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SOME ELECTRICAL PROPERTIES OF THIN LAYERS OF 9,10-DIMETHYLANTHRACENE AND 1-ACENAPHTHENOL

Spectral grade materials obtained in zone-melting process from commercially available 1-acenaphthenol and 9,10-dimethyl-anthracene were characterized electrically. The layers vaporized in 10^{-5} Torr vacuum posses high resistivity of the order of 10^{11}-10^{12} Ωm and the concentration of traps lower than $10^{15} cm^{-3}$.

Keywords: 1-acenaphthenol, 9,10-dimethylanthracene, conductivity, electric characterization.

1. INTRODUCTION

Organic molecular crystals in the type of thin films and aggregates are technologically very attractive materials in the electronic meaning. Their usefulness relies to a large extent on their photoconductivity, light absorption, non linear polarizability etc., which are significant for the properties immediately related to the electronic structure of these materials. Polycyclic aromatic hydrocarbons (PAH) has received much attention since optoelectronics needs materials with high grade of purity. Efficient charge transport requires that

the charges be able to move from molecule to molecule and not be trapped or scattered. The well known 1-acenaphtenol and 9,10-dimethylanthracene (Fig. 1) are the promising materials for technology connected with organic electronics. But their structure was not described faultlessly till the last decade [2]. Commercially available ex-coal tar for acenes contains impurities in the order of 1% . For example for tetracene the typical representative compound of the semiconducting or photoconducting class, even low, e.g. $\leq 10^{-6}$ mol/mol [6] concentrations of the contaminations can essentially deteriorate the performance of mobilities for holes or for electrons, generating structural defects for trapping or scattering of chemical nature.
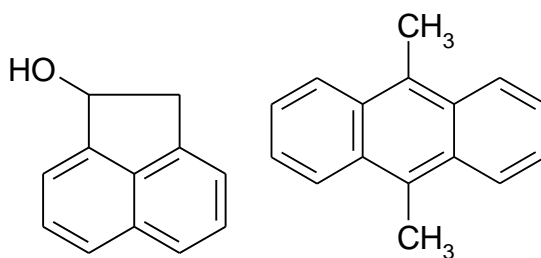

Fig. 1. Structures of 1-acenaphtenol and 9,10-dimethylanthracene

2. EXPERIMENTAL AND RESULTS

During last decade, procedure for obtaining 9,10-dimethylanthracene and 1-acenaphthol of sufficient purity grade for practical applications was developed [1-5]. This task was difficult. For example twenty one compounds and 14 impurities were identified in the commercially available [4] ex-coal tar acenaphthene and pyrene, respectively, with the help of Hewlett-Packard gas chromatographs type 6890 GC System and 5890 series II equipped with fused silica capillary columns and the FID and MS detectors. The naphthalene, 2-methylnaphthalene and 9H-fluorene, and 7-methylanthracene, 1-phenyl-naphthalene, fluoranthene and unknown compound with the molecular weight of 208 may be treated as the major impurities of the above hydrocarbons, respectively. The segregation coefficients of all the remaining detected

impurities with the exception of methyldibenzofuran were lower than unity. This fact enabled to use the zone melting method for purifying. Impurities present in commercially available naphthalene, fluoranthene and anthracene have been concentrated by zone melting and further evaporation of their extracts in chloroform, and then they were identified by gas chromatography performed on CGC-FID and CGC-MS apparatuses. Quantitative contents of fourteen, eight and twelve impurities detected in naphthalene, fluoranthene and anthracene, respectively, have also been determined [3].

Purities of the obtained compounds were of the order of 99.999 mass% from which high quality crystals were grown. In order to characterize the intrinsic structure perfection of such grown crystals the X-ray examinations have been performed. The observed morphologies of these crystals have been compared with that predicted from PBC theory by Hartman-Perdok model growth conditions (vacuum, temperature gradient) effect have been assessed [1,4].
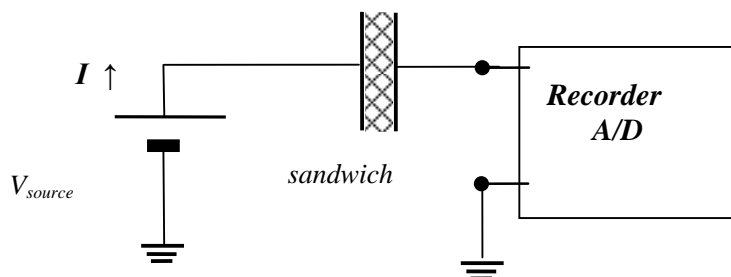

Fig. 2. Measuring setup for determination of *U-I* characteristic

The purity of initial compounds used in experiments for this article was in the grade of 99.999 mass%. The layers of 1-acenaphthenol and 9,10-dimethylanthracene were evaporated in the vacuum of order 10^{-5} Torr on the quartz glass plate supplied with Au electrode. On the top of the sandwich the aluminum electrode was evaporated. Such a structure has properties of plate condenser with the layer of dielectric. For such layers the capacitance was measured with Semi-Automatic RLC Bridge type E314. The width of the layers was evaluated from the capacitance and geometric dimensions of electrodes. Measured layers had the widths in the limits of 16-41 μm for 1-acephthenol and for 9,10-dimethylanthracene.

Electrical characterization, in the form of *U-I* characteristics, were made in the Faraday Cage supplied with a quartz window. Current-voltage characteristics were obtained for the field strength from $E = 2 \cdot 10^5$ to $2 \cdot 10^7$ V/m.
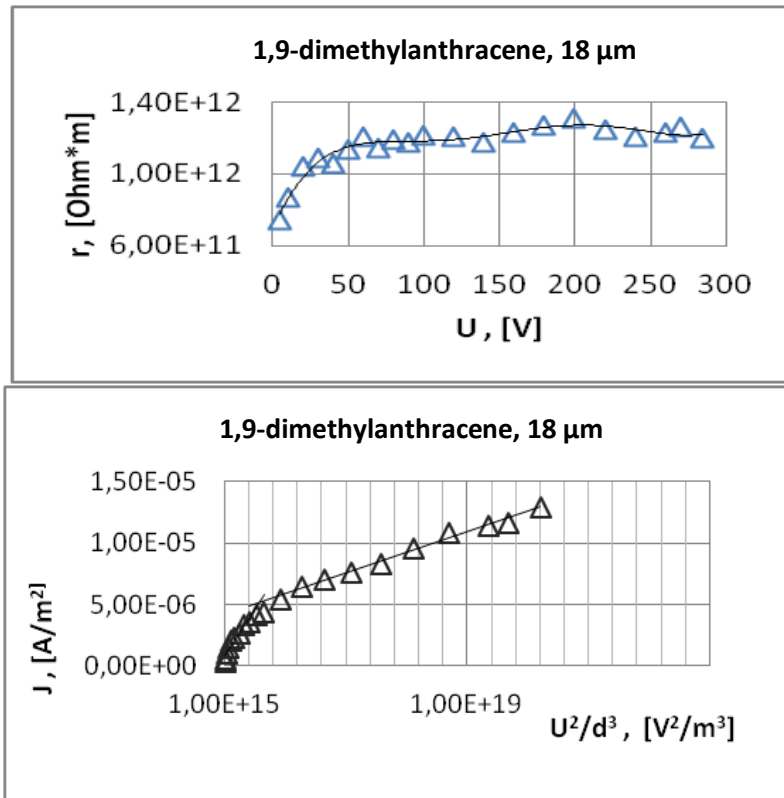
Fig. 3. Resistivity *r* as a function of voltage and current density *J* as a function of U^2/d^3 for 1,9-dimethylanthracene, $d = 18$ μm
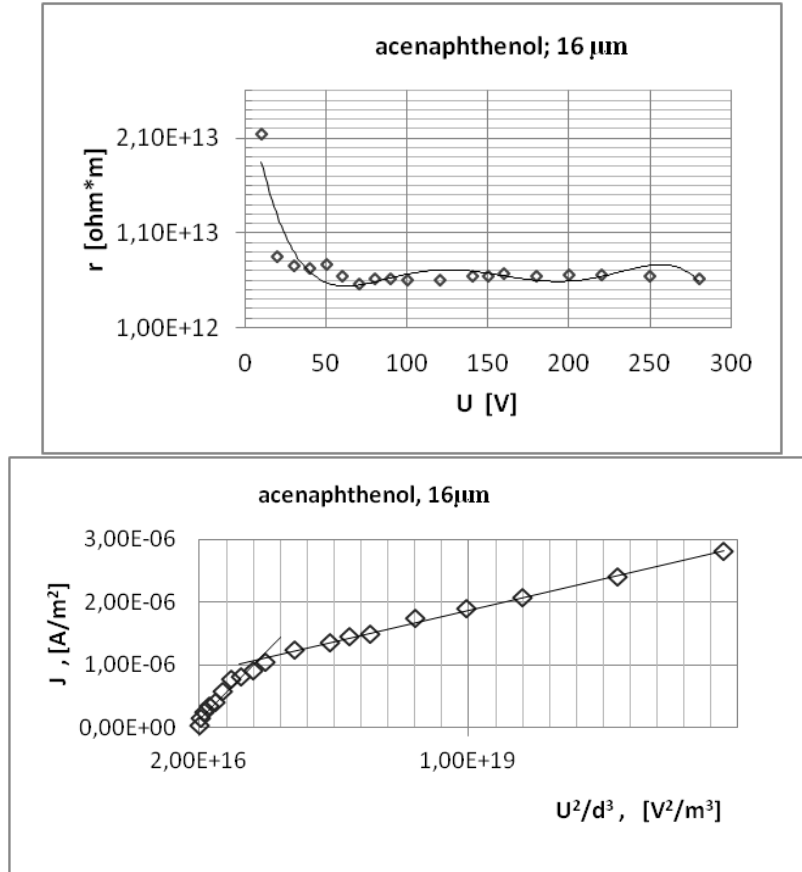
Fig. 4. Resistivity *r* as a function of voltage and current density *J* as a function of U^2/d^3 for 1-acenaphthenol, *d* = 16 μm

The data obtained for current-voltage characteristics are presented in Table 1.

Table 1

No.	compound	resistivity [Ω m]	conductivity [S m^{-1}]
1	1-acenaphthenol	$1.0 \cdot 10^{11} - 9.0 \cdot 10^{12}$	$1.1 \cdot 10^{-13} - 1.0 \cdot 10^{-11}$
2	9,10-dimethylanthracene	$6 \cdot 10^{11} - 1.4 \cdot 10^{12}$	$7.1 \cdot 10^{-13} - 1.7 \cdot 10^{-12}$

The current flow through the thin dielectric layer of the thickness *d*, forced by the applied voltage, can be described by the known formula [8]:

$$J = \frac{9}{8} \varepsilon_0 \mu \vartheta \frac{V^2}{d^3}$$

where μ is the mobility of the charge carriers and *V* is the voltage applied to the sample.

If only shallow traps occur in the studied dielectric then

$$\vartheta(T) = n/n_t$$

where *n* is the total density of free charge carriers and n_t is the density of the trapped carriers. Those dependences are valid in the limits of the foundation of the bound model of transport with the shallow traps localized in the forbidden gap. Density of trapped carriers can be estimated from the intersection of two lines approximating two domains of *J* vs U^2/d^3 dependence in the manner presented in Figs. 3 and 4. This intersection points out the value of voltage for which the traps are filled. From this intersection point it was possible to determine the concentration of the traps. For 1-acenaphtenol layers the valuation gives the quantity in the limits $2 \cdot 10^{11}$-$1 \cdot 10^{14}$ cm^{-3}, and for the 1,9-dimethyl-anthracene layers the value of $9 \cdot 10^{14}$ cm^{-3}.

3. CONCLUSIONS

The layers of spectral grade compounds of 1-acenaftol and 1,9-dime-thylanthracene are characterized with very high resistivity up to the electric field of $2 \cdot 10^7$ V/m. Such great value can be attributed to lack of the double bonds in the ligands and to the herringbone structure not favorable the conduction.

Stabilization of the resistivity level is observed for the fields between $2 \cdot 10^6$ V/m and $2 \cdot 10^7$ V/m.

In the available measuring range the obtained resistivities of the examined layers were in the range $1,0 \cdot 10^{11}$-$9.0 \cdot 10^{12}$ Ωm for 1-acenaphthenol and in the range of $6 \cdot 10^{11}$-$1.4 \cdot 10^{12}$ Ωm for 9,10-dimethylanthracene. The same field limits as for domains of stabile resistivity were valid for linear higher voltage part of the diagram J vs U^2/d^3. The domain seen in this diagram indicated the conditions of conductivity with fulfilled traps. Observed absence of other linear domains for higher voltages vote for existence of only one shallow trap state or only one shallow narrow band of traps. Such behaviour is valid for high purity grade organic materials. The data confirm the stability of these compounds in the conditions of thermal vaporization in the vacuum and their ability to nucleation layers on the gold electrodes without additional defects. Such materials can be used in the synthesis for obtaining more complicated organic materials for organic electronics [8].

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PEWNE WŁASNOŚCI ELEKTRYCZNE CIENKICH WARSTW 9,10-DIMETYLOANTRACENU I 1-ACENAFTOLU

Streszczenie

Zbadano własności elektryczne materiałów o czystości spektralnej uzyskanych metodą dodatkowego oczyszczania strefowego komercyjnie dostępnych 1-acenaftolu i 9,10-dimetyloantracenu. Warstwy wymienionych związków, naparowywane w próżni 10^{-5} Tr, wykazywały wysoką oporność właściwą w granicach 10^{11}-10^{12} $\Omega \cdot$m i charakteryzowały się bardzo niską zawartością pułapek rzędu 10^{11}-10^{14} cm^{-3}. Wyniki świadczą o stabilności molekuł badanych materiałów w warunkach naparowywania termicznego w próżni 10^{-5} Tr oraz o ich zdolności do łatwej nukleacji na złotych elektrodach. Warstwy wykazują stabilność rezystancji aż do wartości pola polaryzacji $2 \cdot 10^{7}$ V/m.