Absolute Calibration of Kodak Biomax-MS Film Response to X Rays in the 1.5- to 8-keV Energy Range

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Summary

The x-ray sensitivity of Kodak Biomax-MS film was calibrated and compared to Kodak DEF film.

- Kodak DEF x-ray film is no longer in production. Biomax-MS is one of Kodak’s replacement films.

- Five emission lines were used to measure the absolute sensitivity of Kodak DEF and Kodak Biomax-MS films.

- Measurements of the DEF sensitivity compare favorably to previously published measurements.*

- Biomax-MS appears to be a good replacement for DEF but has reduced sensitivity in the 3- to 8-keV range.

Standard development procedures and calibrated instruments were used to make these measurements.

- Monochromatic x-ray beams were used to expose Kodak DEF and Biomax-MS films.
- The x-ray photon fluence was measured with an absolutely calibrated ORTEC Si(Li) detector.
- The film was developed by the Kodak-recommended procedure in an autoprocessor.
  - 5 min in GBX developer
  - 30 s in stop bath
  - 6 min in fixer
- The film was digitized with a calibrated Perkin–Elmer photomicrodensitometer using a $50 \times 50 \mu m$ aperture and an 0.25 numerical aperture (NA) lens.
A film pack or photon detector was placed in the path of a monochromatic x-ray beam (photon detector shown in beam path). The beam passed through He gas at ~1 atm.
Five different emission lines were used for Kodak DEF and Kodak Biomax-MS film calibration measurements.

A crystal or multilayer was used to provide a monochromatic source of x rays.

<table>
<thead>
<tr>
<th>Line</th>
<th>Energy (keV)</th>
<th>Monochromator</th>
<th>2d (Å)</th>
<th>θ\text{Bragg} (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al Kα</td>
<td>1.49</td>
<td>WB\textsubscript{4}C</td>
<td>26.3</td>
<td>18.44</td>
</tr>
<tr>
<td>Ag Lα</td>
<td>2.98</td>
<td>WB\textsubscript{4}C</td>
<td>26.3</td>
<td>9.10</td>
</tr>
<tr>
<td>Ti Kα</td>
<td>4.51</td>
<td>LiF(200)</td>
<td>4.027</td>
<td>43.06</td>
</tr>
<tr>
<td>Fe Kα</td>
<td>6.40</td>
<td>LiF(200)</td>
<td>4.027</td>
<td>28.76</td>
</tr>
<tr>
<td>Cu Kα</td>
<td>8.04</td>
<td>LiF(200)</td>
<td>4.027</td>
<td>22.49</td>
</tr>
</tbody>
</table>
The sensitivity of Kodak DEF and Biomax-MS film were measured in the LLE x-ray laboratory.

Example

\[ D = 0.37 \]
Example exposure

\[ D = 1.9 \]
Example exposure

Kodak Biomax-MS Example Exposures

Example lineout

\[ f = 0.55 \text{ photons/\(\mu\text{m}^2\)} \]
Kodak DEF and Kodak Biomax-MS (BMS) x-ray films were calibrated in the LLE x-ray laboratory.

![Graph showing film density vs. fluence for Al Kα, 1.49 keV.](image)

**Film density**

**Fluence (photons/μm²)**

*J. P. Knauer et al. HTPD 2006, WP42.*

Kodak DEF and Kodak Biomax-MS (BMS) x-ray films were calibrated in the LLE x-ray laboratory.

Ag Lα, 2.98 keV

Note: DEF film had a high fog level due to age (≈0.5)

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Ti Kα, 4.51 keV

<table>
<thead>
<tr>
<th>Film density</th>
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<tbody>
<tr>
<td>2.5</td>
</tr>
<tr>
<td>2.0</td>
</tr>
<tr>
<td>1.5</td>
</tr>
<tr>
<td>1.0</td>
</tr>
<tr>
<td>0.5</td>
</tr>
<tr>
<td>0.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fluence (photons/μm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
</tr>
<tr>
<td>1.0</td>
</tr>
<tr>
<td>10.0</td>
</tr>
</tbody>
</table>

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Note: DEF film had a high fog level due to age (~0.5).

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Cu Kα, 8.04 keV

Note: DEF film had a high fog level due to age (~0.5)

Fluence (photons/μm²)

Fim density

*J. P. Knauer et al. HTPD 2006, WP42.
The grating-dispersed KB microscope* was used for film sensitivity comparison

OMEGA shot 35284
15-atm-D\textsubscript{2}-filled, 27-\textmu m-thick CH target

KB3, image (a) (Kodak Biomax-MS) KB3, image (b) (Kodak Biomax-MS)

Image (a) and image (b) are recorded on the same film for sensitivity check of the two microscope images

Analysis of grating-dispersed KB images verifies that image (a) and (b) are nearly identical when the same film is used in both.
Grating-dispersed KB images with DEF and Biomax-MS films show a sensitivity difference.

OMEGA shot 35281
15-atm-D$_2$-filled, 27-$\mu$m-thick CH target

KB3, image (a)  
(Kodak DEF)

KB3, image (b)  
(Kodak Biomax-MS)

Film density

865 $\mu$m
The DEF- and BMS-film–recorded KB spectra show sensitivity differences close to the calibration values.

OMEGA shot 35281
DEF versus BMS recorded images

Film density

Energy (keV)

Image (a) (DEF)

Image (b) (BMS)

Reduction inferred from model results
Summary/Conclusions

The x-ray sensitivity of Kodak Biomax-MS was calculated and compressed to Kodak DEF

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