

Latent Image Fading in Nuclear Emulsions

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THE magnitude of the regression of the latent image produced by charged particles incident on a nuclear emulsion is, in general, a function of the emulsion characteristics, the flux, kind, and energy of the particles, and of the time and conditions of storage in the interval between irradiation and development. This effect is much more marked in nuclear emulsions than in optical-type emulsions because of the extremely small size of the silver speck development centers in the former, which is caused by inefficiency in the photolytic process when the time of exposure of the halide grains is very short. This occurs in traversal by a radiation particle, where it will be in the vicinity of a halide grain for a time of the order of 10^{-14} sec. Since latent image regression is a surface phenomenon of the specks, the smaller ones will be affected to a proportionally greater extent, accounting for the relative instability of nuclear emulsion latent images.

Investigations by Lauda¹ and Mather² demonstrate a reduction of about 90 percent in the fading of the latent image after predevelopment storage in an evacuated chamber. This indicates that the dominant agent involved is a constituent of the atmosphere, with the known susceptibility of the silver specks to oxidizing agents suggesting the oxygen and water vapor present as causative factors. This is corroborated by studies³ of the variation of fading with storage in atmospheres of oxygen, nitrogen, and air, and with water vapor added to the above. The fading rate was found to be greatest in oxygen and least in nitrogen, with the addition of water vapor greatly increasing the fading rate in all cases. The temperature of storage will influence the rate of latent image oxidation, and may also act in connection with a purely thermal regression process⁴ that could account for part of the 10 percent residual fading observed even after vacuum storage.

To obtain a relation between the magnitude of the regression and the time of storage, the fading rate under a constant set of conditions may be considered proportional to the number of development centers present at any time. In integrated form this gives the expression

$$(N_0 - N)/N_0 = 1 - \exp(-ct),$$

where N_0 is the initial number of centers present after irradiation, N the number after a time t , and c a constant dependent on the size of the silver specks and on the storage conditions. For nuclear emulsions the density D after development will, to a good approximation, be proportional to N . Thus, the fading coefficient will be given by

$$(D_0 - D)/D_0 = 1 - \exp(-ct), \quad (1)$$

with D_0 being the density produced upon immediate development. $(D_0 - D)/D_0$ is plotted in Fig. 1 as a function of t for various values

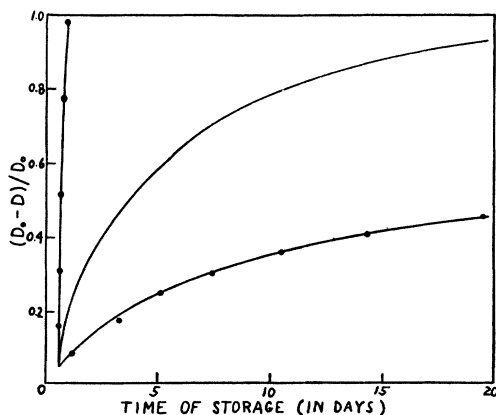


FIG. 1. The variation of fading with time of storage for various values of c .

of c , in good agreement with the experimental values given by Yagoda and Kaplan⁵ for two storage conditions.

The variation of the fading index c with temperature and humidity may be determined from a consideration of the effect of temperature on the velocity of a gas-solid reaction. Combining the Arrhenius relation

$$dN/dt = A \exp(-E/RT),$$

where T is the absolute temperature and A , E , and R constants, and the empirical Freundlich adsorption isotherm

$$dN/dt = kC^n,$$

where C is the concentration of the gas and n a fraction whose value lies between 0 and 1, gives for c in this case

$$c = k_1 H^n \exp(-k_2/T),$$

where H is the absolute humidity. For storage in air the oxygen concentration varies to a negligible extent and therefore can be included in k_1 . Since for reactions of this kind $n \sim \frac{1}{2}$,

$$c = k_1 H^{\frac{1}{2}} \exp(-k_2/T). \quad (2)$$

Equations (1) and (2) are adequate to describe the major part of fading phenomena in nuclear emulsions.

¹ J. Lauda, Sitzber. Akad. Wiss. Wien, Abt. IIa 145, 707 (1936).

² K. B. Mather, Phys. Rev. 76, 486 (1949).

³ Albouy and Faraggi, Report of Conference on Fundamental Mechanisms of Photographic Sensitivity. Part III, ONRL-66-50, 4 (1950), unpublished.

⁴ A. Beiser, Phys. Rev. 80, 112 (1950).

⁵ H. Yagoda and N. Kaplan, Phys. Rev. 73, 634 (1948).

Decay of the Hydrogen Discharge*

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THE decay of the electrodeless hydrogen discharge has been studied by the previously described techniques¹ of electron density, optical spectrographic, and optical light intensity measurements as a function of time after termination of the exciting fields. The electron density is measured by the shift of resonance of a microwave cavity due to the presence of free electrons, and this measurement has been improved by the technique of sweeping the exploring microwave signal through resonance in a few microseconds rather than depending upon the decay transient of the discharge to plot a resonance indication. Pressures studied varied from 1.0 to 19.8 mm Hg; times from 35 to 3500 μ sec; and electron densities from 5×10^7 to 5×10^9 electrons/cm³.

The character of the decay curves for electron density indicates that two-body recombination of electrons occurs from about 7 mm Hg to 20 mm Hg, and that the recombination coefficient, α , defined by the relation $dn/dt = -\alpha n^2$, where n is the electron concentration, is constant within experimental error at 6.2×10^{-6} cm³/electron-sec. Measurements at the lower pressures indicate that ambipolar diffusion predominates. The decay curve is taken to be represented by Biondi's expression²

$$n/(1 + \alpha \tau n) = [n_0/(1 + \alpha \tau n_0)] \exp[-(t - t_0)/\tau]$$

and by the use of three experimental points, τ is extracted without the necessity of assuming the behavior of α at low pressures. At the same time, α is determined, provided the distribution of electrons within the cavity can be assigned with certainty. The use of τ enables $D_a p = \Lambda^2 p / \tau$ to be calculated at the constant value 600 cm²-mm Hg/sec for pressures in the range 1 to 3 mm Hg, where D_a is the ambipolar diffusion coefficient, p the pressure, and Λ the characteristic diffusion length. In this range α is observed to rise from 2×10^{-6} cm³/electron-sec toward the above value at 7 mm Hg.

Spectrographic examination of the discharge under excitation shows most of the energy to be in the molecular spectrum of hydrogen, including the ultraviolet continuum associated with the