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LIMITATIONS OF RETARDED (BISULFITE)
X-RAY FILM PROCESSING

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ABSTRACT

We demonstrate the limitations of using retarded (bisulfite) developer to abate film sensitivity of x-ray films that have been exposed to intense radiation. We compared the measured densities of a large number of Kodak Type-M x-ray film samples exposed to a known fluence of monochromatic x-rays. These film samples were processed in three separate batches of bisulfite developer mixed in the same proportions. We concluded that reproducible film-density information cannot be obtained using different batches of (bisulfite) developer solutions.

INTRODUCTION

Retarded developer processing is used to expand the film latitude of x-ray films that have been exposed to intense device radiation. During a reexamination of calibration-data files for Kodak Type-M x-ray film, we uncovered data that demonstrated that this technique is unreliable. These data showed that the density results of film samples given identical exposures were inconsistent when the samples were processed in different batches of bisulfite solution prepared to be as identical as possible. At the time these tests were made, the known users of bisulfite processing were told of our results, but no formal report was circulated. This report is intended to inform potential users of the limitations of the bisulfite processing technique.

RETARDED PROCESSING TECHNIQUE

The addition of sodium metabisulfite to photographic developer is a well-known technique for expanding the film latitude during the development stage. This results in decreased optical density in areas of high exposure. Claude Dittmore of Lawrence Livermore Laboratory (LLL) extended and utilized this technique over a wide range of x-ray exposures, film types, and developer conditions.

The most important factors for successful use of the retarded processing procedure are temperature control, constant and uniform hand agitation of the film in the developer solution, and careful observation of the images as they begin to appear. If density-gradient information is desired, the film must be transferred to a stop bath at the point when the resolved images lie in a linear density region. This is not always possible because the image-exposure latitude may range from below the linear region to saturation.

In the application described here, Kodak (Powered) X-Ray Developer is mixed to the normal consistency and diluted with an equal volume of water. To make the retarded developer, 17.5 g of sodium metabisulfite is added to 946 ml (32 oz.) of the diluted developer.

HISTORY OF RETARDED PROCESSING AT LLL

In 1975, emission- and absorption-line data acquired from a bent-crystal spectrometer were recorded on Type-M film and processed in bisulfite developer. To accommodate the full range of exposures produced by the experiment, three Type-M film strips were transferred to the stop bath after 4.5, 6.0, or 8.0 min in the developing bath. The qualitative results were excellent.

To get absolute intensity information for the emission-line data, an attempt was made to obtain a bisulfite calibration for each of the three processing periods. A set of about 40 Type-M film samples were exposed to 17.5-keV Mo(K α) and 25.3-keV Sn(K α) x-rays over a wide exposure range from about 20 to about 30,000 erg/cm². Several samples exposed in the lower fluence region (<1000 erg/cm²) at each energy were processed using standard procedures: 5-min development in Kodak R X R at 72°F under nitrogen-bubble agitation. Four samples exposed in a higher fluence region (>1000 erg/cm²) at 25.3 keV were not processed but reserved for later use. Both of the two sets of film samples were divided according to exposure into three subsets and processed in bisulfite developer at 68°F for 4.5, 6.0, or 8.0 min. Figure 1 compares the results of standard processing with those of bisulfite processing for 25.3-keV data and shows the effects of processing time in bisulfite processing.

Fig. 1. Density obtained by standard processing (5 min, Kodak R X R) and by retarded processing for three different processing periods. The suppression of optical density by bisulfite development is apparent.

The characteristic curves derived from films exposed at 17.5 and at 25.3 keV and developed under standard processing conditions agreed well with the curve obtained at 17.5-keV by Leipelt and Slivinsky¹ and with our earlier (unreported) curve at 25.3 keV, respectively.

We also analyzed the results obtained by bisulfite processing. We normalized the exposure-vs-energy results of an earlier comprehensive calibration of Type-M film developed using standard processing to the 17.5- and 25.3-keV bisulfite-processed data. These results were used to calibrate spectra generated by the bent-crystal spectrometer, and we found large discrepancies between these spectra and consensus spectra from other experiments. This disagreement prompted us to initiate a re-examination of the retarded processing technique.

EXPERIMENTAL

About 10 weeks after the first set (Set 1) had been processed, a second set of Type-M film (Set 2) was exposed at 25.3 keV. Five exposures of Set 2 were developed using the standard processing procedures, 9 were set aside undeveloped, and the remaining 20 were processed for either 4.5, 6.0, or 8.0 min using bisulfite developer solution of the same formulation and prepared under the same conditions as Mix 1, which was used to develop Set 1. The four samples retained from Set 1 were also included in the second processing (two at 4.5 and two at 8.0 min).

Density values from the average characteristic density-vs-exposure curve (derived from the two exposure sets at 25.3 keV using standard processing) agreed within $\pm 7\%$ at any given exposure. Similar comparisons of the results for two exposure sets developed under bisulfite processing, however, revealed that, for the 8.0-min processing period, the densities of the film samples processed with Mix 1 differed from those of Mix 2 by factors of 2.5 or more (Fig. 2a). For the 4.5 and 6.0-min processing periods, the density variations between exposure sets was even greater (Figs. 2b and 2c). (For the 4.5-min period, the comparison is not as straightforward since the characteristic curves derived from the Mix 2 processing still lie in the nonlinear region of the density-vs-exposure curve). The results obtained for film samples from both Sets 1 and 2, which were processed with Mix 2, all fall on the same curve

Fig. 2. Film samples taken from two exposure sets (25.3 keV x-rays) on different dates and processed in identically mixed bisulfite developer solutions. Processing periods were (a) 8 min, (b) 6 min, and (c) 4.5 min. Figures 2a and 2c show that when film samples from either Set 1 or 2 were developed in the same developer solution (Mix 2 in this case), the density values fell on the same curve; this confirms that the nonreproducibility of density values that is observed when film samples from the same set are processed in different developer solutions is due entirely to processing.

(Figs. 2a and c), which confirms that the nonreproducibility is entirely attributable to processing.

Shortly after the Mix-1 and Mix-2 results were compared, a third bisulfite mix (Mix 3) was prepared. Again, careful attention was given to the mixing procedure in an attempt to reproduce Mix 1. Surplus film samples from Set 2 processed in Mix 3 gave results falling in a region between those obtained using Mixes 1 and 2. The curves shown in Figs. 1 and 2 were obtained using a least-squares fitting routine of a second-degree polynomial and have no significance other than separating data sets.

A few surplus film samples from the second exposure set were used to estimate the dependence of density on film agitation and bisulfite aging in Mix 2. Agitation effects were evaluated by comparing densities of films that were developed under two conditions: 1) the film samples were agitated continuously in the developer solution (the normal procedure) and 2) the samples were agitated continuously for 15 s and then turned at 30-s intervals until development was complete. The latter samples showed about 15% lower density after 6 min of processing and about 35% lower density after 8 min of processing.

Developing film in a bisulfite bath aged for 5 h reduced the film density by about 60% in 8-min development compared with the density of films processed in freshly prepared retarded developer. We selected the 5-h time period because this was the average time required to process a complete set of crystal-spectrometer film.

CONCLUSIONS AND RECOMMENDATIONS

We have shown that retarded bisulfite processing gives unpredictable results. Although absolute density information can be extracted from bisulfite-processed detector film if a set of pre-exposed control films of known exposure are developed simultaneously in the same solution, the number of control films required becomes unmanageable if the energy band-width of the detector-film data is large. We feel that the number of control films should be restricted to about 15 samples to permit the processing technician to give adequate attention to both agitation and observation of the detector-film images. The control films should not exceed 2 by 4 in. in size.

An alternate approach that reduces the number of control films required is cross-calibrating the control film processed in bisulfite developer to a broad energy-range calibration derived from standard processing. The calibration film has perhaps three or four carefully selected energy points consisting of several exposures at each energy value. Using good collimation, the film could be moved after each exposure to capture two or more additional exposures on each film sample. Prolonged x-ray exposures of up to 7 h are generally necessary to obtain net density values greater than 2.5 for the films that will receive retarded processing. Considerable exposure time can be saved by stacking the film so that a single exposure provides a different fluence value for each film in the stack.

REFERENCE

1. G. Leipelt and V. W. Slivinsky, "X-Ray Calibration of Kodak Type M Film with Retarded Development," Lawrence Livermore Laboratory, Livermore, CA, UOPE 73-13 (1973).