IAEA-CN301-8

Preservation of Photographic and Cinematographic Films by Electron-Beam Irradiation

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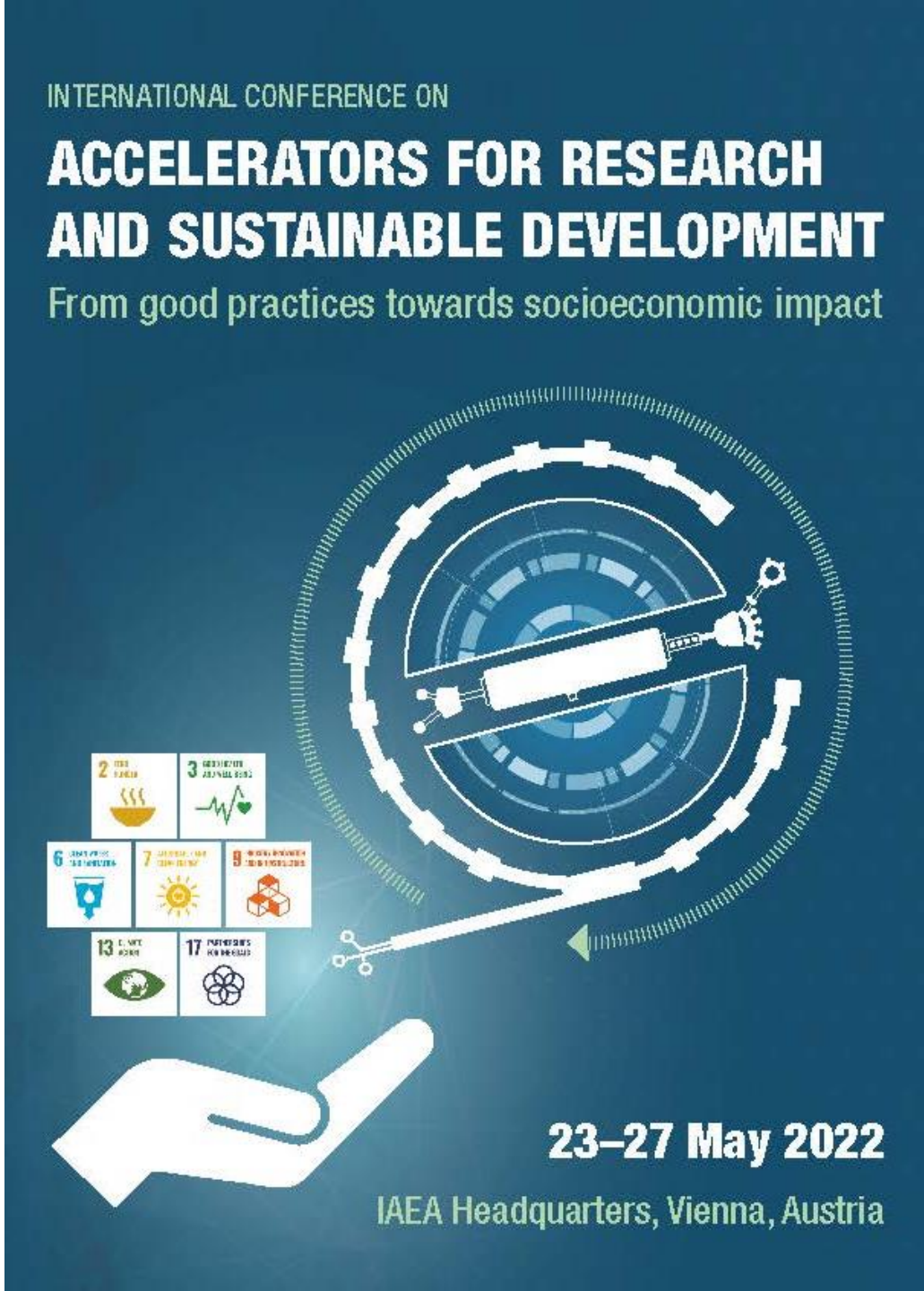


Nuclear and Energy Research Institute -IPEN

Ministry of Science and Technology

National Nuclear Energy Commission

CNEN Comissão Nacional de Energia Nuclear

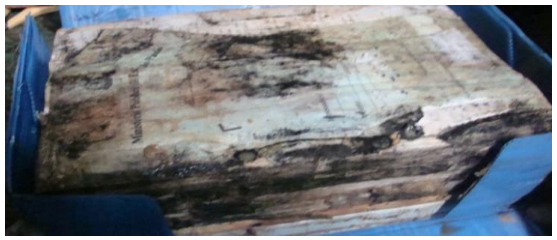
Nuclear and Energy Research Institute

ipen

Brazilian weather conditions have been affected directly tangible materials

Natural disasters

Insects



Fungi attack

Biodeterioration

Ionizing Radiation to Support Conservation and Preservation of Tangible Cultural Heritage (CH) in Brazil

1. Disinfection by ionizing radiation

material characterization, R&D on several materials,

Side-effects studies

2. Consolidation by ionizing radiation

-resins – polymerization – cross linking

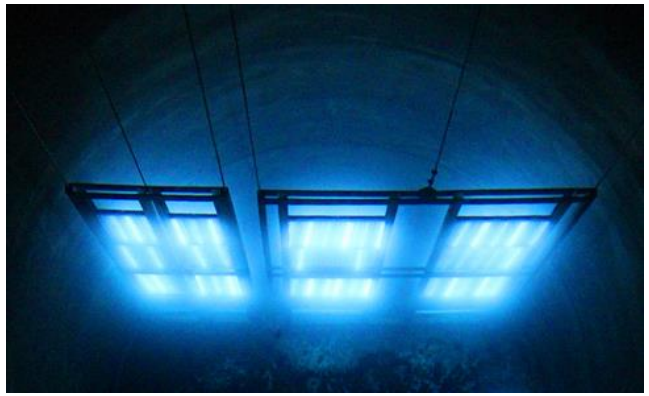
3. Developing of new nanostructured materials for cleaning surfaces of CH by ionizing radiation

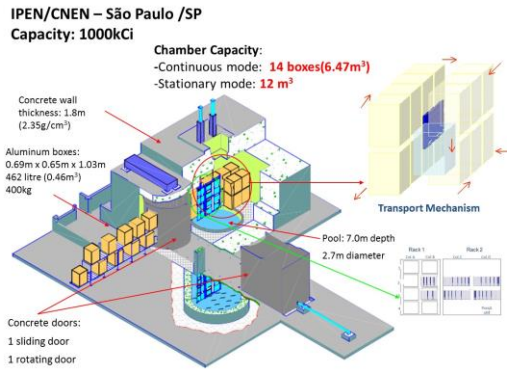
R&D, natural polymers, blends

Radiation Technologies available at IPEN

Gamma Irradiation

Cobalt-60





Brazilian technology - 2004 :
1000kCi
Category IV (IAEA -SSG-8)

EB Accelerators

JOB 188 – 1,5 MeV 37.5kW
Radiation Dynamics, Inc. (RDI), R&D

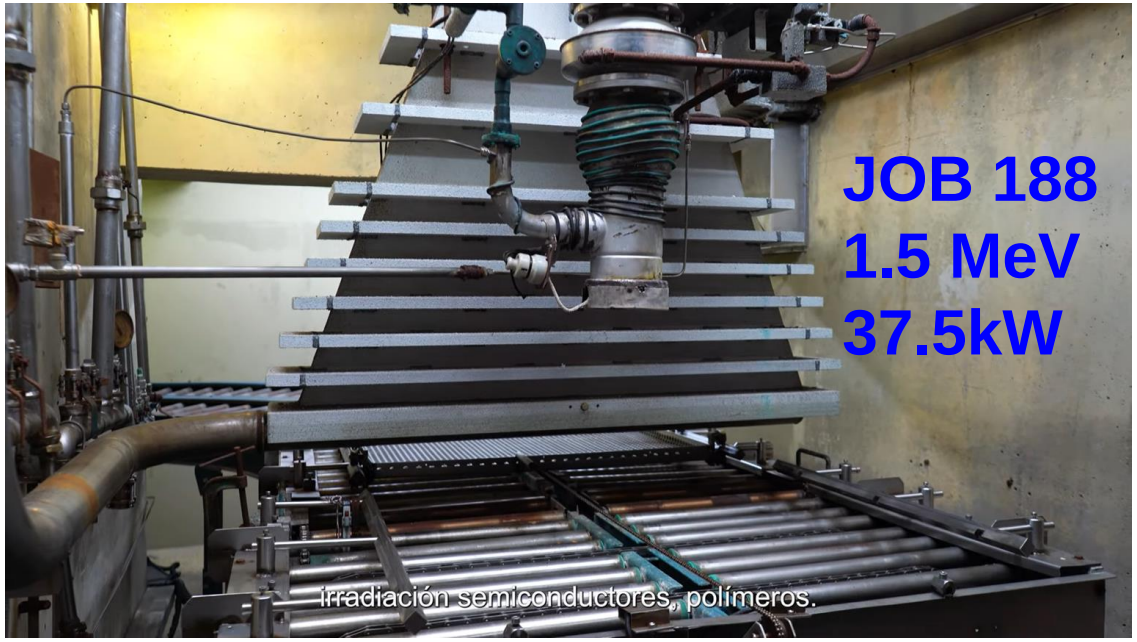
JOB 307 - 97.5 kW, 1.5MeV
Continuous treatment system (300 m/min)
Commercial aplications

-Mobil Unit

0.7MeV-20kW

Multipurpose Gamma Irradiation Facility


DYNAMITRON
RDI-DYNAMITRON-DC1500/25/4-JOB 188
HIGH VOLTAGE
BEAM
SCAN
AUXILIARY
instalado
en IPEN en el año de 1978.


JOB 188
1.5 MeV
37.5kW
irradiación semiconductores, polímeros.


JOB 307
97.5 kW
1.5MeV
Dentro de la misma sala de radiación (búnker),
existe otro acelerador de electrones


el mismo que se utiliza para la investigación,
y otro acelerador

E-beam Irradiation Facility

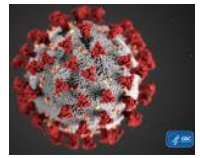
Irradiation or radiation processing

a) Physical effects
b) **Chemical effects**
c) **Biological effects**

Polymerization
Cross-linking
Grafting

γ

Biocidal action
***Eliminates/inhibits/sterilizes**... **insects and Microorganisms such as bacteria and fungi**



Virus Inactivation

- **Electron Beam Accelerator JOB 188 (Dynamitron®)**
- energy 1.5 MeV
- beam current 25 mA
- scan 60 to 120 cm
- beam power 37.5 kW

Applications:

- irradiating and sterilizing medical products
- silicon wafer processing
- food
- composites modification
- polymer modification
- shrink wrap sheet products
- tire and rubber pre-cure treatment
- chemical or biological wastes

Films Timeline

Albumin
1847 - 1860

Glass - collodion
1851 - 1885

Glass - gelatin
1878 - 1925

Cellulose nitrate
1889 - 1950

Cellulose acetate
1925 - now

Polyester
1955 - now

Paper
1841 - 1865

1840 1860 1880 1900 1920 1940 1960 1980 1990 2000 nowadays

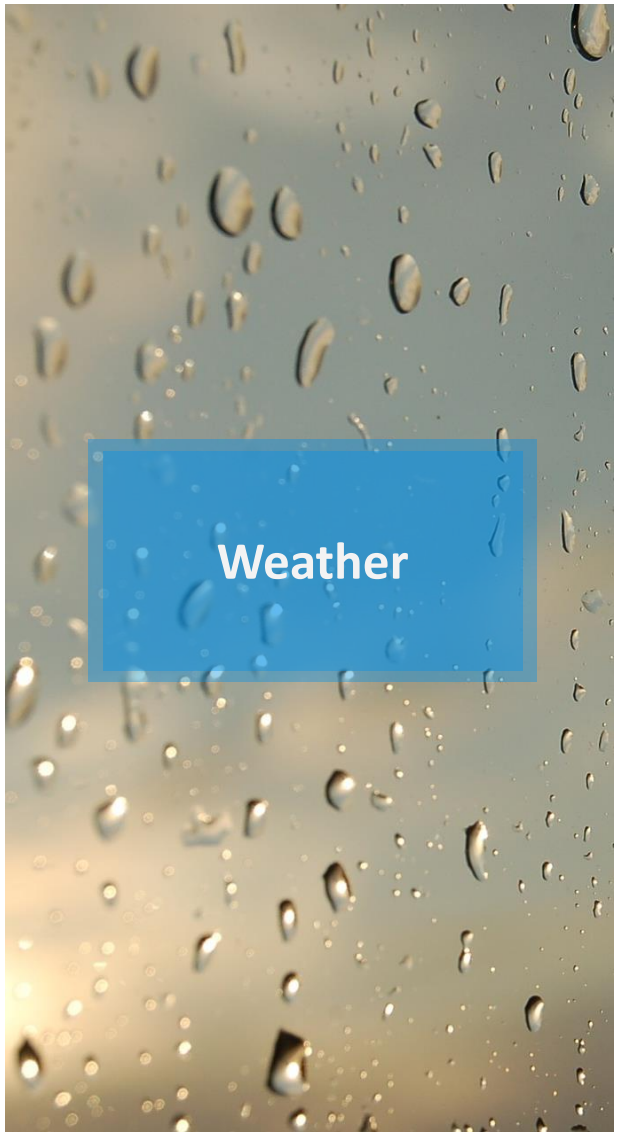
https://www.imagepermanenceinstitute.org

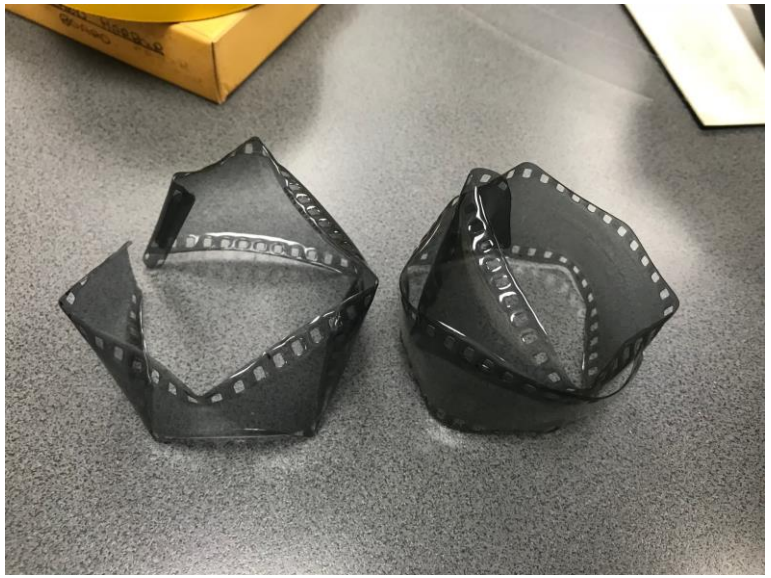
Typical deterioration in cellulose acetate films

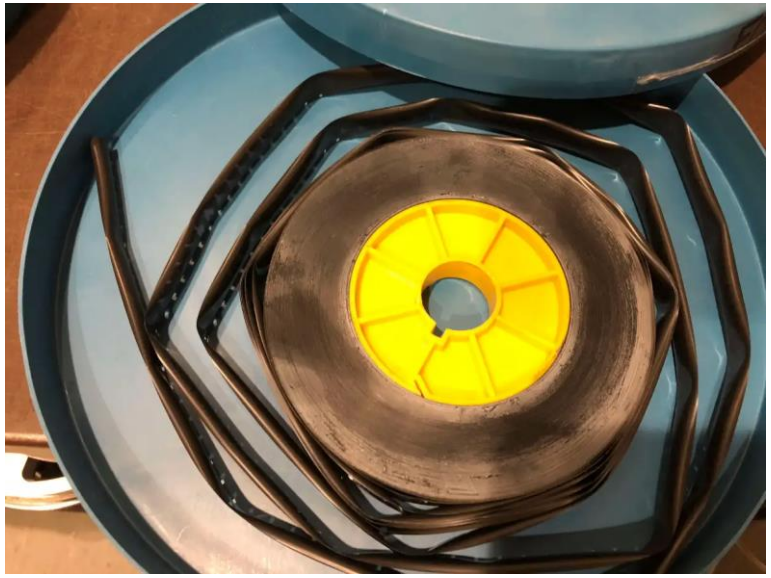
Brazilian weather conditions affect photographic and cinematographic collections.

Fungi contamination main causes of biodeterioration in photographic and cinematographic collections.

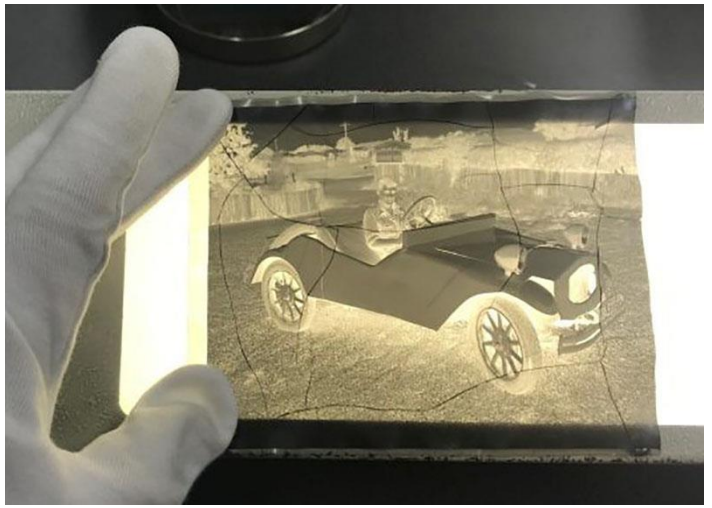
Vinegar Syndrome
Chemical deterioration,
Substrate: buckle, shrink and brittle.
Production of acetic acid (vinegar)
Deacetylation







Vinegar Syndrome Examples



https://www.nfsa.gov.au/preservation/preservation-glossary/vinegar-syndrome

http://www.micrographics.co.nz/wp-content/

Films Samples

(N5)

(F1)

Figure 1. Samples of photographic negative (N5) and cinematographic film (F1) selected from University of Sao Paulo libraries.

Goal of the study

- Characterization of the films.
- Evaluate electron beam radiation effects for the disinfection of photographic and cinematographic films.
- Check the effect of ionizing radiation-induced crosslinking (vinegar syndrome)

Research Model

Film samples selection → Caracterization: FTIR-ATR, FEGSEM-EDS → electron beam irradiation: 2-200 kGy → Irradiation effects evaluation: UV-Vis/FEG-SEM/TG/DSC

Results

FTIR-ATR samples characterization

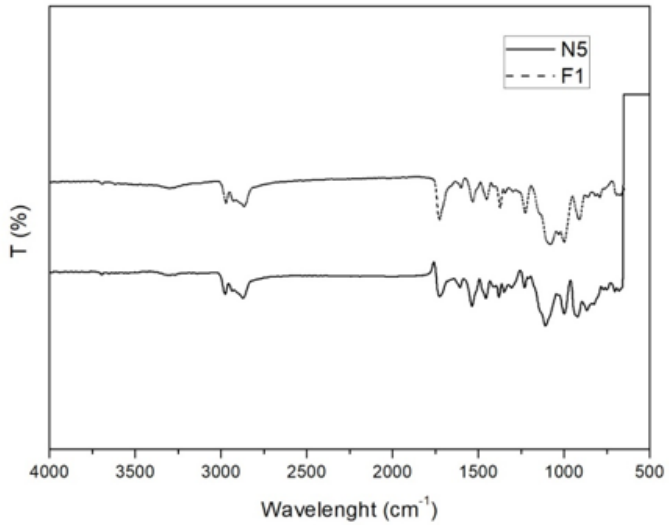
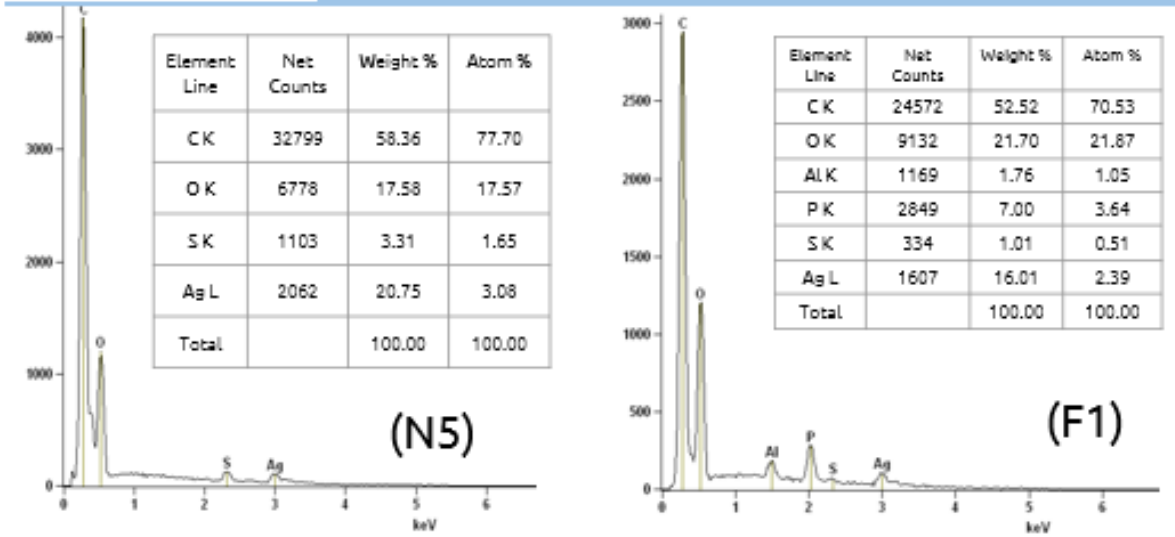


Figure 2. The infrared spectra of two samples showed coincident peaks of cellulose triacetate (CTA), gelatin and triphenyl phosphate (TPP).

FEG-SEM micrographs

FEG-SEM



Element Line	Net Counts	Weight %	Atom %
C K	32799	58.36	77.70
O K	6778	17.58	17.57
S K	1103	3.31	1.65
Ag L	2062	20.75	3.08
Total		100.00	100.00

Element Line	Net Counts	Weight %	Atom %
C K	24572	52.52	70.53
O K	9132	21.70	21.87
Al K	1169	1.76	1.05
P K	2849	7.00	3.64
S K	334	1.01	0.51
Ag L	1607	16.01	2.39
Total		100.00	100.00

Figure 3. Spectrum of the elements distribution non irradiation samples. All samples show carbon and oxygen as majority elements due to the organic compounds of film materials. Coating samples with carbon enhances the carbon peak of the EDS spectrum. Silver are the photosensitizing element. Phosphorus from TPP plasticizer can be observed in sample F1. Sulfur came from the fixing solution of thiosulfate. Aluminum can be attributed to the sample-holder material.

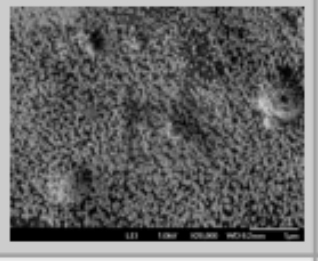
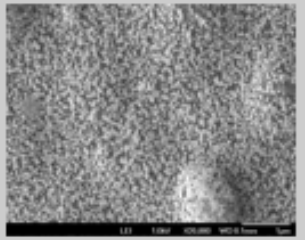
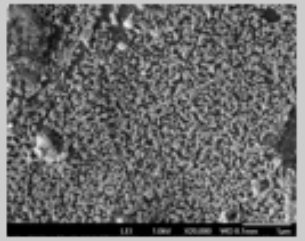
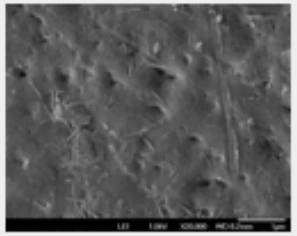
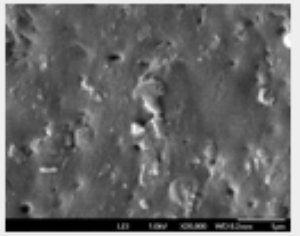
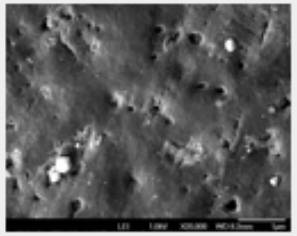
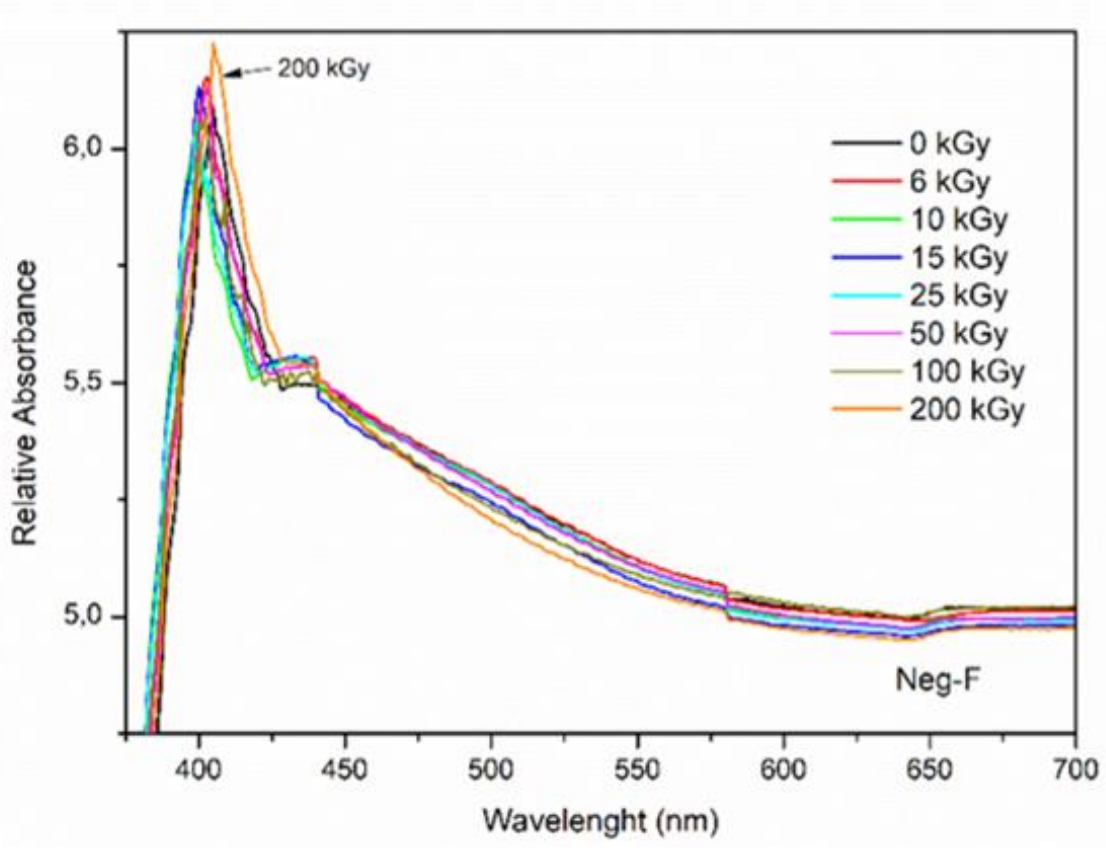
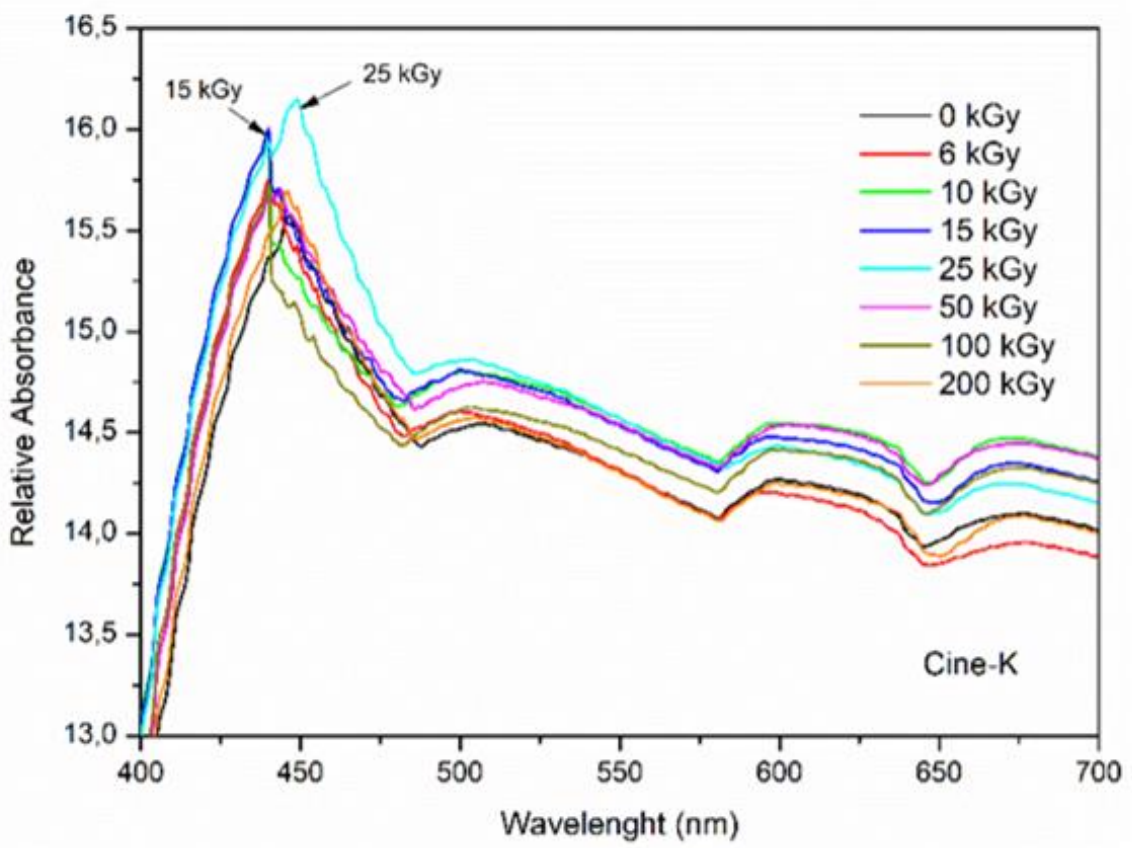
Sample	non-irradiated	10 kGy gamma irradiated	10 kGy e-beam irradiated
N5			
F1			

Table 1. Micrographs of the non–irradiated (0kGy) and irradiated samples (10kGy). Different kind of intensities and variations of white and black contrast can be associated with specific elements or with impurities and superficial contamination.

UV-Vis spectrophotometer outcomes



Sample: Neg-F

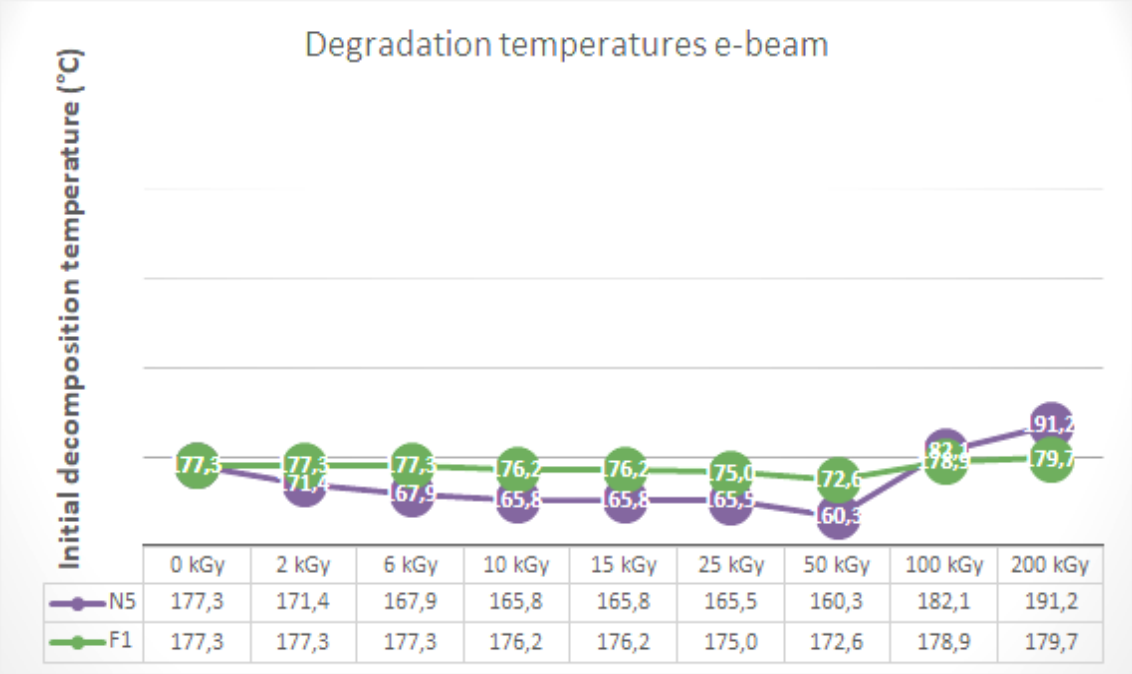


Sample: Cine-K.

- **Limit for disinfection: 10 kGy**

Thermal analysis

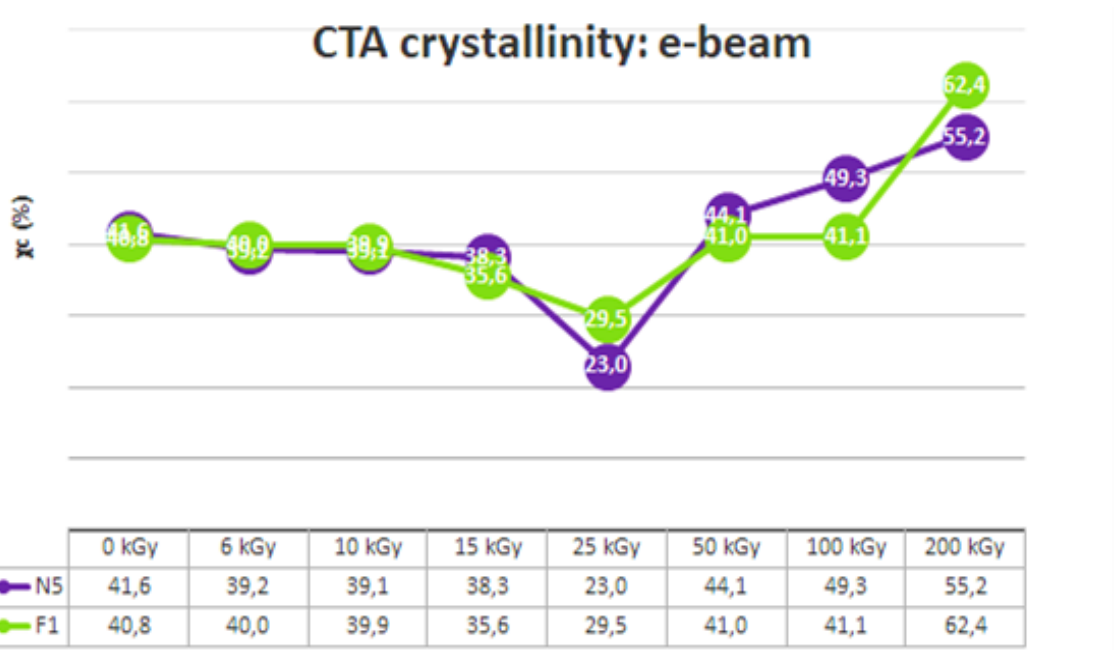
Thermogravimetry (TG)



	0 kGy	2 kGy	6 kGy	10 kGy	15 kGy	25 kGy	50 kGy	100 kGy	200 kGy
N5	177,3	171,4	167,9	165,8	165,8	165,5	160,3	182,1	191,2
F1	177,3	177,3	177,3	176,2	176,2	175,0	172,6	178,9	179,7

. TG results of samples N5 and F1 irradiated with different irradiation doses. crosslinking at doses strating at 50 kGy.

Differential Scanning Calorimetry (DSC)



	0 kGy	6 kGy	10 kGy	15 kGy	25 kGy	50 kGy	100 kGy	200 kGy
N5	41,6	39,2	39,1	38,3	23,0	44,1	49,3	55,2
F1	40,8	40,0	39,9	35,6	29,5	41,0	41,1	62,4

DSC results of samples N5 and F1 irradiated with different irradiation doses. Higher degrees of crystallinity (indicative of crosslinking) were identified at doses starting at 50 kGy.

- **crosslinking dose: 50 kGy**

Conclusions

- **Disinfection** by electron beam radiation can be achieved safely applying radiation absorbed doses between **6 kGy to 10 kGy** with no significant change or modification of main properties of the constitutive polymeric materials.

- Electron beam irradiation, due to the effect of **crosslinking** is presented as an alternative to treat films affected by “vinegar syndrome” applying absorbed dose of **50 kGy** in order to increase shelf life of cultural heritage materials. However, a specialized restoration process is required after irradiation process.


JOB 188
JOB - 307
This is the JOB 188 accelerator,

Thank you

Acknowledgements:

-International Agency of Atomic Energy – IAEA

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-University of São Paulo – USP

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