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## The Dependence of the Photographic Characteristic of a Polymer – zinc oxide – salt of Metal Photosensitive Compositions by the Polymer Structure Peculiarity

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### Abstract

In this presented paper, we will investigate the photographic characteristics of a photosensitive compositions which consist of a polymer, zinc oxide and salt of metal using the examples of PVA-ZnO-BiCl<sub>3</sub> and PVA-ZnO- Pb(CH<sub>3</sub>COO)<sub>2</sub> compositions. Advanced, is an experimental result of the dependence between the photographic characteristics of a similar system and the content of the acetate groups in the polymer structure.

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### 1. Introduction

Photosensitive compositions which consist of a polymer matrix dispersed with a photocatalyst, and sensitized by a salt of metal, are widely researched on the following examples: polyvinyl alcohol – zinc oxide – bismuth chloride (PVA-ZnO-BiCl<sub>3</sub>) [1-3], polyvinyl alcohol – zinc oxide / titanium dioxide – lead acetate (PVA-ZnO/TiO<sub>2</sub>-Pb(CH<sub>3</sub>COO)<sub>2</sub>) [4], polyvinyl alcohol – cuprum chloride / ferric chloride [5] and some others. These classes of compositions exhibit photosensitivity to UV irradiation. Another general factor for these compositions are realizing the direct blackening processes in it, which means that the visible image

forms directly under irradiation without an additional development stage.

Improving or changing any properties of such photosensitive compositions – improving the photosensitivity and/or maximal density of the optical blackening, changing the spectral sensitivity range, - is key. As a rule, such changes of the properties of the photosensitive compositions are achieved from modofocations in the photocatalyst or salt of metal (sensitizer). But the influences of the polymer matrix on the photosensitive composition properties were not studied.

In this paper the dependence of the photographic properties of PVA-ZnO-BiCl<sub>3</sub> and PVA-ZnO-Pb(CH<sub>3</sub>COO)<sub>2</sub> from the chemical structure of the PVA are investigated.

## 2. Sample preparation and experimental conditions

The photosensitive composition samples of PVA-ZnO-BiCl<sub>3</sub> and PVA-ZnO-Pb(CH<sub>3</sub>COO)<sub>2</sub> were prepared by the well-known technique [1, 4] with insignificant changes.

To prepare both samples in the first stage it is necessary to disperse the zinc oxide into the polymer matrix. For this, 12 grams of zinc oxide (II) moistened with water was put into 100 ml of the 10% PVA water solution (which was homogenate on the bain-marie before it). After one hour of settling time, the 60 grams of the resulting mixture was coated on the glass plate with an area of 234 sq.cm. Then the composition was dried in a horizontal orientation at room temperature for 24 hours.

Next, the sensitizing of the compositions was made by using the salts of lead and bismuth by dipping the PVA-ZnO composition for the 30 seconds in 1 M bismuth chloride aqueous solution (to obtain the PVA-ZnO-BiCl<sub>3</sub> photosensitive composition) or in the 0.1 M lead acetate aqueous solution (to obtain the PVA-ZnO-Pb(CH<sub>3</sub>COO)<sub>2</sub> photosensitive composition). Finally, the photosensitive compositions are dried in a heated air flow for 5 minutes to eliminate moisture.

In the way described, six sets of samples were prepared. Each one they differed by the type of the usable polyvinyl alcohol and by the sensitizer agent. It is well known [6] that a different PVA type has a different count of the acetate groups in its structure. In table 1, the acetate group concentration in the different PVA types, which were used in the experiment, are shown. The acetate group concentration was determined by the standard method [6].

Table 1. The acetate group concentrations in the PVA used in the different sample sets

Sample sets sign	The PVA type	Acetate group concentration, %
PVA-ZnO-BiCl <sub>3</sub> (I)	11/2	1.24 – 1.25
PVA-ZnO-BiCl <sub>3</sub> (II)	16/1	1.31 – 1.32
PVA-ZnO-BiCl <sub>3</sub> (III)	18/11	13.72 – 13.78
PVA-ZnO-Pb(CH <sub>3</sub> COO) <sub>2</sub> (I)	11/2	1.24 – 1.25
PVA-ZnO-Pb(CH <sub>3</sub> COO) <sub>2</sub> (II)	16/1	1.31 – 1.32
PVA-ZnO-Pb(CH <sub>3</sub> COO) <sub>2</sub> (III)	18/11	13.72 – 13.78

## 3. Experimental

To determine the rate of influence of the used PVA on the direct blackening photochemical processes which occurs in the photosensitive composition, it was chosen to use the characteristic curve construction method. It was applied to the each set of six samples, whereupon the basic photographic characteristics of the

photosensitive compositions were determined on the basis of getting characteristic curves.

To achieve these aims, samples of the photosensitive compositions were exposed to the integrated spectrum light of a DRT-125 mercury-vapor lamp during various exposure times. The illumination on the sample surface was  $E=0.105 \text{ W/sq.cm.}$ , the optical blackening determination was carried out by the approved method using the author's hardware-software complex [3].

#### 4. Results

Fig. 1 and 2 shows the characteristic curves of the PVA-ZnO-BiCl<sub>3</sub> (I-III) and PVA-ZnO-Pb(CH<sub>3</sub>COO)<sub>2</sub> (I-III) photosensitive composition.

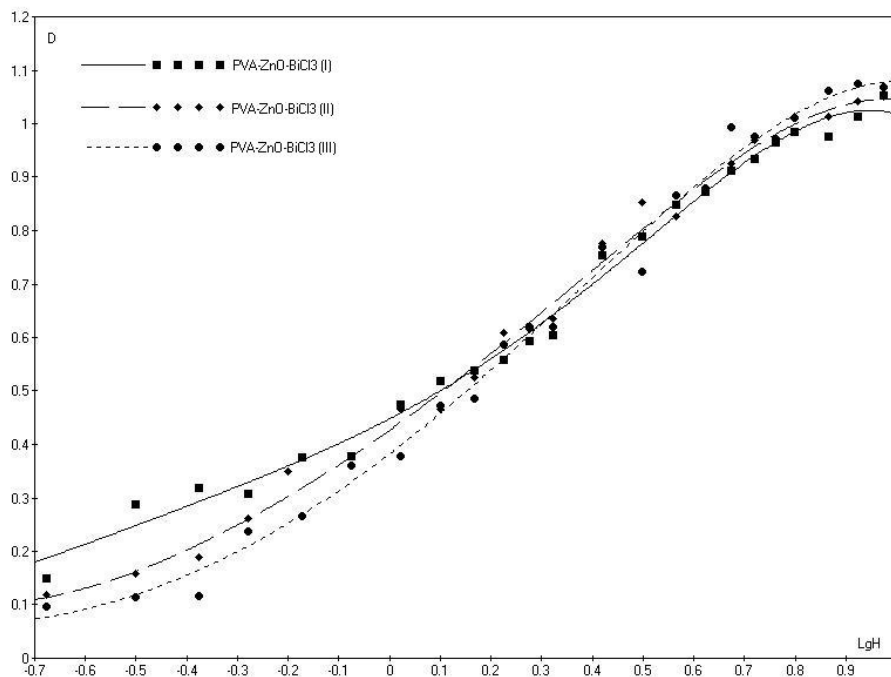


Fig. 1. Characteristic curves of the PVA-ZnO-BiCl<sub>3</sub> photosensitive compositions containing various rates of the acetate group

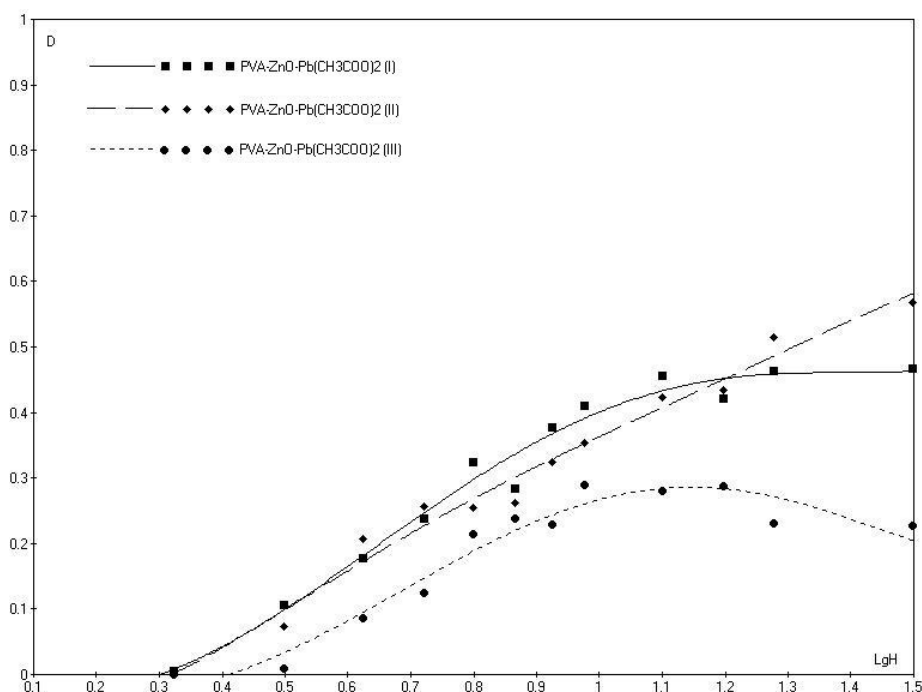


Fig. 2. Characteristic curves of the PVA-ZnO- Pb(CH<sub>3</sub>COO)<sub>2</sub> photosensitive compositions containing various rates of the acetate group

From the figures it is obvious, that both the maximal density of the optical blackening, and the rate at which it rises, depend on the chemical structure of the PVA being used. The basic photographic characteristics of PVA-ZnO-BiCl<sub>3</sub> (I-III) and PVA-ZnO-Pb(CH<sub>3</sub>COO)<sub>2</sub> (I-III) photosensitive composition, were calculated on the basis of their characteristic curves, and are described below in table 2.

Table. 2. The basic photographic characteristics of PVA-ZnO-BiCl<sub>3</sub> and PVA-ZnO-Pb(CH<sub>3</sub>COO)<sub>2</sub> photosensitive compositions are depend on the PVA chemical structure

Sample sets sign	Acetate group concentration, %	Maximal density of the optical blackening	Photosensitivity, S <sub>iso</sub>	Contrast
PVA-ZnO-BiCl <sub>3</sub> (I)	1.245±0.005	1.15	4.20	0.76
PVA-ZnO-BiCl <sub>3</sub> (II)	1.315±0.005	1.07	6.81	0.75
PVA-ZnO-BiCl <sub>3</sub> (III)	13.75±0.03	1.12	11.83	0.83
PVA-ZnO-Pb(CH <sub>3</sub> COO) <sub>2</sub> (I)	1.245±0.005	0.68	0.284-0.297	0.622
PVA-ZnO-Pb(CH <sub>3</sub> COO) <sub>2</sub> (II)	1.315±0.005	0.52	0.284-0.290	0.506
PVA-ZnO-Pb(CH <sub>3</sub> COO) <sub>2</sub> (III)	13.75±0.03	0.27	0.21-0.215	0.574

From the table it can be seen that the acetate group concentrations in the polymer structure have a different

influence on the photosensitive composition sensitized by the bismuth chloride or by the lead acetate. So, for the PVA-ZnO-BiCl<sub>3</sub> composition, the acetate group volume in the PVA structure has no significant influence on the contrast and the maximal density of the optical blackening, but strongly influences the photosensitivity. In the PVA-ZnO-Pb(CH<sub>3</sub>COO)<sub>2</sub> photosensitive composition, we can see another effect: increasing the acetate group rate in the PVA structure leads to the significant decrease of the maximal density of the optical blackening and practically doesn't influence the contrast and photosensitivity.

## 5. Conclusions

Getting results allows the conclusion that the chemical structure of the polymer matrix (the acetate group rate) can influence the photosensitivity of the polymer – semiconductor – salt of metal photosensitive compositions. Of notable importance that photosensitivity is a value that is proportional to exposure which changes the density of the optical blackening of the sample surface on the 0.1 in the comparison with unexposed sample. So, this characteristic describes the increasing density of the optical blackening value in the early stage of the image formation process. On the other hand, it is well known that in the small values of the optical density, the following equation is correct:  $D \sim \sigma$ , ( $D$  – density of the optical blackening,  $\sigma$  – colour centre surface density).

Thus, the dependence identified is evidence that the acetate group in the PVA structure is participating in the early stage of the visible image formation on the PVA-ZnO-BiCl<sub>3</sub> photosensitive composition surface.

Secondly, finding differences in the influence of the acetate group in the PVA structure on the photographic characteristics of PVA-ZnO-BiCl<sub>3</sub> and PVA-ZnO-Pb(CH<sub>3</sub>COO)<sub>2</sub> photosensitive compositions shows us that there exists the principally differences between the photoprocesses in these two types of the photosensitive compositions.

## References

- [1] Shtarev D.S., Makarevich K.S., Syuy A.V. Behavioral features of photostimulated processes in the heterogeneous composition of polymer - semiconductor - salt of a metal. *Journal of Photochemistry & Photobiology A: Chemistry* Vol 222 (2011), p. 146-158.
- [2]. Syui A.V., Shtarev D.S. Photosensitive Composition Based on Polyvinyl Alcohol. *Optics and Spectroscopy* Vol. 110, No. 2 (2011), p. 224–226.
- [3] Shtarev D.S., Makarevich K.S., Syuy A.V. Impact of a chlorine ions concentration in sensitizer solution on the photographic characteristics of polyvinyl alcohol – zinc oxide – bismuth chloride composition. *Optik - International Journal for Light and Electron Optics* 123 (2012), pp. 1095-1097.
- [4] Prosanov I.Ju.. *The journal of the scientific photography and cinematography*. Vol. 48, No 1 (2004), p. 67-69 (in Russia).
- [5] Sirec O.F. *The journal of the scientific photography and cinematography*. Vol. 30 No 6 (1985), p. 408-412 (in Russia).
- [6] Finch C.A. *Polyvinyl Alcohol, Properties and application*. - New York: John Wiley, 1973. - 622 p.