CHARACTERISTICS OF AMORPHOUS Se ELECTROGRAPHIC LAYERS ON SUBSTRATES WITH OXIDE FILM

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The electrographic amorphous Se layers are prepared by Se sublimation of OSCh trade mark 17-3 on cylindrical metal substrates with barrier oxide film. The influence of film thickness on layer photoelectric characteristics is investigated. It is shown that for achieving of optimal dark and light parameters it is necessary to form the oxide film by 3μm thickness on substrate.

Keywords: photoreceptor, oxide film, barrier layer.
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1. INTRODUCTION

The development of science, technique and national economics, the increase of efficiency of control by this process is accompanied by intensive information volume. In this connection the non-polygraphic methods of operating document copying and duplication on the base of industrial gage application such as diazoprocess, photography, electrography, thermography and electronography joined by general term which is the reprography. The principal difference of reprography from polygraphy is the fascimility, i.e. the supply of total identity of disposition order of image elements, their configuration, print type in original and copy.

Nowadays, the electrophotography the principles of which are connected with achievements of semiconductor physics [1] is the one of the extended and intensively developed methods of reproduction.

Electrophotography (EPh) is the set of methods and industrial gages of image obtaining on special surfaces, electric properties of which change in the correspondence with light radiation quantity accepted by these surfaces. The electrolyzed thin layer of photosemiconductor (for example, amorphous Se) marked on conducting substrate is the supersensitive one in EPh.

EPh image obtaining process is caused by physical phenomena taking place in high-ohmic semiconductor layers at their electrization, exposure and also electric interactions between charged states at revealing and transfer of the image on paper or other base. In the difference from the ordinary photography in EPh scheme of image obtaining there are additional principally new two stages which are layer electrization (sensitization) before exposure and transfer of revealed image with layer on other material.

The wide application of EPh causes the necessity in improvement of existing photoreceptors and in obtaining of new ones. The photosensitivity in visible and especially red spectrum region is the important criteria. Nowadays, the schemes of xerographic image reproduction based on use of amorphous Se, compounds by A^2B^6 type, organic semiconductors and etc. are realized. The fabrication technique of EPh layers of photosemiconductors of $A^2B^3{}_2$ $C^6{}_4$ type having the high photosensitivity in visible spectrum region is developed. The investigation on photoreceptor creation on the base of amorphous silicon enriched by hydrogen [12] are carried out.

2. EXPERIMENT AND RESULT DISCUSSION

Se which is elementary semiconductor attracts the attention of the investigators by their unique properties. It has the high photosensitivity, it can be obtained in amorphous and crystalline (trigonal and monoclinic) states. All this makes it unchangeable at creation of different transformers (first power rectifiers, photoreceptors, vidicons, photo-isolator and etc.). Se high technology (low melting point, the possibility of any form marking on the surface and etc.) is important. Wide-ranging use of Se in different technique region constantly stimulate the investigation of its properties all over the world.

The photoreceptors on the base of amorphous Se have the high EPh parameters (they are well chargeable ones and have photosensitivity), but at the same time they have disadvantages. They are weakly sensitive to red light, the layers of amorphous Se crystallize under influence of many factors and break down in the result of explosure [3].

Trigonal Se is known as photosemiconductor with spectral sensitivity in spectrum visible region. Usually, the layers from trigonal Se are prepared by dispersion of its particles in polymer bonder layer and marking of suspension on conducting substrate. They have well photosensitivity, but simultaneously have relatively low initial potential of charging and dark semi-drop that is the result of Se high conductivity [4].

The elimination of above-mentioned disadvantages belonging to layers from amorphous Se prepared in complex vacuum equipment and search of the improving ways of their parameters and characteristics is the task of the given work. The search of relevant ways is carried out with this aim.

Se electrographic layer (SEL) is the complex system which consists of the conducting substrate, barrier (shutoff) layer, multifunctional layer of photosemiconductor and often the external protective layer. The physical properties of such systems are studied all over the World, however, the many

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questions stay unsolved ones up to now, in particular, the interconnection between system composite elements in formation of photoreceptor property complex isn't established. So, by others opinion the oxide film on substrate carries out the several functions: it carries out the interface in boundary substrate – photosemiconductor, improves the photosemiconductor adhesion to substrate, makes barriers preventing the carrier injection from substrate into photosemiconductor and reactive diffusion between them. Thus, the oxide film should significantly influence on photoreceptor parameters. Concerning this, oxide film thickness and the time of substrate chemical oxidation time which changes in interval (0,1–15min) are chosen in the capacity of alternative parameters.

The oxide films on metallic (duralumin) substrate can be obtained by thermal oxidation in oxygen atmosphere, ion-plasma spraying, spraying of aluminum in oxygen atmosphere, pyrolysis of hetero-organic compounds, anode oxidation in electrolytes and by chemical oxidation [5].

Se electrographic layers the oxide films of which on duralumin substrates are formed by chemical oxidation in solution containing the chrome anhydride (3-7g/l), sodium fluoride (3-4g/l) and orthophosphoric acid (40-50g/l), are investigated. The oxidation is carried out at 25°C and curing time in solution is (0,1-15) min. This supplies the formation of oxide films with thickness from 40 Å up to 5μm.

The film thickness is defined by capacity method with the help of bridge L2-7 at frequency 465kHz (dielectric constant of oxide film is equal to 8). The measurements show that film thickness d monotonously increases with tendency to saturation at $t_{xo} \geq 12$ min with increase of oxidation duration t_{xo}. The solution aging time plays the significant role. The most thickness (d=5μm) forms at the use of fresh solution whereas the films of less thickness form in used solutions though the grow character d on t_{xo} is the same. The quality of oxide film begins to worsen with t_{xo} increase.

After oxidation the cylindrical substrates are degassed at 140°C during 60 min and Se by trend mark OSCh 17-3 is marked by sublimation method during 25 min at program change of temperature substrate from 40 up to 82±0,5°C. The thickness of Se layer is 60-85μm. The samples have the form of ring fragments by height 100mm. Their EPh parameters are investigated on test bed prepared on the base of apparatus EP-300K2 (dynamic mode). The parameters are measured after 30 minutes of the charge-exposure cycle. The dark drop time of the potential $\tau_{1/2}$ and the velocity of its dark relaxation υ_{15} (15sec after charging), integral photosensitivity S_{int} and spectral distribution of photosensitivity S_λ in the interval of wave length 300 – 1000nm are defined. The light source is graduated by radiation compensated thermo-element PTH-30.

The nature of interface photosemiconductor-substrate is the determinative factor of potential dark drop. It is important that contact substrate-semiconductor should be shutoff for the carriers even if for one sign. The contact region substrate-semiconductor should be barrier for the electrons preventing their injection from the substrate to the layer at relatively high electric field strength at positive photoreceptor electrization for surface charge retention. The measurements show (Fig.1) that $\tau_{1/2}$ increases with increase of oxide film thickness d passing through at $d \simeq 2{,}5$τm ($t_{xo} \simeq 5$min.) and it strongly decreases with further thickness increase. The change υ_{15} also has the extreme character with minimum at $d \simeq 2{,}5$μm (Fig.1). The coincidence of d dependences on t_{xo}, $\tau_{1/2}$ and υ_{15} on d allow us to suppose that the extremal change $\tau_{1/2}$ and υ_{15} is caused by the following reasons. The oxide film forms on the substrate at interaction with solution and its growth slows after achieving of the thickness $d \simeq 3$μm.

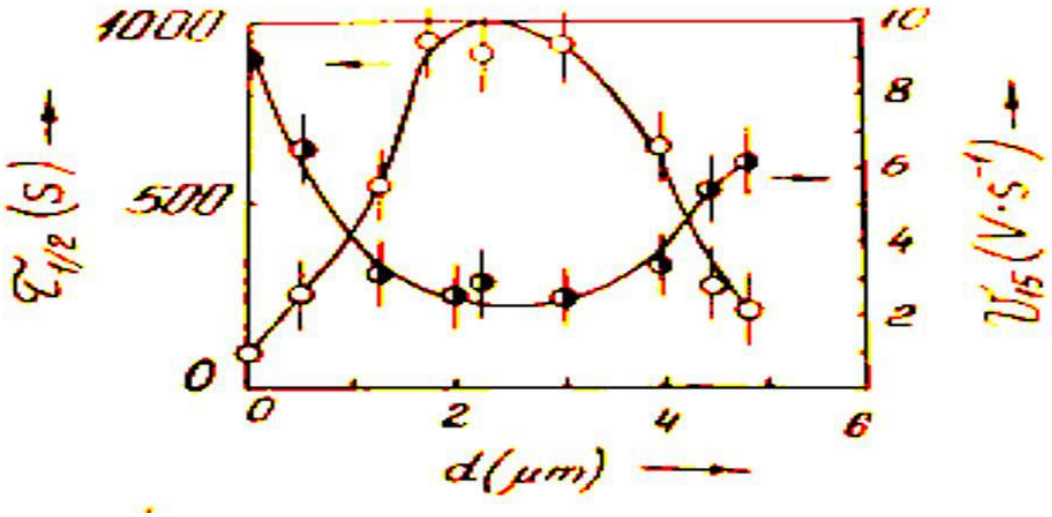

Fig.1. The dependence of dark drop time $\tau_{1/2}$ and relaxation rate of surface potential υ_{15} on d.

The barrier layer efficiency increases with d increase and this leads to increase of $\tau_{1/2}$ and decrease of υ_{15}. The further storage in the solution (t_{xo}>5min.) leads to undercutting of oxide film as a result of which the obtained films are porous ones with defect structure and dirty ones. As a result, the oxide film conditions worsen

and the efficiency of anti-injection barrier ($\tau_{1/2}$ decreases, υ_{15} increases) increases.

EL photosensitivity is defined by the quantity of incident quantums on layer unit of area per definite time, i.e. by exposition $H=L\tau_0$ (L is illumination, τ_0 is time of exposure). Note that near 20% light energy with λ=200-2500nm reflects from SEL [6]. The generally accepted technique of photosensitivity definition doesn't exist. Sometimes it is estimated by contrast of electric latent image, residual potential, semi-drop time of initial potential at the given exposure. Last time the photosensitivity in foreign literature is defined by the value of exposure supplying the drop of initial potential from 1000 up to 50V. S_{int} of investigated SEL defined by potential semi-drop in the dependence on d oxide film thickness, is shown in Fig.2.

The curve has the extremal character. S_{int}=0,66(Lx·sec)$^{-1}$ and it is observed at $d\simeq$ 3 μm. The further increase leads to strong decrease S_{int} up to 0,42 (Lx·sec)$^{-1}$.

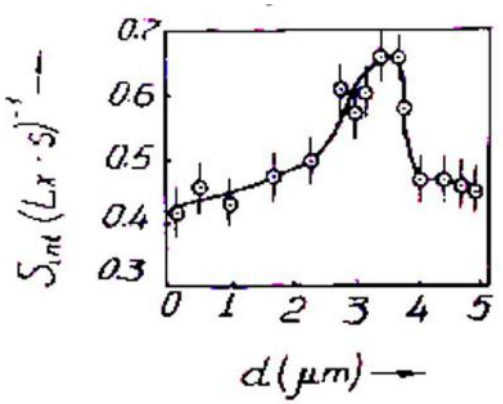

Fig.2. The dependence of S_{int} on d.

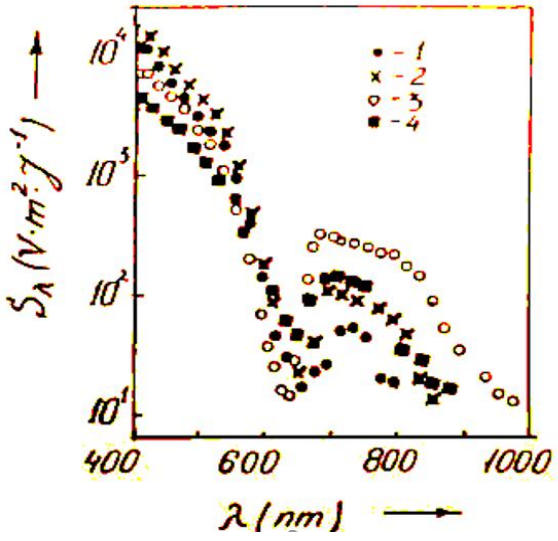

Fig.3. The spectral distribution of SEL photosensitivity at different thicknesses of oxide films.

The necessity of definition of S_{int} and S_λ of SEL under conditions corresponding to their work in the different systems appears very often. As exposure time in such conditions is given by system kinematics then for S_λ definition by semi-drop criterion it is necessary to give the illumination L_λ supplying this criterion at different λ. However, these conditions aren't correspond to exploitation ones that's why it is necessary to define the spectral distribution of photosensitivity SEL as $S_\lambda=\Delta u/L_\lambda\cdot\tau_0$ (Δu is contrast in V, L_λ in Vt/m^2, $\tau_0\simeq$1c for apparatus EP_300K2 at the given sizes of monochromator slot).

S_λ measurements of SEL with different oxide film thickness on substrate reveal the presence of two maximums: in blue (λ=410nm) and red (λ=710nm) spectrum regions (Fig.3).

The photosensitivity in blue region weakly changes with d increase whereas the photosensitivity in the red region changes significantly (≥5 times).

The exiton-like (bound) electron-hole couples in surficial photoreceptor region (in depth $\leq 1\mu m$) are generated at SEL exposure by strongly absorbed light ($\lambda\leq$410nm). The photosensitivity is defined by monopolar carrier drift and photoreceptor surficial region plays the dominating role, the nature of border region of photosemiconductor-substrate region isn't significant.

The electrons and holes excite from impurity layers in the thickness of amorphous selenium at illumination of SEL by weakly absorbed light (λ>650nm). The electrons drifting to layer surface (it is possible the electron attachment) neutralize the positive surface charge. The ionized donor centers and captured electrons create the volume charge leading the layer thickness efficiency corresponding to increase of capacity and finally to decrease of surface potential. The holes excited in amorphous selenium by weakly absorbed light drift to substrate and neutralize the negative compensating charge that also leads to decrease of surface potential in accompany of appearing volume charges taking under consideration the above-mentioned phenomena. Besides, the light with λ>650nm achieved the trigonal layer, excites the electron-hole couples. The holes drifting in the sublayer thickness (it is possible their attachment) neutralize the compensating charge. The electrons drifting in the amorphous selenium neutralize the surface charge. Also, it is possible the formation of volume charges, capacity change and etc. These phenomena cause SEL photosensitivity in red region. In order to avoid the volume charge accumulation in photoreceptor leading to fatigue effects it is charged in negative crown and lighted by white light before beginning of the following cycle charge-exposure. As SEL is complex multilayer system then for the explanation of extreme change of photosensitivity in red region on d it is necessary to take under consideration whole phenomenon diversity taking place in layer thickness and in border region to substrate.

The dependence of curve maximum of photosensitivity spectral distribution S_m of SEL in red region on oxide film thickness d is constructed. S_m achieves maximum value at $d\simeq$ 3μm. Such dependence of S_m on d can be caused by the following facts. The dense and qualitative oxide film which causes to formation of trigonal selenium sublayer homogeneous by phase and uniform on thickness, forms and this layer

defines S_m in the beginning oxidation process up to $d \simeq 3\mu m$. Simultaneously, the dense oxide film effectively prevents to carriers. The defects, labyrinths form in oxide film with further d increase. It enriches by impurities and it can inject carriers into layer. The sublayer of Se trigonal layer forming on such thin film also be heterogeneous, defect and dirty by different impurities. All this can lead to the decrease of photosensitivity, worsen the layer dark characteristics.

The transient relaxation phenomena leading to the stabilization of structures and parameters take place after 20 hours after evaporation of SEL. After long-term storage of SEL (6 months and more) in ordinary conditions and darkness the significant change of S_{int} and S_m aren't observed. It evidences about the fact that the existing changes of structures and properties in investigated SEL don't take place.

Thus, it is necessary to form the oxide film of $3\mu m$ thickness on substrate for achieving of optimal dark and light parameters of SEL.

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