Modification of lanthanum doped barium titanate and potential application

Sara Milošević
Supervisor: Nikola Srzentić
Regional Center for Talented Youth Belgrade II, Serbia, sara020501@gmail.com

1. Introduction

Barium titanate ($BaTiO_3$–BT) is a significant ferroelectric material, which after many years of study is still interesting, and its application continues to expand rapidly and develops by introducing different dopants into the structure. Pure BT at room temperature is an isolator, and by doping with defined ions in the place of Ba or Ti, it becomes a semiconductor. Interaction with laser beams in different dynamic modes can be used for different modifications of the starting material. [1,2]

2. Material and methods

The auto-combustion method for the synthesis of the $BaTiO_3$ + La (BTL) material is represented by the following equation:

$$0.985\ Ba(NO_3)_2 + C_6H_8O_7 \cdot H_2O + Ti(OCH(CH_3)_2)_4 + 0.015\ La(NO_3)_3 \cdot 6H_2O \rightarrow Ba_{0.985}La_{0.015}TiO_3 + 7\ H_2O \uparrow + 6\ CO_2\uparrow + 2\ NO_2\uparrow$$

Using uniaxial press, samples with dimensions D = 8 mm and h ~ 1 mm were prepared. Isothermal sintering was carried out in a tube furnace at 1300 °C / 4 h; heating speed 10 °C / min. Au electrodes were applied on both sides of the sample for the electrical measurements. Crystal structure was determined by XRD diffraction measurement and SEM was used for the microstructure analysis.

3. Results and Discussion

The barium titanate tetragonal crystal structure was confirmed by X-ray diffractometer (Figure 1).

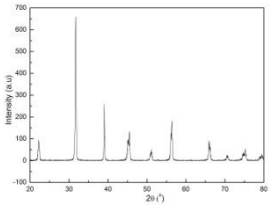

Figure 1. - X-ray diffractogram

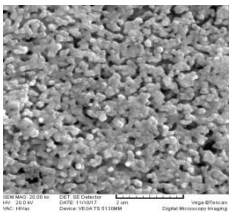

Figure 2. - SEM micrograph of (BTL) ceramics of a sintered sample

In order to determine the possible application of this material as a moisture and hydrogen sensor, the dependence of the electrical resistance of the sample on the relative humidity (Figure 3) and the hydrogen atmosphere was monitored (Figure 4).

Experimental results (Figure 3) show that electrical resistance decreases with relative humidity increase. The introduction of hydrogen into the system showed a rapid lowering of resistance (Figure 4); and after 15 min. when the flow of hydrogen was turned off a reintroduction of nitrogen resulted in the resistance increase.

The BTL sample porous microstructure is presented in the SEM micrograph (Figure 2).

Laser interaction was performed with parameters: wavelength 1064 nm, mean power 3 W, Q switch mode (t=10 ns), repetition 30 Hz, target laser diameter 0.3 mm, step 35 μm.

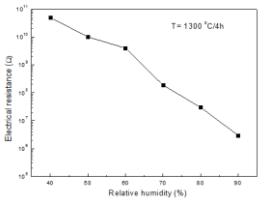

Figure 3. - Electrical resistance vs. relative humidity for BTL

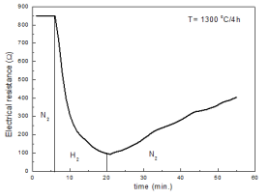

Figure 4. - Response transients to hydrogen at 430º C

The length of the damage line on the sample, 3 mm, is shown in Figure 5.

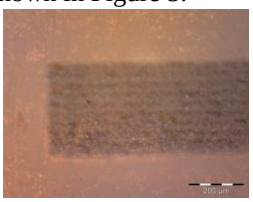

Figure 5. - Surface of the laser exposed area

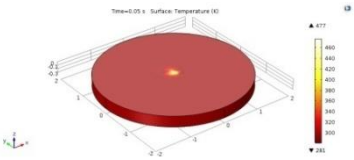

Figure 6. - Maximum surface temperature after 0.1 s

The simulation of the interaction to estimate the temperature, to which the sample was locally exposed, was done in order to analyze possible transformations of the structure. The Comsol Multiphysics ver.5.2 program was used in the solid body transport module. Solving the thermal equation using the numerical finite element method, FEM was performed with the following assumptions: the laser beam was modeled as Gauss, (R = 0.3 mm) and 30 Hz pulse repetition frequency. The beam was directed normally to the surface of the sample. As a result, the temperature distribution on the surface of the sample was obtained after 0.01 s; 0.05 s; 0.1 s; 0,15 s; 0.18 s and 0.2 s (Figure 6).

4. Conclusion

Based on the measurements carried out in this paper, it can be concluded that barium titanate doped with lanthanum is a good candidate for application in moisture and hydrogen sensors. Further analysis will be focused on the modification of preparation method, in order to determine the conditions for obtaining the moisture and hydrogen sensors with the highest sensitivity. Its properties can also be modified by different laser methods.

Based on the interaction that has been achieved, it can be concluded that the lasers of these characteristic can be used to mark labels on patterns, trimming, etc.

References

[1] M. Srećković et al., *Laser interactionwith material. Theory, experiment, and reality*, Belgrade, 2012

[2] M. VijatovicPetrovic,*The influence of dopants on structure and properties of barium titanate ceramics and films obtained from organometallic complexes*, PhD thesis, University of Belgrade, Belgrade 2010.