Near the Surface Phenomena in Silver Azide Under the Condition of the Injection of its Own Charge Carriers [1]

V.Yu. Zakharov, V.I. Krasheninin, A.P. Rodzevitch

Kemerovo State University, Krasnaya str., 6, Kemerovo, 650043, Russia, E-mail: zakharov@kemsu.ru

Abstract – The present work shows that the decomposition processes in reactionary areas in whisker silver azide crystals when irradiated by fast electrons (the energy of the electron 0,15 MeV), by gamma-irradiation (the absorbed dose 0,135 MRad), by UV-irradiation and under the influence of the electric field (under the conditions of a monopolar injection of the holes) bring about the same results. One of the employed methods to study the decomposition processes was the method, developed in our laboratory, to estimate ambipolar drifting mobilities of the charge carriers both during, and after the action of the electric field. It was earlier expected that under the influence of the energy, the decomposition reaction in an anion sublattice becomes stationary. In our paper it is shown for the first time that during the action of the electric field in the reactionary areas, it is possible to observe the changes of an oscillatory nature in the electron-hole subsystem of the crystal.

Up to now silver azides (AgN_3) are used as an initiating explosive whose physical and chemical properties have been studied for more than half a century. So, crystals of this material are used in solid state chemistry as a model object. According to its electrophysical properties silver azide is considered as a p-type semiconductor. As was shown in the paper [1], when these crystals are affected by fast electrons (the energy of the electron 0,15 MeV), by gamma-irradiation (the absorbed dose 0,135 MRad) by UV-irradiation and by the electric field under the conditions of a monopolar injection of the holes, the decomposition is most intensive in certain "reactionary areas" (RA). In space, RA coincide with the emission of edge dislocations onto the surface of the crystals defined according to etching pits and they are located at the depth of not more than 5 mcm.

Traditionally, silver azide decomposition is studied by volumetric methods since the major product in an anion sublattice is molecular nitrogen which evolves from the external surface and is formed in terms of: $2\ N_3 \rightarrow 3N_2$ [2]. However, in RA, this process, due to the spatial restriction, stops at the stage of forming the intermediate product N_6 accompanied by energy evolution 3–4 eV, which is large enough for the reaction to occur in terms of the chain mechanism [3].

Usually, to study the decomposition process in an anion sublattice the Hill method is used [4]. According to it, the crystal after the energy exposure is placed into the dish with a solvent and the dissolution process is observed by means of a microscope. The decomposition degree is estimated relative to the volume of the gas evolved into the solvent (molecular nitrogen). The present authors [1] show that this method allows one only to identify the fact of the decomposition process but it does not give any information on its degree. Besides, after the end of the exposure, the specific volume of the gas depends on the time of its storage, while the kinetics of the change is of an oscillatory fading nature.

Besides, we used the whisker AgN_3 crystals with average sizes 1 x 0,01 x 0,003 cm^3, grown according to the method [5]. As a physical agent we used the electric field in the contact type (the contact material – gallium). 300 V was applied per one millimeter of inter-electrode space for 5 minutes. Then, the crystals after different time intervals were dissolved in the 0,38 N aqueous solution of sodium thiosulfate and the volume of the evolved gas was measured. The kinetics of the change of the relative volume of the evolved gas (the relative volume of the gas is the relation of the volume of the evolved gas (nitrogen) to the crystal area between the electrodes) is shown in Fig. 1.

Simultaneously, the mobility of the charge carriers was estimated by the method, which is analogous to the time-of-flight method [1]; the results of the experiment are submitted in Fig. 2. The mobility, as well as gas evolution, is of an oscillatory fading nature; however, the mobility is alternating in size.

The drift of the charge carriers is described within the framework of ambipolar mobility by $\mu = (n-p) / (n/\mu_p - p/\mu_n)$, (see, for instance, [6]), where μ_p, μ_n and p, n are the mobilities and the concentrations of the vacant holes and electrons, respectively. Thereby, the kinetics of the change of the relative volume of the gaseous product and the mobility allows us to assume the periodicity of the change of the correlation between vacant electrons and holes in RA.

How does the system under study behave when exposed to the electric field? To answer this question,

we used a different configuration of electric fields (the scheme of the experiment is submitted in Fig. 3). The electric field, initiating the decomposition process, was a transverse semicontact one (300 V/mm). Like in the previous experiment, the "pulling" electric field (the square-wave pulse, voltage 10 V, interelectrode space 1 cm, the duration of the pulse 2 msec) was applied in a noncontact type after some time after the exposition to a "degrading" electric field. Then the crystals were dissolved and the decentration of the

gaseous product masses from the decomposed part of the sample was valued. The kinetics of the change of the mobilities of the charge carriers is presented in Fig. 4. Let us note the coincidence of the periods of the dependencies obtained both during the influence of the electric field and after its withdrawal.

Hence, a simplified method, providing the information on the condition of an electron-hole subsystem in the "reactionary areas" under the decomposition of silver azide crystals was developed and used.
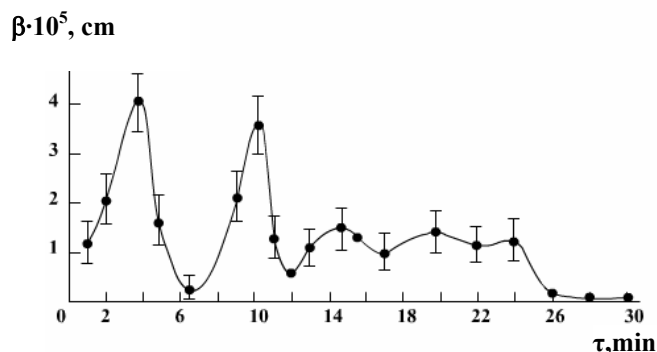
$\beta \cdot 10^5$, cm

Fig. 1. The relative volume value of the evolved gas β vs. the storage time of the AgN_3 crystal after the exposure to the electric field under the conditions of monopolar injection of the holes
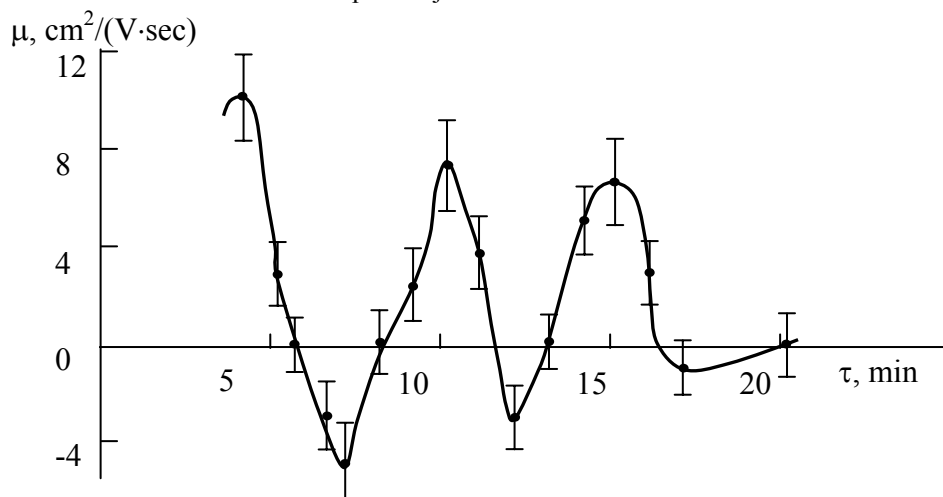
μ, cm^2/(V·sec)

Fig. 2. The mobilities of the charge carriers vs. the storage time of the samples after their exposition to the constant electric field under the conditions of monopolar injection of the holes (for AgN_3)
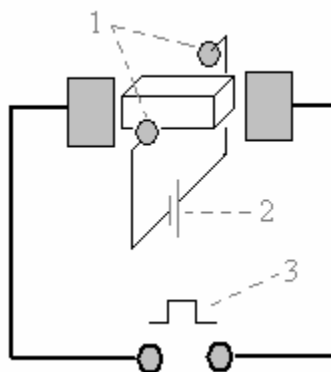

Fig. 3. The scheme of the experiment: 1 – gallium contacts, 2 – the source of the direct current, 3 – the generator of the square-wave pulse
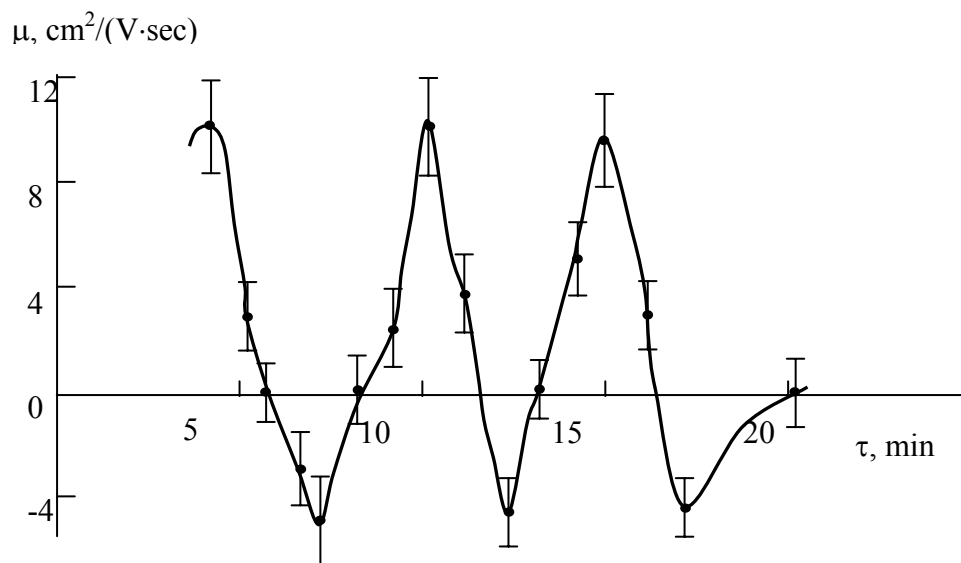
μ, cm^2/(V·sec)

Fig. 4. The mobilities of the charge carriers vs. the storage time of the samples after their exposition to the transverse semicontact electric field (for AgN$_3$)

References

[1] V.Yu. Zakharov, V.I. Krasheninin, *Slow decomposition of silver and lead azides,* Tomsk, NTL Publishing House, 2006, 168 p.

[2] F. Bouden, A. Joffe, *Fast reactions in solids,* Moscow, Inostrannaya Literatura, 1962. 243 p.

[3] V.Yu. Zakharov, E.D. Aluker, B.P. Aduev, G.M. Belokurov, A.G. Krechetov, *Preexplosive phenomena in heavy metal azides,* Moscow, "Chimmash", 2002, 115 p.

[4] H.G. Heal, *A microgazomeiricprocedure,* Nature, 1953, V. 172, 30 p.

[5] F.I.Ivanov, L.B. Zuev, M.A.Lukin, V.D. Mal'tsev, *On growing the whisker crystals of lead and silver azides.* Crystallography, 1983, V. 28, № 1, 194–196 p.

[6] V.L.Bonch-Bruevich, S.G.Kalashnikov, *Physics of semiconductors,* Moscow, Nauka, 1977, 672 p.