THE PROPERTIES OF FINE-GRAINED NUCLEAR EMULSION TYPE PR-2

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Introduction

In conducting physical investigations, the need often arises for nuclear emulsions possessing both a high dispersity of microcrystals, for a more precise determination of the nature and energy of particles, and a high sensitivity of individual emulsion crystals which permits to record tracks of relativistic singly-charged particles with a rather great density of grains. A higher initial density of grains in the tracks of particles in essential in the case of a long exposure of photographic layers, particularly at low temperatures or whenever there is a considerable interval between the irradiation and the development of a layer, when the density of grains after the development is I.5 to 2 times lower. Moreover, a higher density of grains in the tracks of particles with minimum ionization is necessary for increasing the efficiency of recording such particles when tracing along the track, for improving the conditions of tracing by means of instruments operating without an observer, as well as for increasing the precision of measuring specific losses of energy in the range of netrarelativistic particles.

The super fine-grained nuclear emulsion PR, formerly elaborated by us, combines all the above-mentioned properties.

A higher sensitivity of this type of emulsion, however, may be achieved by additional hypersensitization in triethanolamine (I). In some instances it may appear necessary to exclude the hypersensitization stage, e.g. when using stacks of pellicles or because such layers do not withstand long storage, as well as on account of the difficulties arising in the hypersensitization of backless layers directly before their irradiation.

In recent years a fine-grained emulsion type PR-2 (2) has been elaborated by us which permits to obtain, as compared to the existing kinds of nuclear photoemulsions, a higher density of grains in the case of relativistic particles, without additional hypersensitization with triethanolamine prior to irradiation.

This emulsion is used not only in solving different problems of nuclear physics, but also in contrast and track autoradiography. At the present time the emulsion is likewise made use of in electronomicroscopic autoradiography.

The synthesis of the emulsion is accomplished on the basis of the method, previously worked out by us, of double-jet slow emulsification in the excess of silver ions with constant potentiometric control over the concentration of the ions in the course of emulsification and first ripening of the emulsion (I,3). The activation of the emulsion is accomplished by gold sensitization alone.

The higher density of grains in the tracks of the emulsion was obtained not only through different additions and technological changes in the manufacturing process, but also due to the use of a special pyrogallol-amidol developer.

Photographic processing of PR-2 nuclear emulsion

In the course of research and selection of developers for the processing of type PR-2 photographic emulsion tests were made with the "levelling" developers with phenidon, as well as a series of quick-acting developers containing high concentrations of such developing substances as pyrocatechol, pyrogallol or amidol. The contents of the developers used by us in this case are generally widely employed in developing photosensitive materials.

The best results were obtained with the pyrogallol-amidol developer used for the quick processing of photosensitive materials (4). In the formula of this developer, soda was substituted by borax, which to a certain degree lowered the pH and increased the life of the developer 400 µ backless layers were tested during the investigations. A comparison of the effect of the pyrogallol-amidol developer and of the methol-hydroquinone (ID-I9) and amidol developers most widely used in nuclear photography, is represented in Table I.

Table I. Results of developing backless layers in different developers

Item No.	Type of emulsion layer	Developer	Nэ -grain density in tracks of relativistic electrons (I/I00 μ)	N ф -fog back-ground (I/I0^{-9} cm^{3})	Relative disper-sion of grain density %
I	PR-2 - 400 μ	Methol-hydro-quinone (ID-I9)	3I ± I.7	2.5	35.5
2	PR-2 - 400 μ	Amidol (NIKFI)	34 ± I.8	2.4	27.5
3	PR-2 - 400 μ	Pyrogallol amidol with borax	42 ± 2	2.3	25.5
4	M-NIKFI	Amidol NIKFI	29 ± I.7	2.4	3.8

It will be seen from the table and the drawing that the development of nuclear photolayers in the pyrogallol-amidol developer ensures better recording properties than in the methol-hydroquinone or amidol developers. With the development of fine-grained emulsion in the pyrogallol-amidol developer the density of grains in the tracks of relativistic electrons rises approximately by 25 %, the fog value remaining unchanged.

Electronic microscope investigations showed that in case of the development in both the ID-I9 and the pyrogallol-amidol developers the shape and the structure of the developed grains were identical. There is, however, some difference in the duration of the induction period (shorter for the pyrogallol-amidol developer in the case of β - particles).

Contents of pyrogallol-amidol developer

Distilled water	- 700 ml at 50°C
Sodium sulphite anh.	- 37 g
Amidol	- 2 g
Pyrogallol	- 25 g
Borax	- 50 g
KB q	- 3 g
Water to make	- 1000 ml

Before developing nuclear photolayers, the pyrogallol-amidol developer should be allowed to age for 24 hours. The development in freshly-prepared developer would lead to a heavy fogging of the layers. The use of the developer kept over 48 hours is not recommended since in this case there would be a considerable decrease of the density in the tracks of relativistic electrons. The optimum conditions for processing nuclear photolayers of the PR-2 emulsion are represented in Table 2.

The fixing, washing, plasticizing, drying in alcohol solutions and sticking of backless 400 μ photolayers before and after processing are done according to the NIKFI technique for backless layers of type R-NIKFI (5).

Emulsion properties

Mean diameter of developed grains in tracks of relativistic electrons 0,36 μ.

Table 2. Development of the PR2 emulsion photolayers in the pyrogallol - amidol developer

Item No.	Photolayer thickness μ	Photolayer characteristics	Impregnation in distilled water	Impregnation in developer (0-2°C)		Development at I8-I8.5°C		Stop bath (2-5°C)	Fixation at 5-6°C			Washing in water
			duration minutes	dilution in water	duration minutes	dilution in water developer / water	duration minutes	concentration of acetic acid solution	duration minutes	concentration of sodium thiosulphate solution %	duration hours	duration hours
I	2	3	4	5	6	7	8	9	I0	II	I2	I3
I	400	Plates and backless layer stuck on glass	I20	Concentrated	I20	I:2	30	0.5	I20	20 with bisulphite	48	48
2	400	Backless layer, unstuck	60	ditto	60	ditto	ditto	ditto	60	ditto	I8	Up to and over 20
3	200	Plates	60	ditto	60	ditto	ditto	I	50	ditto	ditto	ditto
4	I00	Plates	-	ditto	30	ditto	30	I	20	30-40	4	4
5	50	Plates	-	-	-	ditto	20	I	I0	30-40	I	I
	20 and less	Plates and speciments for electronic microscope	-	-	-	ditto	I0 and less	0.5	I0	30-40	0.5 and less	0.5 and less

Mean density of developed crystals in tracks of relativistic electrons 40 ± 5.

Number of aggregates in 10^{-7} cm^3 3

Number of fog grains in 10^{-9} cm^3 .... up to 66.... 5

Teble 3 represents a comparison of the properties of type PR-2 nuclear emulsions and of some other most widely used relativistic photolayers.

Comparative studies of the discrimination of B^{10} and C^{12} ions in various types of emulsions (6) have shown that the use of type PR-2 emulsion as well as of the previously elaborated by us type PR- emulsion, hypersensitized in the 6 per cent solution of triethanolamine, secures good identification of multiply charged particles of various nature,

Table 3. Characteristics of modern nuclear photoemulsions

Item No.	Type of emulsion	Mean diameter of microcrystals μ	Content in dry layer	Sensitivity to electrons, grain density / 100 μ	Fluctuations in density, %
1	PR-2 -plates	0.12	83	48	24
2	PR-2 -layers	0.12	73	42	25.5
3	PR	0.08	83	55	20
4	P-NIKFI	0.28	83	24	54
5	M-NIKFI	0.14	-	30	38
6	G-5	0.30	84	24.0	34.5
7	L-4	0.16	-	25	45

Irradiated layer of PR-2 emulsion, kept at room temperature for 7 days, shows a 20 % decrease in the density of grains in the tracks of relativisitic electrons. The keeping of an irradiated layer for 45 days brings about, as a result of latent image regression, a 45 % decrease in the density of grains in the tracks after the development.

The PR-2 emulsion has adequate sensitivity-retaining characteristics. If solidly packed, the photolayer may be kept in a refrigerator for 4 months, undergoing practically no changes of sensitivity and fog. After the PR-2 emulsion has been kept under such conditions for a year, the sensitivity of the layer decreases approximately by 30 %. However, due to the high initial density the emulsion would still possess relativistic sensitivity and, in spite of a substantial background of cosmic particles, could be used for some purposes, since in that case the tracks of background particles consist of finer grains.

In follows from the above that the high initial density of grains in the tracks of relativistic particles for the PR-2 emulsion, the posibility of a long interval between irradiation and development, as well as the high preservation characteristics of the photolayers, all this makes it possible to obtain satisfactory results even in case of unforeseen deviations from the conditions of experiment and processing and, in some cases, to use the emulsions even after the expiration of the term of guarantee.

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