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THE ELECTRICAL-GENERATING STRUCTURE BASED ON NiPc IN AMMONIA MEDIUM

ABSTRACT *In this work we presented a result of structural and electrophisical investigation of electrical-generating barrier structure based on organic semiconductor NiPc. It was studied the current-voltage and impedance characteristics of structure ITO/NiPc/Al under the influence of ammonia vapors and was revealed the current and conductivity increase of structure in ammonia medium. Also we modeled impedance characteristics using the Constant Phase Element CPE what shows that the change in resistance occurs as a result of a chemical interaction.*

Keywords: *organic semiconductor, ammonia vapors, conductivity.*

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1. INTRODUCTION

Search and comprehensive study of basic structures and materials for alternative power sources is a priority direction of modern science and technology [1, 2]. In this context a small molecular complexes, especially based on phthalocyanine, are very interesting materials. In phthalocyanines under the influence of external factors (light exposure, humidity, vapors of various gases) electrochemical reaction takes place resulting in the generation of electricity [3]. The promising organic material that can be used in electrical-generating element is a small molecular p-type semiconductor nickel phthalocyanine (NiPc). This material is a sensitive to atmospheric gases and is thermal and chemical stability, characterizes by relatively high carrier mobility[4, 5]. For deposition the thin films from NiPc is used thermal vacuum method, because this method allows to save the molecular structure NiPc after the deposition [6].

In this paper the electrophysical characteristics of semiconductor structure based on nickel phthalocyanine (NiPc)/aluminum under the influence of ammonia vapors are studied to check the possibility of using such structure as electrical-generating cell. The basic attention is concentrated to study current-voltage characteristics and conductivity of experimental structure.

2. EXEPEREMENTAL

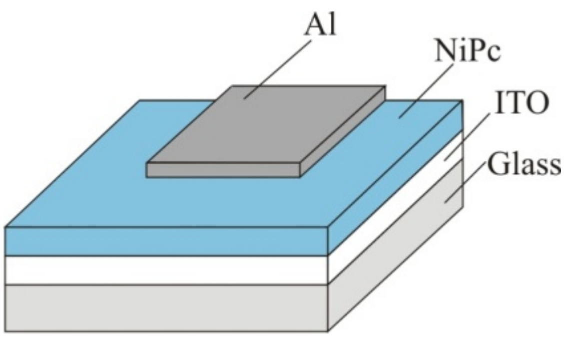


Fig. 1. Schematic drawing of ITO/NiPc/Al structure

In Figure 1 is shown schematic drawing of the experimental structure. NiPc thin film was deposited by thermal vacuum method on glass substrate with ITO (indium tin oxide) precursor. The formation of a NiPc film was carried out by sublimation of NiPc powder from a molybdenum boat resistively heated up to ~ 400^{o}C in vacuum ~ 10^{-5} Torr. During the deposition the temperature of the substrate was ~ 100^{o}C. The thickness of this NiPc film was ≈ 40 nm. Aluminum film is also formed by vacuum evaporation. Thickness of Al film was 200 nm. Film thicknesses was measured by ellipsometric method. X-Ray film analysis was conducted using Rigaku Rapid diffractometer. Current-voltage and impedance characteristics were measured using an galvanometric electronic unit and Autolab Software. GPES software was used for VCC formation. The voltage during measurement changes within –2V – +2V range. FRA software was used for impedance characteristics. Frequencies range of measurement was equal to 1 – 10^6 Hz.

3. RESULTS AND DISCUSSION

For definition of thin film NiPc modifications was analysed of X-Ray diffraction pattern (Fig. 2). The α polymorphic modifications of NiPc film are more sensitivity to the influence of gas media than other polymorphic modifications [7, 8].

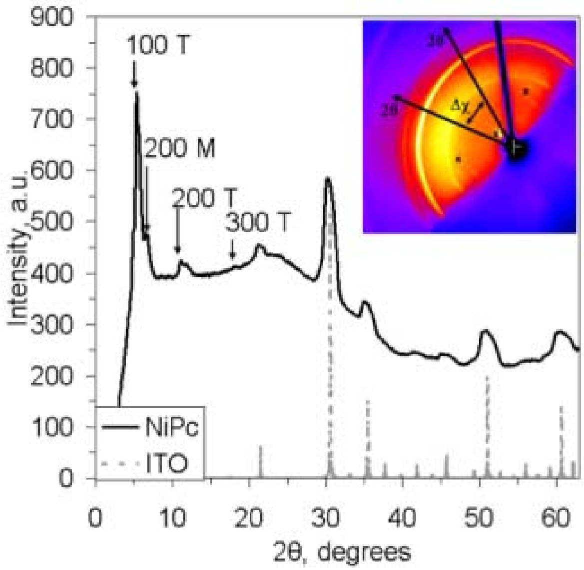
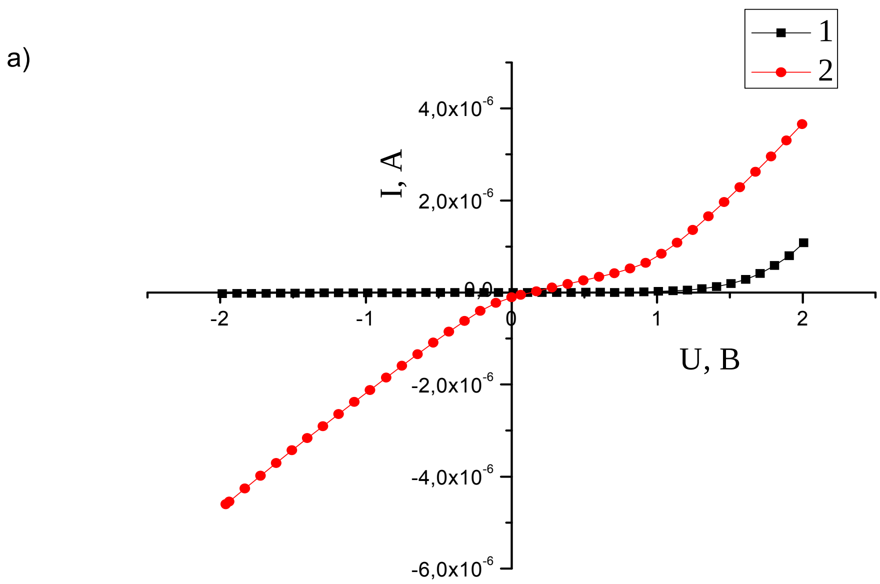


Fig. 2. Results of X-ray analysis in configuration "sliding fall" for NiPc films deposited on ITO substrate (M-monoclinic and T – tetragonal form) [8]

For this purpose temperature of substrate during evaporating process should be held in a range of 50-150^{0}C [9].

As shown in Fig. 2, X-ray photograph is characterized by narrow small-angle reflexes (2θ – 5.7, 7.1, 11.4, 12.1) and peaks at large angles (2θ – 22, 32, 35, 42, 46, 51, 60). Reflexes at large angles characterizes the ITO polycrystalline structure and glass substrate as shown in Fig. 2, and is consistent with literature data [10].

To understanding the interaction processes in ITO/NiPc/Al structure with the gas environment was analyzed current-voltage characteristics and impedance spectroscopy. Sample was conducted in the same closed volume in air environment and in environment of 10% ammonia at room temperature. The current-voltage characteristics is shown in Fig. 3a. Air environment doesn't have an active influence on the sample. Current value in this case changes from $-1\cdot10^{-7}$ A to $1.3\cdot10^{-6}$ A in voltage range from -2 V to +2 V. If the sample is exposed to ammonia vapor at the change of voltage in the same range, the increase in current value – $5\cdot10^{-6}$ A – $4\cdot10^{-6}$ A is observed.



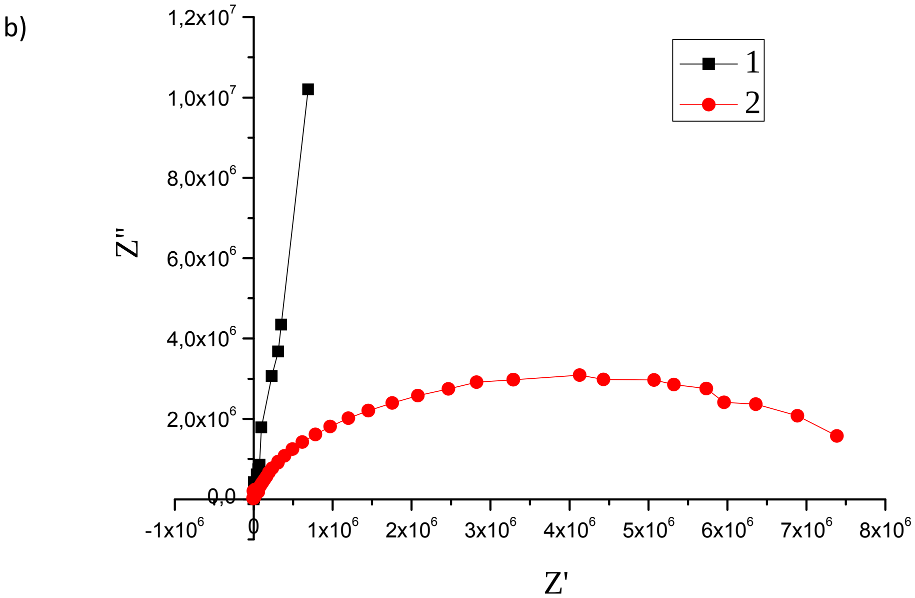


Fig. 3. Current-voltage (a) and impedans (b) characteristics of ITO/NiPc/Al structure without influence (1) and under influence (2)of ammonia vapors

The increase of current and NiPc conductance in the ammonia medium is due to the absorption complex α-NiPc + xNH_3 = α-NiPc*xNH_3. It is known that nitrogen atom in the ammonia molecule has a couple of unoccupied electrons and it causes conductivity increase for α-NiPc*xNH_3 absorption complex.

Impedance characteristics without and under the influence of ammonia vapors, is shown in Fig. 3 b. For air environment impedance curve looks like the beginning of the loop and the for 10% solution of ammonia look as almost complete loop. As seen from this dependence structure resistance decreases under the influence of ammonia vapor on the sample, and correspondingly conductivity increases.

The results of impedance characteristics simulation at bias of 0.05 V is shown in Fig. 4.

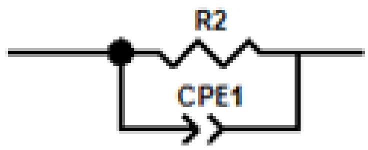


Fig. 4. The simulation results of equivalent circuit of the device

The results showed that our simulation scheme for the structure under the influence of ammonia vapor has a simple layout. It consists of a resistance and constant phase element (CPE), which are interconnected in parallel. CPE element shows that the change in resistance occurs as a result of a chemical interaction [11], which confirms our assumption.

4. CONCLUSIONS

The study of electrophysical characteristics of ITO/NiPc/Al structure shows, that under influence of ammonia vapor the increase of electrical conductivity takes place and it is caused by formation of NiPc*xNH_3 absorption complex. Experimental results can be used in developing electric-generating devices that are sensitive to ammonia vapors.

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STRUKTURA Z WEWNĘTRZNĄ BARIERĄ POTENCJAŁU OPARTA NA WARSTWIE NiPc W ŚRODOWISKU AMONIAKU

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STRESZCZENIE *W pracy przedstawiono wyniki badań dotyczących strukturalnych elektrofizycznych własności bariery generującej napięcie elektryczne opartej na półprzewodniku organicznym NiPc. Przebadane zostały charakterystyki prądowo-napięciowa i impedancyjna struktur ITO/NiPc/Al umieszczonych w amoniaku. Wykazano, że dzięki zastosowaniu amoniaku, wzrasta natężenie prądu i konduktywność całej struktury. W dalszej części zamodelowano charakterystykę impedancyjną używając elementów o stałej fazie (ang. CPE), co udowodniło, że zmiany rezystancji pojawiają się w wyniku reakcji chemicznej.*

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