



Application Note:

Dosimetry for Low Voltage Electron Beams for AEB Customers

April 20, 2009

Summary

This application note is intended for use by AEB customers in order for them to perform dosimetry of their low voltage electron beam in a manner that matches experimentation protocol established at AEB.

Application

This application note may be applied to AEB 10 inch (250mm) and 16 inch (400mm) emitter products in either an AEB system or a custom system.

Safety

Please follow all normal safety measures associated with the operation of electron beam systems.

If You Need Assistance

Please contact AEB Applications Support at inquiries@aub.com for assistance with dosimetry issues.

Background

AEB uses radiachromic films in order to perform low voltage electron beam dosimetry. There are three components of a dosimetry measurement process:

1. radiachromic film
2. film curing equipment
3. film measurement equipment

The electron beam radiation induces a chemical reaction in the dosimeter film that causes a color change. Curing, in turn, drives the chemical reaction to completion in a repeatable manner. The thickness of the film (T) combined with the color change, measured as a change in optical density (ΔOD), is then determined. T and ΔOD are then converted to absorbed dose by using a calibrated conversion equation. The conversion equation is generally traceable to a national standard laboratory.

Equipment and Materials Requirements

AEB recommends radiachromic film manufactured by GEX Corporation (Centennial, Colorado USA) to be used as dosimeter for general applications development. This film has a measurement range of 0 – 140kGy. The saturation of color change begins to occur near 75kGy. The following equipment and materials are required in order to perform dosimetry using GEX Corporation films:

Equipment/Materials	Manufacturer	Qty	Use
B3000 Radiachromic Films (18-20 μ m)	GEX Corporation	20 per foil pack 50 packs/box	Dosimeters to absorb electron beam and respond with color change
B3WINdose Dosimeter Film Heat Treatment Incubator System with Timer and Calibration Certificate, P4000	GEX Corporation	1	Baking/curing films after electron beam exposure to drive the color change chemical reaction to completion
Genesys 20 Visible Spectrophotometer	Thermo Electro Corporation or GEX Corporation	1	Radiachromic film optical density measurements
Hinged Black Film Holder	GEX Corporation	1	Sample holder of Genesys 20, custom made for B3000 film
Software	GEX Corporation	1	WINdose for Excel 2002 Interlink Software Program to Genesys 20. Automatically converting optical density into dose values.
Filmetrics F20 Optical Measurement System	Filmetrics	1	Radiachromic film thickness measurements

While there are alternative approaches to performing dosimetry that have a lower cost, these approaches significantly reduced measurement precision. These alternative approaches are provided in the Appendix.

Dosimeter Measurement Procedure

1. Measure an initial optical density (OD_0) of 32 dosimeters using Genesys 20 Visible Spectrophotometer. Calculate the average value of the 32 dosimeters. The average value is a representative of the entire batch of dosimeters received from the manufacturer. Note that this is a one time measurement to check the dosimeter quality. The average result should be within 0.035 to 0.041. If the optical density of non-irradiated dosimeter is outside of this range, please contact GEX Corp. for further action. Refer to GEX document #100-256.
2. Attach the dosimeter to the surface at the point where you want to measure dose. Handle the dosimeter films with gloved hands. Care should be taken when attaching the dosimeter tags to the measurement location. The path from the electron beam source to the dosimeter must not be obscured, with no blocking of the dosimeters by any objects. Ensure that the dosimeter tags do not overlap and that any adhesives do not come into contact with the open dosimeter film.
3. Irradiate the materials with the dosimeter affixed.
4. Remove the irradiated dosimeters from the materials and cure the irradiated dosimeters in the incubator at $57.5^\circ\text{C} \pm 2^\circ\text{C}$ for 15 minutes immediately after electron beam exposure.
5. Measure the final optical density (OD_F) of the dosimeter. For the highest precision, it is recommended to take measurements within 4 hours of cure.
6. Measure the thickness of dosimeter films using transmission probe of Filmetrics F20 system.

Handling Dosimeters

To ensure repeatable and accurate results, care must be taken when handling and storing dosimeter films. Please note the following precautions:

- **Physical Handling.** Clean tweezers and covered hands should be used to handle the films. Fingerprints can change the optical density readings and provide incorrect results. Vinyl gloves without powder are recommended for hand coverage.
- **UV Light.** Dosimeter films are sensitive to ultraviolet (UV) light. Storage and experimental areas should have UV filter sleeves covering fluorescence light fixtures. Do not leave dosimeters close to windows where the exposure to sunlight is possible. Exposure to UV light will cause the dosimeters to change color and optical density, impacting final absorbed dose values. Dosimeters must be kept inside the foil envelopes, as originally packed by manufacturer, when not in use.
- **Temperature and Humidity.** Dosimeter performance depends on the environmental temperature and humidity levels during storage and electron beam exposure. Recommended storage conditions are: temperature $20^\circ\text{C} - 30^\circ\text{C}$; humidity 30% - 70% RH.
- **Archiving.** Thin film dosimeters are not archival. Make readings within 4 hours after electron beam exposure in order to obtain maximum accuracy and precision of the dose readings.

Calibrated Conversion Equation

AEB recommends the “Laboratory Calibration” method serviced by GEX Corporation in order to establish the dose calibrated conversion equation. The source of calibration is a 10MeV high-energy electron beam, traceable to a national calibration laboratory. Details of the calibration process can be found in the S1101 calibration service package from GEX Corporation. The dosimetry performance depends on manufacturing lot; therefore, the calibration must be performed for each dosimeter lot.

Appendix

Alternative 1: Lower Cost Equipment/Reduced Measurement Precision

The Filmetrics F20 Optical Measurement System is the preferred instrument for measuring transparent, unsupported film thickness. Contact profilometry may also be used, though it introduces higher uncertainty in the thickness measurement. We recommend the following equipment set for users who prefer contact profilometry:

Option 1 Equipment Set: Lower Cost, Lower Precision Equipment			
Equipment/Materials	Manufacturer	Qty	Use
B3000 Radiachromic Films (18-20 μ m)	GEX Corporation	20 per foil pack 50 packs/box	Dosimeters to absorb electron beam and respond with color change
B3WINdose Dosimeter Film Heat Treatment Incubator System with Timer and Calibration Certificate, P4000	GEX Corporation	1	Baking/curing films after electron beam exposure to drive the color change chemical reaction to completion
Genesys 20 Visible Spectrophotometer	Thermo Electro Corporation or GEX Corporation	1	Radiachromic film optical density measurements
Hinged Black Film Holder	GEX Corporation	1	Sample holder of Genesys 20, custom made for B3000 film
Software	GEX Corporation	1	WINdose for Excel 2002 Interlink Software Program to Genesys 20. Automatically converting optical density into dose values.
Model 355 with F1 Standard Thickness Probe (1 –1500 μ m)	Elcometer	1	Contact profilometer for general material thickness measurement

Alternative 2: Lowest Cost Equipment Set/Lowest Precision

Electron beam dose metrology can also be performed without measuring the dosimeter thickness. If this method is employed, the user must specify the thickness range for dosimeter film purchased from GEX Corporation and maintain a calibration curve that references that thickness, recommended in a 18 μ m to 20 μ m range. Use the nominal thickness reported by GEX Corporation (written on the foil pack) in the dose calculation. The reduced equipment set for this option:

Option 2 Equipment Set: Lowest Cost, Lowest Precision			
Equipment/Materials	Manufacturer	Qty	Use
B3000 Radiachromic Films (18-20 μ m)	GEX Corporation	20 per foil pack 50 packs/box	Dosimeters to absorb electron beam and respond with color change
B3WINdose Dosimeter Film Heat Treatment Incubator System with Timer and Calibration Certificate, P4000	GEX Corporation	1	Baking/curing films after electron beam exposure to drive the color change chemical reaction to completion
Genesys 20 Visible Spectrophotometer	Thermo Electro Corporation or GEX Corporation	1	Radiachromic film optical density measurements
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Alternative 3: Other Dosimeter System

Radiachromic films from Far West Technology (FWT) can also be used and have a wider available dynamic range (0 – 200kGy) with a saturation starting point of 125kGy. However, we do not believe that the measurement precision is acceptable for most applications development and metrology projects. Please contact AEB if you would prefer to use the FWT films. An equipment list and calibration curve can be provided.