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HYPERSENSITIZATION OF KODAK IIIa-J PLATES BY BAKING IN FORMING GAS

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ABSTRACT

Experiments of hypersensitization of Kodak IIIa-J plates (batch 2K7) by baking in forming gas with a sealed baking tube were conducted. We tested baking conditions about temperature and time to find the optimum baking condition by means of relative detective quantum efficiency. A number of plates baked simultaneously in the sealed tube linearly decreases the speed gain and increases the fog. Effects of time spent until exposure after baking and of processing in different developers are examined.

1. Introduction

Baking in inert gas and/or hydrogenation of blue-sensitive plates is commonly used at many observatories with good results (Babcock 1976, Sim 1978, Millikan and Sim 1978, Smith and Hoag 1979). Baking in forming gas was first applied at the Rosemary Hill Observatory (Smith et al. 1976, Scott et al. 1977), not only with good results, but also with safety. In Japan, this treatment has been used at the Kiso Station of the Tokyo Astronomical Observatory (Aoki 1978, Takase 1978). Hypersensitization should be tested by each observatory and on each emulsion batch because the results depend on procedures and are affected by batch-to-batch variation.

We tested the hypersensitization of IIIa-J plates by baking in forming gas with a sealed tube for use in the Schmidt telescope (40/70/120 cm) at the Ouda Station of our department. The optimum baking condition, the time and the temperature, was determined by means of relative detective quantum efficiency (RDQE).

2. Experimental Procedure

The experimental procedure was as follows:

(1) We used 16×16 cm plates of emulsion batch 2K7 to cut them into eight pieces at test for economy of plates.

(2) After a baking tube was loaded with the piece(s) of plate, the tube was

evacuated for two hours by a rotary pump (down to 10^{-2} Torr) to reduce the oxygen and water vapor of the emulsion. The baking tube is of cylindrical shape with 82 mm in diameter and 166 mm in length.

(3) The tube was filled with forming gas (N_2 92%, H_2 8%) at pressure of 1 kg/cm^2 above ambient.

(4) The tube was then inserted in an oven preheated at a given temperature. The tube was sealed and the gas was not exchanged during the baking.

(5) At the end of a given baking time, the tube was taken out of the oven. While it was allowed to cool, the tube was again evacuated for 30 minutes to prevent more action of forming gas.

(6) The baked plate and an untreated piece from the same plate were exposed successively for 10 minutes on a tube sensitometer (TS) through Hoya Y48 filter, which cuts off shorter wavelengths than λ4800 Å.

(7) These plates were developed simultaneously for 9 minutes in MWP-2 developer (Difley 1968).

3. Measurement

The plates were measured on a microphotometer NLM-IX whose output density is digitized and stored on magnetic tape through a minicomputer PANAFACOM U-200. Desities were sampled at 20 μm intervals with a scanning slit of 20 μm square. Measurement was carried out at about 150 points for each TS spot. Measured semispecular densities were converted to diffuse densities by the following equation:

$$D\,(\text{diffuse}) = 0.742 \times D\,(\text{measured}), \tag{1}$$

which was obtained by calibrating the microphotometer with the Interobservatory Density Standards Wedge No. 34-3 (Sewell 1975).

3.1 Characteristic Curve, Speed Gain, and Fog

In order to obtain a speed gain and a contrast γ, we traced a characteristic curve (CC) for each plate. Densities measured were averaged over each spot. A formula derived by Tsubaki and Engvold (1975) was used to represent the CC:

$$\log I = A_1 D + A_2 \ln(\exp\{BD^{C_1}\} - 1) + A_3 \exp\{BD^{C_2}\} + A_4\,, \tag{2}$$

where I is the intensity, D is the density, and A's, B, and C's are constants. All of the CC's could be fitted to Equation (2) with a standard deviation of log I of 0.02 or less by least squares.

The speed gain was defined as the ratio of the exposures required to produce diffuse densities of 0.6 above fog on the untreated and treated plates. A fog density was measured with zero point defined by no plate in the measuring beam. Speed gains and increases in fog density were obtained for 16 combinations of baking time and temperature as shown in Figure 1.

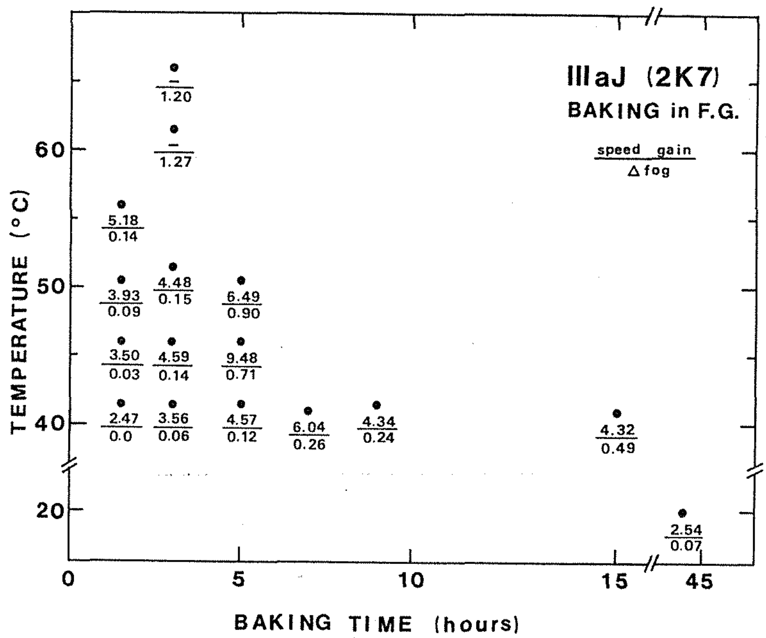

Fig. 1. Speed gains and increases in fog of hypersensitized IIIa-J plates (2K7) for 16 combinations of baking time and temperature. Upper numerals are speed gains, and lower ones are increases in fog.

3.2 RDQE

DQE is defined as the ratio of the square of the output signal-to-noise ratio to the square of the signal-to-noise ratio of the incident radiation, i.e.,

$$DQE = (S/N)^2_{out}/(S/N)^2_{in}\,. \tag{3}$$

This relation can be expressed in photographic terms of exposure E, granularity σ_D, and contrast γ (Marchant and Millikan 1965, Latham and Furenlid 1976, Furenlid et al. 1977). $(S/N)_{out}$ is expressed as

$$(S/N)_{out} = \frac{0.4343\gamma}{\sigma_D}\,. \tag{4}$$

Therefore, we obtain relative detective quantum efficiency (RDQE) as

$$RDQE = \frac{\gamma^2}{\sigma_D^2}\cdot\frac{1}{E}\,, \tag{5}$$

because we could not measure the absolute value of E, i.e., $(S/N)^2_{in}$.

The contrast γ was obtained by differentiating Equation (2). In most cases, γ's of baked plates were about 20% smaller than those of untreated plates.

The σ_D was measured as a root-mean-square of fluctuations on a curve of a density trace fitted by a quadratic polynomial for each TS spot. Because measured fluctuations were reduced at higher densities due to lower sensitivity of the photomultiplier on the microphotometer, they were corrected (Appendix). The σ_D values so obtained were fitted to a linear function of D by least squares.

We obtained RDQE together with $(S/N)_{out}$ for nine cases. As an example, RDQE, $(S/N)_{out}$, CC, and σ_D are shown in Figure 2 for the case of the baking condition of 56.0°C and 1.5 hours. Gains in peak RDQE and those in peak $(S/N)_{out}$ of treated plates, compared with those of untreated plates, were calculated (Table 1). In Figure 3, gains in peak RDQE are illustrated on a baking time-temperature diagram.

Errors in γ, σ_D, and E are roughly estimated as 5%, 8%, and 5%, respec-

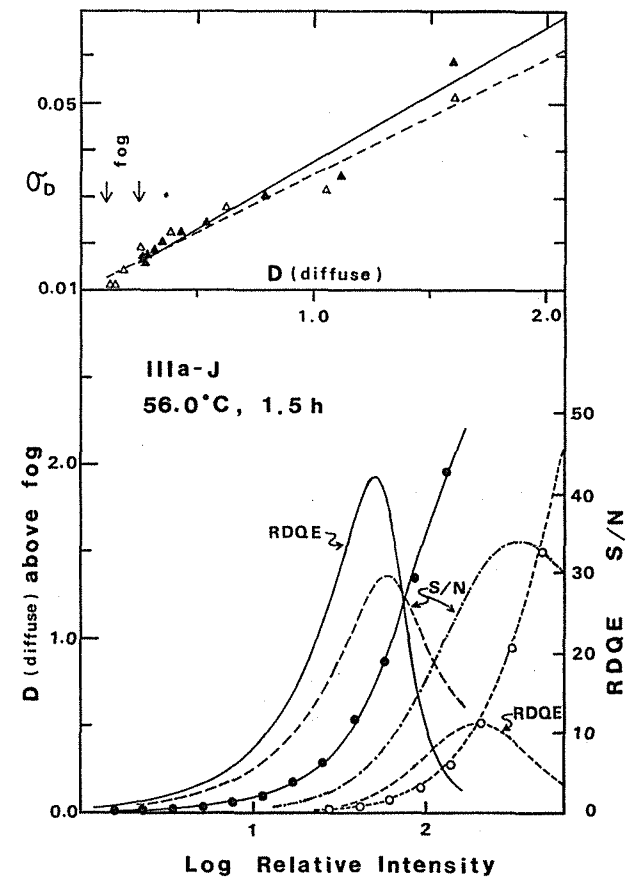

Fig. 2. RDQE, $(S/N)_{out}$, and CC against log I and σ_D against density for a hypersensitized plate (56.0°C, 1.5 hour baking; solide lines and a dashed line for $(S/N)_{out}$), together with those for a reference plate (untreated; dashed lines and a dot-dashed line for $(S/N)_{out}$).

Table 1. Gains in RDQE's S/N's, and Speeds of Hypersensitized IIIa-J Plates.

Baking Condition Temp. (°C) (1)	Time (hours) (2)	Δ fog (3)	Gain in peak RDQE (4)	Density at peak RDQE (5)	Gain in peak $(S/N)_{out}$ (6)	Density at peak $(S/N)_{out}$ (7)	Speed Gain (8)
56.0	1.5	0.14	3.78	0.730	0.875	0.904	5.18
50.5	1.5	0.09	3.70	0.761	0.956	0.892	3.93
51.5	3.0	0.15	2.58	0.793	0.846	1.099	4.48
46.0	1.5	0.03	3.66	0.795	1.066	0.970	3.50
46.0	3.0	0.14	2.96	0.741	0.880	1.091	4.59
41.5	1.5	0.0	3.73	0.697	1.168	0.828	2.47
41.5	3.0	0.06	3.58	0.660	0.973	0.790	3.56
41.5	5.0	0.12	3.46	0.672	0.863	0.847	4.57
41.0	7.0	0.26	1.98	0.764	0.660	1.070	6.04

tively. They yield an error in RDQE of 20% and result in an error of 28% in gain in peak RDQE, and an error of 13% in gain in peak $(S/N)_{out}$.

4. Results

4.1 Optimum Baking Condition

In the case of a single exposure, it may be advantageous to expose to the level of the peak $(S/N)_{out}$. However, when one stacks several plates

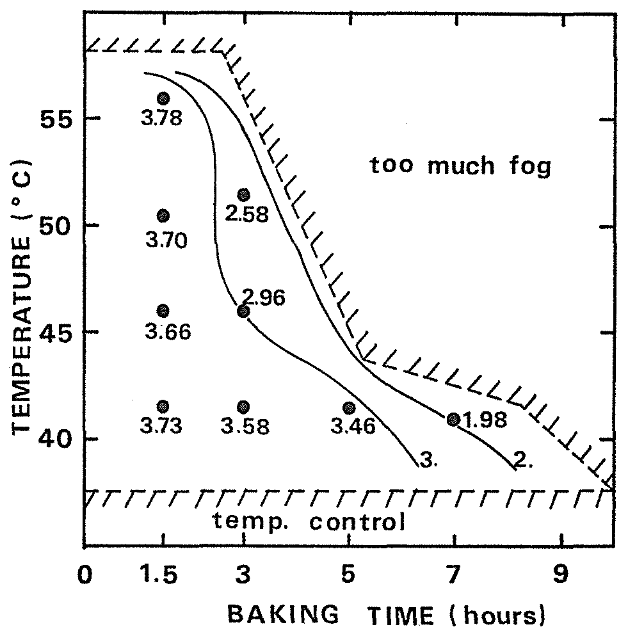

Fig. 3. Gains in peak RDQE on a baking time-temperature diagram. Two contour lines show the gains in peak RDQE of 2.0 and 3.0. The upper right region is inhibited by excessive increases in fog, and the lower region is unsuitable because the temperature control is difficult.

exposed separately to detect faint objects, it is with greatest efficiency to expose each of the plates to the level of the peak DQE. Therefore, we determined the optimum baking condition on the basis of the gain in peak RDQE.

We find the optimum baking condition of 56.0°C and 1.5 hours in 8% forming gas, pre-evacuated for 2 hours, which yields the maximum gain in peak RDQE of 3.78 at the density of 0.73.

4.2 Effect of the Number of Plates Baked Simultaneously

In our case, the tube is sealed and the gas is not exchanged during baking. The number of plates baked simultaneously in the tube should affect the results. We examined three cases of simultaneous baking of 1, 2, and 4 piece(s) of the plate. The amount of gas relative to the area of emulsion was 31.2 cm^3 per cm^2 in the case of one piece in the tube. In Figure 4, it can be seen that speeds and fogs show the linear dependence on the number of plates baked simultaneously.

There is a similar effect in the case of baking with gas flow (Schoening 1975, Sim 1978), but in that case an optimum flow rate can be found.

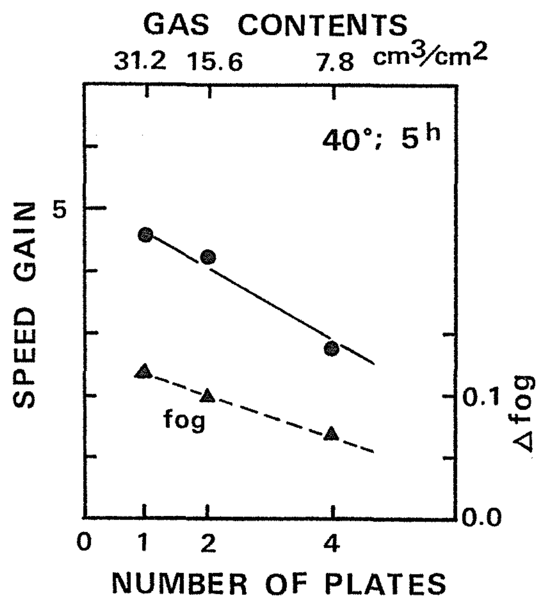

Fig. 4. Speed gains and increases in fog versus the number of plates baked simultaneously in the tube for the case of 41.5°C and 5 hours' baking.

4.3 Effect of Lapse of Time after Baking in Moist Air

After baking followed by evacuation, the plates were left in the dark room in moist air (30°C, RH~100%) for 1, 3, and 5 hours. After 1 or 2 hours the speed gain decreased rapidly by 25%. More time spent in air had little effect on the plate speed, seen in Figure 5. (In these cases the

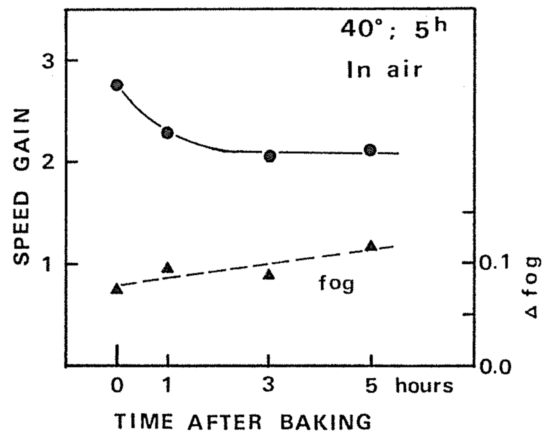

Fig. 5. Speed gains and increases in fog versus time spent until exposure after baking in moist air (30°C, RH~100%) for the case of 41.5°C and 5 hours' baking.

speed gains are low because of baking four plates simultaneously, mentioned above.) Although the atmospheric condition is better at the site of the telescope, the decrease in sensitivity may be unavoidable during exposure in air.

4.4 Comparison of Developers MWP-2, Pandol 1: 1, and D-19

In Japan, a developer Pandol (Fuji Photo Film Co., LTD.) is frequently used. (For use, it is diluted by the same amount of water to make 1 : 1.) This developer produces a low γ and a wide latitude, but yields the considerably low DQE (processing for 8 minutes) compared with MWP-2 by factor of 3.

Jeffers (1971) showed that development in MWP-2 yields a higher RDQE for IIIa-J emulsion than in D-19. We could not confirm his result, but obtained that processing for 9 minutes in MWP-2 yields almost the same or less performance than for 5 minutes in D-19. The long processing time in D-19, compared with 4 minutes by Jeffers, may interprets the discrepancy.

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Calculations of RDQE were carried out on the FACOM M-190/200 at the Data Processing Center of Kyoto University.

Appendix Correction of σ_D Measurements for Sensitivity Variations of the Microphotometer

Because the measuring aperture is small of 400 μm^2, the sensitivity of a photomultiplier on the microphotometer is insufficient to detect the density fluctuations σ_D at high densities: fluctuations decrease above the semispecular density of 1.5.

We measured a few TS spots, together with several neutral density (ND) filters in the beam, to obtain σ_D at several density levels with the same intrinsic density fluctuations. Density fluctuations thus obtained were normalized by the fluctuations measured without ND filter (Figure 6). So we can correct the density fluctuations by the formula

$$\sigma_D(\text{corrected}) = \frac{1.5}{3-D}\sigma_D(\text{measured}), \quad \text{if } D(\text{measured}) > 1.5 . \qquad (6)$$

If $D \leqq 1.5$, σ_D's were uncorrected.

Since density fluctuations depend mainly on overall densities including the back-ground fog, the representative density fluctuations were published as a function of density (Furenlid et al. 1977, Furenlid 1978). Compared with their data, the fluctuations (on a diffuse density scale) including corrected ones were systematically 22% large with a slightly large dispersion.

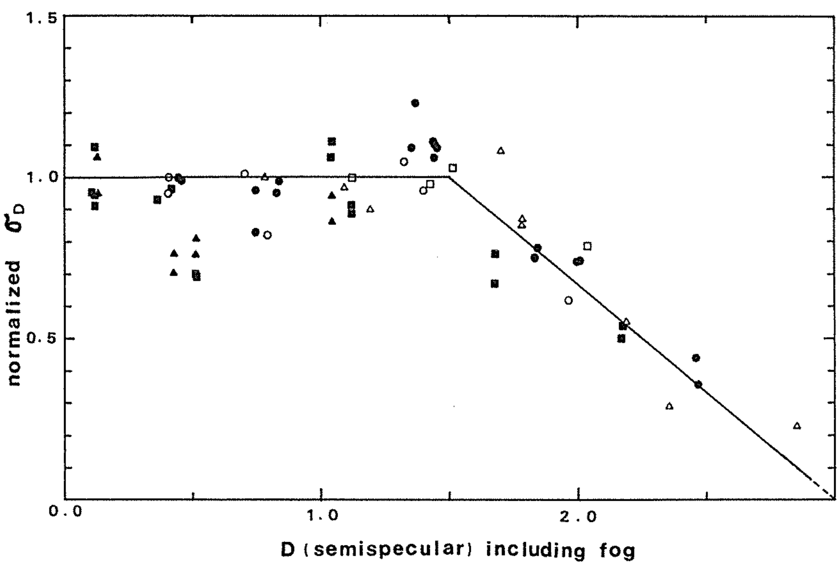

Fig. 6. Plots of normalized σ_D at various density levels. Each symbol corresponds to the same TS spot. Superposed lines show the correction curve of σ_D.

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