Radio photoluminescence (RPL) glass dosimeters

Radical dosimetry

- Radical: compound with unpaired electron
- Most radicals formed in radiation chemistry are short-lived
- Radical dosimetry is an important method for “historic dosimetry, i.e. to measure dose in situation which were not prepared for (bombs, reactor accidents etc.)
- Materials useful for radical dosimetry: alanin, carbogydrates, some rocks, teeth, everything creating something long-lived.
- ESR on sugar and teeth can be used in evaluation of cancer patiens doses; bomb victims; doses to people living in areas with high natural background; contanimated areas etc.

Radio photoluminescence (RPL) glass dosimeters

- RPL glass dosimeters are the accumulation type solid state dosimeters.
- It is based on the radio photoluminescence phenomenon to measure the radiation dose
- They are available in the shape of small glass rods
- Radiophotoluminescent glass block is positioned in the center of a holder.
- To determine the dose, the glass block is removed from the holder and exposed to ultraviolet radiation in a reader.
- The result is that the glass emits light, the intensity of which is proportional to the radiation exposure.
- The reader measures the intensity of the emitted light and converts this into personal dose equivalent.
- Material used is silver activated phosphate glass
- When silver activated phosphate glass is exposed to radiation, stable luminescence centers are created in silver ions (Ag^0 and Ag^{++})

- These luminescence centers emit light upon excitation. Read out technique uses pulsed ultraviolet laser excitation.
- A PMT registers the orange fluorescence emitted by the glass
- RPL signal is not erased during the readout, thus the dosimeter can be re-analyzed sever times.
- Accumulation of the dose is also possible that may be used for registration of the lifetime dose
- Commercially available RPL dosimeters typically cover the dose ranges of 30 μSv to 10 Sv
- They have a flat energy response within 12 keV to 8 Mev
- RPL signal exhibits very low fading and is not sensitive to the environmental temperature making it convenient in individual monitoring

Advantages of Radiophotoluminescent glass systems:

- RPL signal is not erased during the readout, thus the dosimeter can be re-analysed several times, and the measured data reproduced. Accumulation of the dose is also possible that may be used for registration of the lifetime dose.
- Commercially available RPL dosimeters typically cover the dose range of 30 μSv to 10 Sv. They have a flat energy response within 12 keV to 8 MeV for *Hp(10).*
- RPL signal exhibits very low fading and is not sensitive to the environmental temperature making it convenient in individual monitoring.

Radio-Photoluminescence Glass Dosimeter (RPLGD)

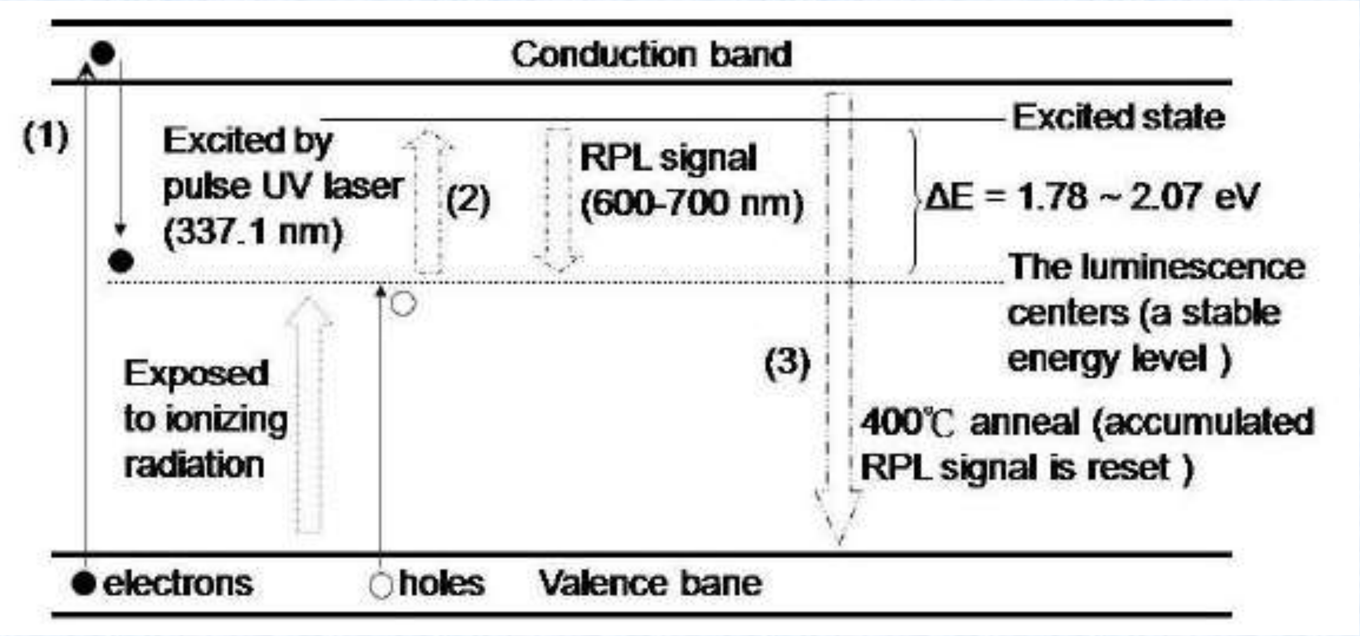
- OSLD is made of the same luminescent material as one used in TLD.
- The only differences are different excitation source and different readout technique used.
- However, RPLGD uses glass compound as the luminescent material and applies different excitation method along with different readout technique.
- The luminescent material of compound glass (25% of KPO3, 25% of Ba (PO3)2 and 50% of Al (PO3)2) with proper amount of silver activated phosphate glass.
- It is very difficult to measure dose under 1 mGy, because it has a high pre-dose (residual dose).
- Pre-dose is the phosphorescence light emitted from RPLGD without any irradiation and excitation process. It is the minimum radiation can be measured with RPLGD.
- Therefore, RPLGD is not a popular dosimeter in day to day applications in those days.

Principle of RPLGD and its readout methods

○ The basic principle of RPLGD is that the color centers are formed when the luminescent material inside the glass compound exposed to radiation and fluorescence are emitted from the color centers after irradiated with ultra-violet light.

○ The excited electrons generated from the color centers return to the original color centers after emitting the fluorescence. This process is called radio-photoluminescence phenomena.

○ Because the electrons in the color centers return to the electron traps after emitting the fluorescence, it can be re-readout for a single irradiation.



Characteristics of RPLGD for clinical applications:

1. Repeatable readout

The luminescence signal does not disappear after readout; therefore, repeated readout for a single exposure is possible for RPLGD.

2. Small difference in individual sensitivity

The readout variation between different PRLGDs with the same exposure is small. RPLGD is manufactured with melted glass; therefore, its individual sensitivity is small as compared to that of either TLD or OSLD.

3. No correction factor needed

The luminescence single can be converted to the exposure dose directly without the need of correction factors. The exposure dose can be determined with the help of readout from reference PRLGD built-in to the readout system.

4. Small energy dependence

The energy dependence existed in FD-7 glass, if there is no energy compensator filter with it. However, energy dependence can be reduced with energy compensator filter.

5. Small fading effect

The stability of color centers in RPLGD is high. Hence the effects of environment conditions such as humidity and temperature have very little impact to color centers, hence low fading effects for RPLGD.

6. Better reproducibility

By using pulse ultra-violet laser as excited source, the accuracy of repeated readout can be maintained. Therefore, RPLGD has a very good reproducibility.

7. Wide measurable dose range

The dose linearity range for RPLGD is 0 – 500 Gy. This range covers the dose range used in the medical field. RPLGD can therefore be applied for dose verification in radiotherapy as well as in diagnostic radiology. RPLGD is also desirable for high dose gradient area, such as IMRT (Intensity Modulated Radiotherapy) procedures or HDR (High Dose Rate Remote Afterloader) procedures because of its small effective readout area.

8. Feasibility of personal dose monitor tools

The characteristics, physical and chemical, of RPLGD are equal to or better than that of TLD and OSLD because of its luminescence material and readout technique. Hence, RPLGD can be used as dose monitor for radiation field worker.

Applications of RPLGD

- ❖ RPLGD can also be placed in the anthropomorphic phantom to evaluate dose received during the clinical procedures for diagnostic radiology and radiotherapy.
- ❖ With its characteristics of repeatable readout and small effective readout area, RPLGD can also be used in brachytherapy procedures to evaluate the dose delivery accuracy for each procedure as well as for entire course.
- ❖ On the top of that, with the help of dedicated tube to hold RPLGD, one can apply RPLGD in the area of adjacent critical organs to monitor the organ dose to avoid the dose exceeding the tolerance during the radiotherapy procedure. It can improve the patient life quality after radiotherapy.

	TLD	OSLD	RPLGD
Principe of measurement	luminescence signal	optically stimulated luminescence signal	radiophotoluminescence signal
Luminescence material	crystal	crystal	glass
Excitation source	heat	visible light	ultra-violet laser
Sensitivity	material-dependent	material-dependent	good
Repeatable readout	no	yes, but intensity reduced	yes, with the same intensity
Range of measurement	material-dependent (10μGy - 10 Gy)	material-dependent (10μGy - 10 Gy)	10μGy - 10 Gy 1 Gy - 500 Gy
Geometrical shape	chip and powder	powder	various shapes
Fading effect	material-dependent (5 - 20 % / quarter)	material-dependent (0 - 10 %/year)	less than 5%/year
Energy dependence	material-dependent	material-dependent	± 20% (having energy compensation filter)
Capability to distinguish the types of radiation	yes	yes	yes
Re-useable	yes	no	yes

Pocket Ion-Chamber Dosimeter

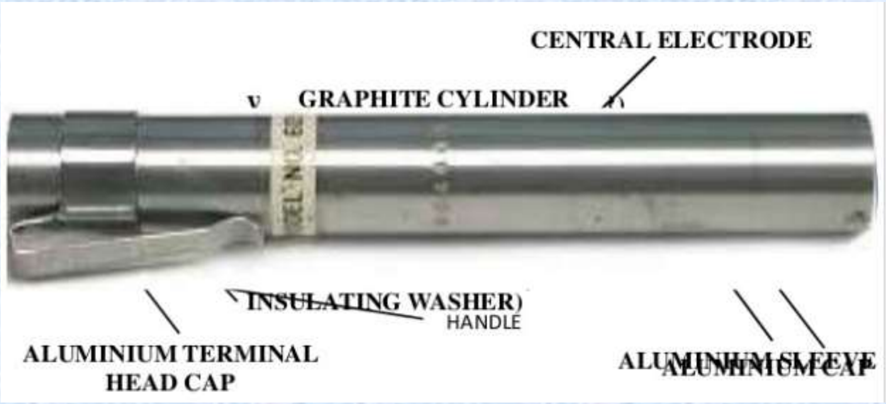
What is a Pocket Dosimeter?

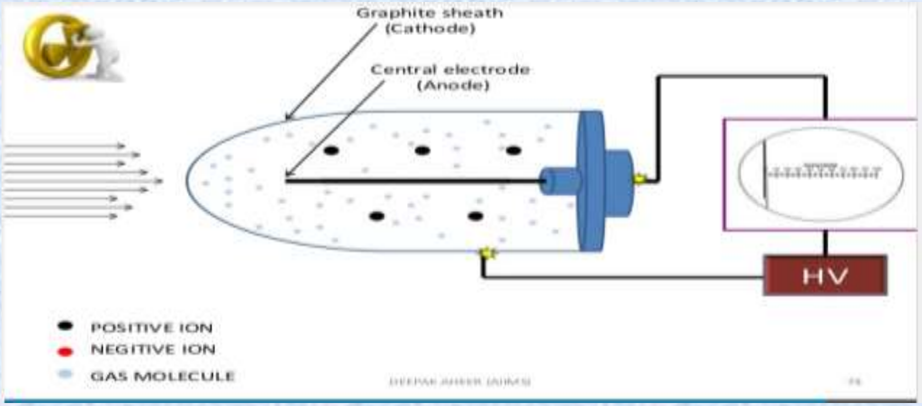
Pocket dosimeter

- Film badge and TLD will not show accumulated exposure immediately.
- In addition to regular TLD radiation, dose received by the worker can be assessed by wearing pocket dosimeter.
- It is small and portable.
- Gives instant exposure/dose rate and total dose.
- Can track dose received from day to day activities.
- It gives instantaneous radiation exposure and very useful in non routine work in which radiation level vary considerably and may be quite hazardous.

Construction:

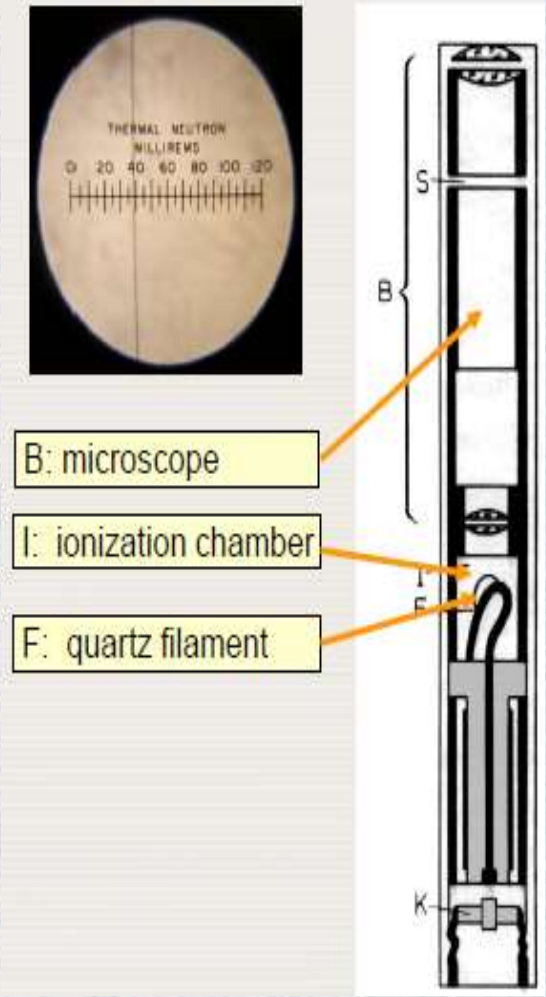
- These detector are filled with gas (non electronegative)
- They are cylindrical in shape with two electrode
  - ✓ Cathode: Outer sheath made of graphite
  - ✓ Anode: Center wire which is insulating from the outer sheath
- Radiation produced ionization in gas resulting positive ions and negative ion are produced inside the detector volume
- Positive and negative ion drift to the negative and positive electrodes respectively due to applied voltage between electrodes
- In an outer circuit the current is measured which is proportional to the number of ion pair produced per second
- These dosimeters should fully charged prior to their use so that the initial reading of the dosimeter is set at zero.





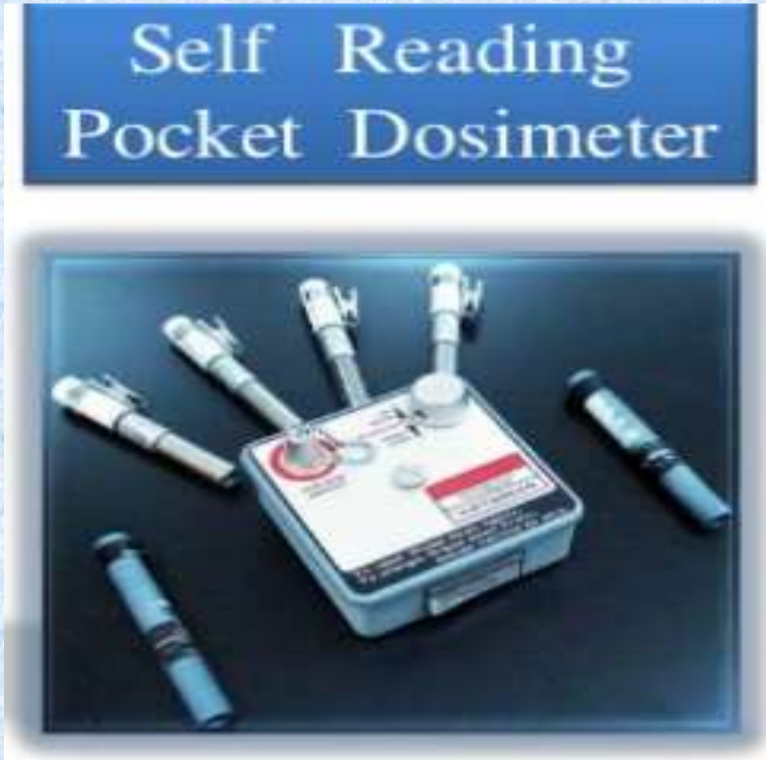
How does the Dosimeter work?

- Read by looking at the hairline indicator against scale
- Must be set to zero before use
- It consists of a sealed air-filled cylindrical device contains a thin quartz or carbon fiber aligned to a radiation exposure scale.
- Inside it is a metal electrode strip that is attached to a terminal on the end of the pen for recharging.
- The other end of the electrode has a delicate gold-plated quartz fiber attached to it, which at rest lies parallel to the electrode.
- The ends of the chamber are transparent and the microscope is focused on the fiber



- When a particle of ionizing radiation passes through the chamber, it collides with molecules of air, knocking electrons off them and creating positively and negatively charged atoms (ions) in the air.
- The ions of opposite charge are attracted to the electrode and neutralize some of the charge on it.
- The reduced charge on the electrode reduces the force on the fiber, causing it to move back toward the electrode.
- The position of the fiber can be read through the microscope. Behind the fiber is a scale graduated in units of radiation, with the zero point at the position of the fiber when it is fully charged.
- Since each radiation particle allows a certain amount of charge to leak off the electrode, the position of the fiber at any time represents the cumulative radiation that has passed through the chamber since the last recharge.
- Recharging restores the charge that was lost and returns the fiber to its original deflected position.
- During recharging, the charger applies a high DC voltage, usually around 150-200 volts, to the electrode, charging it with electrostatic charge.
- The quartz fiber, having the same charge, is repelled by the surface of the electrode due to the coulomb force and bends away from the electrode. After charging, the charge remains on the electrode because it is insulated

Types of pocket dosimeter



Advantages:

- Small in size and portable
- Easy to use
- Give instantaneous radiation exposure
- Reasonably accurate and sensitive
- It also has the advantage of being reusable

Disadvantages:

- Dose not provide permanent record
- Sudden mechanical shock may result in wrong reading
- Should be handled very carefully
- Limited range
- Reading loss due to dropping or bumping

Electronic Dosimeter

- Activated using the Electronic Dosimeter reader
- Self-reading, digital display of accumulated dose and dose rate
- Records accumulated dose and “highest dose rate field” in milliroentgen (mR) and milliroentgen per hour (mR/hr), respectively (can be set to record in units of Roentgen)
- Visual and audible alarms for accumulated dose and dose rate
- Silicon diode detector to detect gamma radiation (sensitive to gamma only)
- Resistant to shock
- Downloads dose and dose rate data to Radiation Exposure Control database when deactivated by the ED reader

Electronic dosimeter

- Battery powered dosimeters have a digital readout and may have an audible alarm.
- Some contain a small Geiger Mueller (GM) tube; others use cesium iodide scintillators or silicon semiconductors.
- **Electronic dosimeters record accumulated dose and can also give real time dose rate information to the wearer.**
- **They typically measure a wide dose range from routine to emergency levels with high precision.**
- **Formats include badge and pager sized, designed to clip on to clothing or to be carried in a pocket.**
- **Batteries are required and some electronic dosimeters may be sensitive to interference from radiofrequency electromagnetic fields.**
- **The unit cost (e.g. a few hundred dollars) can be significantly greater than that for other dosimetry technologies.**