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PERFLEX: Flexible films for dosimetry

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3rd ELICSIR Training School

I. Objectives

1. To select and characterize **new colourimetric radiochromic materials**.
2. To **select** and **characterize flexible supporting materials** easily adapted to different clinical situations.
3. To develop **efficient reading systems for measuring** the colour changes produced by radiation in the radiochromic materials.
4. To **characterize and calibrate the dosimetric methods**.
5. To evaluate the capabilities of the developed dosimeters in **actual clinical applications**.

II. Introduction: Cancer & Radiotherapy

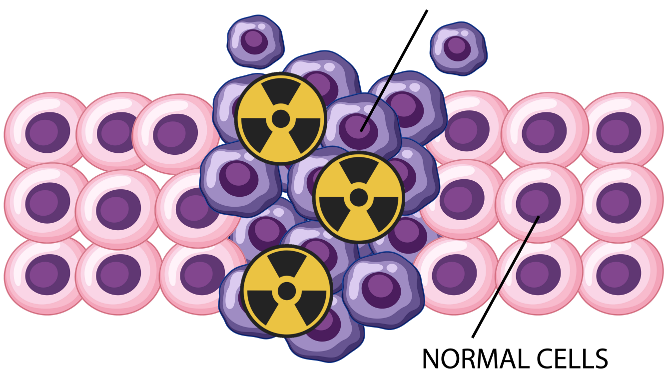
- Cancer is still the **leading cause of death** globally.
- Cancer is usually treated with a **combination of techniques**, such as *surgery*, *chemotherapy* and ***radiotherapy***.
- About **50%** of people with cancer get radiotherapy → High – energy X – rays.

II. Introduction: Cancer & Radiotherapy

RADIOTHERAPY

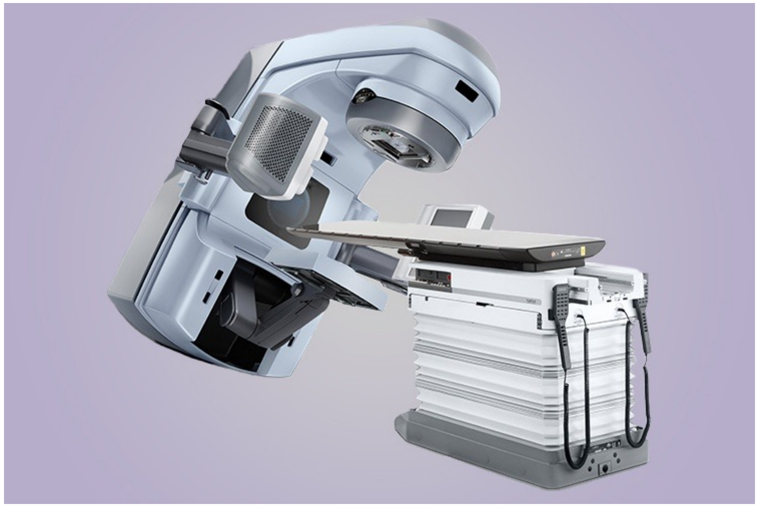
Radiation must hit the tumor while avoiding the healthy tissue that is next to it (**accuracy**)

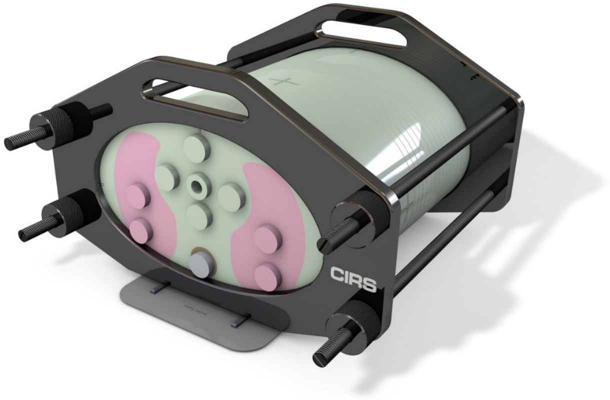
And this must occur over and over again (**precision**)



Electronic and Chemical sensing solutions

II. Introduction: Dosimeters





- Radiation oncologists **define empirically** the planning target volume.
- The 3D **dose distribution** in the patient is **determined** by advanced computerized **dose calculation algorithms**.
- **Experimental verification** of the treatment plan is **necessary** due to the complexity of dose distribution.

II. Introduction: Dosimeters

POINT DOSIMETERS

Ionization chambers
Diodes
Diamonds
MOSFET
Etc.

They are mainly used for beam **calibration** and **quality assurance**

I. Introduction: Dosimeters

https://slideplayer.com/slide/1429309/

- **Radiochromic films** withhold all the advantages of old silver halide films.
- **Disadvantages of silver halide films**: lower sensitivity to UV light, low energy dependency, tissue equivalent, no need to process, easy to cut and handle, and can be immersed in water.
- On the other hand, radiochromic films develop the **radiation-induced image** by the self-developing post-irradiation process, which is governed by different chemical processes such as **polymerization of dye monomers**.

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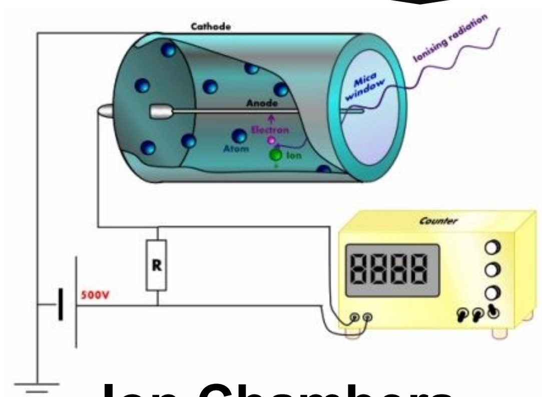
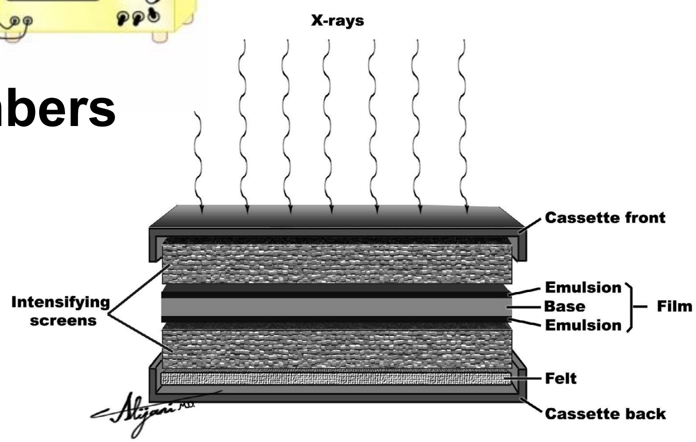
II. Introduction: Dosimeters

Use in treatment validation → **Suitable characteristics**



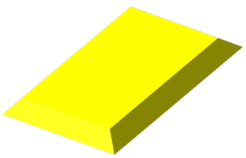
Ion Chambers



Radiographic films

- ✓ Soft – tissue equivalent
- ✓ Yield a **linear dose – response** in a range of clinical treatments
- ✓ Provide **accurate** and **quantitative** dose distributions
- ✓ Maintain guaranteed **stability** during relatively *long periods of analysis*

II. Introduction: Dosimeters



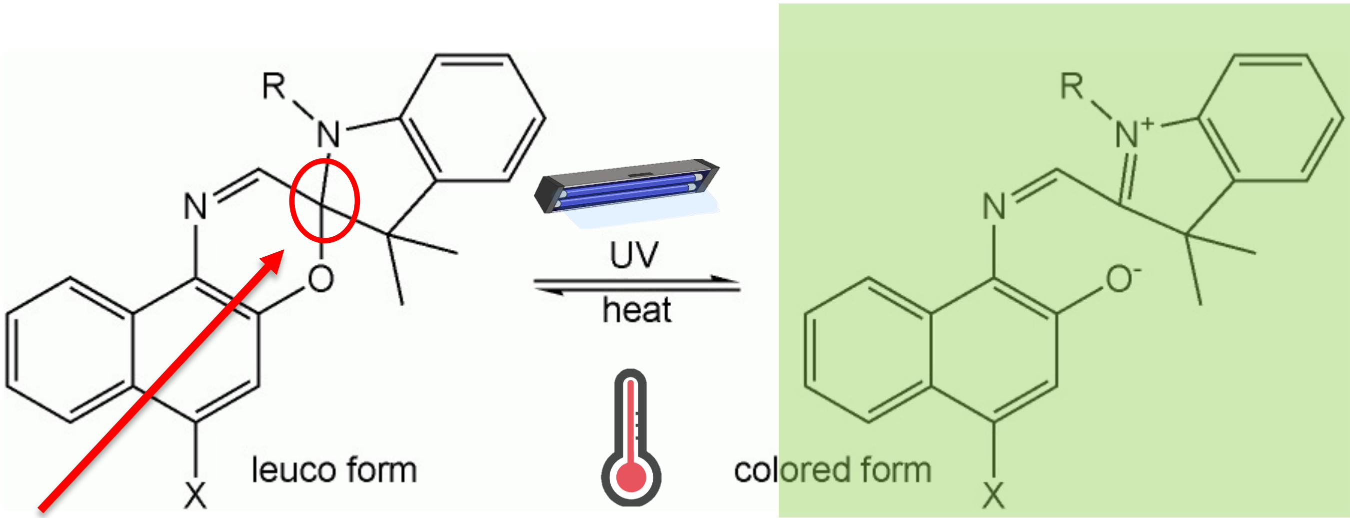
Radiochromic films → **Reference dosimetry systems** → **Can measure absolute dose**

ESSENTIAL PARTS

- Particular film model used
- Scanner used to measure film's response to radiation
- Protocol

II. Introduction: Chemistry used in radiochromic films

a) Leuco dye based radiochromism



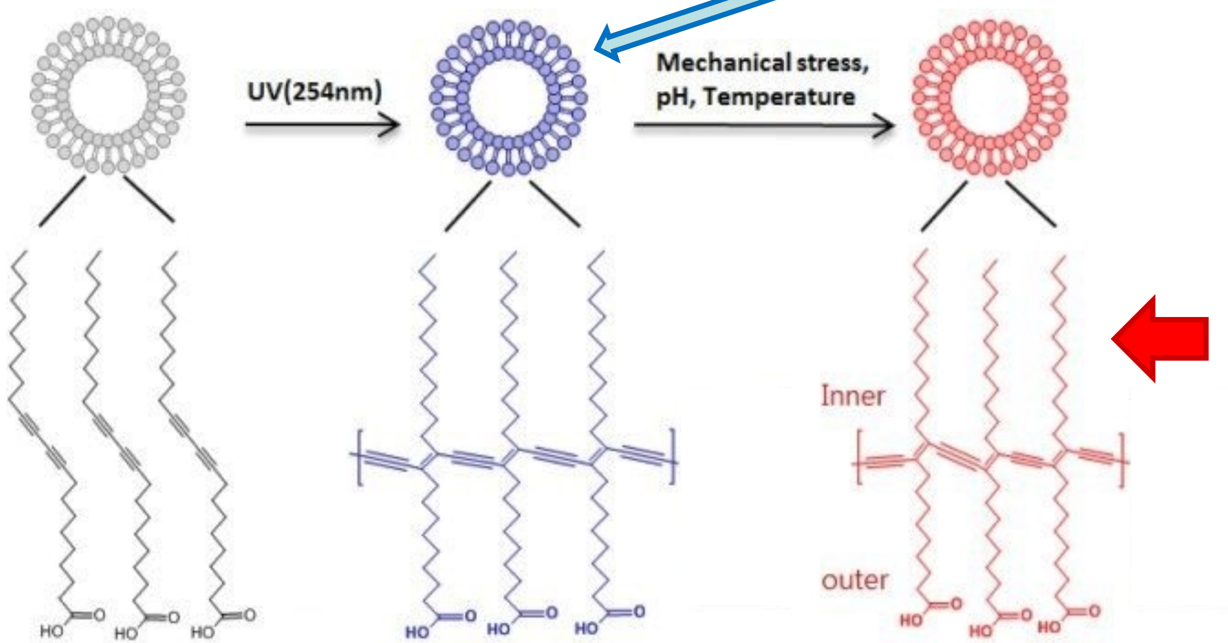
The **bond between** the spiro carbon and the oxazine **interrupts** and the **ring opens**.

A conjugated system forms, with **ability to absorb photons of visible light**, and therefore appears **colourful**.

II. Introduction: Chemistry used in radiochromic films

b) Diacetylene dye based radiochromism

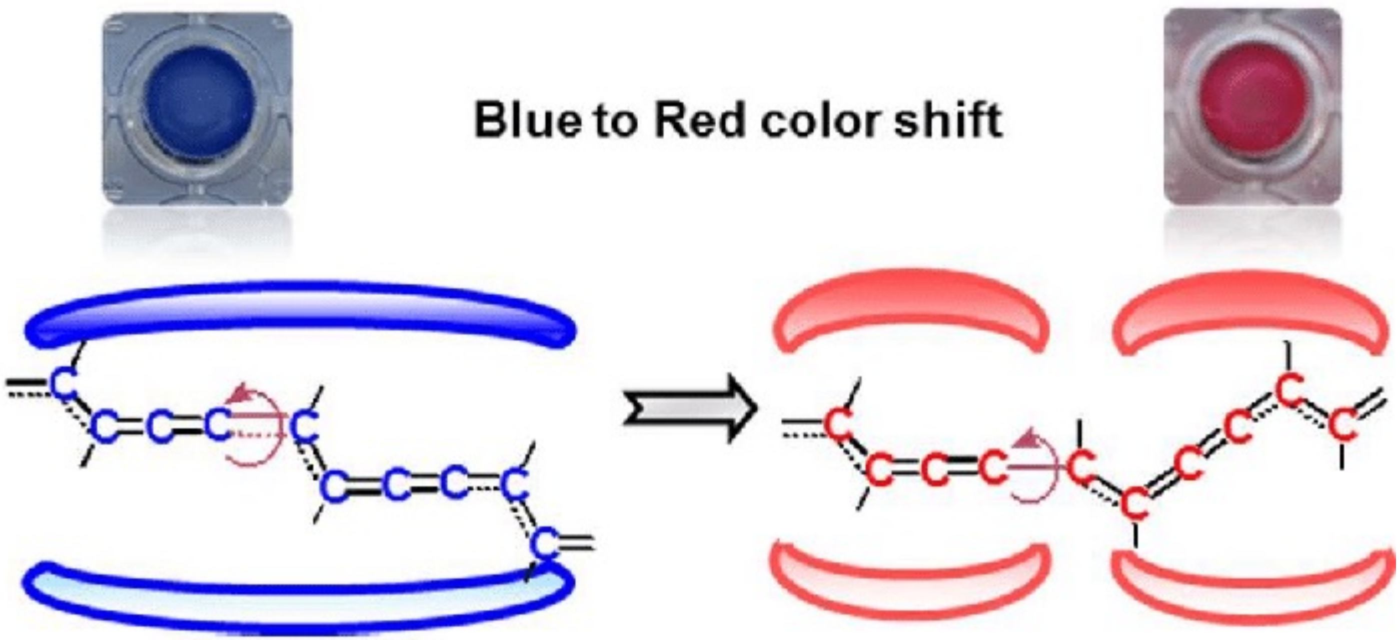
Blue: Extended π – delocalization in the conjugated polymer.



Red: Whith further stimulation, polydiacetylenes will turn red due to *spatial conformation change*.

Polydiacetylenes is formed via a *topotactic 1,4 – addition* mechanism that results in a linear conjugated backbone polymer consisting of alternating **triple and double bonds**.

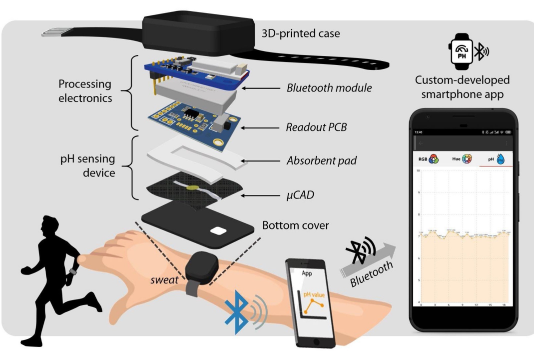
II. Introduction: Wearable devices



Topotactic describe a transformation, within a crystal lattice, involving the displacement or exchange of atoms.

II. Introduction: Wearable devices

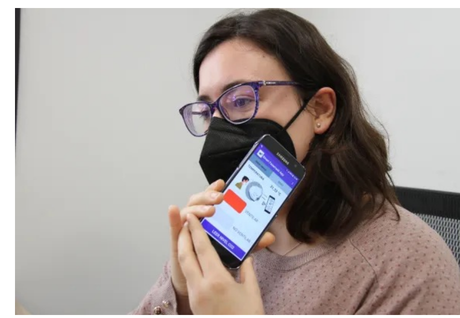
Glucometer used to measure blood **sugar levels** in patients with **diabetes**



Wireless wearable **wristband** for continuous **sweat pH monitoring.** Designed by scientists and engineers from the **UGR**.

Our aim is to work in the field of wearable devices in this case for ionizing radiation. Field in which we have some experience.

Smart watch used to measure heart rate, sports activity, sleep, etc.

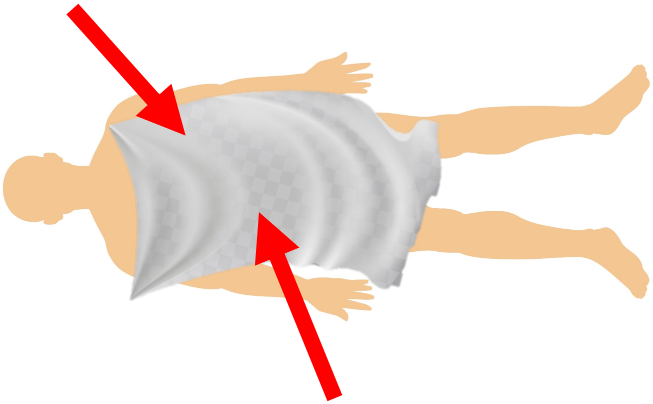


Smart mask to measure **CO2** levels.
Designed by scientists and engineers from the **UGR**.

II. Introduction: Wearable devices

Other advantages

FLEXIBLE



Adapt to different parts of the human body

- ✓ It can be easily **printed** or **impregnated** with inks, chemical reagents, etc.
- ✓ It is a **biodegradable** material.
- ✓ It is a **durable** material, **mechanically strong** and has good **resistance to humidity.**
- ✓ The *surface of the fabric* allows **chemical reagents** to **attach** to it.

III. Materials and method

Flexible substrate

PAPER & NYLON

- ✓ Whatman P81 paper
- ✓ Whatman paper grade 1
- ✓ Nytran SPC
- ✓ Nytran (Nylon)
- ✓ Nylon transfer membrane

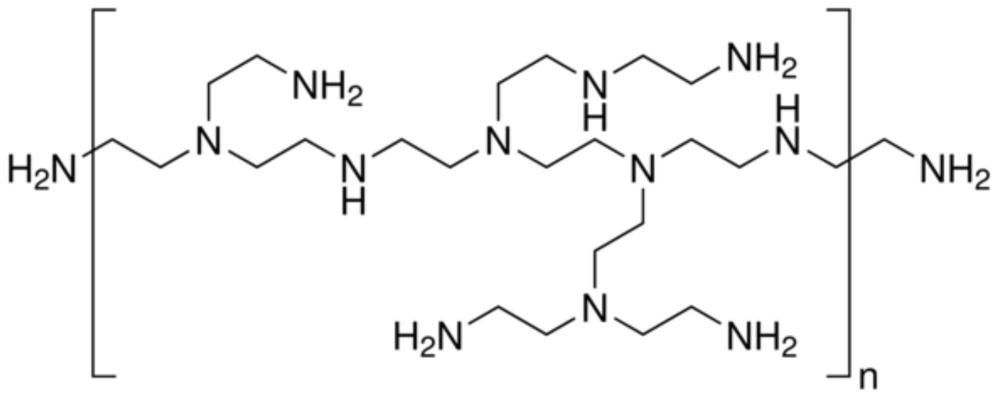
FABRIC

- ✓ Cotton fabric
- ✓ Polyester fabric
- ✓ Polyacrylic
- ✓ Bio baumwolle

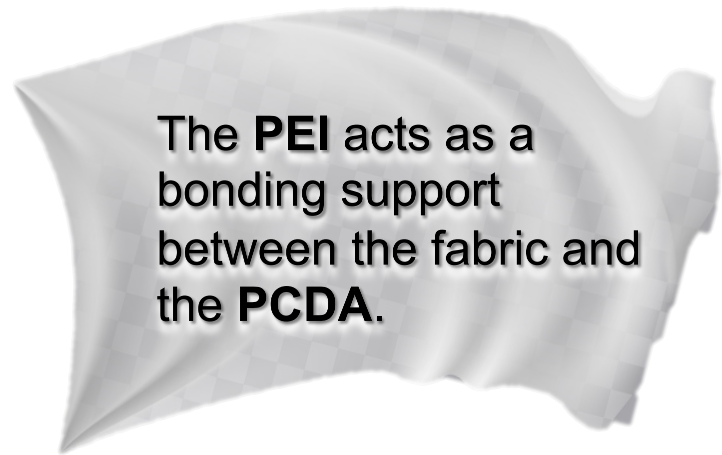
PLASTIC

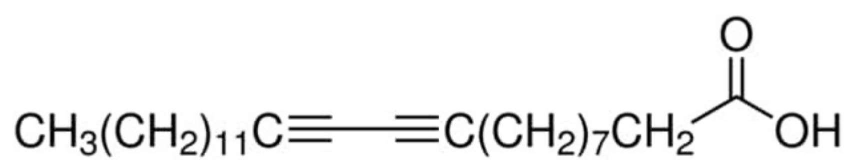
- ✓ Mylar
- ✓ PET
- ✓ Ethylene vinyl acetate

III. Materials and method



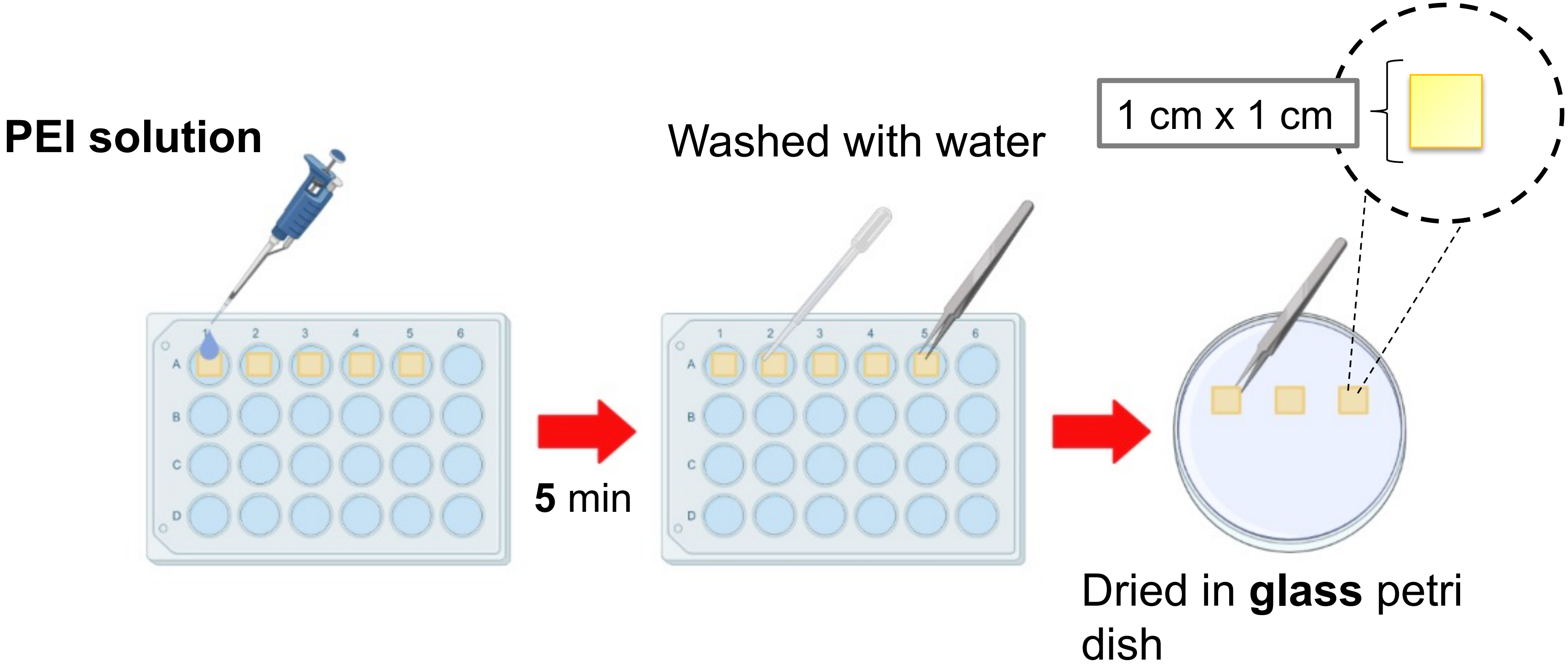
Polyethylenimine
(**PEI**)



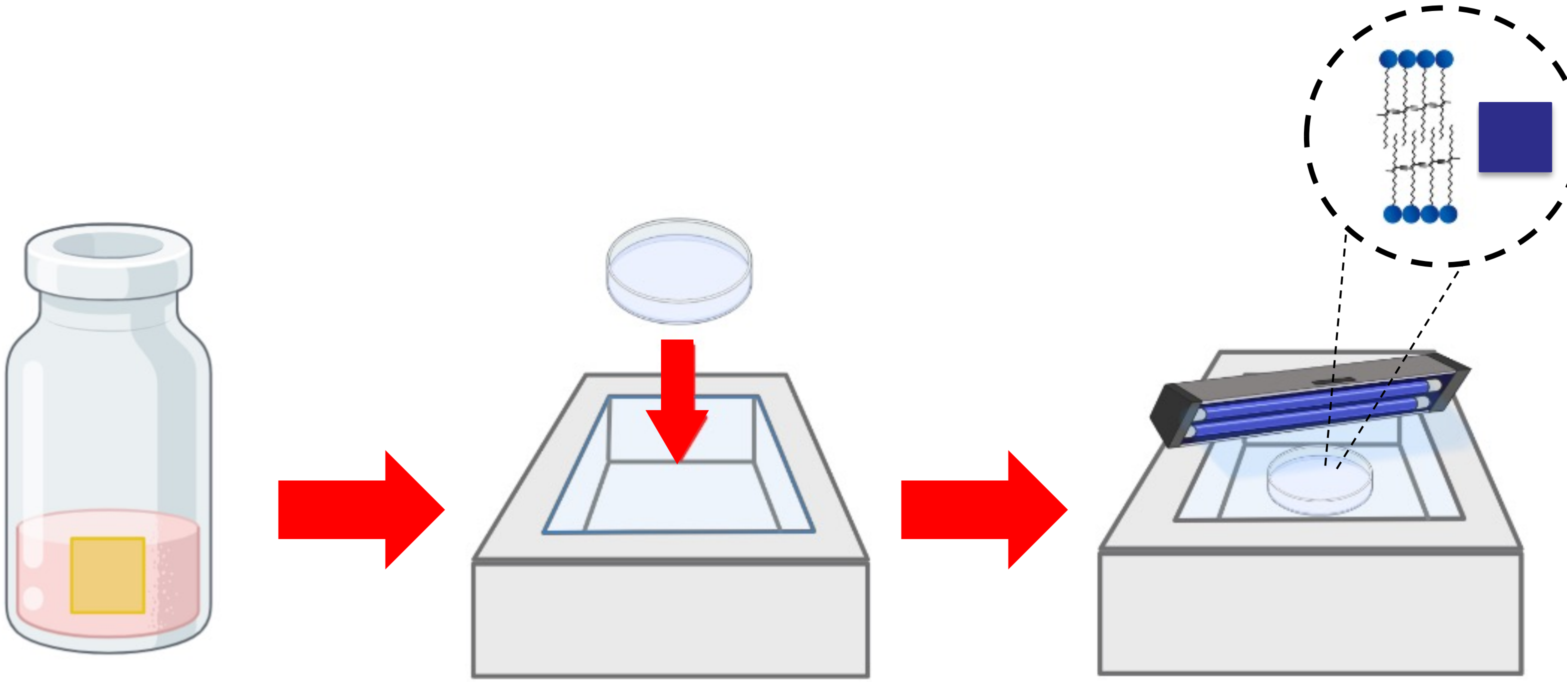


10,12-Pentacosadiynoic acid
(**PCDA**)

III. Materials and method



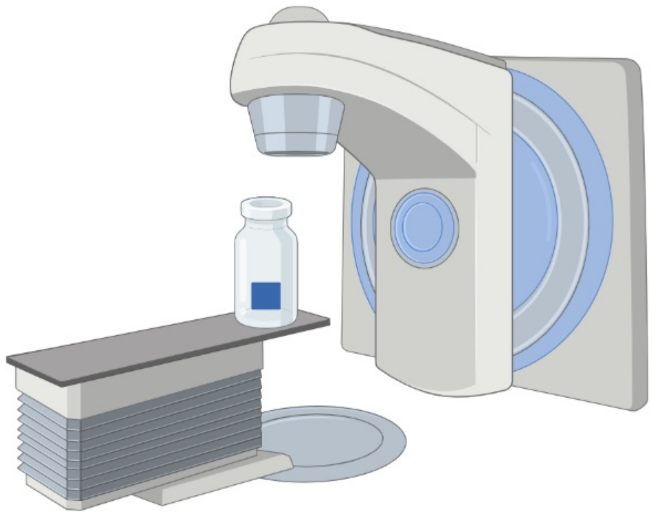
III. Materials and method



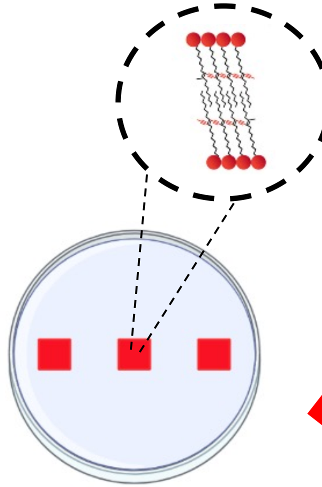
The material is immersed in a solution of **PCDA** in THF and left to dry.

Illuminates with **UV light (254 nm)** for polymerization

III. Material and methods



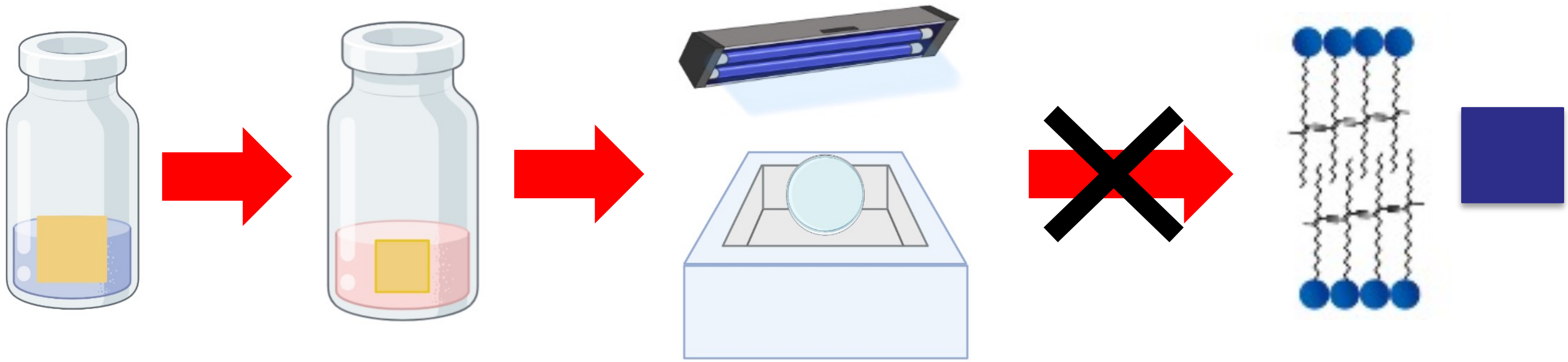
The second step was to irradiate the materials with **ionizing radiation** and for this a **Linear Accelerator** or **LINAC**



The **red colour** appears

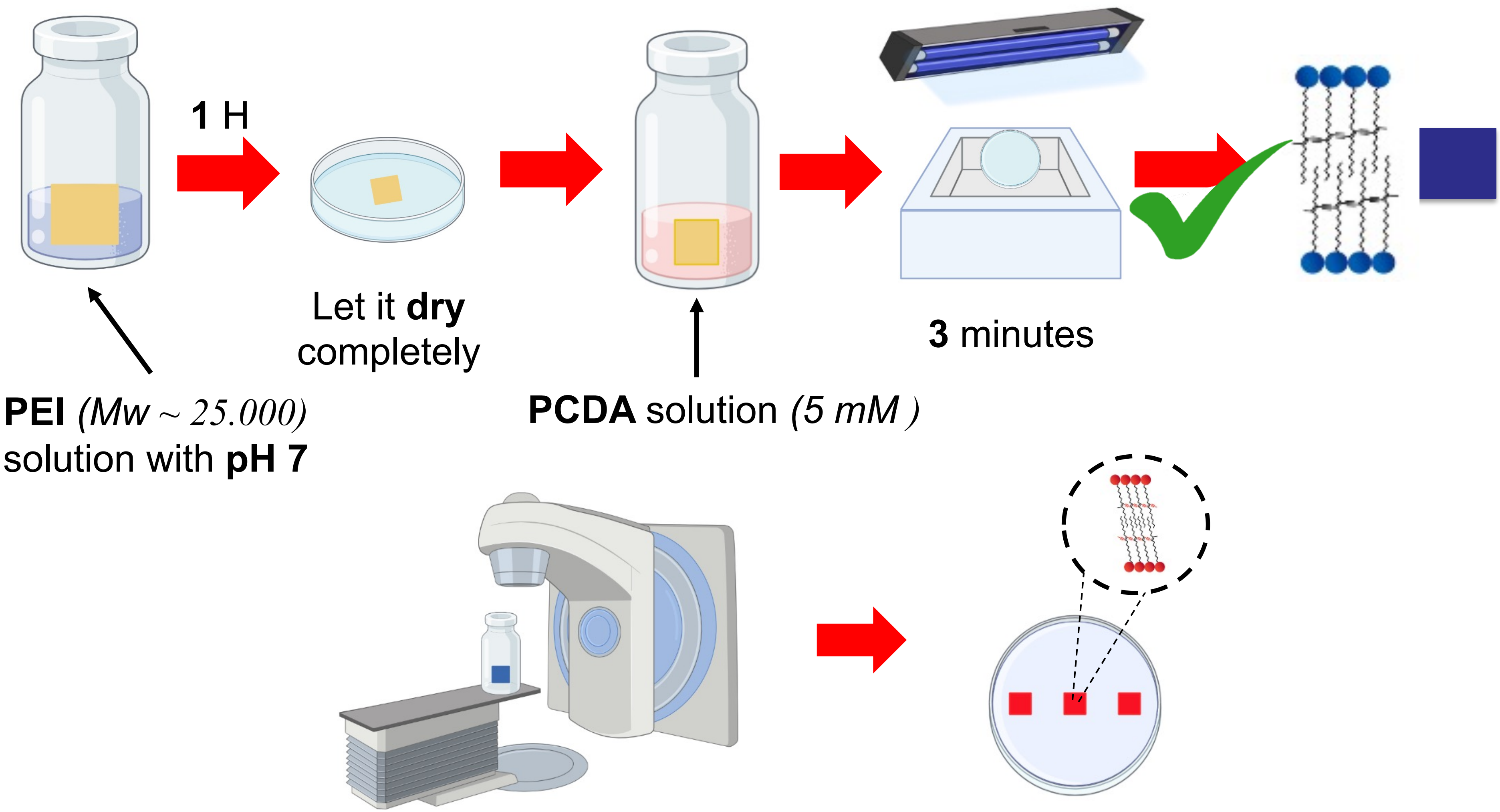
Take a picture with **mobile phone** to *colourimetrically analyse*

IV. Results



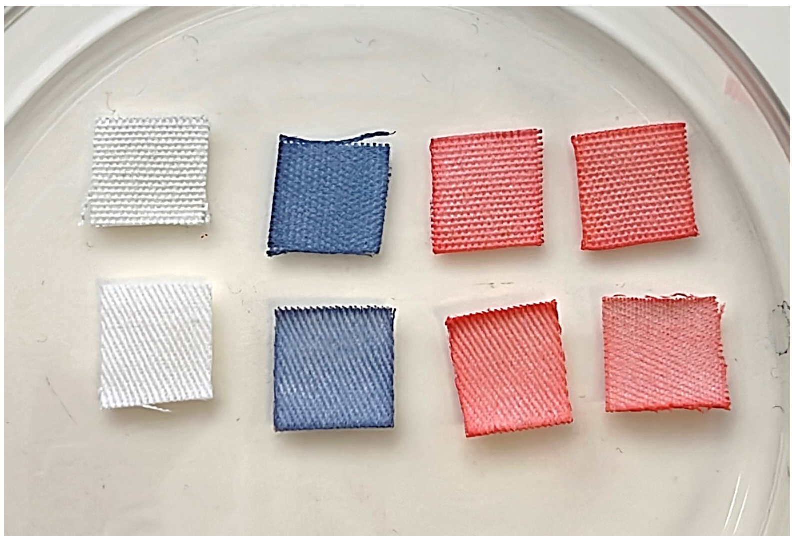
Parameters that affected the polymerization					
pH of PEI solution	~~3~~	7			
Molecular weight of PEI	~~Mw ~ 20.000~~	Mw ~ 25.000			
PCDA solution concentration	~~1 mM~~	5 mM			
Storage temperature	~~22-24ºC~~	4ºC			
Immersion time in PCDA	~~5 m~~	~~15 m~~	~~25 m~~	~~35 m~~	1h
Irradiation time with UV light	~~10 minutes~~	~~5 minutes~~	3 minutes		

IV. Results


1 H
Let it dry completely
3 minutes
PEI (Mw ~ 25.000) solution with pH 7
PCDA solution (5 mM)

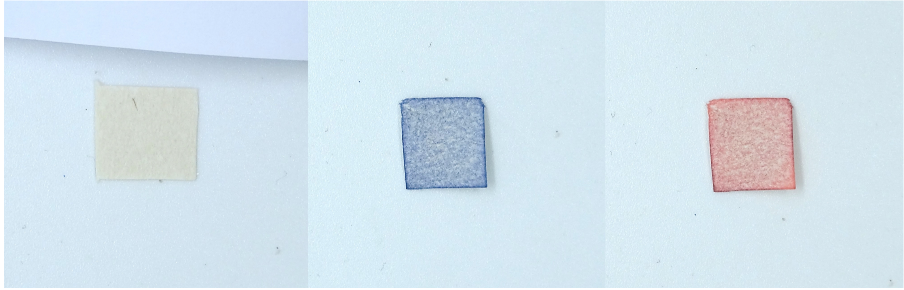
IV. Results

Examples of materials showing color change:



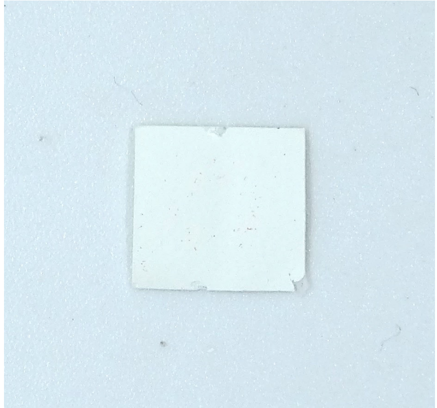
Polyacrylic and cotton

Paper

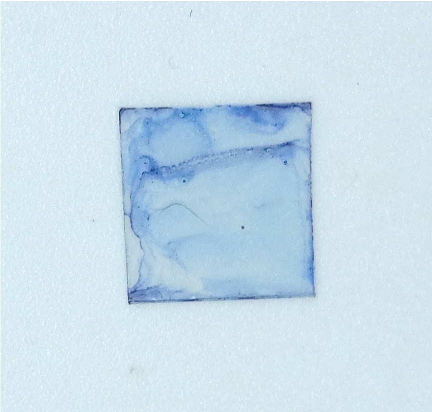


IV. Results

Examples of materials that didn't change color:



Nylon **with treatment** and after receiving **UV radiation**



Mylar did show **color change** but it **didn't change uniformly**

V. Future perspectives

Currently, **radiochromic films** are only marketed by the Ashland company, which means that their price is very high. On the other hand, these films are **semi-rigid**, which makes it impossible to apply them for *in vivo.*

This project intends to develop new dosimeters based on **new radiochromic materials.**

In addition, this project attempts to overcome the need of using **conventional desktop scanners** for the reading and calculation of the material exposed to radiation through the use of smartphones.

VI. Acknowledgments and funding

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UNIÓN EUROPEA
"Una manera de hacer Europa"

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VI. Acknowledgments and funding

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