Specific Aspects of Radiochromic Film Dosimetry AAPM Task Group 235 An Update to Task Group 55 (1998)

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Outline of this Session for the Update of Radiochromic Film (RCF) Dosimetry

1. *General Aspects of RCF Dosimetry*
   Azam Niroomand-Rad (Chair of TG-55)
1. *Applications of RCF in SRS, SBRT, IMRT, VMAT, and kV Imaging*
   Sou-Tung Chiu-Tsao (Chair, TG-235)
3. *Applications of RCF in Brachtherapy*
   Samuel Trichter
4. *Applications of RCF in Small Electrons and Proton Beams*
   Indra Das

Members of AAPM TG-235: Rdiochromic Film Dosimetry

Radiochromic Film Dosimetry (TG-55)
The AAPM Report No. 63
Medical Physics, Vol. 25, Issue 11, 1998

Charges of TG-235
An Update to TG-55)

- ***To review the literature on recent radiochromic films and dosimetry of RCFs since TG-55,***
- ***To assess the densitometers/scanners used for digitizing RCF since TG-55,***
- ***To outline the procedures for accurate dosimetry and to evaluate measurement uncertainties, and***
- ***To provide guidelines on recent RCF dosimetry for clinical radiotherapy applications.***

Where We Are in RCF Dosimetry

Different Types of RCF for Clinical Use

- *The chemistry, dosimetry, size, and application of RCF have evolved very rapidly over the past few decades*
- *At the time of TG-55 (1998):*
  - *Various Types of RCF, referred to as GafChromic films, have been identified by the the catalog number of manufacturer (International Specialty Products (ISP)) and suppliers (Nuclear Associate)*
  - *DM-1260 rolls (12.5 cm x 15 m)*
  - *HD-810 (formerly DM-1260) (20 cm x 25 cm)*
  - *MD-55-1 – single layer (< 1994, not so sensitive) (12.5x12.5 cm2)*
  - *MD-55-2 (NMD-55), Double-layer – (more sensitive than MD-55-1), (12.5 cm x 12.5 cm)*

Structure and Approximate Thickness of HD-810 (DM-1260), MD-55-1, MD-552

ype	Layer number	Description	Thickness (μm)
HD-810	1	Surface layer	0.75
	2	Active layer (emulsion)	6.5[a]
	3	Transparent polyester	97
MD-55-1	**1**	**Sensitive Layer**	**15**
	1	**Polyester Base**	**67**
MD-55-2	1	Transparent polyester	67
	2	Active layer (emulsion)	16[a]
	3	Adhesive	~20
	4	Transparent polyester	25
	5	Adhesive	~20
	6	Active layer (emulsion)	16[a]
	7	Transparent polyester	67

Recent Radiochromic Films for Clinical Use (Since TG-55 (1998)

- ***EBT Films (EBT2, EBT3, EBT3+)***

  (8" x 10" sheets, 25 sheets / box)

  (14" x 17" sheets, 10 sheets / box)

  EBT3F (8" x 10" sheets: pre-marked with fiducials)

  EBT3+ (8" x 11" sheet separable into 8" x 9.5" sheet + 8" x 1.5" strip)

1	Transparent polyester	97
2	Active layer (EBT emulsion)	17[a]
3	Surface layer	6
4	Active layer (EBT emulsion)	17[a]
5	Transparent polyester	97

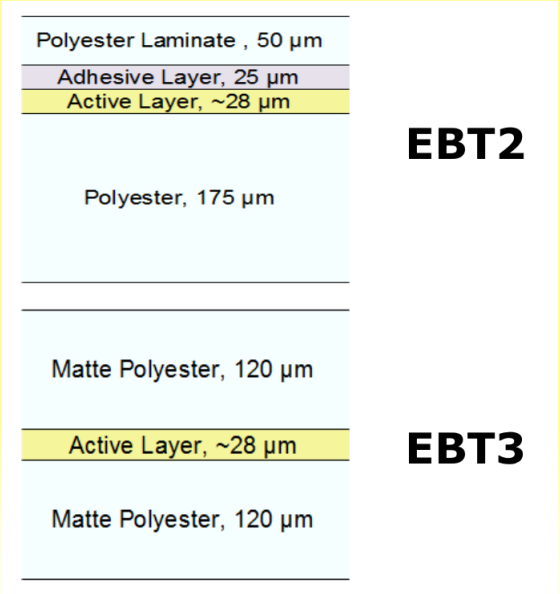
GafChromic EBT2 Film

Layer	Nominal thickness, μm	Density, g/cm^2	COMPOSITION (ATOM%)						
			H	Li	C	O	Al		Effective Z
Smooth polyester film base	50	1.35	36.4%	0.0%	45.5%	18.2%	0.0%		6.64
Acrylic adhesive	20	1.2	57.1%	0.0%	33.3%	9.5%	0.0%		6.26
Active layer (assumes 7.5% moisture)	28	1.2	56.8%	0.6%	27.6%	13.3%	1.6%		7.26
Smooth polyester film base	175	1.35	36.4%	0.0%	45.5%	18.2%	0.0%		6.64
Overall Composition			40.3%	0.1%	42.6%	16.9%	0.2%		6.67

GafChromic EBT3 and EBT3+ Films

Layer	Nominal thickness, μm	Density, g/cm^2	COMPOSITION (ATOM%)						
			H	Li	C	O	Al		Effective Z
Matte polyester film base	125	1.35	36.4%	0.0%	45.5%	18.2%	0.0%		6.64
Active layer (assumes 7.5% moisture)	28	1.2	56.8%	0.6%	27.6%	13.3%	1.6%		7.26
Matte polyester film base	125	1.35	36.4%	0.0%	45.5%	18.2%	0.0%		6.64
Overall Composition			38.4%	0.1%	43.7%	17.7%	0.2%		6.69

Radiochromic Film Configuration EBT2 and EBT3



Recent Radiochromic Films (Cont.)

- *HS Films*
- *XR-RV2*
  (sensitive to low energy photons for diagnostic radiology dosimetry)
- *XR-QA*
- *XR-T*
- *RTQA*

1	Transparent polyester	97
2	Active layer (emulsion)	38[a]
3	Transparent polyester	100

1	Yellow polyester	97
2	Adhesive	12
3	Surface layer	3
4	Active layer (XRQA emulsion)	17[a]
5	Opaque white polyester	97

1	Transparent polyester	97
2	Active layer (XRQA emulsion)	25[a]
3	Surface layer	10
4	Active layer (XRQA emulsion)	25[a]
5	Opaque white polyester	97

1	Transparent yellow polyester	97
2	Active layer (XR-T emulsion)	18[a]
3	Transparent yellow polyester	97

1	Transparent yellow polyester	97
2	Adhesive	12
3	Surface layer	3
4	Active layer (RTQA emulsion)	17[a]
5	Opaque white polyester	97

Note a: Thickness of the active layers (emulsion) for all the recent films is adjusted from lot to lot to achieve the design sensitivity and may very by 10% from the nominal thicknesses given for these recent films.

Specific Aspects of Radiochromic Films

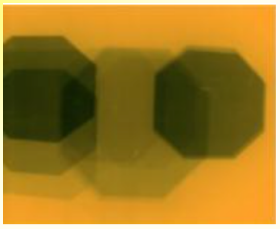
Few Considerations for RCFs (Old, new):

- ★ *Change color when exposed to ionizing radiation*
- ★ *Color changes instantly*
- ★ *No chemical or physical processing ➔ Eliminate processor*
- ★ *Can be handled in room light*
- ★ *Best to store in the dark at , at temp. < 25°C, humidity < 50%*
- ★ *Avoid dust, fingerprints, or crimping*
- ★ *Can be cut to size & bend to shape*
- ★ *Can be immersed in water*
- ★ *Has wide dynamic range*
- ★ *Has high spatial resolution*
- ★ *New software and protocol make RCF much more accurate and user-friendly*
- ★ *Don't expose to UV Light*
- ★ *Don't expose to high temperature (> 60° C) ➔ (Non-Reversible)*
- ★ *Humidity Dependent ➔ (Reversible, Watch Film Gradient) ➔ < 50%*

Radiochromic Films for Dose Measurement and QA for Radiotherapy and Radiology

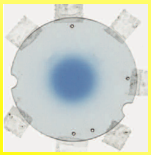
- ***Radiotherapy (High Energy MV photons, electrons, protons, HDR)***
  - **EBT2, EBT3, EBT-XD – 1 cGy to >40 Gy**
  - **MD-V3 – 2 Gy to 100 Gy**
  - **HD-V2 – 10 Gy to 400 Gy**
  - **RTQA2 – 2 cGy to 8 Gy**

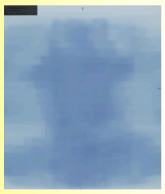
- ***Radiology (Low Energy: kV photons)***
  - **XR-RV3 – 5 cGy to 15 Gy**
  - **XRQA2 – 1 mGy to 20 cGy**
  - **XRCT2 – 1 mGy to 20 cGy**
  - **XRM2 – 1 mGy to 20 cGy**

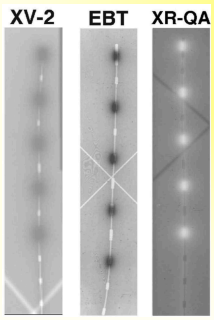


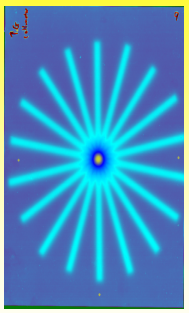
Some Example of Exposed RCFs for Radiotherapy (hv, e, p, HDR), QA

- ***EBT film (IMRT, H&N, Coronal, Phantom) with Fiducial marks at crosshair and lot label @ UL***
- ***EBT film (2.6 mm from inner surface of a CCX plaque)***
- ***HDR source positioning QA measurements (Photographic Film (XV-2), EBT, XR-QA)***







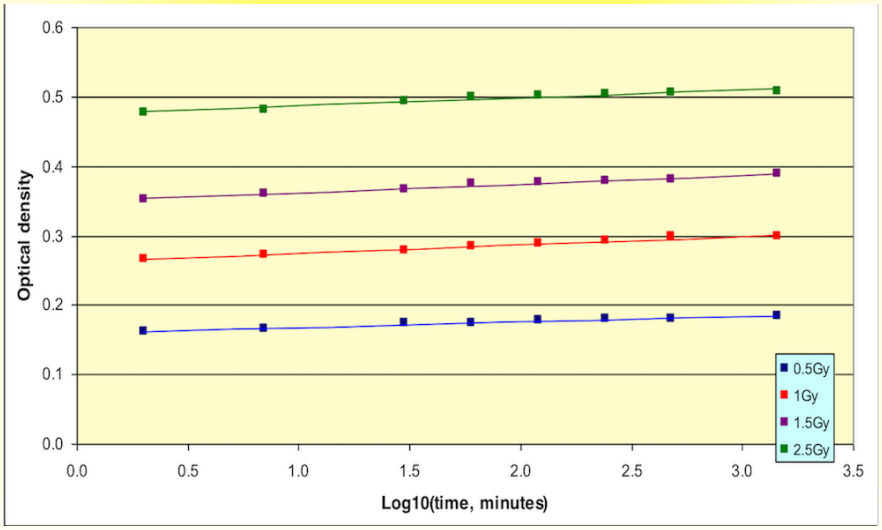


Information Analysis from Irradiated RCFs

- ***The signal information is obtained from a light transmission measurement when compared with the incident light intensity:***
  Transmission (T) = It / Io
- ***Transmission and delivered dose is inversely proportional and non-linear***
- ***Absorbance / Optical Density (OD) is defined as inverse log of T***
  $OD = \log_{10} (1/T) = \log_{10} (I_o / It)$
- ***OD is expressed in Absorption Units (AU) such as:***
  OD = 1 (IU) ➔ 10% transmission
  OD = 2 (IU) ➔ 1% transmission
- ***OD is a function of the wavelength at which T is measured.***

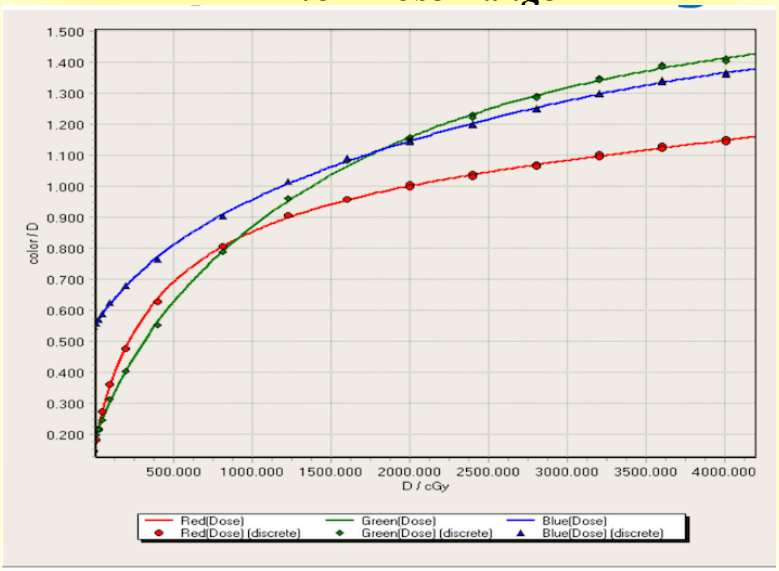
➔ ***Measured OD and delivered dose can be considered unique for the film and delivered dose only if sampled by spectrometer of a known wavelength, or by an optical densitometer with monochromic light source.***

RCF (EBT-2): Post-Exposure Changes in OD for typical Doses (Gy) Logarithmic growth approaching asymptotic value



Radiochromic Films Dose and Dynamic Range

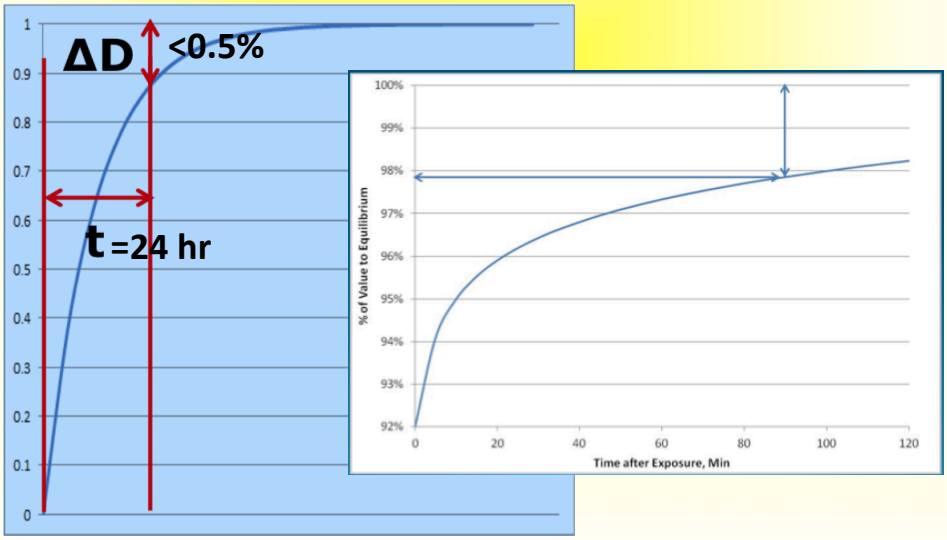
EBT2/3 - Dose Range



Dynamic range ~2 cGy to >>40 Gy

Radiochromic Films Dosimetry
Post Exposure Density Growth

Absolute aging Compensate by waiting t = 24 h, ΔD(t) < 0.5%



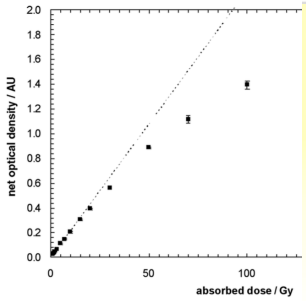
RCF Characteristics for Readout at 633 nm at typical Useful Dose Range (Gy)

Film Model	Emulsion thickness (μm)	Sensitivity (mAU/Gy)	Useful range (Gy)
HD-810	6.5	3	10–1000
MD-55-2	32	20	1–100
HS	38	35	0.5–50
EBT	34	400 to 800[a]	0.05–10
XR-RV2	17		0.01–5
XR-QA	50	0.001–0.2	

Calibration Curve For MD-55-2 RCF (Read at 633 nm)

Net OD / AU & Absorbed Dose

The dashed line indicates the region of linearity between 5 Gy and 20 Gy



Benefits of New Generation of RCFs

➔ *High spatial resolution Shoot from any angle*

➔ *Near water-equivalent Nearly energy independent Handle in light*

➔ *Cut to size, bend to shape Immerse in water*

➔ *Wide dynamic range*

❖ *Highly Valuable for Conformal Therapy:*

SRS, SBRT, IMRT, VMAT, and kV Imaging

❖ *Highly Valuable for QA checks and Special procedures:*

- **Linacs and HDR Commissioning**
- **Brachytherapy Dosimetry**
- **Dosimetry of Superficial Regions**
- **Small Fields Dosimetry**
- **In vivo Dosimetry**