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Possible use of Polyethylene films for Dosimetry with low energy electrons

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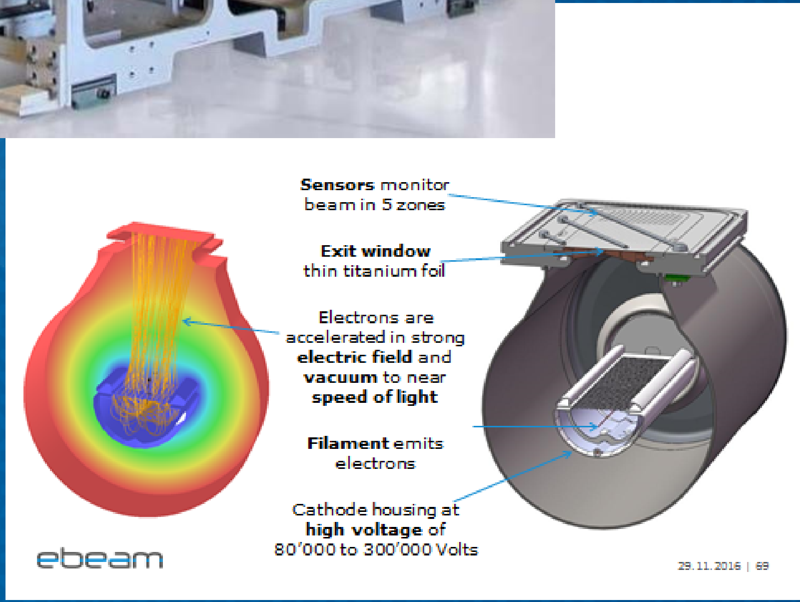
Introduction

- New electron beam accelerators with beam energies in the interval from 100 to 200 keV have emerged recently.
- Systems are affordable with low maintenance costs
- Applications include:

1. Surface decontamination
2. Coatings
3. Adhesive materials
4. Radiation effects in nanomaterials.



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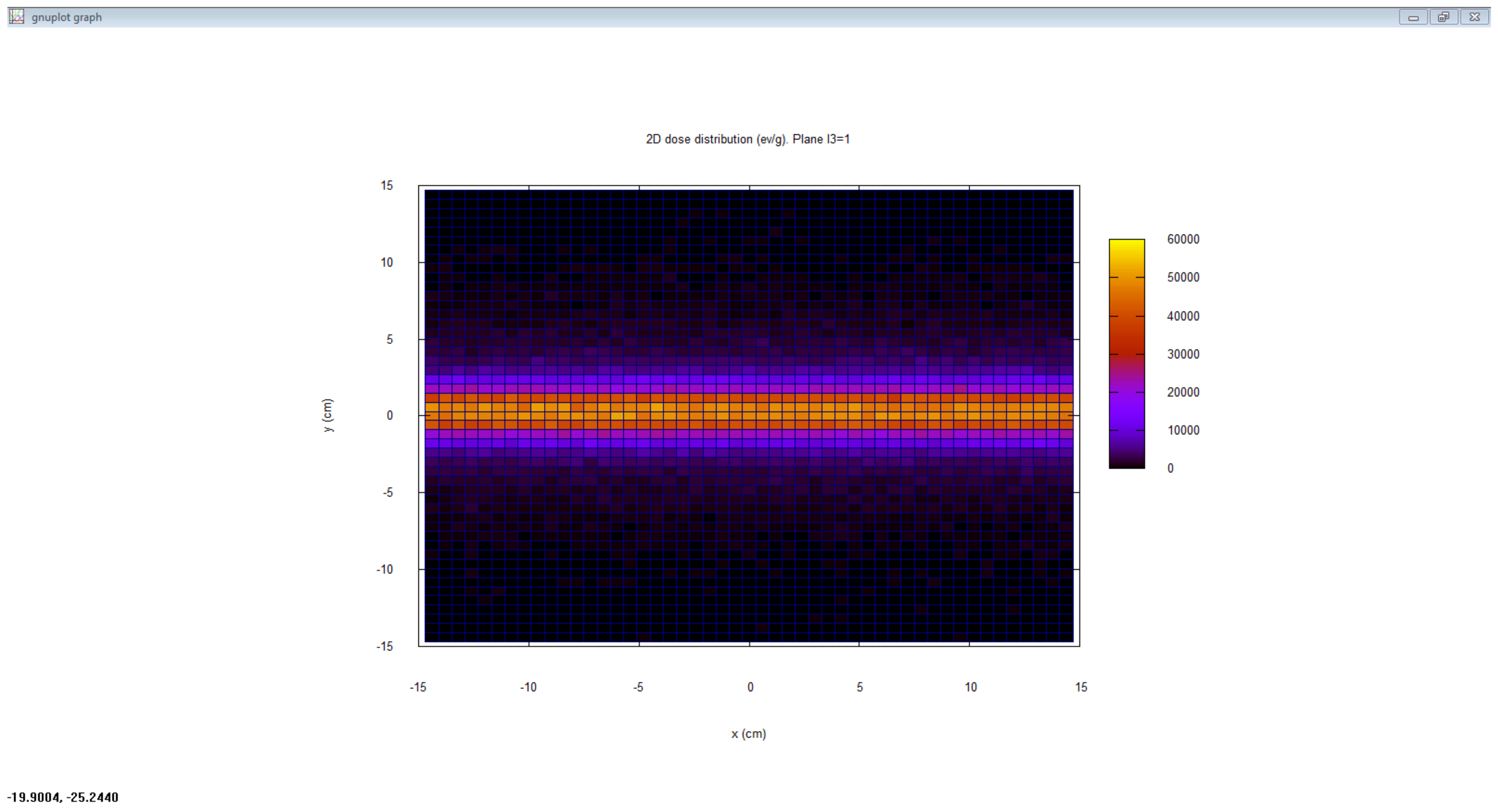
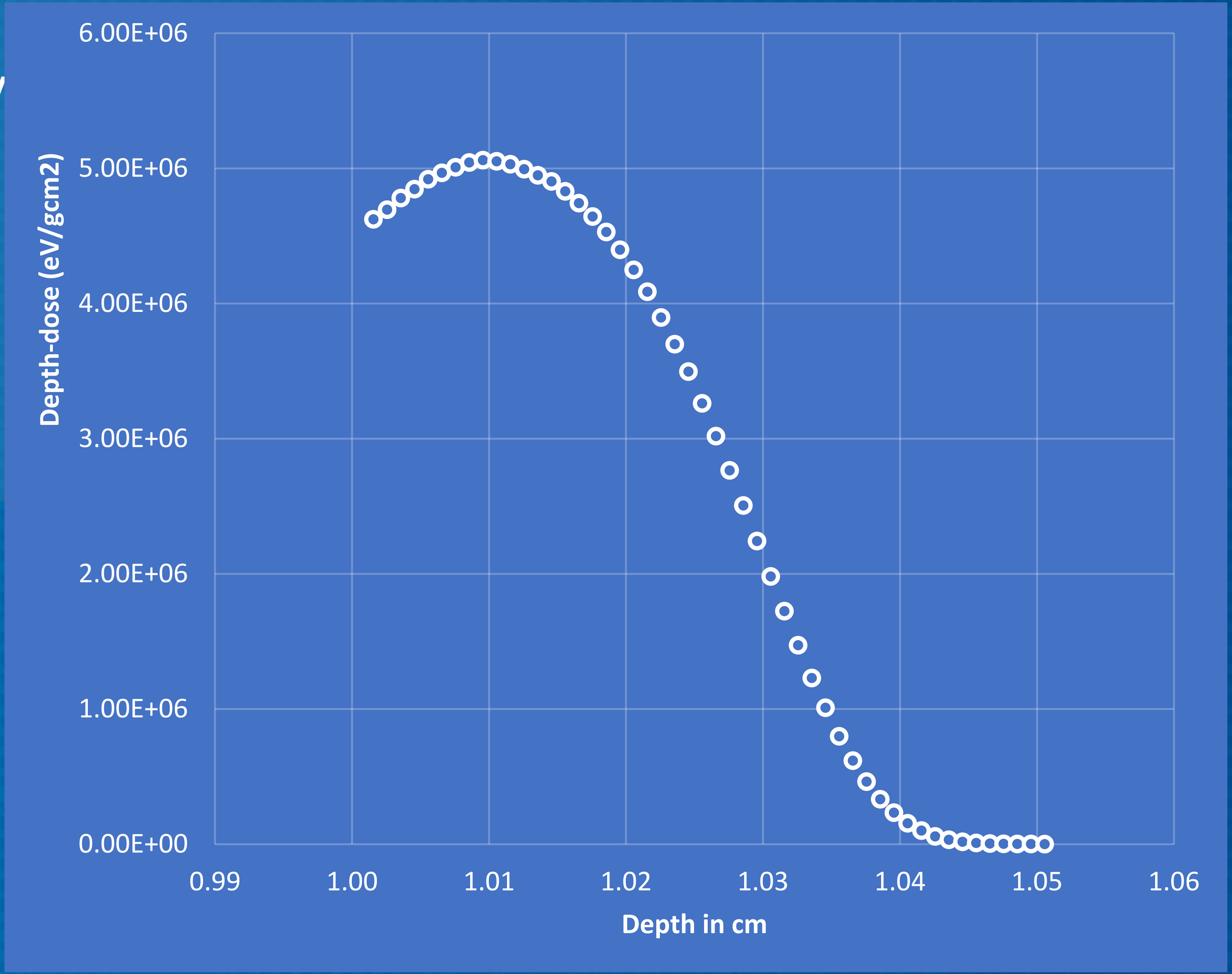
200 keV simulation



Dosimetry

- Dose measurements with low energy electrons are difficult to carry out because of the low penetration of the electrons at those energies (usually around 400 μm)
- Needed: a thin film able to record the dose at the level of 1-2 μm
- The only available technique at the present time that can be used for dosimetry with 100 to 200 keV electrons is Dμ with thin radiochromic films (usually B3 films, GEX Corp.)



Dosimeter requirements

- Small enough to not disturb the radiation field in the irradiated material
- Equivalent to unit density material (water)
- Well defined response *(R)* as a function of dose *(D)*
- Response independent of dose rate
- Response independent of the energy of the electrons
- Response independent of type of radiation
- Response stable with time after irradiation
- Response independent of environmental factors (humidity, temperature, UV and visible light)

Polyethylene dosimetry

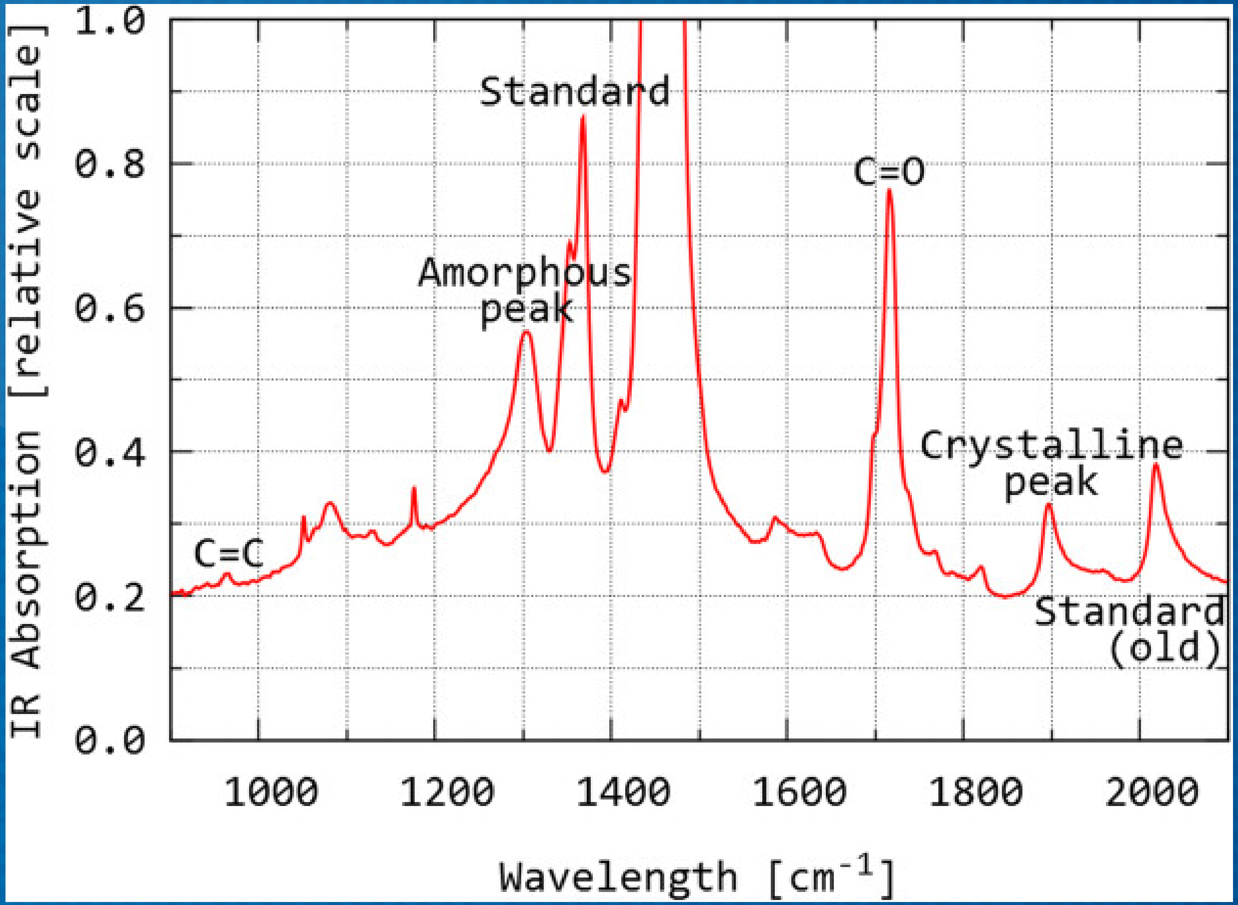
- In this presentation we share the results of a study to determine how PE films can be used as radiation dosimeters for low energy electron irradiation.
- The study included:
  - Dose against response *(R)* characteristics
  - Effect of the dose rate (beam current) on the response *(R)* of the dosimeter
  - Stability of the response *(R)* with the time between irradiation and its measurement
  - Effect of the energy of the radiation on the response *(R)* of the PE film
- **The effect of radiation on PE is well documented and goes back to the seminal work by Arthur Charlesby (1952):**

$$CH_4 + e^- \rightarrow CH_2 = CH_2 + H_2$$

Determination of the Radiation effect on Polyethylene:

The presence of the transvinylene double bond in polyethylene can be measured by IR spectroscopy at a wave number of 965 cm^{-1}

Usually this is determined by FTIR using either Attenuated Total Reflectance (ATR) or Transmission spectroscopy.



Materials and Techniques

- **The PE film was obtained from ExxonMobil (LD 103 Series) with a density of 0.919 g/cm^3 and a thickness of 33 μm**
- **For this study the films were cut in 3 cm on a side squares labeled and taped from the corners to paper.**
- **Alanine films (Kodak) were used to measure doses at high energy electron irradiations**

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High energy electron irradiation dose measurements

Alanine Films

Effect of electron irradiation was obtained through the intensity of the ESR signal according to ISO/ASTM –51607

ESR signal was obtained using a Bruker e-Scan spectrometer and the dose determined through a calibration curve obtained with dosimeters irradiated at NIST.

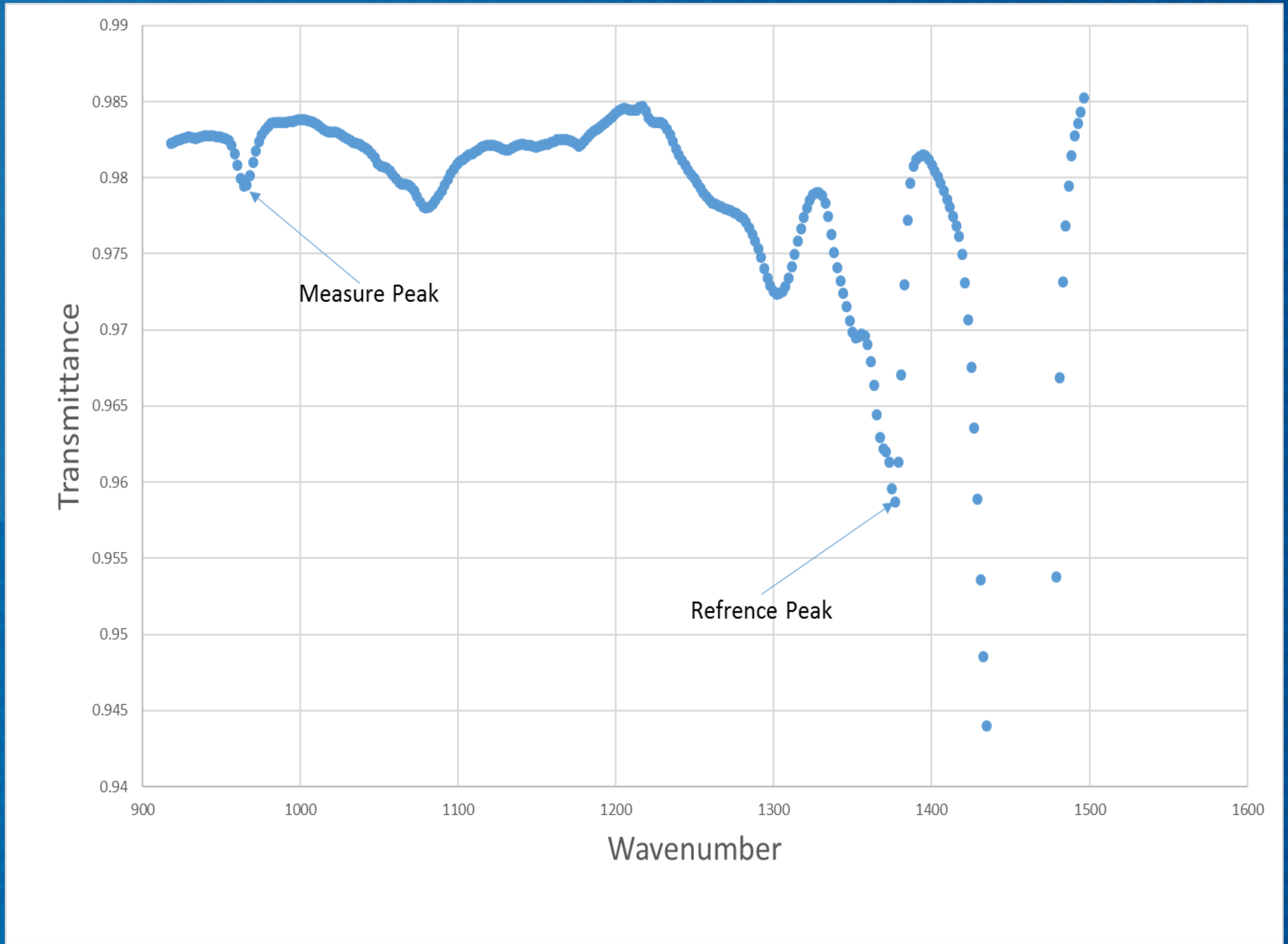
Temperature corrections on the irradiation temperature were determined through the use of GEX temperature indicators.

Response measurements

PE films

The response of the PE films to irradiation was determined by IR spectroscopy using a Bruker Vector 33 FTIR supplied with an ATR accessory that uses a ZnSe crystal.

The response was determined by comparing the ratios of the peak heights of the main peak at 965 cm^{-1} to the reference peak at 1374 cm^{-1}



Irradiations

- **High energy (3.8 MeV) electron irradiations were carried out at NEO Beam using a Dynamitron electron accelerator**
- **Low energy (100 to 200 keV) electron irradiations were carried out using a COMET EBLab-200 electron accelerator at KSU**

Experiments and Results

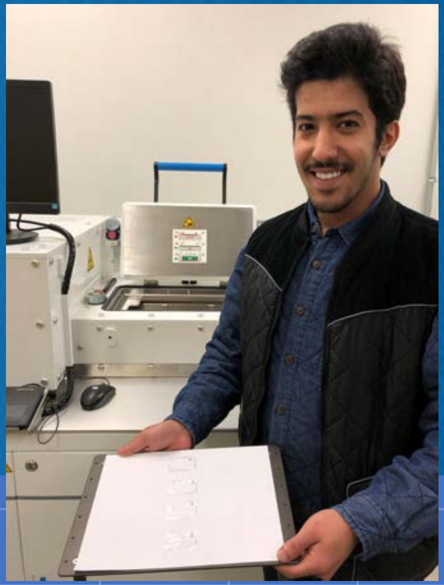
Dose vs Response for PE films:

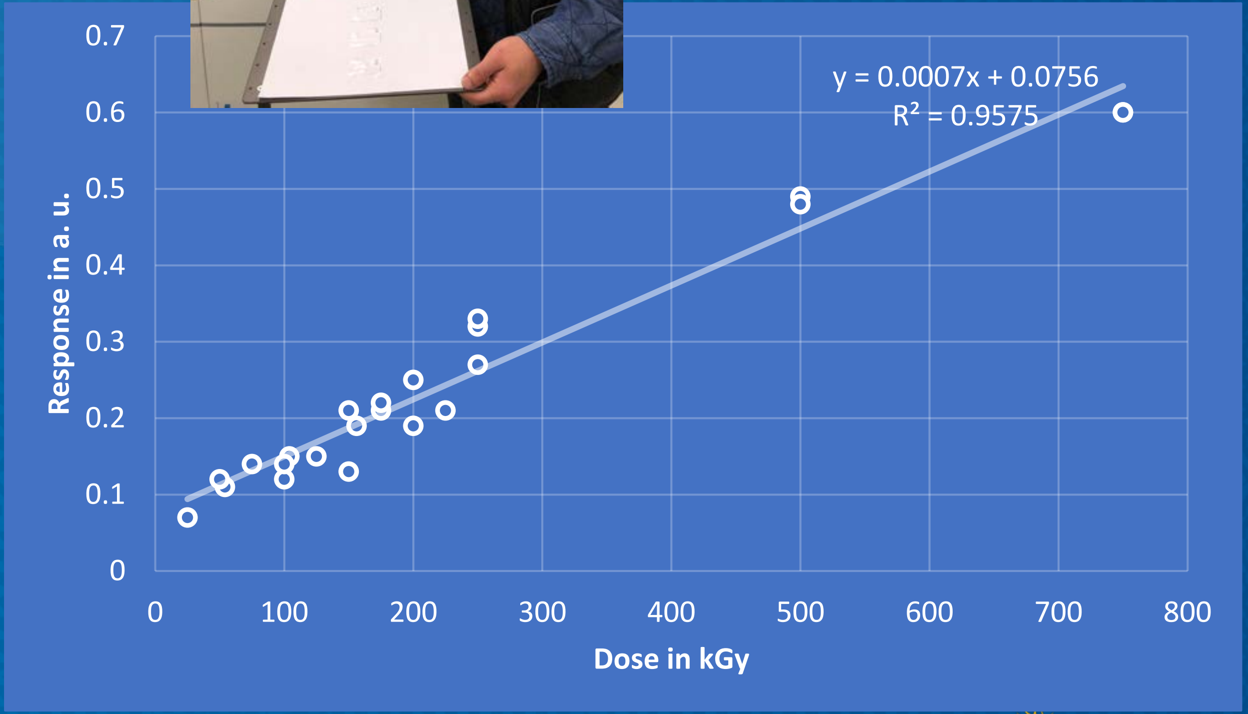
PE films were irradiated with 200 keV electrons in the dose interval from 25 to 750 kGy.

The dose was determined from the electron beam unit parameters confirmed by radiochromic films and the D_μ technique.

Response *(R)* of the PE film:

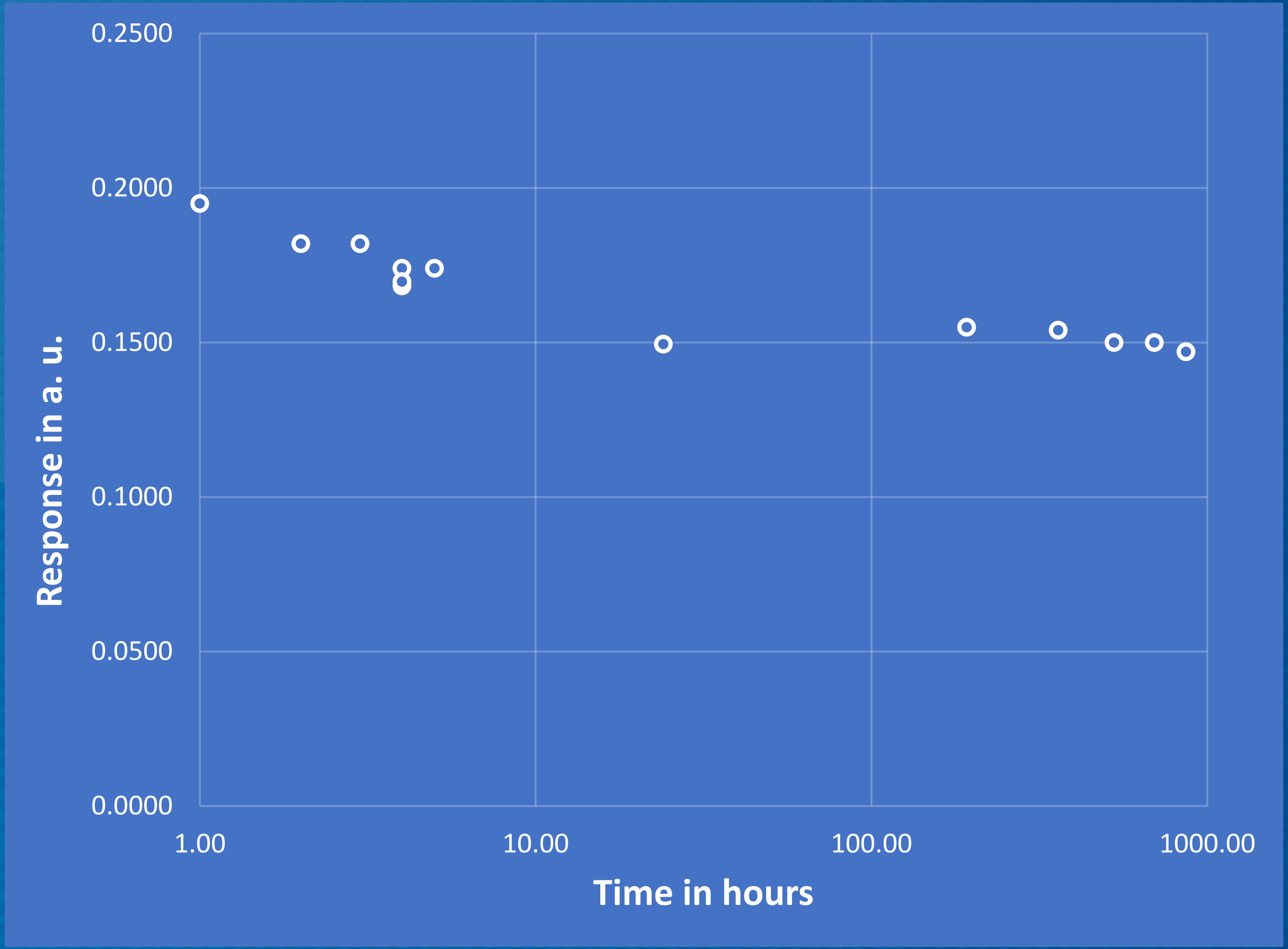
$$R = \frac{PH(965\ cm^{-1})}{PH(1374\ cm^{-1})}$$





Time stability of the PE film response

- Four PE films were irradiated with 200 keV electrons to a dose of 100 kGy
- The response *(R)* was determined following irradiation and then for a period of 1000 hrs
- Films were stored at room temperature (21 ^{o}C) between measurements
- The response drops 25% over a period of 24 hrs. Afterwards it is stable.



Dose rate effect on the response of the PE film

Four PE films were irradiated with 200 keV electrons to a dose of 100 kGy (determined from the setting parameters of the electron beam unit) and four different beam currents.

Response of the films was determined and compared for the four different beam current settings

Within the experimental interval used in this study the response is not affected by the dose rate.

Current (mA)	Platform speed (m/min)	Dose rate (kGy/s)	Response (a.u.)
2.79	3	63	0.149
5.58	6	125	0.150
8.37	9	188	0.149
11.16	12	250	0.151

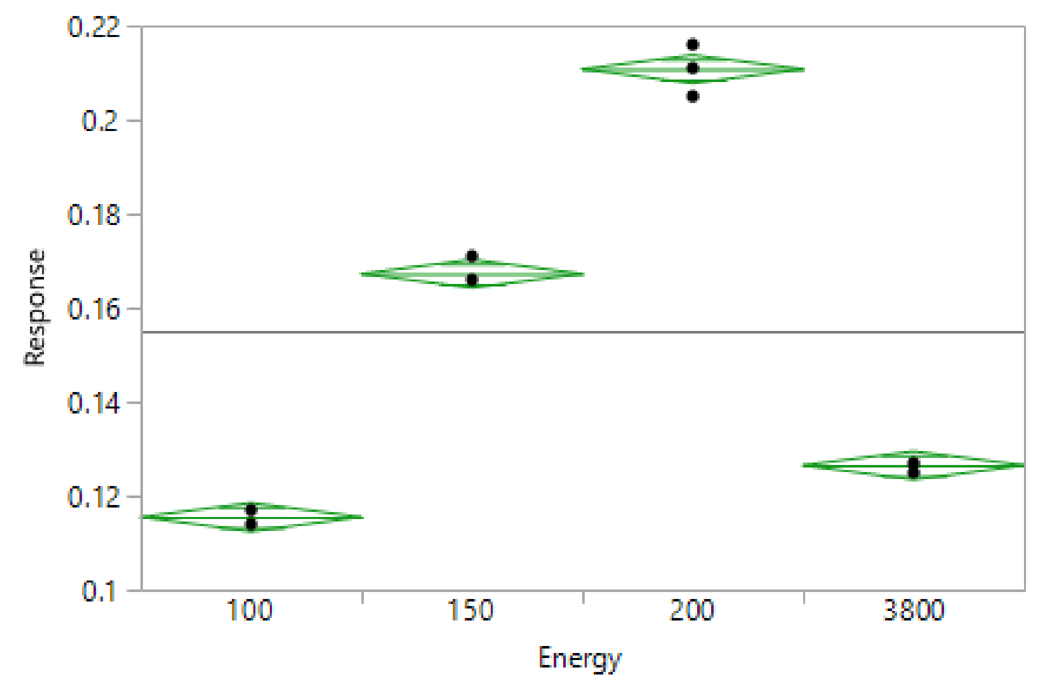
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Current (mA)	3	0.00000875	2.917e-6	0.1872	0.9031
Error	12	0.00018700	0.000016		
C. Total	15	0.00019575			

Effect of Beam Energy on the Response of the PE fim

Four different PE films were irradiated with electrons having energies of 100, 150, and 200 keV, and 3.8 MeV. The irradiation dose was 139 kGy, either determined with alanine films (3.8 MeV electrons) and electron accelerator Lab unit setting in the case of the rest.

After irradiation the films were stored for 24 hrs and then measured with the FTIR instrument.



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Energy	3	0.02252250	0.007507	984.5902	<.0001*
Error	12	0.00009150	7.625e-6		
C. Total	15	0.02261400			

Conclusions

- **Dose vs Response**
  - The response of the PE film with dose shows a linear effect within the interval from 25 to 750 kGy. The dose can be calculated from this relationship using the equation:

$$D(kGy) = 1284.8R - 87.4$$

- **Time stability of the response**
  - The response of the PE film following irradiation drops 25% within the frst 24 hrs following irradiation. Afterwards the value of the response remains constant.
- **Effect of the Dose rate on the response**
  - Within the limits of this experiment (63 to 250 kGy/s), which are the usual dose rates available in the experimental instrument used, the response does not change with dose rate.
- **Effect of the electron beam energy on the response**
  - The response seems to be affected by the energy of the electron beam used. This is currently been investigated further.

Thank You!

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