A Comparison of Kodak DEF, CX and AX films using soft X-ray wavelengths

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(**Received:** 27 / 3 / 2011 ---- **Accepted:** 26 / 10 / 2011)

Abstract

Kodak direct exposure film (DEF), Kodak industrex films CX and AX have been compared , using a DC X-ray source generating 1.5KeV soft X-rays .Characteristic curves are presented for the three films, also detective quantum efficiency were measured as a function of the incident X-ray flux.The effect of developer temperature on the characteristic curve has been also investigated.

1- Introduction

X-ray spectroscopy is a widely used experimental diagnostic technique of laser produced plasma (LPP) and laser fusion, thermally generated X-rays from (LPP) are brighter than any other single pulse laboratory source for photon energies less than about 5 KeV and sufficient for measurements using a variety of techniques [1]. Bragg reflection of soft X-rays from crystals is providing new information on the response of the lattice to both shock waves and thermal waves. Traditionally X-ray film has been used, with a flat, or bent dispersing crystal [2]. Kodak DE film is used as the standard–detecting medium for the soft X-rays emitted in experiments associated with X-ray absorption and emission spectroscopy [3,4]. Industrex CX and AX films have been used when slower but less grainy films have been required. The aim of this work presented in this paper is to study the characteristic of these three films so that users can have better knowledge of the film characteristics for data reduction and for choice of film.

2- Experimental

A conventional DC X-ray source was used using an aluminum target at 3KV operating voltage. It was anticipated that emission from this source would be predominately from AlKα. The films were loaded in a 50 mm × 30 mm cassette fitted with a 30μm thick beryllium window to exclude longer wavelengths . This cassette was placed behind a 1mm thick black polystyrene screen with a 5mm square hole cut in it . Timed exposures were made at constant X-ray flux by translating the film behind the aperture . The films were processed according to the manufactures instruction ie[5],

Development 4 mins in Kodak LX24 developer at 20°C and with constant agitation.

Stop 30 secs in Kodak indicator stop bath.

Fix 10 mins in Kodak FX-40 fixer.

Wash 30 mins in running water.

A comparison of the relative speeds of the film was made by loading two films side – by – side in the cassette and exposing them to same flux of X-rays with the polystyrene screen removed.The films were analysed using a Joyce – Loebl densitometer with 0.25 numerical apertures for both the objective and condenser lenses. To obtain the characteristic curves for the films a large scanning area was used to smooth out granularity effects as far as possible. Measurements of clear film level above 100% transmission were made as well as measurements of exposed density above clear film. The clear film density levels above 100% transmission were 0.21 , 0.25 , 0.23 , for DEF, CX and AX respectively. For granularity measurements each recorded density level was scanned, using a 100μm square aperture, over a sufficiently large area to produce at least 100 independent density measurements.A measure of the spectral distribution was made by exposing a piece of DEF film to the source with one half of the cassette having 130 μm of beryllium filter and the other half 30 μm.

3- Results & Discussion

The experiment with the two beryllium filter thicknesses gave film densities of 0.56 and 1.9 respectively for 130 μm and 30 μm of beryllium. This represents a ratio of about 3:1 in intensities. If the emission was entirely from AlKα the ratio would have been about 10:1 . This result was therefore consistent with there being a 30% contribution of harder X-rays (λ < 6A°) from the source . Nevertheless the supposition that the source was dominated by AlKα , or at any rate radiation at round about 1.5 KeV energy was considered to reasonably well justified. DEF was calibrated at X-ray wavelengths on an absolute basis by Henke et al [6] and Dunn et al [7]. This data was used to put our relative DEF calibration onto an absolute scale. The CX and AX film calibration could then be made absolute by means of the film comparison described in the last section . The resulting calibration curves are presented in Fig 1.The AX film was also calibrated at 17°C and 24°C developer temperature to determine the sensitivity of the characteristics curve to temperature, and the three characteristic curves are presented in fig 2. Densities are plotted above 100% transmission level to illustrate the effect of temperature on background fog level. It can be seen that the effect of temperature on the slope of the characteristic curve is pronounced, and the effect on background fog level is also significant.The granularity of the films was then measured at each density level by scanning the films with a 100 μm^2 appertur. Film granularity g, is defined by the expression

$$g = \sqrt{A} \quad \sigma_D \quad (1)$$

Where A is the scanning area and σ_D is the r.m.s fluctuation in density measured by scanning area A.
It is a property of film granularity that

$$g^2 \alpha D \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where D is the film density level.In fig 3 g^2 is plotted against density for the three films and the linear relationship is seen to hold within the 25% error loss (not drawn). CX film was found to have the same granularity as DEF at a given density.

Defective Quantum Efficiencies

The relative performance of a particular emulsion is a function both of its sensitivity and granularity. These two properties are integrated in the concept of detective quantum efficiency [8,9], which is defined as the ratio of the number of photons in principle necessary to achieve a given signal – to – rasie ratio, to the number in fact necessary. It is readily shown that this is equivalent to the squared ratio of the S.N.R of an actual detector to the S.N.R of an ideal detector for the same number of incident photons [10].

Ie , $$DQE = \frac{(S.N.R)^2\ out}{(S.N.R)^2\ in} \quad \text{----- (3)}$$

Hence $$DQE = \frac{E}{(\Delta E)^2} \quad \text{---- (4)}$$

ΔE can be extracted at any given E from the film sensitivity curve and the (granularity)^2 versus density curve, hence the DQE can be plotted. The resulting DQE curves are presented in fig 4. This curve shows that DEF has the highest DQE (~15%), and it also has a higher DQE than the other two films up to an exposure level of a 2ph/μm^2 . Industrex AX film is better at higher exposure levels than this, but the fact that DEF has reached density 3 at this exposure level , whereas compared with density 1.5 for AX film, would tend to make AX film more easily usable at exposure levels somewhat below this. CX film does not seem to have any advantage over DEF film at any exposure level.

4- Conclusion

Kodak films DEF, Industrex CX and AX have been compared when exposed to 1.5 KeV soft X-ray regions. The results have shown that the information inferred from the DEF film is found to have the highest detective quantum efficiency up to an exposure level of ~2 photons/μm^2. Above the exposure level Industrex AX film has the highest DQE. In DQE terms there is no advantage in using CX film at any exposure level .

Figures Caption

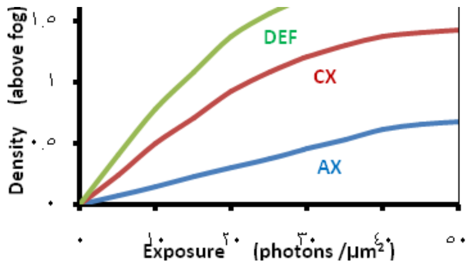

Fig. 1 Film Sensitivity Curves

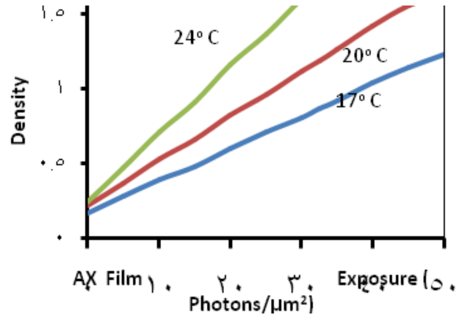

Fig. 2 Effect Of Developer Temperature On Characteristic Curve For AX Film

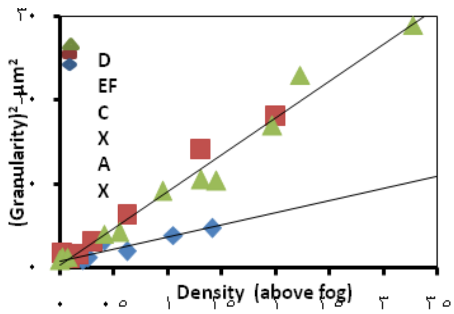

Fig. 3 Granularity Measurements

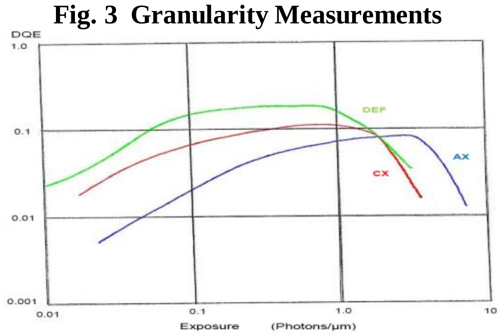

Fig. 4 Detective Quantum Efficiency As a Function Of Exposure

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مقارنة بين أفلام كوداك (DEF ، CX و AX) باستخدام الأطوال الموجية للأشعة السينية الخفيفة

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(**تاريخ الاستلام:** 27 / 3 / 2011 ---- **تاريخ القبول:** 26 / 10 / 2011)

الملخص

تم استخدام مصدر مستمر للأشعة السينية الخفيفة بطاقة (1.5) كيلو فولت وذلك لمقارنة خصائص الأفلام كوداك (DEF) ، (CX) ، (AX) المستخدمة لتصوير الأطوال الموجية للأشعة السينية الخفيفة . تم دراسة خصائص الأفلام الثلاثة والمقارنة بينها من خلال المنحنيات التي تم الحصول عليها ، وكذلك دراسة العلاقة بين كفاءة الكشف الكمية كدالة لسيل الأشعة السينية الساقطة على هذه الأفلام. أن تأثير درجة حرارة مظهر الصور قد تمت دراسته لكل أنواع الأفلام الثلاثة المذكورة أعلاه .