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REVERSAL FILM DEVELOPMENT FOR STREAMER CHAMBER TRACK PHOTOGRAPHS

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1. INTRODUCTION

The primary physical results of streamer chamber film processing like particle impulse and ionization information depend on the quality parameters of photographic recording of streamer track information. There are special conditions of image recording and image processing of streamer chamber films like streamer image intensity jitter, flares in the chamber and the demand to easy discrimination of the streamer image. To optimize the information gain from streamer chamber pictures we intend to match the photographic process to these special conditions, whereby a high sensitivity, good rendering of details and a low noise level have to be reached.

2. STREAMER CHAMBER TRACK PHOTOGRAPHY

2.1. Photographic Recording of Particle Tracks in Streamer Chambers

The streamer chamber is an optical track chamber working on the principle of gaseous discharge. Particle impulse and information on the ionization of the charged particles are the primary physical results from streamer chamber photographs of a magnet spectrometer (i.e., RISK[1]), where the impulse is gained from the track geometry. In refs.[2,3] streamer production and the principle of measurement in streamer chambers are discussed. Streamers are small cylindrical gas discharges whose emitted photon number corresponds approximately to the sensitivity of high speed films. Therefore the whole photographical system consisting of camera, photographic film, film processing and image processing influences the physical result. Evaluations of the quality of the optical systems of the spectrometer RISK are referred in papers[4,5]. In the case of measuring primary ionization the application of electro-optical image intensifiers is necessary. In ref.[6] the results of investigations on image intensifiers and the mechanical-optical interaction of image intensifier and photographic film in streamer chamber photography are given.

2.2. Photographic Exposure Conditions in Streamer Chambers

Streamers are originated in the streamer chamber under the influence of an electrical field of 15-20 kV/cm applied nearly 5 ns from an avalanche discharge. Its dimensions, radiance, emitted energy and spectral distribution depend on the mixture and pressure of the chamber gas, the properties of the applied electrical pulse and the delay time between the signal of the particle trigger and the application of the high voltage. For the spectrometer RISK we assume a gas mixture of 50% helium, 50% neon, streamers of 10 mm length and 1 mm diameter and a mean radiance of $2 \cdot 10^{-4}$ erg/(mm^{2}s·sr). The radiance fluctuates within the tracks and depending on the voltage jitter by two orders of magnitude. The utilization of two stage intensifiers on the spectrometer RISK is necessary because the provided measuring of primary ionization requires the nearly complete registration of the streamers and a f-number 5.6 has to be used because of the large chamber depth (80 cm). Though using image intensifiers the utilization of high sensitive films for example ORWO N27 (27°DIN) is necessary. The resolving power on the film amounts to approximately 20 lp/mm. The streamer image intensity depends furthermore strongly on the distance of optical axis of the electrostatic-focused image intensifiers and on the defocusion.

2.3. Resulting Aims to Photographic Recording Process

Taking into account the conditions and aims of the streamer chamber method we can summarize some aims to the photographic process. First, the sensitivity of the speedy film has to be completely expropriated to realize the demand all streamers are to be registered. The streamer images are to be suitable for the processing on all ordinary measuring and scan devices (HPD, SOLAS, HEVAS, AELT-2) to obtain geometry and ionization information.

Therefore it is necessary that a sufficient image contrast (high modulation transfer from 1...30 lp/mm) and signal-to-noise ratio are given. The image background caused by scattering light, detector noise, film grain, amplifier noise as well as fog are to be minimized. The images of intensive flares in the streamer chamber are to be suppressed. The dependence of streamer image density is to keep small against variation of the streamer image intensity which amounts generally to a range of 10^3. In the case of measuring the primary ionization by track photometry the recognition of the streamer images and the discrimination of streamers and gaps is very difficult if the transmittance of the streamers varies. Streamer image

diameter and the gap length have to depend slightly on the variation of the streamer image intensity. This demand follows from the latter and from the limited resolution. The transmittance distribution of the streamer image is bell-shaped. Therefore the streamer image diameter increases generally with increasing image intensity (and usually density). That is why one should try to make the streamer image transmittance independent of the image intensity.

Because of the variations of the image intensity it is necessary to obtain an exposure latitude of $10^2 \ldots 10^3$.Within this range resolution, modulation transfer and granularity should have only a small variation.

The shape of the characteristic curve is then ideal for application on streamer chambers if the density jumps nearly the exposure corresponding to the ultimate sensitivity on a certain, not very high value (i.e., $D = 0.6 \ldots 0.8$) and does not vary for increasing exposure (similar a step-function).

The development of the streamer chamber films of the spectrometer RISK will take place on a cinefilm processing machine. Therefore the developer composition and developing conditions have to be matched to machine conditions.

3. REALIZATION OF THE PHOTOGRAPHIC PROCESS REQUESTED

To meet these demands in a photographic process it is necessary to take into consideration this process as a whole, consisting in the formation of the latent image and the building up of the photographic density by development. The first one primary depends on the photographic material used, and so sensitivity and consequently the size of the silver grains of the ready silver image will be decided on it. The quality of the silver image given by its density, its characteristic curve, its resolving power a.s.o. can be affected by processing considerably.

3.1. The Film Material

Because one of the most important demands to obtain a very high sensitivity cannot only be caused by processing, we started from NP7 respectively BV 2 ORWO (22° DIN) films. For final experiments NP 7 was used only by practical reason. It must be pointed out, that just the peculiarity of these materials is quite opposite to the realization of the other desirable qualities of the image, like a characteristic curve with high γ or detail rendering as much as possible independent of exposure.

3.2. Photographic Processing

3.2.1. Development

To approximate the characteristic curve to a step-function a developer has to be found obtaining a high contrast without decreasing the sensitivity. With formula (1) the sensitivity was nearly duplicated in comparison with the information of the establishment. With it first of all the toe of the curve was lifted while an extended top and therefore an extended exposure latitude (more than three powers) with maximum densities of three resulted.

3.2.2. Limiting the Maximum Density

There are different possibilities to limit the maximum density and with it the too large exposure latitude. It would be a good chance to restrain the development by an autocatalytic reaction, known from compensating developers and from tanning development. This method has the pull, that simultaneous the so-called micro-characteristic curve is made more steep so that the spreading of the streamers caused by scattering of light within the layer will be restrained.

The second possibility is to reduce the whole quantity of AgBr available to form the maximum density either from the outset or during processing. When the film with its fixed content of AgBr is given, AgBr can be partially solved before or during development. Dissolving the AgBr before development it is necessary to stabilize the germs of the latent image by a pre-development, by baths of noble metals or by latensification to prevent a loss of sensitivity. Fixing developers are doing this stabilization simultaneous to the developing reaction. So they should be the most similar means for limiting the maximum density as requested. However the loss of sensitivity nevertheless occurring is too great (2...3 DIN). A suitable practice basing on this method has to be balanced carefully with the film employed and the processes of solving, stabilizing and developing. One of a technic discovered should be informed, with which a constant value of D_{max} could be maintained about more than 3 powers of exposure. The gradient of this curve will be one and the sensitivity of the optimal negative development is not decreased.

After exposure a short pre-development in a surface developer (formula (2)) occurs, followed by partially dissolving in the solvent (formula (3)) for ca 15 sec. After washing thoroughly the actual development takes place in the developer formula 1. Increasing temperature from 20° C to 30°C even an additional increase of sensitivity to 30...32 DIN is possible.

3.2.3. The Reversal Process

Though the quality of the photographic receiver requested is maintained by this practice, another technic will give much more reliable results and will be less sickly to troubles. This is the reversal development, where by developing done twice a positive arises. The streamer appears clear on the black ground. In this process the final picture originates from AgBr grains of the second development, which were not exposed by exposing the object. These are the less sensitive grains and with it the smallest grains of the layer. Considering the wide grain size distribution of high sensitive emulsions this reversal image is much more fine-grained than the corresponding negative image.

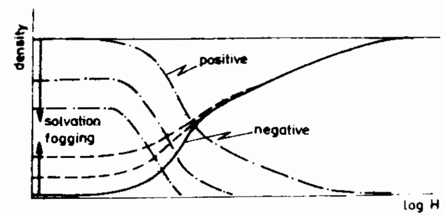
Moreover by building up the image twice, the limiting of the maximum and minimum density and their keeping on a constant value are easier to govern.

Reversal development is done in the following way:

1. First exposure: The object is copied to the layer;
2. First development: The negative silver image arises;
3. This silver image is bleached and washed;
4. Second development: The positive image is built up.

The diagram (fig.1) showing the negative and positive curve of the reversal process illustrates that the limiting of D_{max} is possible in two ways. Either the fog of the first development is increased or before building up the reversal image the amount of the remainded AgBr is decreased. The first method results in a flat characteristic curve with a very low gradient at the top of the curve. With it parts of the sensitivity obtained by the first development are given away. Compared to it the characteristic curve obtained by the second method keeps the gradient at the top and at the toe and no sensitivity is lost. In praxis of course the constructed positive curve is not obtained exactly. Additional factors take

Fig.1. Creation of reversal characteristic curve by influence of fogging and solvation. H - irradiation, relative, D-density, relative.



part. For instance the velocity of solution is not constant for all parts of the image. It depends on the amount of the first image and tanning of the gelatin during the bleaching of the first silver image causes modification. We used to some purpose the following technic (see appendix II). After first exposure and development in formula 1, the image was bleached in a bleaching-bath (formula 4), cleared (formula 5), and washed thoroughly. The reversal image was not produced by reduction in a developer solution but by blackening in a solution of sodium sulfide (formula 6) to produce Ag_2S. This image obtained is of brownish colour with high covering power. To dissolve the surplus of AgBr for the second image the blackening process was divided in two parts. The first short pre-blackening comparable with the stabilizing pre-development protect the small details and low densities of the positive from solving too quick. Dissolving process (formula 7) and the final blackening (formula 6) were carried in this way that positive curves resulted. With maximum density on a low constant value and the minimum density given by the fog of the reversal process for more than 3 powers of exposure.

4. RESULTS

The reversal process was investigated in two stages, by hand development and later, after successful testing on the processing machine with a considerable amount of film more than 1000 m. In the following we shall present the results and compare them with the aims established in 2.3.

Figure 2 shows the characteristic curve of the applied reversal process using typical parameters compared with the characteristic curve of the negative process (formula 8) applied to RISK streamer chamber films. The curve is a non ideal step-function with a transition region of $\Delta \log H \leq 0.7$. There are practically two density levels, the upper $D_{max} \sim 0.6$ and the lower $D_{min} = 0.05 \div 0.10$. The level D_{max} was fixed on this value to have convenient conditions for visually image scanning.

The resulting macro-contrast

$$C = (T_{min} - T_{max})/(T_{min} + T_{max}) \qquad T - \text{transparency}$$

with

$$D_{min} = -\log T_{min}$$

$$D_{max} = -\log T_{max}$$

is $C = 0.63$. This value can be compared with that measured on films of the bubble chamber Mirabelle [7]. The mean contrast of bubble images on Mirabelle-films is $C = 0.32$.

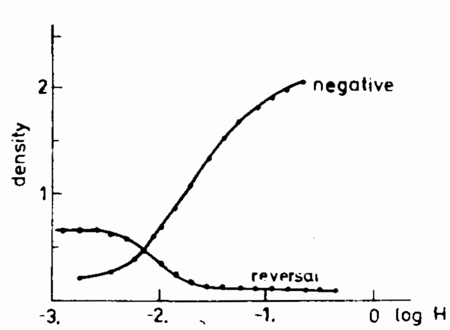


Fig.2. Characteristic curves of reversal process and RISK standard negative development. H - irradiation (lxs), D - density.

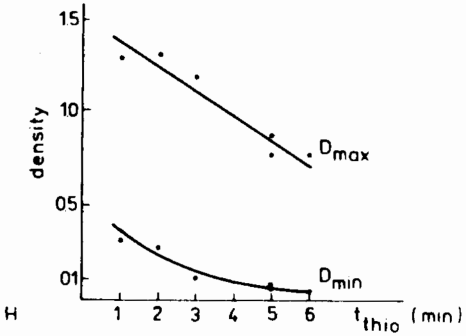


Fig.3. Dependence of minimum density D_{min} and maximum density D_{max} on the processing time t_{Thio} (in minutes) in the solvation bath.

In fig.2 it is shown, that the sensitivity of the reversal process is minimally the same as for the negative process. The minimum exposition for both processes in streamer images amounts to about the same exposure. The exposure latitude for the reversal process is greater than two orders of magnitude corresponding to the constant value of D_{min}. Extended bright objects like flares in the streamer chamber are relatively suppressed by the reversal process, i.e., not intensified to maximum densities as for the negative process. There is a possibility to vary parameters of the characteristic curve by changing parameters of the reversal process to adapt the pictures to measuring devices. In fig.3 an example for the dependence of the densities D_{max}, D_{min} on the duration of the solving bath is shown. The maximum resolving power of the reversal process is the same ($R = 74$ lp/mm) as for the negative process ($R = 75$ lp/mm) and the dependence of the resolution on exposition does not differ for both processes. That means, that the relative independence of resolution on the exposition requested is not reached, because it is caused by light scattering in the layer and of the first step of the reversal process similar to the usual negative process.

The discussion of noise and background characteristics shows some advantage of the reversal process. The fine grain gives a lower and narrow noise signal to be filtered easier. There is a lower noise scanning the clear streamer images by a slit comparing with the results on black streamer images. Furthermore fog is no more a problem, that is a success in practical handling of the high sensitive films and results in a better signal-to-noise ratio. As written above high exposition background is relatively suppressed.

Because of these noise properties, the two-level characteristics and the possibility of tuning some properties of characteristic curve the reversal process is very suitable to measure the so-developed film on automatic and semi-automatic measuring devices. As was also mentioned above this special reversal process can be used for machine developing and a considerable amount of film is already developed.

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APPENDIX I

Formula 1

0.14 g phenidone — to 1000 ml H_2O
13 g hydroquinone
60 g Na_2SO_3
18 g NaOH — p_H 11.3
8 g KBr
4 g KSCN
1 g benztriazole

Formula 2

0.227 g phenidone — to 1000 ml H_2O
1.136 g ascorbid acid — p_H 9.5

Formula 3

50 g $Na_2S_2O_3 \cdot 5H_2O$ — to 1000 ml H_2O
10 g Na_2SO_3

Formula 4

5 g $K_2Cr_2O_7$ — to 1000 ml H_2O
10 ml H_2SO_4 conc.

Formula 5

70 g Na_2SO_3 — to 1000 ml H_2O

Formula 6

20 g Na_2S — to 1000 ml H_2O

Formula 7

150 g $Na_2S_2O_3 \cdot 5H_2O$
30 g $K_2S_2O_5$ — to 1000 ml H_2O
1 ml H_2SO_4 conc.

Formula 8 ASP-20 developer

5 g Methol
6 g hydroquinone — to 1000 ml H_2O
50 g Na_2SO_3
31 g Na_2CO_3
2 g KBr
0.1 g benztriazole
1 g poliox-100 (resin)

APPENDIX II

Reversal development

1. First development	formula 1		25K	4 min
2. Bleaching	formula 4		20K	3 min
3. Clearing	formula 5		20K	3 min
4. Pre-blackening	formula 6	(1:20)	20K	2 min
5. Solving	formula 7		20K	4 min
6. Blackening	formula 6		20K	90 sec

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Бер Ю., Шмидт И. E13-82-421
Обратимое проявление фотографий треков из стримерных камер

Цель этой работы - найти метод фотографического проявления, который пригоден для записи изображений стримерных треков, т.е. метод, для которого характерна высокая чувствительность, только два уровня сигнала на пленке, нижняя зависимость трекового сигнала от яркости стримера и его изображения, которая колеблется в большом диапазоне, и подавление шума. Необходимо применять этот метод на проявочной машине в случае работы с пленками высокой чувствительности. Эти требования можно выполнить, используя обратимое проявление. На первом этапе процесса проявления достигнут высокий уровень вуали с применением процедуры растворения бромида серебра после обращения. Характерная кривая имеет только два уровня фотографической плотности с малым переходным диапазоном. Следовательно, плотность стримерных сигналов практически не зависит от яркости стримеров и достигается хорошее разрешение, низкая зернистость, подавление засвечивания и низкий уровень шума в сигналах ярких стримерных изображений.

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Reversal Film Development for Streamer Chamber Track Photographs

It is the aim of this work to create a method of photographic development specially adapted to streamer image recording, i.e., with high sensitivity, only two signal levels, low dependence of the track signal on image intensity having a great jitter and noise suppression. The method has to be suitable for machine development of high speed films. A reversal photographic development was used to realize these demands, whereby strong fogging in the first step negative development and a solving process for silver bromide after blackening are specially introduced process stages. This results in a step-function shaped characteristic curve with small transition region having only two signal levels, i.e., independence of streamer image density, good resolution, fine grain, suppression of flares and low noise in the signal of the clear streamer images.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna 1982