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INVESTIGATION (STUDY) OF PHYSICAL PROPERTIES OF NATURAL SEMICONDUCTOR FIBERS

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ANNOTATION

It was revealed that the photoconductivity spectra of various grades of cotton fibers doped with iodine are quite different. It was found that the electrical conductivity of cotton fibers undipped and doped with iodine and $KMnO_4$ increases exponentially with increasing temperature. Infrared quenching and long-time relaxation of the photoconductivity of cotton fibers doped with iodine were detected. For the first time, it was found that with small doses of UV irradiation of silkworm green, the quality of silk fibers improves, and with large doses it worsens.

KEYWORDS: Cotton and Silk fibers, alloying, Photoconductivity, Electrical conductivity.

I. INTRODUCTION

Recently, research has been successfully conducted in the field of physics of natural fibers. This, in particular, is due to the fact that semiconductor properties are detected in cotton and silk fibers (CF and SF).[1,2] Natural polymers such as cotton and silk fibers have structures of successively alternating crystalline and amorphous regions.[3,4] The electrophysical and optical properties of CF and SF are very sensitive to external influences (temperature, alloying, uniaxial pressure, humidity, light) and can easily be modified to obtain materials with desired properties. Based on cotton fibers, thermistors,[5,6] photosensitive materials,[7] humidity sensors,[8] photodiodes[9] and field effect transistors[10] were created. When treating the surface of CF, it was revealed that the properties are mainly determined by grade and cuticle of the surface part of CF with a thickness of the order of 1 μm with a conditional fiber diameter of 10-15 μm.[11] Photoluminescence[12] and photoconductivity (PC) in the intrinsic absorption region of CFs doped with iodine were also found in CF.[13] Also, the infrared quenching and the long-time relaxation of photoconductivity are due to the adherence of charge carriers to the deep levels formed upon the introduction of iodine into an CF were found.[14-18]

It follows from the foregoing that a new scientific direction "Physics of Natural Semiconductor Physics and New Original Scientific Results have been developed.

However, despite the successes achieved, there are still many unresolved issues, including the physics of these phenomena are not fully understood. Therefore, expanding the research area in this scientific direction will reveal ways to regulate the electrophysical and optical characteristics of natural polymeric nanostructured semiconductor materials and will open up wide possibilities for creating new discrete semiconductor elements and electronic equipment on their basis.

This paper presents the new research results of CF and SF.

For this study, the samples were prepared using the following technology. The object of the study was cotton and silk fibers. In order to dope CF with iodine, first, a seed of CF was thoroughly combed with a fine comb (with a spike period of 0.5 mm), then seeds were cut from the side. Then, CF was soaked in 5 or 10% alcohol solution of iodine. Then iodine diffusion was carried out at T = 60-90^{0}C for 6-10 hours. Further, in order to make ohmic contacts, an electrically conductive adhesive based on graphite and liquid glass was developed. The crushed fine-grained graphite was mixed with liquid glass to a thick state. After that, such an electrically conductive adhesive (R = 300 Om with a thickness of 20 μm and a length of 1 cm) was applied to the end sides of the CF and SF. This made possible to obtain reproducible measurement results. Note that in parallel laid fibers are 2000-7000 pieces. The length of the sample was 5 mm. Electric current and voltage was measured using a DMM 6500 KIETHLEY millimeter. The current-voltage characteristics of the fabricated samples in the forward and reverse directions are linear. Measurements showed that after doping of CF with iodine, the samples had n-type conductivity. Note that the increase in the number of fibers is connected with the limitation of the measurement of small current values by measuring instruments.

Ligature $KMnO_4$ was dissolved in distilled water. We prepared a 2% aqueous solution of $KMnO_4$. This solution was applied to the surface of the CF, after which they were dried for one hour at room temperature, then diffusion was carried out at 60-100^{0}C for 6-10 hours.

To determine the time of the fracture for natural fibers, samples were prepared as follows. First, a fiber grade was selected. One fiber comes off the seeds (if it is CF) and washed in distilled water at 100 ^{0}C. Then, on both sides of the fiber, it is smeared with liquid glass and glued to paper cardboard with a thickness of 0.5 mm with a hole. Then at room temperature it is kept for 10 hours.

Temperature dependences of the electrical conductivity were measured in the temperature range 0-100 ^{0}C. The temperature of the sample was measured with a calibrated copper-constantan thermocouple.

In order to investigate the physical properties of the joint SF, the special cocoon unwinding installation has been created, which allows obtain a single joint SF without breaking up to 1200 m. The layout of the installation for cocoons unwinding is shown in Fig. 1. After unwinding, the welds were washed 3-5 times in distilled water at a temperature of 75^{0}C. The remaining procedures for the preparation of CF samples are similar to the technology used for CF.

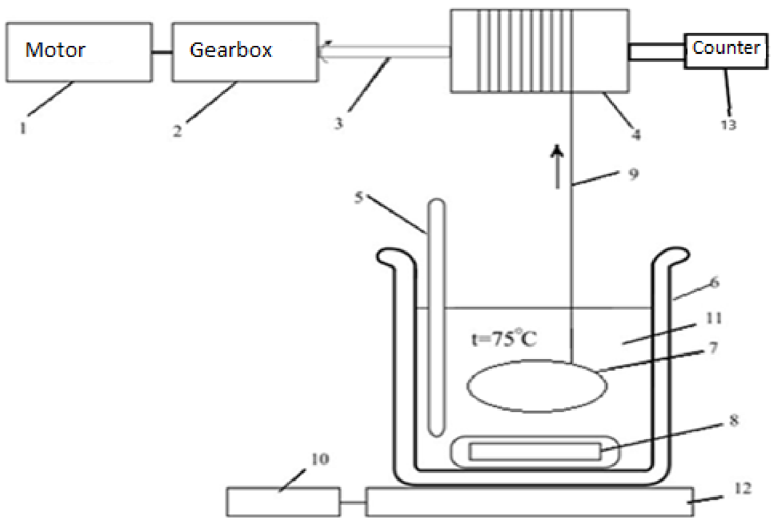

Fig. 1: Installation for cocoons unwinding.

1-motor, 2-gearbox, 3-rod, 4-wrap foam board, 5-thermometer, 6-glass beaker, 7-cocoon, 8-glass insulated metal plastic, 9-SF, 10- temperature controller of water , 11 - distilled water, 12-magnet and stove, 13-motor rev counter.

To determine the time of rupture of the fiber under uniaxial mechanical stress, a setup was created that allows determine the rupture time from the applied load. The fabricated sample is mounted to the linkage system. Then the load is applied and at the same time the stopwatch starts. After a certain time, the sample is torn. At this moment, an electric bell rings and the measurement stops. Thus, we determine the time to break the fiber, when a certain load is applied.

II. EXPERIMENTS AND DISCUSSION

It follows from the experiments that, under the same initial conditions, the spectra of the PC of various CF grades doped with iodine are different from each other. This can be explained by the fact that the upper shell - cuticle of CF depends on their grade which manifest itself in the PC spectra. The PC spectra of various types of CFs doped with iodine are shown in Fig. 2, measured at temperature of T = 300K. PC spectra were measured using an IRM-1 monochromator with a NaCl prism. The slit width was 0.01 mm.

The experimental fact that iodine in various grades of CF creates the different deep level peaks in the PC spectra can be used to identify cotton fiber varieties. Experiments show that the iodine doping of the various classes of CF produces different deep levels. The ionization energies of the deep levels in CFs produced by the iodine doping are given in table 1.

Table 1: Ionization energies of the deep levels formed upon the introduction of iodine in the forbidden zone of CFs (Eg = 3.2 eV).

№	CF grade	Ionization energy, Et	
		in the upper half of E_g	in the lower half of E_g
1	175F<J>	E_c – 0,8 eV	-
2	Gulbahor<J>	E_c – 0,67 eV	E_v + 0,8 eV
3	ATM-1	E_c – 0,36 eV E_c – 0,78 eV	- -
4	Khazina <J>	E_c – 0,42 eV	E_v + 1,5 eV
5	Golib<J>	E_c – 0,78 eV	-
6	Dyor <J>	E_c – 0,35 E_c – 1,00 eV	E_v +0,5 eV -

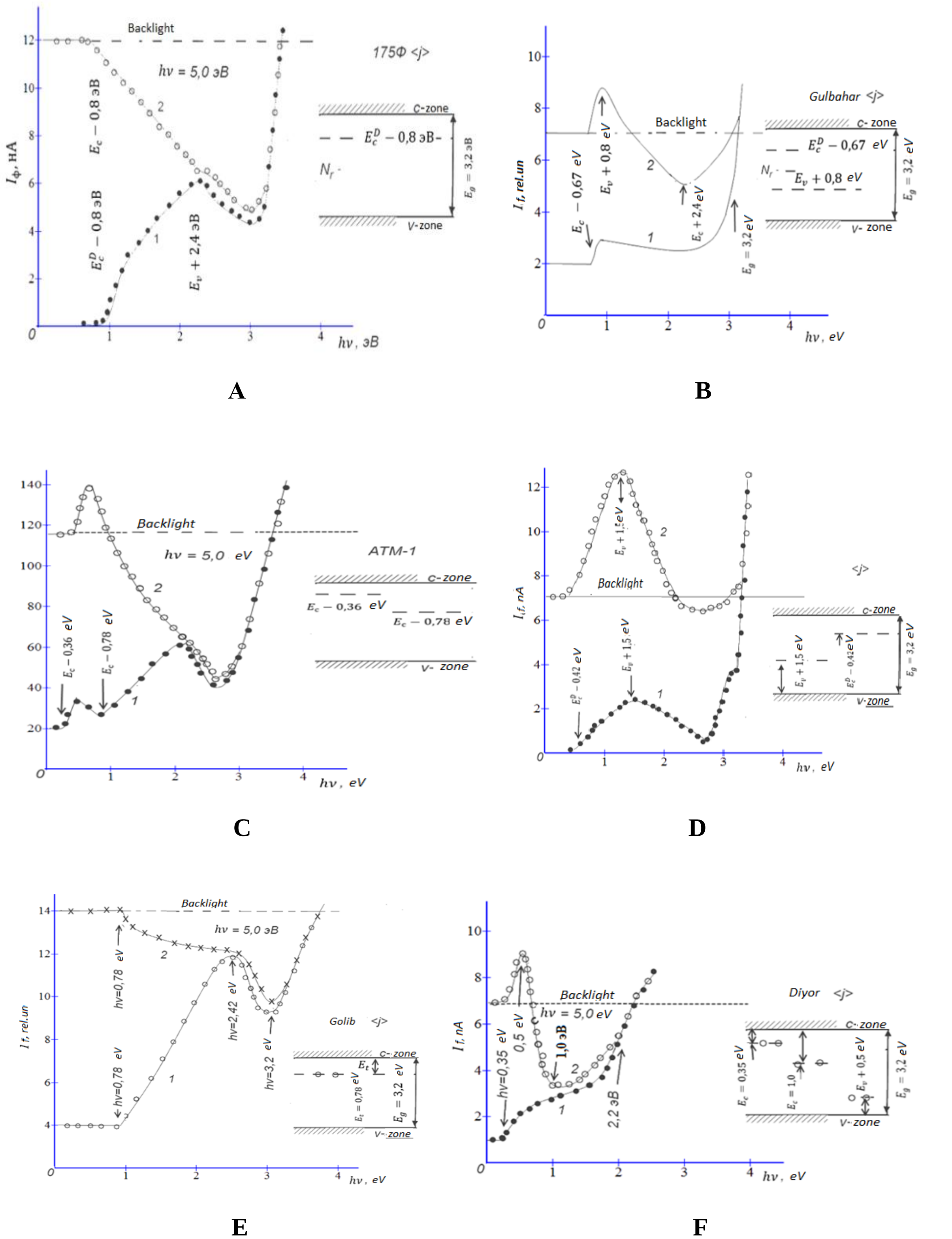

Fig. 2: PC spectra of the various grades of CFs doped with iodine.

A - 175F <J>, B - Gulbahor<J>, C - ATM-1 <J>, D - Khazina<J>, E - Golib<J>, F - Dyer <J>. Curves 1,2 without and under constant illumination with light energy hν ≥ Eg, respectively.

It has been established that the electrical conductivity of the CF of grades 175F, Gulbahor, and ATM-1 undoped and doped with iodine and $KMnO_4$ increases exponentially with a certain thermal ionization energy with increasing temperature. Figure 3 shows the temperature dependences of the electrical conductivity of various CF grades doped with iodine and $KMnO_4$

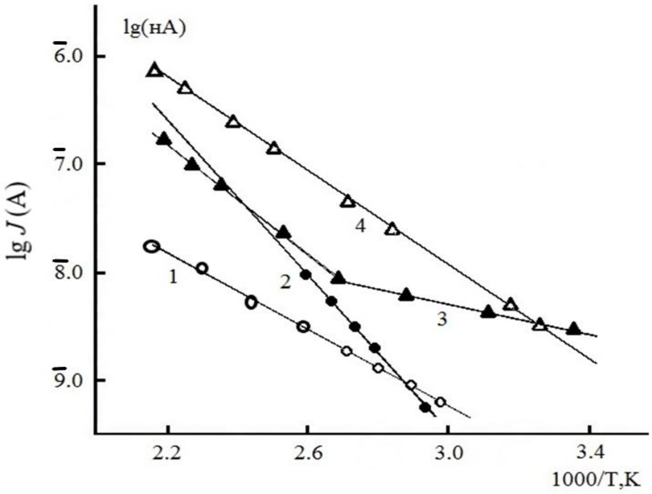

Fig. 3: Temperature dependences of electric current passing through various grades of CF. 1-175F <J>, - Gulbahor<J>, 3- ATM-1 <J>, 4-ATM-1 <$KMnO_4$>

It was established also that, after CFs doping, the ionization energy of deep levels changed, which is apparently connected with the interaction of the structure of CFs with iodine.

The photoconductivity (PC) of various types of CFs doped with iodine was studied. It was revealed that when a sample is illuminated with light energy hν = 5.0 eV, the photocurrent increases exponentially with time. The ratio of the photocurrent to the dark current is equal to I_{ph} / I_d = 22-100. This allows make photodetectors operating in the UV region of the spectrum. Under combined lighting, IR quenching of photoconductivity was observed in all varieties of CF. IR quenching of CF is explained by the recharging of deep levels under combined lighting. After illumination of the sample with light of $h\nu \geq E_g$, (E_g is the band gap), long-time relaxation of the PC after turning off the light is revealed. With an increase of the intensity of its own backlight, an increase in PC was detected. This is due to a change in the degree of filling of a deep level of iodine in the forbidden zone of CF.

The dependence of the breaking strength of a single silk fiber on the time of UV (hv = 5.0 eV) irradiation of silkworm green was determined.

It was revealed that at low radiation doses, the tensile strength increases, and then decreases 1.6 times. This, apparently, is due to the effect of UV light on the surface of the gray worsening the growth and development of the silkworm caterpillar. Note that a low dose of radiation (t <0.5 min.) improves the quality of silk fibers.

III. CONCLUSIONS

A technology has been developed for doping cotton and silk fibers with an admixture of iodine and $KMnO_4$. An installation has been created for unwinding cocoons to a single silk fiber without breaking up to 1200 meters. A setup has been created for determining the time of rupture under uniaxial mechanical stress of single natural fibers. It has been established that at the same initial conditions the photoconductivity spectra of different varieties of cotton fibers doped with iodine are different from each other. This is due to the interaction of iodine with the surface - cuticles, which have different properties depending on the grades of cotton fibers. This can be used to identify varieties of cotton fibers. It has been established that the electrical conductivity of unalloyed and doped with iodine and $KMnO_4$ of various types of CF increases with increasing temperature exponentially. It was revealed that upon doping of CFs, the ionization energies of deep levels changed, which is associated with the interaction of the structure of CFs with iodine. IR quenching and long-time PC relaxation after illumination of CF<J> was detected. IR quenching of PC is explained by recharging of deep levels under combined lighting.

For the first time, the dependence of the tensile strength of a single silk fiber on the time of UV irradiation of silkworms was studied. It was revealed that the low doses of radiation improves the quality of silk fibers.

ACKNOWLEDGMENTS

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