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Synthesis and structural investigation of La_2O_3 doped anthracene nanocrystallites as an advanced dielectric material

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In recent years organic-inorganic hybrid nano materials have been significantly studied. These samples can prevent leakage and tunneling currents through ultra-high vacuum chambers, drug electrochemical sensors and electronic chips. Moreover, they can be used as controller gate dielectrics in nano transistor devices and memories.

In the present work, La_2O_3 doped anthracene (Ant) nano crystallites are synthesized by a sol-gel method, and their nano structural properties are studied by XRD, EDX and SEM techniques. The obtained results indicate that Ant-La_2O_3 nano particles with amorphous structure at a temperature of 300˚C are suitable as a gate dielectric for organic nano transistor devices.

Keywords: Nano, Transistors, Hybrid composite, Anthracene, La_2O_3.

INTRODUCTION

In recent years, organic-inorganic hybrid nano materials have been the subject of thorough studies. These materials are obtained by a sol-gel method [1]. The most important challenge for hybridation is the phase separation between the organic and inorganic components. Thus, to overcome this problem, strong bonds such as hydrogen bonds and especially covalent bonds have been used to increase the interaction between the two phases [2]. These nano materials combine the benefits of the organic phase such as flexibility, light weight, easy reactivity and those of the inorganic phase such as high mechanical resistance, chemical and physical stability and good optical properties. Due to their potential use in some fields such as optics, optoelectronics, electronic devices and drug electrochemical sensors, these materials are used in industry, as well as in research laboratories [3].

Pentacene as an organic material with polycyclic aromatic hydrocarbon (PAH) structure and five benzene rings is a strong gate insulator and can be the appropriate choice for research on organic electronic devices such as organic thin film transistors, organic field-effect transistors and polymer electrolyte fuel batteries [4-8]. Anthracene is a PAH compound with three benzene rings, more accessible and cheaper than pentacene with approximately the same properties. Therefore, the use of anthracene can be more affordable on industrial scale [5].

The application of high-k dielectric materials such as Gd_2O_3 [9], Al_2O_3 [10], ZrO_2 [11], Y_2O_3 [12], CrO_2 [13], HfO_2 [14] and La_2O_3 [15-16], has been investigated in inorganic electronic devices. Among them, La_2O_3 with a high dielectric constant (K=27) [17], largest band gap and minimum energy networks is more attractive as a gate insulator than others. Moreover, La_2O_3 has a hexagonal crystal structure at low temperatures [17] and can be used as an important component in automobile exhaust-gas convectors. Also, it is a promising agent in catalytic materials and optical filters [18]. Furthermore, La_2O_3 has been employed as an antibacterial agent for water purification [19-20]. Thus, La_2O_3 has attracted much attention in recent years [21]. Therefore, we performed a series of experiments to synthesize La_2O_3-Ant nano hybrid composites by a sol-gel method and studied their nano structural properties with XRD (X-ray diffraction), SEM (scanning electron microscopy) and EDX (energy dispersive X-ray) techniques. The obtained results showed that the sample containing 0.28 g Ant, synthesized at 300 ºC can be used in nano-chip devices.

EXPERIMENTAL PROCEDURE AND DETAILS

The Ant-La_2O_3 nano crystallites were prepared by a sol–gel procedure (figure 1). First, lanthanum chloride ($LaCl_3.7H_2O$, 5.9 g) was dissolved in 300 ml of distilled water under magnetic stirring at room temperature. Then, cetyltrimethylammonium

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bromide (CTAB, 2.7 g) was added to the solution at room temperature on stirring until the solution became completely transparent. Subsequently, 6.0 ml of ammonia was added to the solution to adjust the pH value between 6.0–10.0. Following the addition of ammonia, the solution turned opaque. After vigorous stirring for 2 h, Ant (0.07 g) dissolved in 2 ml of o-xylene was dropwise added and the solution was vigorously stirred for 24 h, then was dried at 80 °C for 72 h. Finally, the resultant white solid product was washed with distilled water and ethanol, centrifuged to remove the undesirable ions from the final product and dried at 80 °C. In this way Ant-La_2O_3 powder was obtained. The same procedure was performed with two more amounts of Ant (0.14 g and 0.28 g), then all products were calcined at two different annealing temperatures (300 °C and 500 °C) for studying the effect of temperature and concentration on morphology.

The crystal phases of the nano crystallites were identified by XRD analysis. Morphology analysis was performed using SEM technique. The size of nano crystallites was determined using X-powder software.

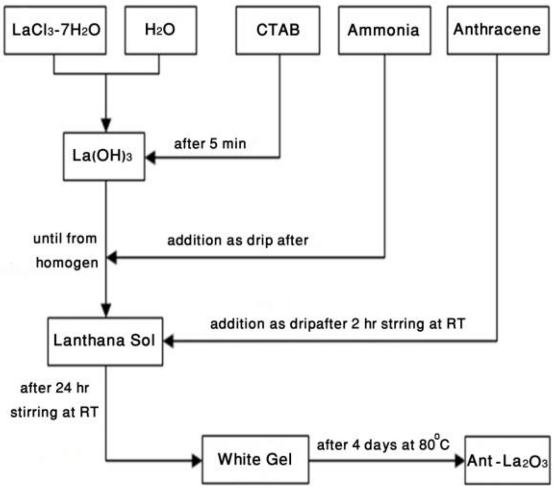

Fig. 1. Steps of Ant-La_2O_3 powders preparation

RESULTS

The structural features of the Ant-La_2O_3 nano crystallites were analyzed using XRD analysis. Figure 2 displays the XRD patterns of the calcined Ant-La_2O_3 at 300 °C. It shows that by increasing the concentration of Ant, the number of peaks decreased. Figure 3 displays the XRD patterns of Ant-La_2O_3 at two temperatures (300 and 500 °C). Here, by increasing the temperature, the quantity and intensity of peaks increases.

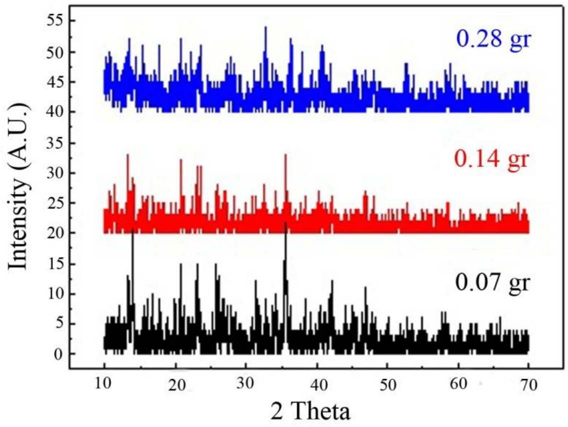

Fig. 2. XRD patterns of Ant-La_2O_3 at different Ant concentrations.

Figure 4 shows the sizes of Ant-La_2O_3 nano crystallites at 300°C and 500°C, determined by X-powder software. X-powder analysis indicated that the size of the nano crystallites increased by increasing the temperature (figure 4a and 4b) and decreasing Ant concentration (figure 4c to 4e) ranging from 30-48 nm (Table 1).

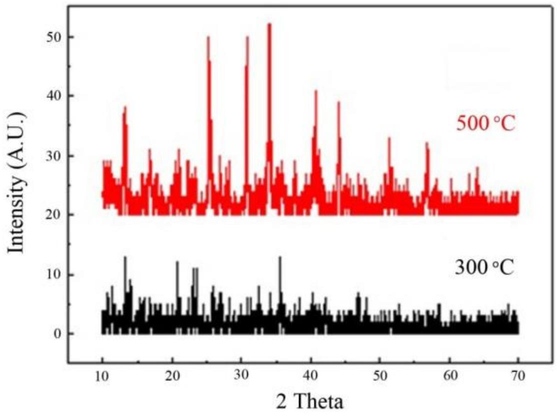

Fig. 3. XRD patterns of Ant-La_2O_3 at different temperatures (300 °C and 500 °C).

Table 1. Comparison of the size of Ant-La_2O_3 nano crystallites.

Size of nano crystallites	Calcination temperature	Sample
41 nm	300 °C	0.07 g Ant/La_2O_3
48 nm	500 °C	0.07 g Ant/La_2O_3
41 nm	300 °C	0.07 g Ant/La_2O_3
40 nm	300 °C	0.14 g Ant/La_2O_3
30 nm	300 °C	0.28 g Ant/La_2O_3

The same pattern is confirmed in figure 5 which shows images obtained by the SEM technique at two different annealing temperatures. These images illustrate the micro structural alteration of the nano crystallites. On the surface of the sample calcined at 300 ˚C (figure 5a), no recognizable crystal particles

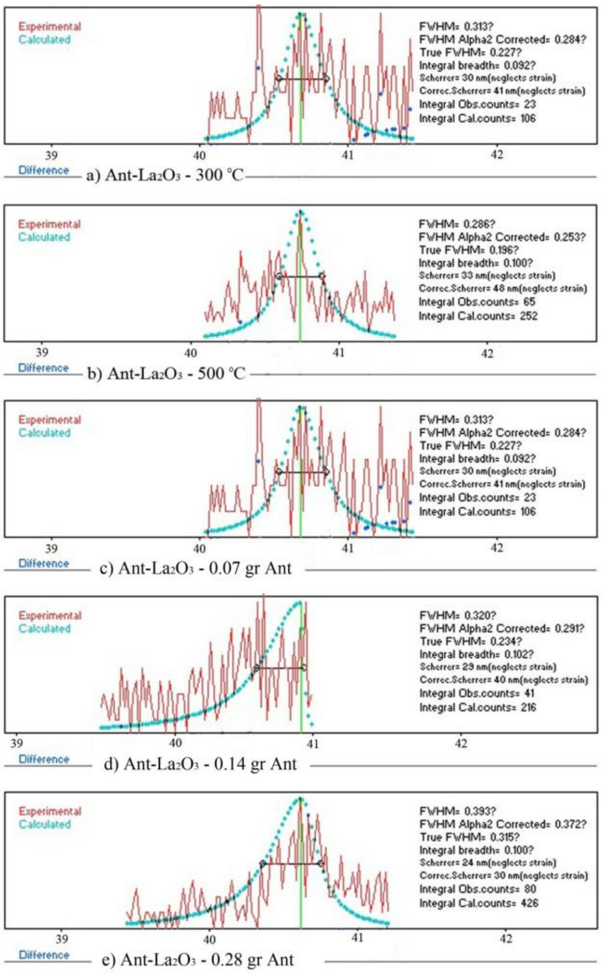

Fig. 4. Study of nano crystallite peaks using X-powder software.

are found. For the sample calcined at 500 ˚C (figure 5b) a regular shape of grains with clear boundaries can be seen.

Figure 6 shows the results of the EDX analysis confirming that the nano crystallites consist of La and O atoms.

DISCUSSION

According to the XRD results, at 300˚C the nano crystallites have amorphous structure and with increasing Ant concentration the amorphicity increases. On the other hand, at a temperature of 500˚C, the particles display crystalline structure.

SEM images confirmed the results of the XRD analysis and showed that La_2O_3 nano particles with Ant are in a film-layer form with amorphous structure at 300˚C, while the structural phases change. The amorphous structure of La_2O_3 at 300˚C [18] can reduce leakage and tunneling currents; moreover, upon adding Ant, the final structure at

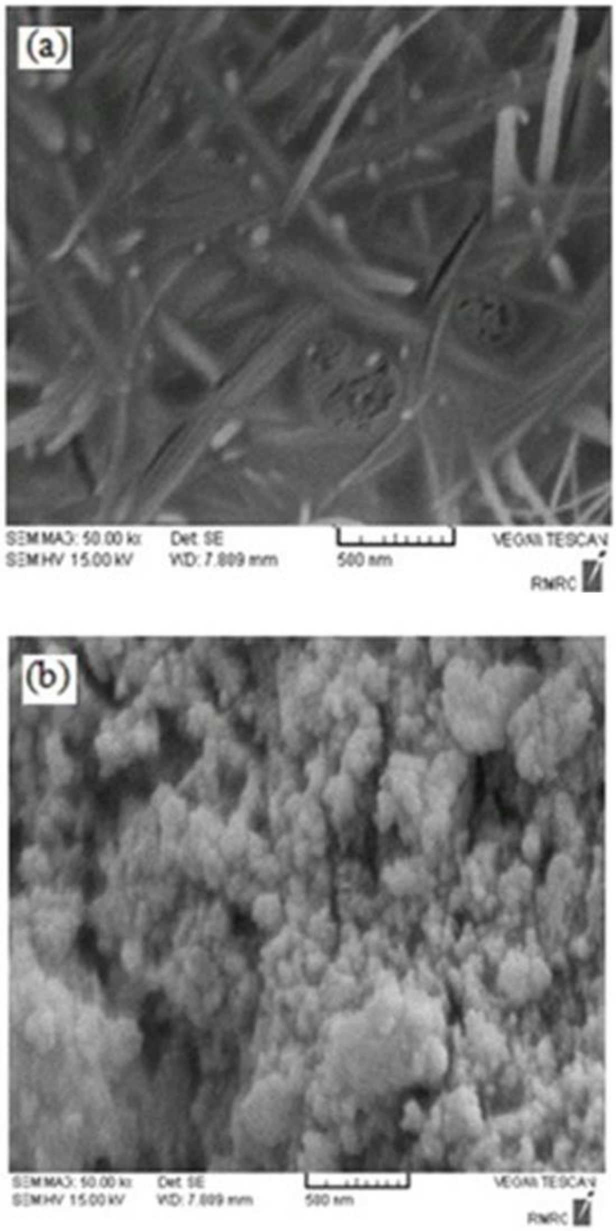

Fig. 5. SEM images of ANT-La_2O_3 nano crystallites: (a) at 300ºC (b) at 500 ˚C.

the mentioned temperature becomes more

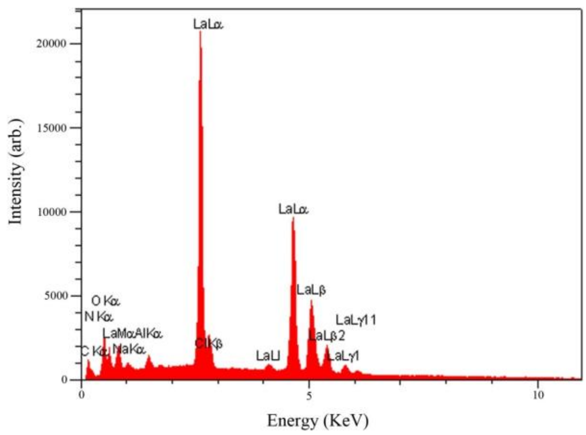

Fig. 6. EDX pattern of Ant-La_2O_3.

amorphous and k-dielectric increases. As a result, La_2O_3 hybrided with Ant can be used as a good gate dielectric in nano electronic devices and organic nano transistors.

CONCLUSION

In the present work, the structural characteristics of Ant-doped La_2O_3 nano particles prepared by a sol-gel method were studied at different temperatures and concentrations. The experimental results showed that Ant-La_2O_3 with amorphous structure at 300˚C can be suggested as a good gate dielectric for nano electronic devices and organic nano transistors.

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СИНТЕЗ И СТРУКТУРНИ ИЗСЛЕДВАНИЯ НА АНТРАЦЕНОВИ НАНОКРИСТАЛИ, ДОТИРАНИ С La_2O_3, КАТО СЪВРЕМЕНЕН ДИЕЛЕКТРИЧЕН МАТЕРИАЛ

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(Резюме)

През последните години интензивно са изследвани хибридни органично-неорганични наноматериали. Те могат да предотвратят изтичане и тунелни токове в камери със свръх-висок вакуум, електрохимични сензори за лекарства и електронни чипове. Освен това те могат да се използват като контролни диелектрици в нано-транзисторни прибори и памет.

В настоящата работа са синтезирани по зол-гел метода антраценови (Ant) нанокристалити, дотирани с La_2O_3. Техните нано-структурни свойства са изследвани чрез XRD, EDX и SEM методи. Получените резултати показват, че наночастиците Ant-La_2O_3 с аморфна структура са подходящи при 300˚C за контролни диелектрици в органични нанотранзисторни прибори.