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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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ON THE STRUCTURE AND DIMENSIONS OF SENSITIVITY CENTERS AND DEVELOPMENT CENTERS OF HIGH-SENSITIVITY NUCLEAR EMULSIONS OF TYPE P

(Presented by Academician I. K. Kikoin, February 26, 1962)

This work is an attempt at an experimental investigation of the dimensions and structure of sensitivity centers and development centers in nuclear emulsions of type P. The work used emulsion layers 400 μ thick, without a backing, manufactured by the Technical Photographic Plates Plant. The investigation was carried out by the method of controlled dissolution of the atomic silver of the traps. In setting up the experiments, the results of work (^{1}) were used, in which it was shown that the atomic silver of development centers dissolves in dilute acids, and that the dissolution rate depends on the acid concentration and the treatment temperature. As a parameter characterizing the degree of action of the dilute acid on sensitivity and on the latent image, the density of clumps in the tracks of relativistic particles was chosen. In interpreting the experimental results, the basic propositions of the theory of Gurney and Mott (^{2}) and of works (^{3}) were used, in which the applicability of the Gurney-Mott theory to explaining the mechanism of formation of the latent image upon irradiation of an emulsion by charged particles was shown.

Fig. 1. Dependence of the track density of fast electrons on the acid concentration. Irradiation after 2-hour treatment with H_2SO_4 and HNO_3

In the first series of experiments, the action of dilute acids on the sensitivity of the emulsion to relativistic particles was studied. For this purpose, unirradiated emulsion layers were treated in acid solutions of different concentration for various times. After acid treatment, the emulsions were washed for 12 hours and then kept for a long time in distilled water at pH 7. Together with the emulsion layers under study, control layers that had not been subjected to acid treatment were also kept in water.

Irradiation of the investigated and control layers was carried out in water simultaneously by a source of γ-quanta producing fast electrons in the emulsion.

Fig. 2. Dependence of the density of tracks of fast electrons on treatment time. Irradiation after treatment with H_2SO_4, HNO_3, HCl (pH = 1). K –control.

Figure 2: Fig. 2. Dependence of the density of tracks of fast electrons on treatment time. Irradiation after treatment with H_2SO_4, HNO_3, HCl (pH = 1). K –control.

Development was performed with an amidol developer by the isothermal method described in work (^{4}).

The results of measurements of track density as a function of acid concentration at a constant treatment time (2 hours) are given in Fig. 1. In this experiment, the density of clumps in the control layers was 25 per 100 μ. From the course of the curve it follows that at high pH (up to pH 3) the density of clumps, and consequently the sensitivity of the emulsion, does not change and practically coincides with the control. The effect of disappearance of clumps begins to appear noticeably at pH $\simeq 2$. At pH 1 the track density falls to 18 clumps per 100 μ.

Figure 2 presents data on the sensitivity of an emulsion treated with acid at pH 1 for different lengths of time. The experiment showed that the density of clumps in the tracks of fast electrons drops sharply from 20 clumps per 100 μ in the control layers to 14 within the first 15 min (the minimum time required for the layer to be impregnated with the acid solution), and then remains practically constant even for long treatment times (up to 6 h).

Since all emulsion grains, including those forming the track of a relativistic particle, are in identical conditions with respect to the solvent–a weak acid solution (the treatment times are long compared with the time for acid diffusion in the layer)–the character of the dependence of emulsion sensitivity on the degree of treatment of the layers with the acid solution makes it possible to draw certain conclusions about the nature of the sensitivity centers in a relativistic emulsion of type P. Indeed, experiments have shown that at sufficiently high acid concentrations, sufficient to dissolve the atomic silver of the sensitivity centers in a reasonable time, the sensitivity of the emulsion decreases; however, even with prolonged acid treatment at pH 1, the decrease in sensitivity amounts to no more than 30% of the nominal value.

Fig. 2. Dependence of the density of tracks of fast electrons on treatment time. Irradiation after treatment with H_2SO_4, HNO_3, HCl (pH = 1).
K –control.

This kind of stability of the greater part of the sensitive grains of the emulsion can be explained by the fact that, in the process of chemical ripening and gold sensitization, about 70% of the grains undergo such "gilding" of the sensitivity centers that it leads to their absolute stability with respect to the action of acids. It is possible that silver sulfide is also present in the stable part of the center. The 30% of grains that lose their sensitivity upon acid treatment apparently have

Figure 3

Figure 3: Figure 3

sensitivity centers consisting mainly of atomic silver. If, in further study, the interpretation of the experimental data given here is confirmed, the possibility is not excluded of using the observed effect not only to eliminate the greater part of the photographic fog—whose source is mainly grains possessing silver sensitivity centers—but also to obtain a noticeable increase in the developed density of the tracks of relativistic particles.

In the second series of experiments, the action of diluted acids on the latent-image centers formed in emulsion layers by relativistic particles was investigated. In this case, electrons, protons with an energy of 8.6 BeV (synchrophasotron in Dubna), and relativistic μ-mesons of cosmic radiation were used as the fast particles.

The irradiated emulsion layers were kept for different lengths of time in diluted acids with pH < 7. After acid treatment the layers were thoroughly washed and then, together with the control layers, kept for a long time in distilled water at pH 7. Development and the subsequent photographic processing of the investigated and control layers were carried out simultaneously.

Figure 3 shows the dependence of the density of clumps in the tracks of relativistic particles on the acid concentration for a constant treatment time (2 h). At pH ≥ 3, the track density practically coincides with the control (in this series of experiments, 25 clumps per 100 μ). With a further increase in the acid concentration, the track density decreases rather sharply and at pH 1 is only 10 clumps per 100 μ—the minimal

track density that is measurable. From the course of the curve one may expect that a decrease in track density would also occur further on.

In Fig. 3, for comparison, the curve of Fig. 1 is shown by a dashed line —the same dependence, but with treatment of the emulsion with acid before irradiation. From the course of the curves it follows that dissolution of the atomic silver of the development centers and of the sensitivity centers begins at approximately the same acid concentration, pH ≤ 3. Subsequently, however, as the concentration is increased, the curves diverge sharply, which unambiguously indicates a substantial difference in the nature of the centers: the atomic silver of the latent-image center can be dissolved completely, which leads to the loss by the grain of its ability to be developed, whereas a large part of the sensitivity center is not dissolved in acid.

Fig. 3. Dependence of the track density of fast electrons on the acid concentration.
a—2-hour treatment with H_2SO_4 and HNO_3 after irradiation; **b**—irradiation after 2-hour treatment with H_2SO_4 and HNO_3.

Figure 4

Figure 4: Figure 4

The results of measurements of the track density of relativistic particles at a constant acid concentration, pH 2, as a function of the treatment time of the irradiated emulsions are shown in Fig. 4. In this case a gradual decrease in track density, extended in time, was observed from 25 (in the control) to 11 clumps per 100 μ. Unfortunately, the subsequent behavior of the track density cannot be traced.

The rapid fall of track density at comparatively short dissolution times indicates the presence of a large number of grains (approximately one third) in which the number of silver atoms in the latent-image centers exceeds only very slightly the minimum required for development. With increasing dissolution time, however, the rate of change of the track density decreases sharply. From the course of the curve at long dissolution times it is seen that no less than 25–30% of the grains have development centers that do not dissolve even for treatment times of several tens of hours. It is natural to suppose that, when the treatment time is increased by an order of magnitude, the number of silver atoms in the development center also increases, if not by an order of magnitude, then at least severalfold. These considerations make it possible to assert that the latent-image centers that arise when a relativistic particle passes through emulsion grains differ sharply from one another in the amount of atomic silver formed in them.

Fig. 4. Dependence of the track density of fast electrons on the treatment time. Irradiation before treatment; acid pH equals 2. **a**—H_2SO_4; **b**—HNO_3; **c**—HCl.

One may attempt to estimate the absolute amount of atomic silver in the latent-image centers. In emulsions of type *P* there is undoubtedly a noticeable number of grains with silver sensitivity centers (see above). Taking the average number of silver atoms in such a center to be 2–3, for the minimum number of atoms necessary in the development center of a track ⋯

⋯makes it possible to choose a number of ~ 10 (5). Since some of the electrons produced in the grain by the charged particle are expended ineffectively, being captured by both internal and surface traps that do not reach the sizes of development centers, a loss of energy of 150–200 eV per grain corresponds to a number of atoms ~ 10 in one center (assuming that about 6 eV is expended on the formation of one electron), which is close to the mean energy loss. This does not exclude the possibility that a developable grain may be formed when only 60–80 eV per microcrystal is released. On the other hand, fluctuations in the ionization losses of relativistic particles (6) lead to the release, in a single grain, of substantially greater energy (up to 5 keV). In this case a development center containing several hundred silver atoms may form in the grain. The experimental data obtained in the present work on the dissolution of development centers indicate that, along with grains in which the minimum and mean amounts of energy are released, the tracks of relativistic particles contain, in appreciable quantity (~ 30%), grains corresponding to large energy losses.

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Note: Figure translations are in progress. See original paper for figures.