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THE EFFECT OF TEMPERATURE ON THE LATENT TRACK FADING RATE IN AgCl (CADMIUM DOPED) CRYSTAL DETECTORS

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ABSTRACT

In order to determine the effect of temperature on the latent track fading rate, qualitative observations are made on tracks with stabilization lag times (the time between exposure and stabilization during which the tracks fade) of 0 and 20 minutes. Charged particle tracks in AgCl (cadmium doped) detectors incubated at 40°C prior, during, and after exposure to 350 MeV/amu neon ions are compared to tracks in AgCl(Cd) detectors kept at 22°C. Also, two groups of AgCl(Cd) detectors were exposed to 5.5 MeV alpha particles under various incubation conditions and stabilization lag times of up to 120 minutes. The comparison of neon track quality for 40°C to those at 22°C, and the comparison among the alpha exposures indicate that there is little or no difference in the latent track fading rate between crystals at 22°C and those at 40°C.

INTRODUCTION

The objective of the experiment was to determine the effect of temperature on the latent track fading rate in AgCl(Cd)* crystal detectors. The experimental results will provide valuable information that will reflect on the reliability of AgCl(Cd) crystal detectors in applications where some excursion in temperature is expected, such as aboard spacecraft. When a track is formed in an AgCl(Cd) crystal, it immediately begins to fade until stabilized by inactinic (non-decorating) light of at least 10^{15} quanta/cm^2 total dose.[1] After this point, tracks cease to fade -- yet the crystal is still sensitive to additional track formation. It is possible to make several exposures on one crystal by rotating the crystal with respect to the beam line. (Only two exposure angles were used in the neon experiment to avoid a possible overcrowding of tracks.) The tracks are developed by exposure to 4170 Å light of 5×10^{18} quanta/cm^2 total dose. In addition to the possibility of a temperature dependence of the latent track fading rate, the fading response of two different types of crystals, distinguished by a parameter τ, was investigated. This step was accomplished by including one $\tau = 15$ min (τ_{15}) crystal and one $\tau = 400$ min (τ_{400}) crystal per stack.†

In addition to the latent neon track fading experiment, additional experiments were performed with alpha tracks. These latent alpha track

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*The crystals are doped with cadmium (5000 ppm).

†τ is the estimated lifetime (in minutes) for α particles. τ is strongly dependent upon the temperature gradient used in cooling the crystal at the time of manufacture -- a larger τ corresponds to a larger temperature gradient and therefore a larger α lifetime. τ is determined by the time necessary for the mean track width (MTW) to equal 1/e $(MTW)_0$.

experiments were similar to the neon fading tests in that the effect of temperature on latent track fading was investigated. However, since an americium-241 source was used, the latent alpha track fading experiments required no accelerator time, and were performed in a laboratory darkroom.

EXPERIMENTAL PROCEDURE (350 MeV/amu NEON TRACKS)

Two stacks of two crystals per stack were irradiated at the Lawrence Berkeley Laboratory Bevalac (September 18, 1974) with 350 MeV/amu neon ions. The temperature dependence of the latent neon track fading rate was realized by incubating the crystal stacks, one stack at 22°C (room temperature) and the other stack at 40°C in Millipore Type B1 ovens. The track fading for stabilization lag times of 0 minutes and 20 minutes was recorded by exposing the crystal stacks at angles of 0° and 45° (nominal) to the beam, and stabilizing at 0 and 20 minutes post-irradiation, respectively. The crystal stacks were rotated by turning the polyvinylchloride (PVC) box inside the oven between exposures. One τ_{15} crystal and one τ_{400} crystal were used in each stack to investigate characteristic differences in temperature behavior between the two types of crystals.

During incubation and exposure the crystal stacks were each mounted in light tight PVC boxes containing the crystal stack, crystal stack holder, yellow-orange filter, and #238 light bulb and holder. Experiments with alpha track stabilization showed that a #238 bulb (6.3 V, 0.5 A) and Cinemoid brand yellow-orange filter gave optimum stabilization for the small chamber. The exposure chamber is shown in Fig. 1. Figure 2 shows the orientation of the crystals inside each of the exposure chambers.

Each of the two exposure chambers contained one stack of two crystals. One exposure chamber was incubated at 22° C and the other at 40° C for about 1 hour before and after exposure. The exposure took about 1 hour also, so both crystal stacks were incubated approximately 3 hours. The exposure scheme consisted of the following steps:

Step No.	22° C Oven	40° C Oven
1	Incubate 1 hour	Incubate 1 hour
2	Expose to beam at angle 1 (zero degrees). Stabilize simultaneously (38 sec stabilization).	
3	Rotate clockwise to 45° (angle 2) and expose. Wait 20 min to stabilize (20 sec stabilization).	
4		Expose to beam at angle 1 (zero degrees). Stabilize simultaneously (38 sec stabilization).
5		Rotate clockwise to 45° (angle 2) and expose. Wait 20 min to stabilize (20 sec stabilization).
6	Incubate 1 hour	Incubate 1 hour

In all cases a stabilization time of at least 20 seconds was used. The reason the simultaneous stabilization took 38 seconds was because the exposure itself took 18 seconds, and stabilization time was extended to give all tracks at least 20 seconds of stabilization light.

RESULTS (NEON)

A comparison of track quality can be made between tracks exposed at 22°C and at 40°C to determine the effect of the higher temperature. A qualitative comparison of tracks in the τ_{15} type crystal with tracks in the τ_{400} type crystal is also possible. In observing the results it was kept in mind that track quality is dependent on the depth of the track in the crystal, the LET the particle had at the point of observation, and of course, the stabilization lag time. The dependence of track quality on depth can be attributed, in part, to the index of refraction of AgCl. The microscope system used is designed for indices of refraction between 1.0 and 1.5 (oil immersion) whereas the index of refraction of AgCl is about 2.0; therefore, the contrast will decrease as one focuses into the volume of the crystal. The LET of the 350 MeV/amu neon particles is constant within a few percent over the 2.5 cm crystal length so that large LET changes were not a problem. But care was taken always to compare tracks at the same depth in the crystal.

Qualitative observations of track quality can be made by comparing the grain density along the tracks. A non-faded track, Fig. 3 (0 min stabilization lag time), should appear after development as a continuous stream of dark grains with only occasional blank spots. Track fading is indicated by the appearance of blank spots along the particle trajectory as shown in Fig. 4. As the stabilization lag time increases the blank spots become more pronounced until development reveals no track at all. Since in this experiment all exposures at a 45° angle to the beam line experienced a 20 min stabilization lag time, the tracks at 45° to the

crystal sides are slightly faded. The exposures at 0° were stabilized simultaneously and these tracks do not appear to be faded at all.

The neon tracks shown in Figs. 3 and 4 (0 and 20 min stabilization lag times, respectively) are from the crystal kept at 22°C throughout the experiment. (The track in Fig. 4 is not representative of the general track type for that exposure.) The tracks from the 40°C crystal are shown in Fig. 5 (zero stabilization lag time) and Fig. 6 (20 min stabilization lag time). A most important fact becomes evident: both the 40°C and the 22°C crystals appear to experience the same track fading rate. The tracks with 20 min stabilization lag times in the 40°C crystal appear no more and no less faded than their counterparts in the crystal kept at 22°C. For the zero stabilization lag time tracks, there also appears to be no difference in track quality between the 22°C crystal and the 40°C crystal. (This fact indicates, in addition to the lack of temperature effect from 22°C to 40°C on the track fading rate, that the overall track quality is not affected by the difference in temperature.) Figures 7, 8, 9, and 10 show the response of the τ_{400} crystals. No difference in the track fading rate was observed between the τ_{400} and the τ_{15} crystals.

ALPHA EXPOSURES

The effect of temperature on latent track fading in AgCl(Cd) crystals was investigated using alpha particles in two groups of exposures utilizing various incubation methods and several different stabilization lag times. Care was taken in each case to keep the stabilization, development, and exposure parameters the same. The crystals were exposed in each case to 5.5 MeV americium-241 alpha particles. The edge of the crystal always

faced the source so that the angle between the track trajectory and the plane of the crystal was small.

In Group One three crystals were used, each with a different incubation method. Six consecutive exposures with respective lag times of 0, 5, 10, 15, 20, and 25 minutes, were made in each crystal by masking off the appropriate areas for exposure and stabilization (the whole crystal was developed at once in each case). The three incubation methods are listed below:

1. The crystal was kept at room temperature throughout the experiment.
2. The crystal was incubated at 40° C for 6 hours prior to exposure, allowed to cool to room temperature for 30 minutes, exposed and stabilized at room temperature.
3. The crystal was incubated at 40° C for 6 hours and then cooled to room temperature for at least 30 min. Exposures and stabilizations were done at room temperature. Then the crystal was heated for 6 more hours at 40° C.

In Group Two, two crystals were used, both incubated differently. Four exposures were made on each crystal with stabilization lag times of 0, 30, 90, and 120 minutes. The two incubation methods are listed below:

1. The crystal was kept at room temperature (22° C) throughout the experiment.
2. The crystal was kept at 40° C throughout the experiment (i.e., incubated from 5 to 11 hours prior to exposure and until after stabilization).

After development, the alpha tracks were easily observed under a microscope at 650×. The track fluence was around 10^4 tr/cm^2 but varied greatly. Care was taken to make observations in areas where the fluence was highest and a large number of tracks could be seen at one time. In Group One there appeared to be no difference in the latent track fading rate for tracks in any of the three crystals. In Group Two a comparison of the track fading rate in the 22°C crystal to the fading rate in the 40°C crystal is possible for stabilization lag times of 0, 30, 90, and 120 minutes. As expected the track fading increased with increasing stabilization lag time in both crystals, but the fading rate in the 22°C crystal appeared to be the same as the fading rate in the 40°C crystal.

Two general observations were made concerning the crystals: first, the very surface of the crystals appear to be insensitive to track formation; second, the tracks at the very edges of the crystals appear to fade very slowly so that good, apparently unfaded tracks are revealed even after very long stabilization lag times.

The second observation can be explained in terms of mechanical stress. After the crystal is manufactured, one of the quartz glass plates is removed from the quartz-AgCl-quartz sandwich. The AgCl surrounding the quartz plate must be cut free to release the plate and this cutting introduces dislocations into the AgCl crystal itself. The fading of the latent tracks is very sensitive to dislocations, and depending upon the extent of the damage done by the cutting, track fading may be restricted up to 1-2 mm from the crystal edges.

CONCLUSION

It appears that in a typical AgCl(Cd) crystal the air surface of the crystal and the area around the perimeter of the crystal, about 15 microns in for the crystals used here, are unusable. Apart from this fact and allowing for minor fluctuations across the crystal and from crystal to crystal, there appeared to be no difference in track response or latent track fading rate between crystals incubated at 40°C and those kept at 22°C. This fact was found to be true for 5.5 MeV alpha particles as well as 350 MeV/amu neon ions and reflects favorably on the use of AgCl(Cd) detectors in the temperature range of 22°C to 40°C.

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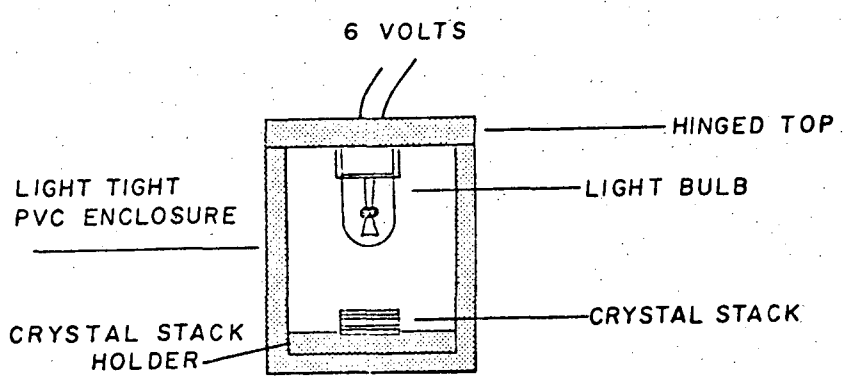

Fig. 1

PVC container showing the crystal stack, crystal stack holder, and light bulb. (Beam is into page.)

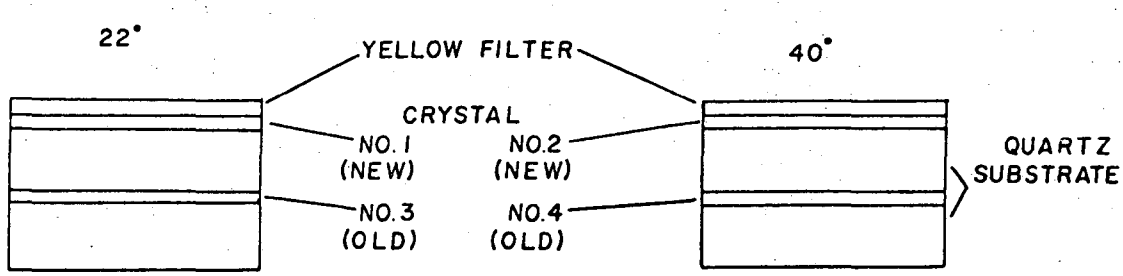

Fig. 2

Crystal stack showing the two crystals per stack, their quartz substrates, and the yellow filter. (Beam is into page.)

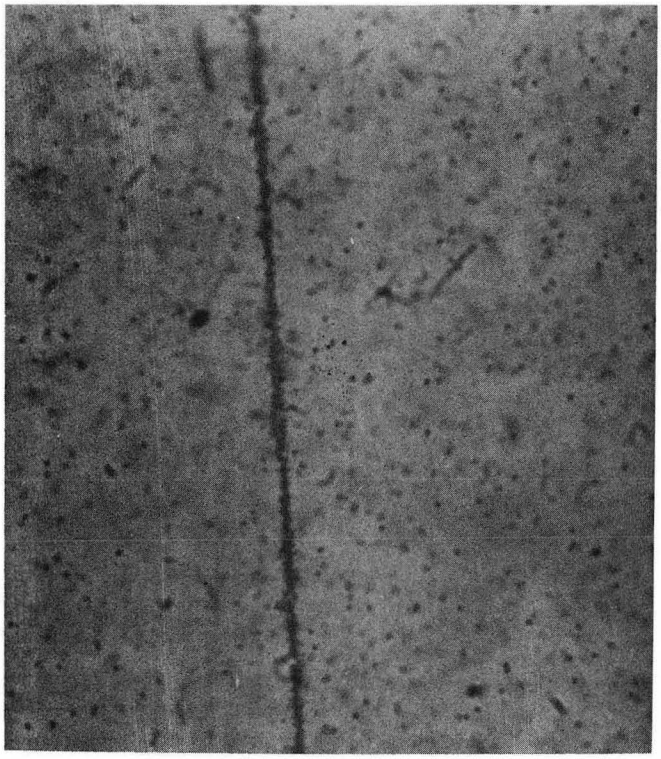

Fig. 3

Neon tracks in τ_{15} AgCl crystal: 0 stabilization lag time, 22° C.

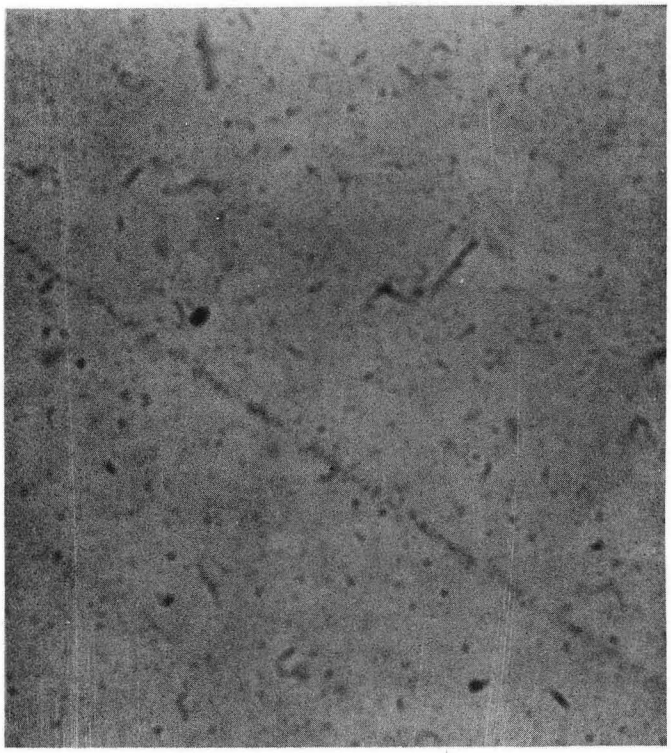

Fig. 4

Neon tracks in τ_{15} AgCl crystal: 20 min stabilization lag time, 22° C.

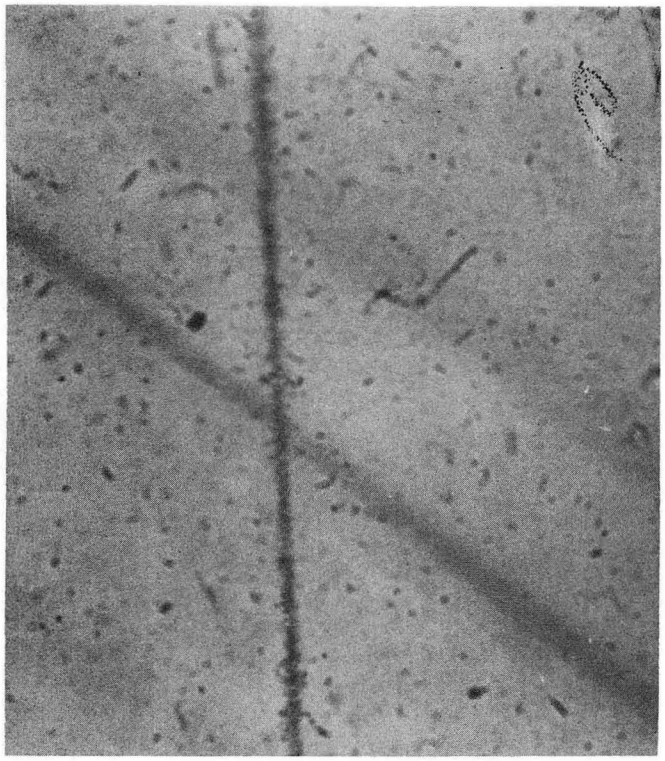

Fig. 5

Neon tracks in τ_{15} AgCl crystal: 0 stabilization lag time, 40°C.

Fig . 6

Neon tracks in τ_{15} AgCl crystal: 20 min stabilization lag time, 40°C.

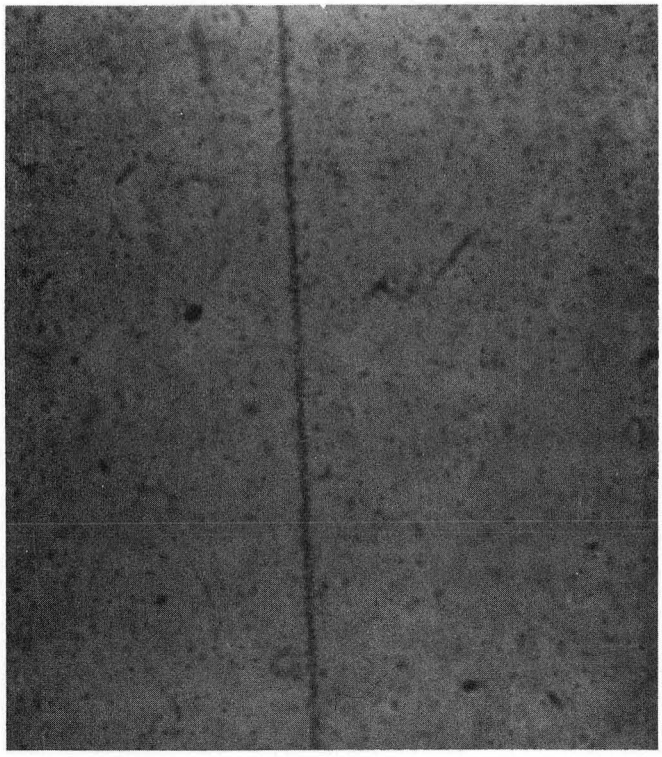

Fig. 7

Neon tracks in τ_{400} AgCl crystal: 0 stabilization lag time, 22°C.

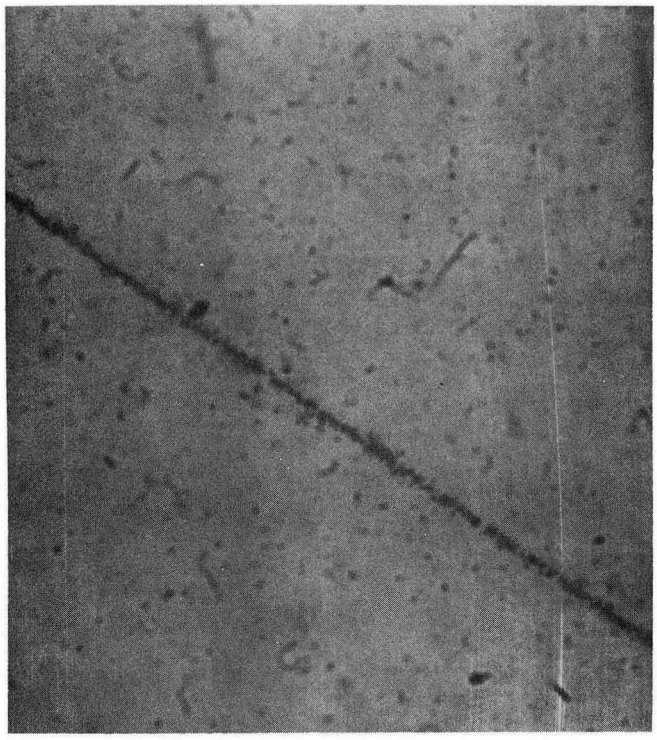

Fig. 8

Neon tracks in τ_{400} AgCl crystal: 20 min stabilization lag time, 22°C

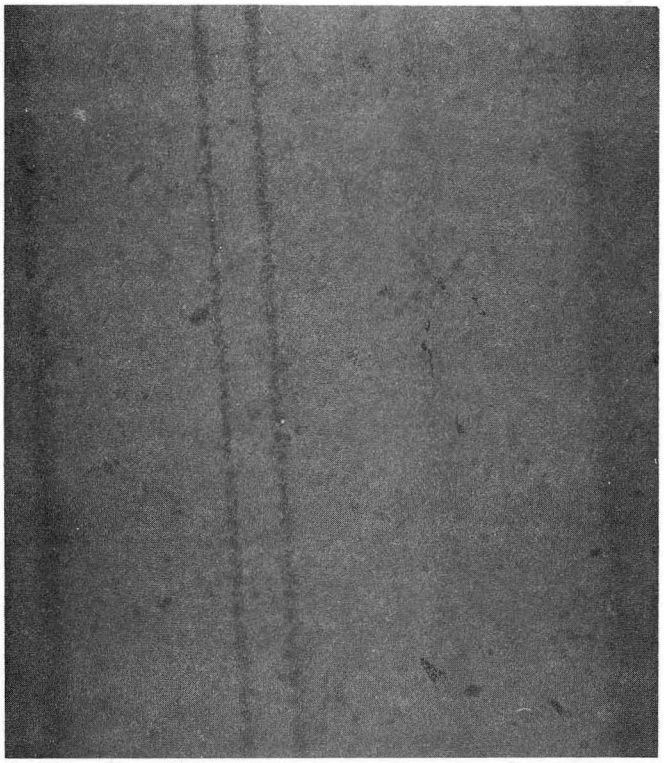

Fig. 9

Neon tracks in τ_{400} AgCl crystal: 0 stabilization lag time, 40°C.

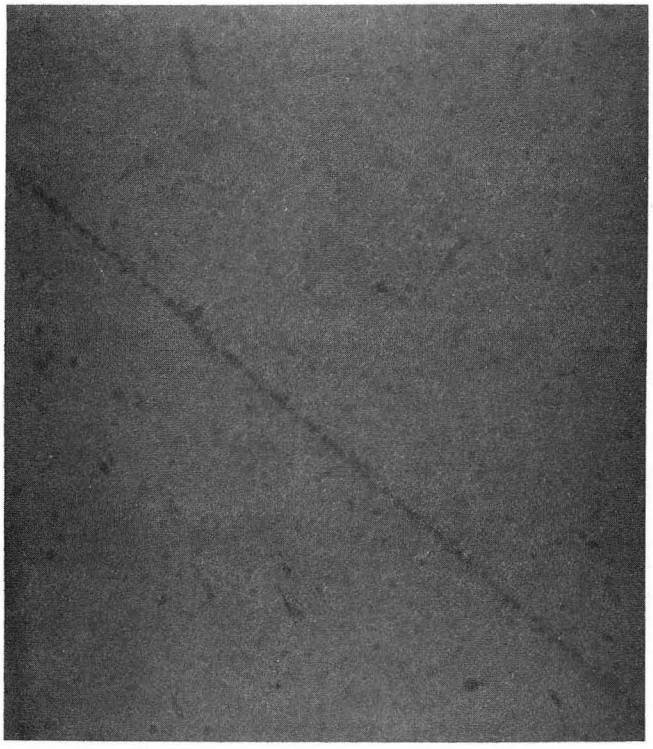

Fig. 10

Neon tracks in τ_{400} AgCl crystal: 20 min stabilization lag time, 40°C

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