting wide range of moisture with small humidity hysteresis [3–7], inevitable shortcomings exist, such as being not resistant to pollution, short lifetime in high humidity environment. Ceramic humidity sensitive materials, such as ZnO, V_2O_5 and Al_2O_3, have good chemical stability, high temperature resistant and low prices [8–10], but susceptible to pollution, and difficult to be used in a wide range of humidity. Perovskite oxides (ABO_3) have been attracting much attention to be humidity sensitive materials because of their good thermal stability, chemical stability and the advantage of the changing resistance [11]. However, layered perovskite phase has not been reported as functional oxides for humidity sensing application. As the site A atoms in perovskite structure are susceptible to environmental moisture, and humidity sensitivity can be enhanced by partially substituting site A atoms with rare earth ions [12], layered perovskite structure might be a good candidate for superior humidity sensing material.

In this paper, a humidity sensor made from Dion–Jacobson (D–J) layered perovskite phase $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$ is reported, showing good humidity sensing performance.

2. Material and methods

2.1. $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$ synthesis and characterization

All chemicals used in the experiments were of analytical grade without further purification.

$K(K_{1.5}Eu_{0.5})Ta_3O_{10}$ powder was prepared by solid state reaction method [13]. The starting materials are weighed in molar ratio of K_2CO_3:Eu_2O_3:Ta_2O_5 = 5:1:3, mixed and grinded 10 min in an agate mortar, annealed in an alumina

* Corresponding author at: School of Materials Science and Engineering, Tianjin University of Technology, Tianjin 300384, China. Tel./fax: +86 22 6021 6800.
E-mail addresses: ljbie@pku.org.cn, ljbie@tjut.edu.cn (L.-J. Bie).

http://dx.doi.org/10.1016/j.measurement.2016.01.003
0263-2241/© 2016 Elsevier Ltd. All rights reserved.

crucible at 800 °C for 6 h, and then sintered at 1100 °C for 20 h.

The X-ray diffraction (XRD) data was collected at a scan rate of 8°/min with a step of 0.02° using Rigaku D/Max-2500 with monochromatized Cu Kα (λ = 1.5418 Å) radiation.

2.2. Humidity sensitive property measurement

The sample was ground with several drops of Triton X-100 in an agate mortar, and then the formed slurry was coated onto an alumina tube, sensor fabrication details can be seen from Ref. [14]. The sensor was aged for 48 h with a heating voltage of 5 V to improve its stability.

The humidity sensing performance was measured using NSU-R4100 smart test apparatus (Zhongke Micro-Nano Science and Technology Co., Ltd., China) at room temperature. The sensor was put into chambers with different relative humidity (RH) to test the humidity sensing response. Different RH were obtained from saturated salt solutions of LiCl, $MgCl_2$, $Mg(NO_3)_2$, NaCl, KCl and KNO_3, which corresponded to RH values of 11%, 33%, 54%, 75%, 85% and 95%, respectively [15].

Response of the humidity sensor is defined as Sr = Gg/Ga, where Gg and Ga represent the conductivity of sensing unit in the test humidity and benchmark. The response or recovery time is defined as the time taken for the sensor to achieve 90% of its final equilibrium conductivity as altered between two relative humidity.

3. Results and discussion

3.1. Phase characterization

Fig. 1 is the XRD patterns of obtained sample, majority of the sample is $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$, and minor phases are Eu_3TaO_7 and an unknown phase. High peak intensity in the XRD implies that the sample is well crystallized.

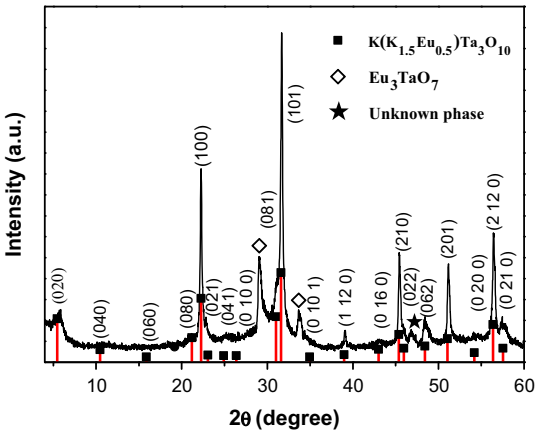

Fig. 1. XRD patterns of $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$.

3.2. Humidity sensing property

The humidity 11% RH is set as a benchmark in the measurement, humidity sensing test of the sensor are measured in 33% RH, 54% RH, 75% RH, 85% RH and 95% RH respectively. Fig. 2a shows the response of $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$ sensors vs RH. The response increases with the increase of RH, two linear fit areas Part I and II can be recognized, the slope goes high in the humidity range of 80–100% RH in Part II. This might be attributed to that the water molecules on the surface of materials have been covered completely by the first layer chemical adsorption, subsequent physical adsorption in high RH begins. In part II, main conductive carrier becomes H_3O^+, so the conductivity increases.

Fig. 2b displays the dynamic response and recovery of the sensors as altered between the humidity of 11% RH and 85% RH. As can be seen, the humidity response and recovery time are 6 s and 2 s, respectively, showing that $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$ is a good humidity sensitive material.

Fig. 3a shows the moisture absorption and desorption under different humidity at room temperature. Setting 11% RH as a benchmark, the humidity hysteresis measurements were taken in the sequence from low RH to high RH, then reverse the process from high RH to low RH. As can be seen, the desorption curve is slightly higher than the absorption one, which is due to the adsorption and desorption of water molecules are exothermic and endothermic process, respectively. At the same humidity, the response difference leads to resistance difference between the adsorption and desorption process. The biggest humidity hysteresis is only 7% RH.

Fig. 3b presents the humidity response results at 85% RH measured in 60 days, which remains almost the same, showing very good long time stability.

The mechanism of humidity sensitive performance is mainly attributed to the ion conductivity. Water molecules adsorbed in the material grain boundary could be dissociated into ions, similar to conducting ions in the electrolyte solution. Under the electrostatic forces, water molecules adsorbed on the material surface would be ionized into protons and hydroxyl anions. And the protons and hydroxyl anions combine with oxygen and metal ions on the surface of the material respectively, forming the first layer on the surface of the material by chemical adsorption.

When the humidity is high, the adsorbed water molecules may combine with protons into H_3O^+ as the charge carrier, forming the physical adsorption layer above the first layer of chemical adsorption. With the increasing of concentration of water molecules, the conductivity of sensing materials will be increased, hence the resistance decreases [16,17]. As the $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$ is a layered perovskite structure, ion exchange may occur between the adsorbed water molecules or H_3O^+ and the perovskite matrix, increasing the conductivity.

4. Conclusions

Dion–Jacobson (D–J) layered perovskite phase $K(K_{1.5}Eu_{0.5})Ta_3O_{10}$ was synthesized using solid-state reac-

Download English Version:

https://daneshyari.com/en/article/730872

Download Persian Version:

https://daneshyari.com/article/730872

Daneshyari.com