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Abstract

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PHYSICS

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ON THE POSSIBILITY OF CHANGING THE SENSITIVITY OF AN EMULSION DURING ITS IRRADIATION

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

The ability of photographic emulsions to continuously accumulate tracks of charged particles from the initial moment of existence of the photographic layer is usually regarded as a positive property of the emulsion. However, in a number of physical experiments this feature is the principal drawback of the photographic method of investigation. Very often the background of particle tracks is comparable with the effect of the experiment and does not permit its result to be interpreted correctly. In cases where an experiment continues for a long time, it is impossible to relate the observed phenomenon to any definite time.

The creation of controllable processes of particle registration in photographic emulsions by means of an external signal would transform the photographic method and would substantially increase its significance. The present investigation is devoted to one of the possible methods of controlling the sensitivity of an emulsion—irradiation in the presence of free hydrogen ions.

According to the Gurney-Mott theory, the process of formation of the latent image consists in the liberation of electrons and their subsequent capture and neutralization in a trap—the sensitivity center of an AgBr crystal—by positively charged Ag^+ ions. It may be assumed that the presence of free H^+ ions at the site of electron neutralization and the competition of H^+ ions with Ag^+ ions for electron capture should lead to a decrease in the sensitivity of the emulsion when irradiation is carried out in the presence of free H^+ ions.

For the experiments an unsupported type P emulsion of thickness 400 μ was used. Irradiation was carried out with a Po—Be source of γ-quanta and neutrons. In the layers, tracks of electrons of various energies and tracks of recoil protons of low energies (up to 12–15 MeV) were recorded. For measurements, tracks of recoil protons of length not less than 500 μ ($E \sim 10$ MeV), lying in the plane of the emulsion, and tracks of relativistic electrons were selected. In proton

Figure 1

Figure 1: Figure 1

tracks the total number of grain conglomerates over a given length of path was counted, starting from the end of the track. In the tracks of relativistic particles the track density was determined, i.e., the number of grains per 100 μ of path in the emulsion.

Before irradiation the layers were immersed in solutions of various acids having pH values from 1 to 5. Layers irradiated in a very weak KOH solution, whose pH was equal to 7, served as controls. In some cases the layers were irradiated at very high pH values (up to 10*). Irradiation of the emulsion began one hour after the layers had been immersed in the solutions, so that the layers had time to swell completely. During irradiation the layers continued to remain in the solutions for 1 hour, and the source was placed in such a way that all the layers were under identical geometric–

* In this case, to obtain high pH values a KOH solution (pH 10) and a triethanolamine solution were used. It is interesting to note that when the emulsion is irradiated in a TEA solution and in a KOH solution, no increase in sensitivity is observed. It follows from this that the increase in the sensitivity of the emulsion during treatment with TEA and KOH, observed upon irradiation after drying the emulsion, is connected not with the presence of free $[OH]^-$ ions, but with specific reactions on the surface of the microcrystal.

under identical conditions relative to it. After irradiation, the layers were thoroughly washed, kept for 12 hours at pH 7, and then developed simultaneously.

Fig. 1. **A**–dependence of the total number of grain conglomerates for protons of different energies on the pH of the solution in which irradiation takes place. **B**–results of measuring the total number of grain conglomerates in emulsions subjected to acid treatments at all pH values (2 hours), washed, and irradiated at pH 7.
1 –E = 9.5 MeV; 2 –8.5 MeV; 3 –7.6 MeV; 4 –5.5 MeV; 5 –3.5 MeV

Fig. 1 gives the results of measurements of the total number of grain conglomerates for different proton energies as a function of the pH of the solution in which irradiation took place.

Up to pH 3, the track density of both protons and electrons remains constant within the limits of measurement error and depends neither on the nature of the acid nor on the pH of the solution. When the pH is changed from 3 to 2, a sharp drop in track density is observed. As the proton energy decreases, i.e., as its ionizing ability increases, the decrease in density is less pronounced. The tracks of relativistic particles at these pH values are not registered in emulsions at all.

In the second series of experiments the same emulsion was irradiated on a syn-

Figure 2

Figure 2: Figure 2

chrophasotron (in Dubna) with a proton beam of energy 8.6 BeV and, after irradiation, was treated with solutions of sulfuric and nitric acids at various pH values and then washed and developed.

Fig. 2 presents the results of this experiment. It follows from the curve that, for a treatment time of 2 hours, i.e., the same time for which the emulsions were kept in acids in the preceding experiments, down to pH 2 no noticeable decrease in the density of relativistic tracks is observed, while between pH 2 and pH 1 the density and number of relativistic tracks drop catastrophically.

Measurements of the density of tracks of protons from nuclear disintegrations, carried out over a sufficiently long range in the same emulsions, showed that such tracks are preserved when the latent image is treated with acid solutions having a pH equal to one.

Fig. 2. Dependence of the density ρ ($E = 8.6$ BeV) on acid concentration; irradiation before treatment. Treatment time: 2 hours

In the third series of experiments, layers irradiated by a source were subjected to acid treatment. Measurement of the density of recoil-proton tracks showed that in this case as well no change in density is observed down to pH 2. At pH 1 a decrease in density of about 10% is observed.

The decrease in track density during processing of the latent image with acid solutions was attributed to dissolution of the atomic silver of development centers; this process was subjected to detailed study, the results of which are given in work ([1]).

Thus, it may be regarded as established that the decrease in the sensitivity of the emulsion is due to the presence of free H^+ ions and arises only in the case when the concentration of hydrogen ions reaches a certain value. With a further increase in concentration, no noticeable decrease in sensitivity occurs.

If the emulsion is washed free of acid before irradiation and its pH is brought to 7, then the sensitivity to low-energy protons is fully restored, while the sensitivity to relativistic particles decreases only slightly ([1]).

A pH value of 3 in our experiments corresponds to the presence of $\sim 2.5 \cdot 10^4$ H^+ ions in the swollen gelatin shell around each microcrystal of the emulsion; when the pH is changed to 2, the number of ions increases to $\sim 2.5 \cdot 10^5$. This approximate calculation shows that, for a noticeable reduction in sensitivity, a very large number of free hydrogen ions is required, many times greater than is needed for the formation of an electric monolayer on the surface of a silver halide microcrystal.

The reversible decrease in the sensitivity of the emulsion in the presence of hydrogen ions is attributed to competition for electron capture between Ag^+ ions and mobile free H^+ ions during formation of the latent image. The irreversible decrease in sensitivity, negligible for emulsions sensitized with gold and varying depending on the degree of dissolution of the atomic silver of the traps for nonsensitized emulsions, must be attributed to dissolution of atomic silver in acids*.

Thus, by changing the concentration of hydrogen ions in the emulsion layers during irradiation of the emulsion, one can change the sensitivity, decreasing and increasing it within very substantial limits. In doing so, it is necessary to take into account the possible dissolution of the atomic silver of the sensitivity centers and development centers.

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CITED LITERATURE

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* Direct experiments by A. I. Rabinovich and Kh. S. Bagdasar' yan showed that hydrogen ions are practically not adsorbed on the surface of a silver halide microcrystal ([2]).

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