Section 3. Physics

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RESEARCH ON ELECTROPHYSICAL PROPERTIES IN $KMnO_4$-DOPED "KOMOLOT-79" GRADE OF COTTON FIBERS

Abstract. The main purposes of the research were the studying of the dependence of the current strength on voltage and temperature, the effect of doping time on the conductivity and photoconductivity of models of mature doped cotton fibers (CF) "Komolot-79" doped with $KMnO_4$. The study was performed in the temperature (298 to 360 K) and voltage range (0 to 100 V). It was observed that the CF model doped with $KMnO_4$ was significantly higher than the non- doped model. It was found that the current flowing from a CF model doped with $KMnO_4$ follows the Ohm's law. It was also analyzed that the development of photoconductivity under the influence of ultraviolet radiation of a model of CF doped with $KMnO_4$ indicates that the photoconductivity is mainly associated with the development of a network electron-hole pair. The obtained results revealed the activation energy of the deep layer formed by doping CF with $KMnO_4$.

Keywords: Mercerization, cotton fibers, electrical conductivity, photoconductivity, *I–V* characteristics, diffusion.

Introduction. Electrical conductivity in polymers has been extensively studied over the past two decades to understand the nature of charge transport in these materials [1–2]. In the recent days, the physical properties of natural fibers have been researching. The reason for this is the discovery of the semiconducting properties of CF [3–5].

It was found that the physical properties of CF are mainly determined by the surface of layer – the cuticle. In diverse varieties of CF, the cuticle has different physical properties. Therefore, expanding a grade of researches allows us to reveal the general rules of the electrophysical properties of fibers and reveal the mechanisms of electronic processes occurring in the fibers, as well as to develop discrete elements of electronic equipment.

The physical properties of different types of CF have been researched [4–6]. However, the electrophysical properties of "Komolot-79" grade of CF have not been researched. This article describes some results of a study of the electrophysical properties of the "Komolot-79" grade of CF doped with $KMnO_4$. The mechanism of conduction is mainly defined by the mobility and concentration of the charge carriers. The doping process is a vital factor in controlling of the permeability of polymers [7; 8]. Depending on the chemical structure and the way that it reacts with the macromolecular matrix, the additives diminish the resistance of the polymers to variable levels [9].

As we know that the photoconductivity of $KMnO_4$-doped "Komolot-79" grade of cotton fibers has not been informed in the literature. This article shows the electrophysical results of pure and $KMnO_4$-doped "Komolot-79" grade of cotton fibers treated with hydroxide solution.

Experimental Part. Initially, the fibers were separated from the ripened cotton of seeds in parallel. The approximate number of parallel fibers is 4000–6000 and the length is 6 mm. Initially, the fibers were separated from the ripened cotton of seeds in parallel. The approximate number of parallel fibers is 4000–6000 and the length is 6 mm. The CF passes a cleaning and stabilizing stage before starting the doping process. The CF is washed in distilled water at 80 °C for 20 min. After washing, the CF was kept in a bath with 20% of NaOH aqueous solution at 18 °C for 2 min. After removal of the CF from the bath, the excess of NaOH that does not form a chemical bond is completely washed off with water and the models are dried under standard conditions [10]. This process increases stability of CF and input of permeability. The CF increases diffusion efficiency with these two impacts. The mercerized CF was placed in a bath containing a 1.5% aqueous solution of $KMnO_4$ within 20 min. After the models were taken out of the bath, they were doped at 75 °C within 1, 2, 7 hours.

Ohmic contacts were created by a superposition of graphite powder with liquid glass. The resistivity of ohmic contacts is 100–200 Ω•sm. The length of model is 6 mm. Experiments show that an increase in the diffusion time from 1 hour to 7 hours, the current flowing through the model at U = 100 V increases from 8 nA to 75 nA (Fig. 1). This is apparently due to the interaction of $KMnO_4$ with the surface layer – the cuticle, the thickness of which is ≈ 1 μm with the nominal diameter of the CF equal to 15 μm. Extremely small currents were obtained in pure CF. The current never exceeded 10^{-9} A up to a voltage of 100 V. The *I–V* characteristics of the model was measured at low current levels (in nanoamperes) using a DMM 6500 electrometer under dark and ultraviolet light (at 254 nm). The measurements were completed in the model between the ohmic contacts at a temperature of 298 to 360 K and a voltage in the range of 0 to 100 V.

Results and Discussion. It was studied that the voltage of dependence of the current strength (in the dark and under light at 254 nm) and the effect of **dop**ing time on the conductivity of pure and $KMnO_4$ **doped** models of mature named "Komolot-79" cotton fibers. We can see that the value of the current is very small when we apply voltage to an un**dop**ed model (Fig 1–1). It was observed that the diffusion process increased the permeability of the model (Fig. 1). I–*V* characteristics are linear in the forward and reverse directions. In the (Fig. 1) shows that the typical *I–V* characteristics of the undoped (straight line 1) and doped $KMnO_4$ at different diffusion times (straight lines 2–4) CF. As can be seen from the graph below, it was observed that the permeability of the model was increased by growing the diffusion time by 1, 2, and 7 hours.

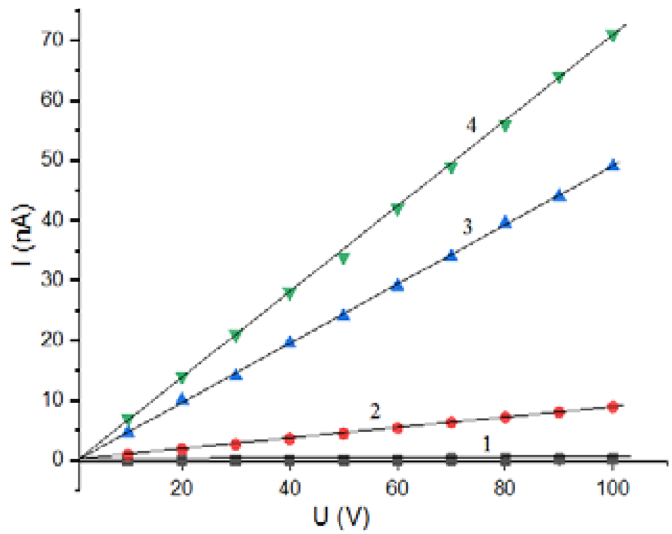

Figure 1. I–V characteristics of undoped (pure) (1) and $KMnO_4$-doped "Komolot-79" grade of CF (2,3 and 4), at different diffusion times, hour: 2–1.0; 3–2.0; 4–7.0

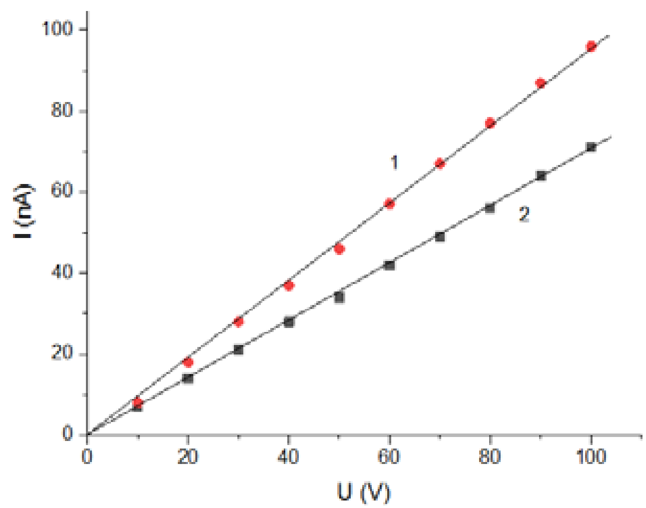

Figure 2. I–V of $KMnO_4$-doped "Komolot-79" grade of CF at t = 75 °C for 7 hour. Direct 1 – darkness, 2 – under illumination with light with hv = 5.0 eV

I–V characteristics were measured in the dark and under ultraviolet radiation in the normal condition. An OBN-60 (hv ≈ 5.0 eV) lamp was used as source of the light. In the *fig.*

3 we can see that in the dark (1) and under ultraviolet light (2) the I–V feature is linear. When we increased the voltage from 0 to 100 V, it was observed that the result obtained under ultraviolet light varied by 30 nA from the result obtained in the dark. Under ultraviolet light (254 nm), the photocurrent (PC) rose to 98 nA at 100V.

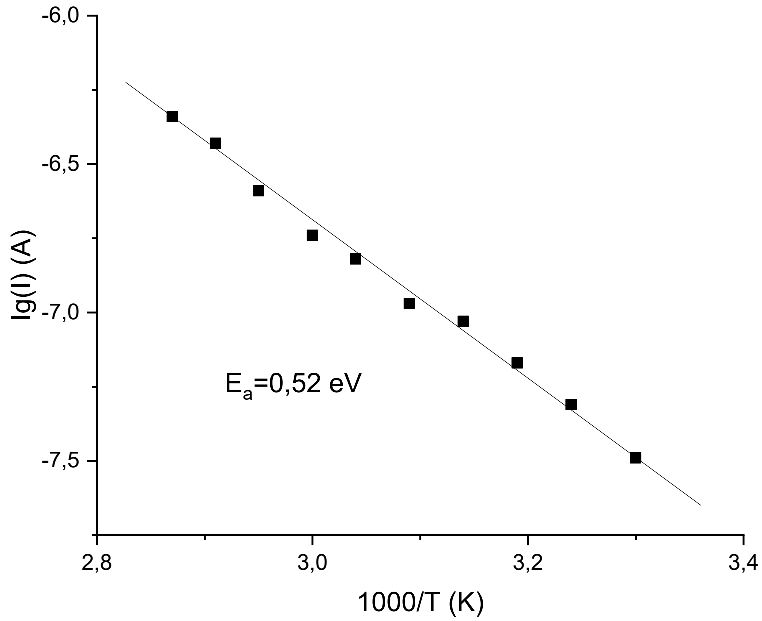

Figure 4. Arrhenius plot, temperature dependence of electrical conductivity of "Komolot-79" cotton fiber mercerized by NaOH and doped with $KMnO_4$ at t = 75 °C for 7 hour. U = 50V

This indicates that the photoconductivity is mainly related to the development of the electron cavity pair. The improvement of photoconductivity in CF can be explained by the doping with $KMnO_4$ [7; 8].

Temperature current features $KMnO_4$-doped "Komolot-79" grade of CF studied the temperature dependence of electrical conductivity to better understand the mechanism of conduction.

In the Figure. 4, we can observe an increase in current with increasing temperature at a voltage of 50V given to the model. In this case, the temperature coefficient of electrical conductivity is positive, and this is a feature of a semiconductor material. This feature of CF has been observed by other scientific groups [11]. It was found that the activation energy of $KMnO_4$-doped "Komolot-79" grade of CF is 0.52 eV through the temperature dependence of electrical conductivity *(law of Arrhenius)*.

Conclusion. In conclusion, it was studied that the electrophysical properties of undoped and KMnO4 doped CF. According to the analysis of the experimental results, the doping of "Komolot-79" CF mercerized with NaOH with $KMnO_4$ increased the permeability by several 10 times and the doping time depends on the permeability. A sharp increase in the conductivity of CF doped with $KMnO_4$ is associated with a growth in the concentration of charge carriers in CF. The insertion molecules settle into the lattice defects of the polymer and form a deep layer in the restricted zone, resulting in the formation of free charge carriers even at room temperature and providing permeability. The permeability of mechanism of undoped CF is mainly explained by the Poole-Frenkel permeability of mechanism. As well as, the formation of photoconductivity under the influence of ultraviolet radiation indicates that the photoconductivity is mainly associated with the formation of a network electron-cavity pair and is explained by the order of charge transfer between $KMnO_4$ molecules and polymer networks possible. Accordingly, the results showed that the activation energy of the deep layer formed by doping CF with $KMnO_4$ was determined. Nowadays, the study of electrophysical properties of natural fibers is not only to create a new type of semiconducted sensitive sensors, it is also important to create "smart clothing actuators".

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