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School of Electronics and Computer Science

Affect of Photo-oxidation Products on Electroluminescence Emission and Conduction Current of LDPE

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Introduction

- Ageing of high voltage insulation
  - Interest in mechanisms behind ageing process
  - Improving dielectric design and life time estimation
  - Role of charge trapping and movement in material ageing.
- Artificial ageing
  - Generation of oxidation products and cross-linking
  - Affect on charge injection, trapping and recombination

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Experiment

- Chosen a standard polymeric system
  - 100 μm low density polyethylene (LDPE) films
  - Ultraviolet ageing with peak emission of 253.7nm
- UV affect
  - Electrical changes and chemical structure
  - Charge movement in the bulk and near the electrode-polymer interface.

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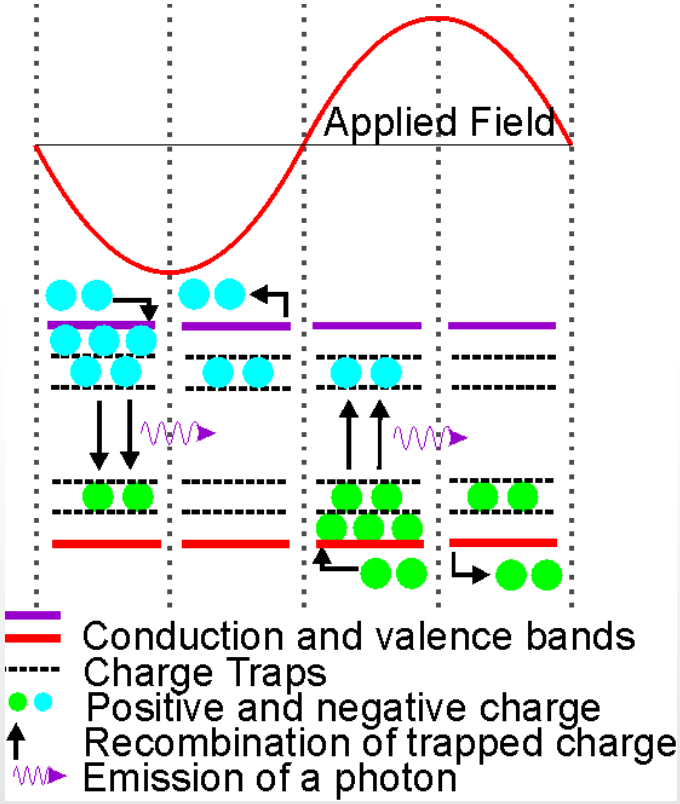
What is Electroluminescence?

- Low level light emission from electrically stressed polymers
- Bipolar recombination of charge carriers
  - AC stress, emission is thought to originate near the electrode-polymer interface.
  - Emission peaks in first and third quadrants



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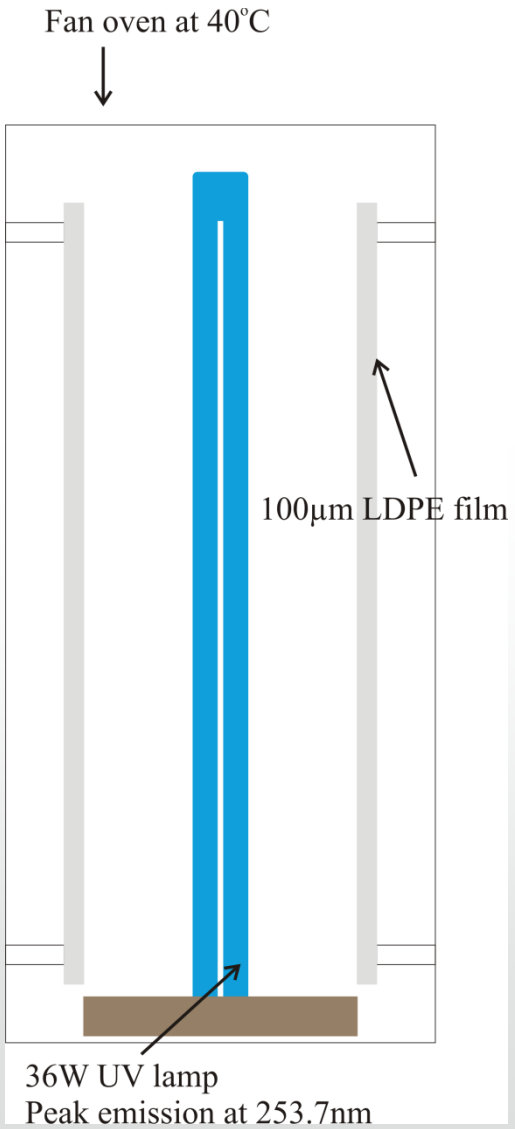
Ageing Process

- Experiment setup
  - 36 W UV fluorescent tube with peak emission at 253.7 nm
  - Samples mounted away from reflective back wall
  - Fan oven at constant 40 °C
  - 100 μm LDPE film
  - Aged in 3 and 7 day intervals up to 17 days.



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Ageing Effects

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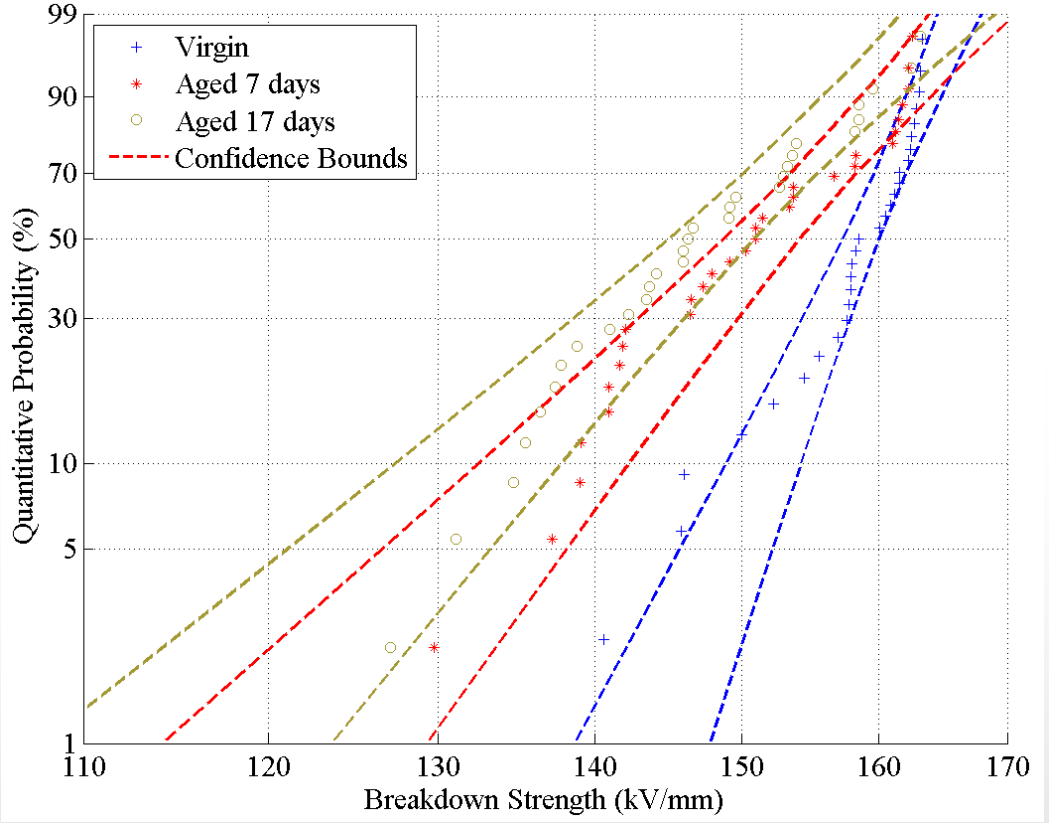
Dielectric Strength

- ASTM D149 standard (50 Hz, 50 V/s ramp, 6.3 mm steel ball bearings)
- Reduced breakdown strength with ageing
- Reduced uniformity



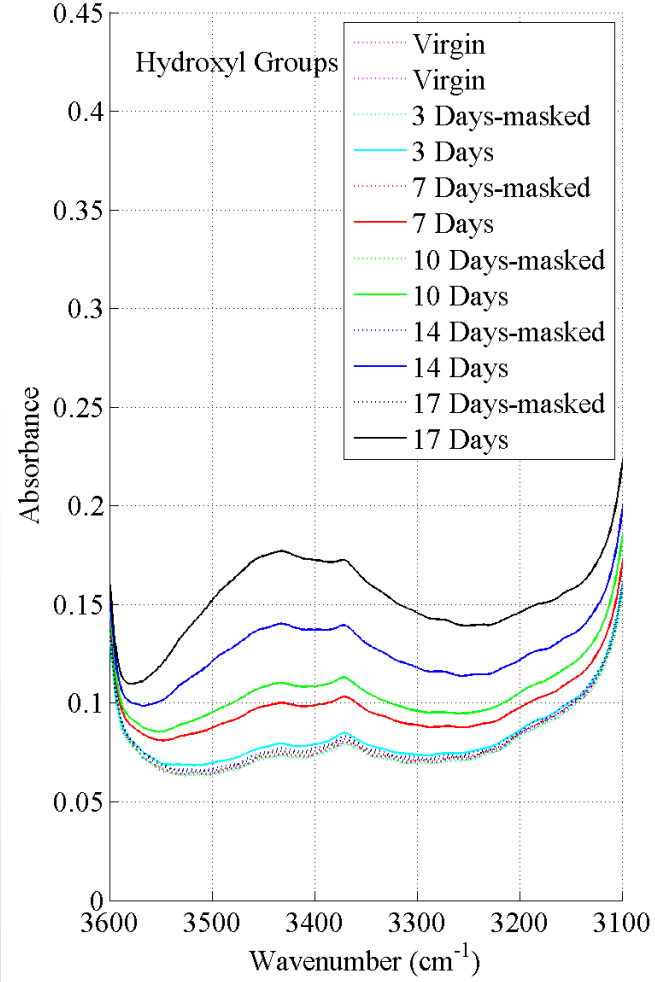
Sample Age	α Value (kV/mm)	β Value
Virgin	160.1 ± 1.2	43.0
7 Days	154.4 ± 2.5	19.9
17 Days	151.1 ± 2.7	17.7

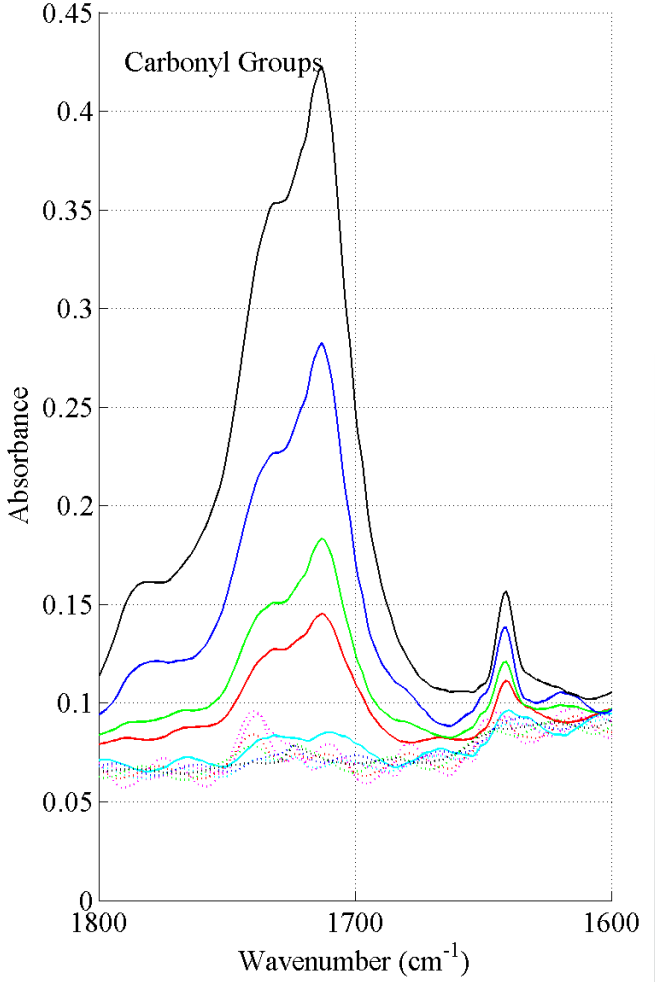
2 Parameter Weibull Distribution

$$P_f(x) = 1 - \exp\left[-\frac{(x - x_t)}{\alpha}\right]^{\beta}$$

FTIR spectra – Oxidation Products

- Increased Carbonyl and Hydroxyl groups
- No effect due to 40 °C temperature
- Chemical (deep) trapping sites





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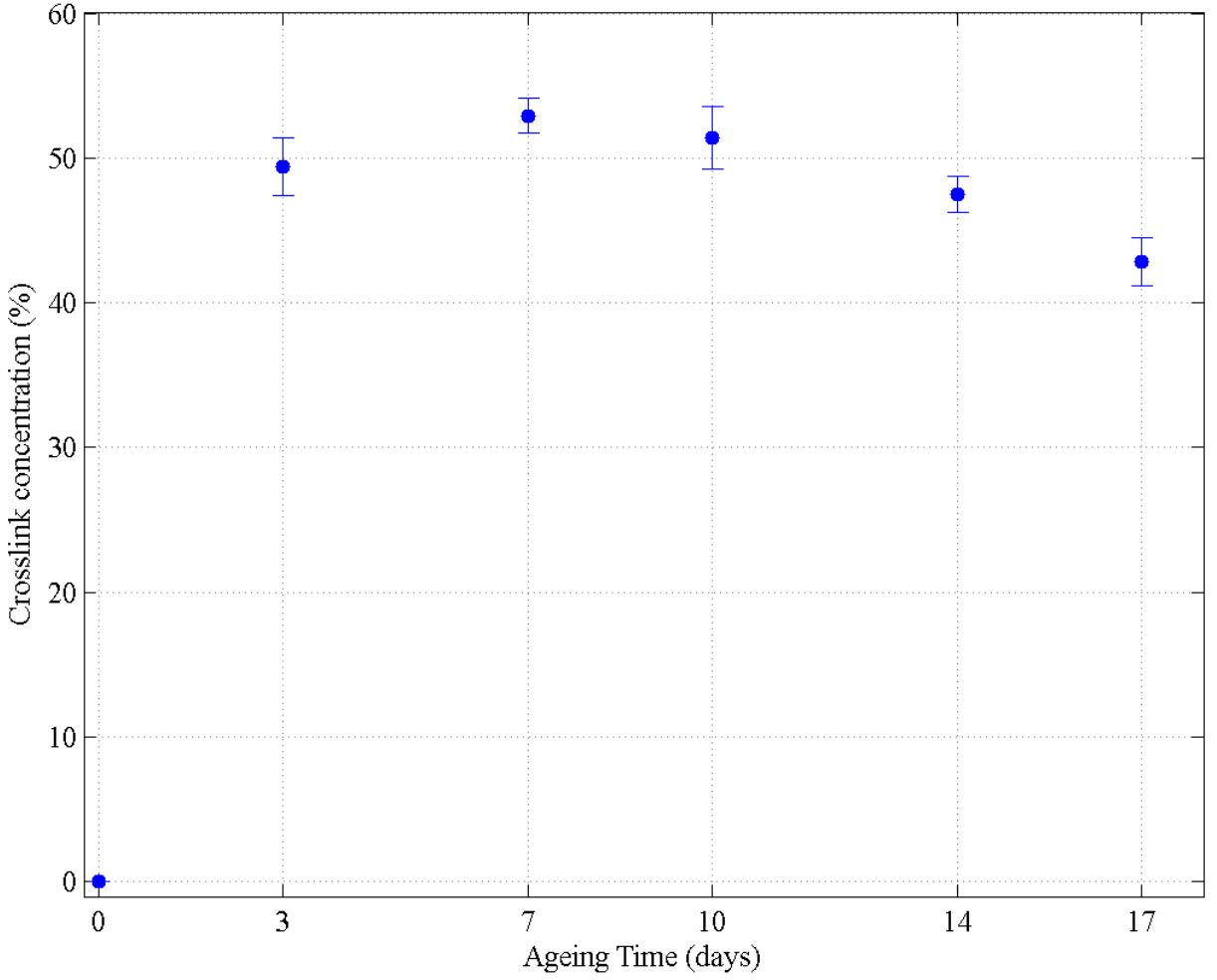
Dissolving in Xylene – Cross-linked

- Samples dissolved in boiling Xylene for 1 hour and then dried.
- Initially large increase in cross-linking
- Cross-linking reduces as ageing time continues



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Charge Transport

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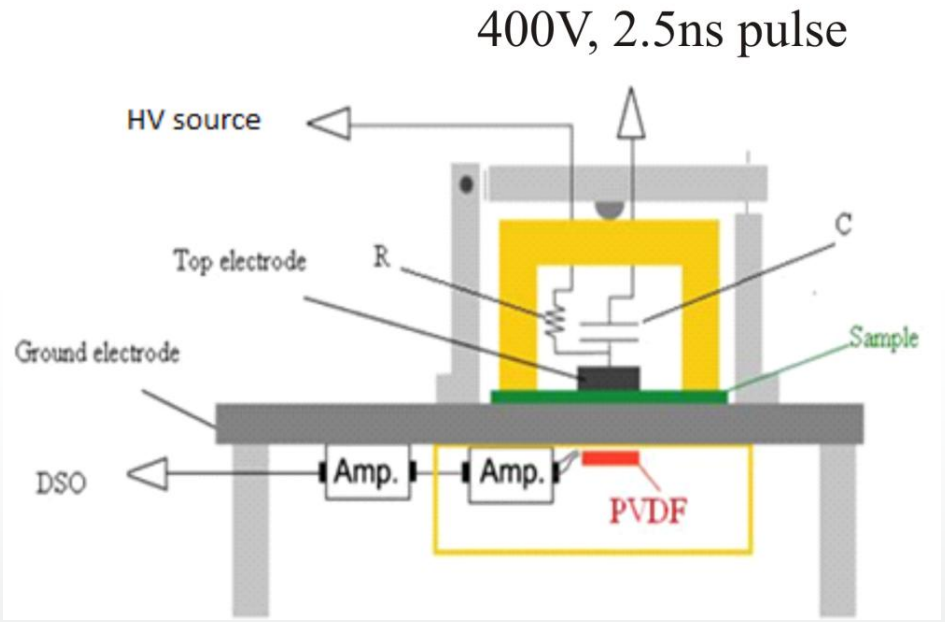
Pulsed Electro-Acoustic (PEA) Experiment

- 40 minutes charging, 20 minutes decay
- 40 kV/mm dc field, calibrated at 10 kV/mm
- Top electrode – semiconducting polymer
- Bottom electrode - aluminium



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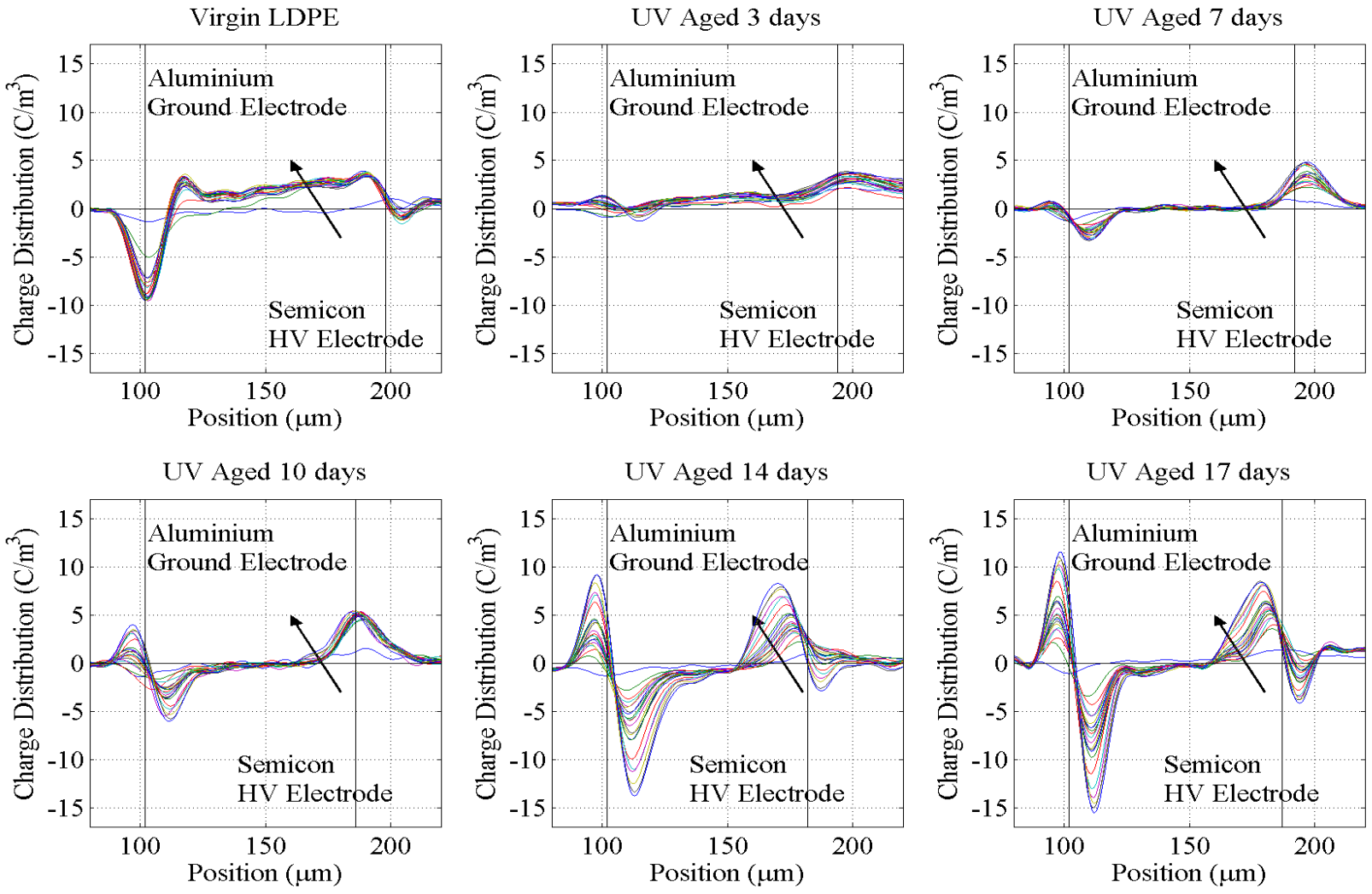
PEA Results



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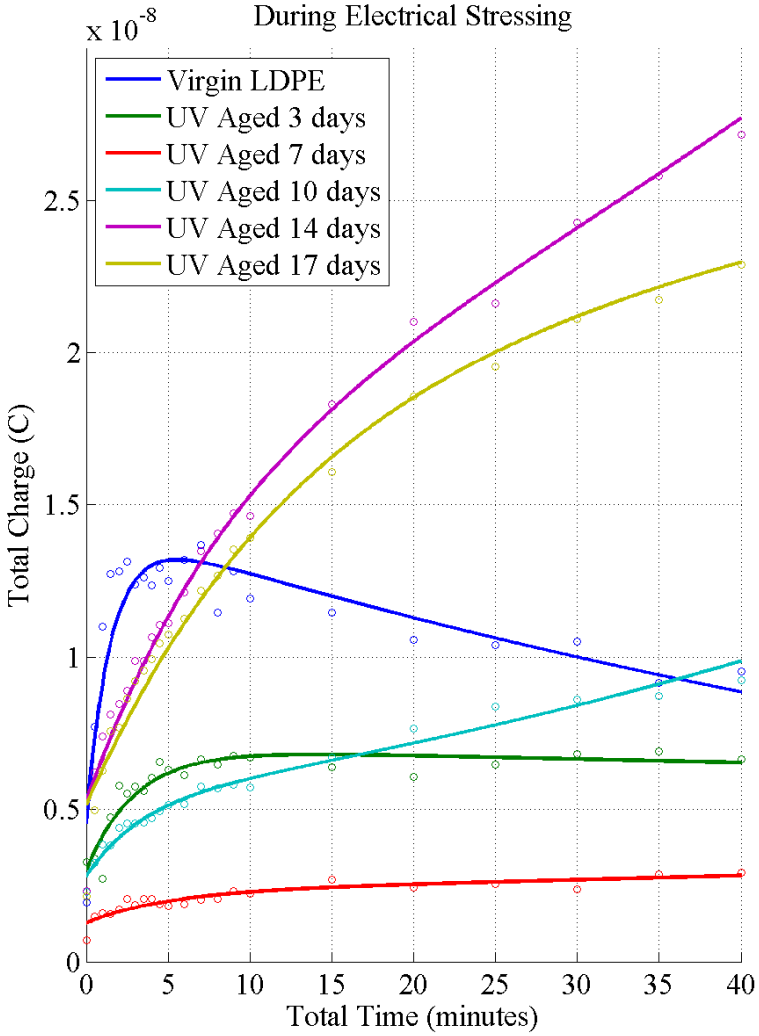
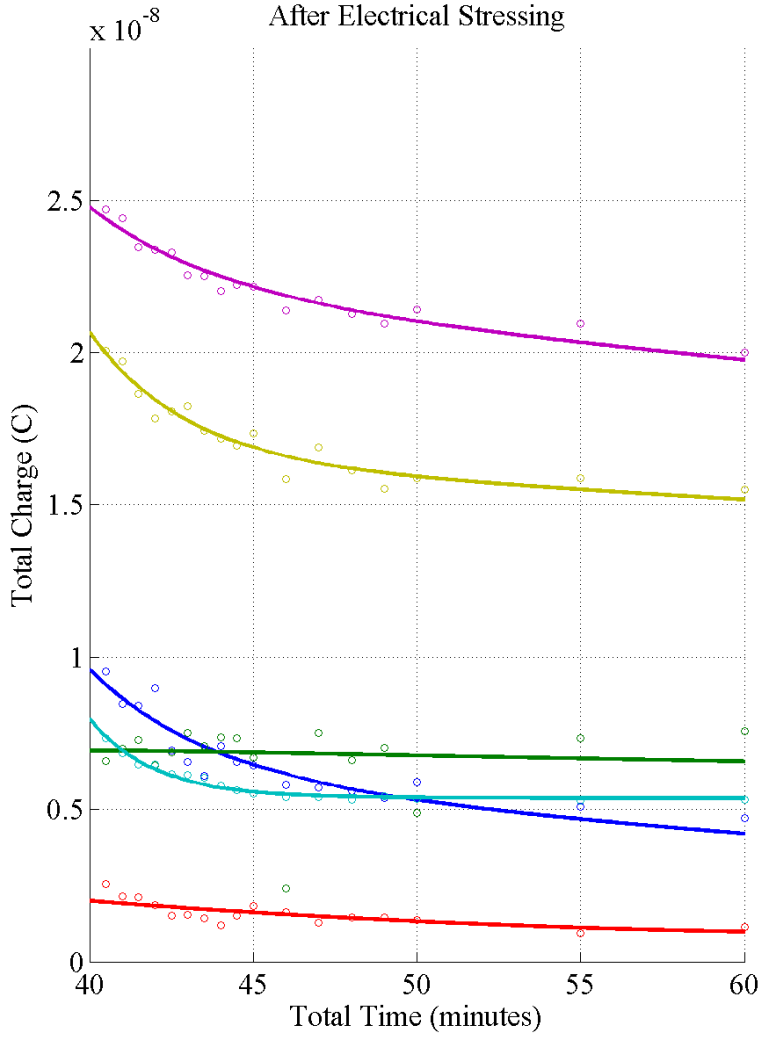
Total Bulk Charge





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Electroluminescence

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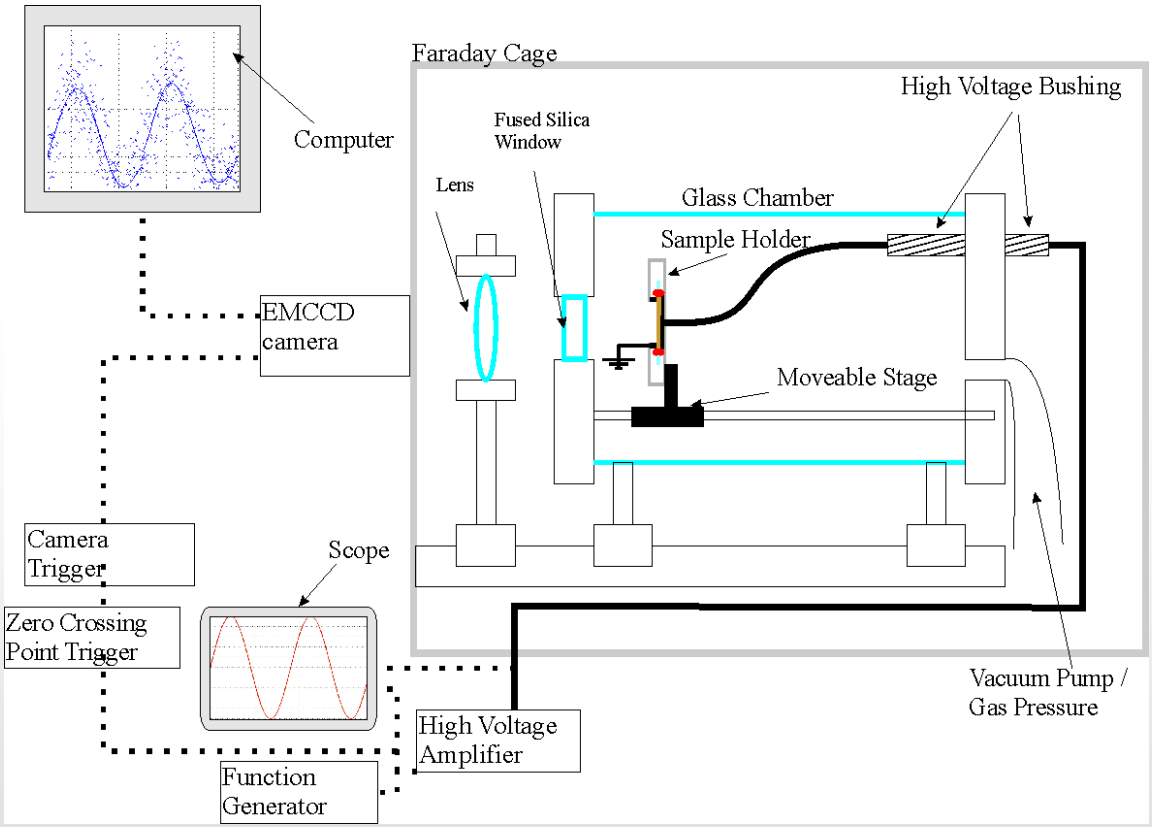
Electroluminescence Experiment

- Experiment under dry nitrogen at 1 bar above atmospheric.
- 50 Hz, sinusoidal field.
- Gold sputter coat ~20 nm each side.
- Total EL emission during 1 ac cycle, averaged over 100 cycles.



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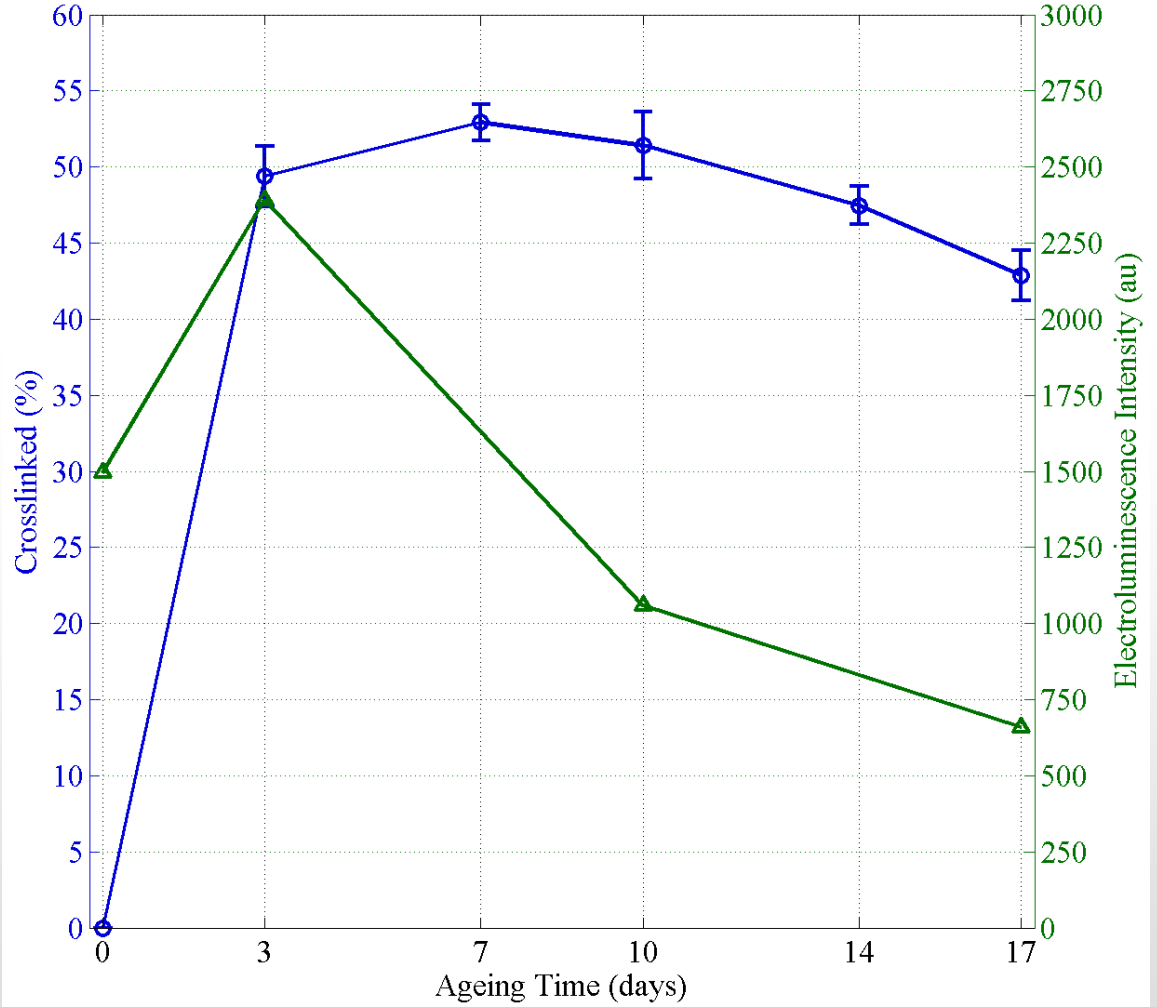
Electroluminescence Results

- Increased EL and cross-linking initially.
- Increased cross-linking maintained, reduced EL with further ageing.



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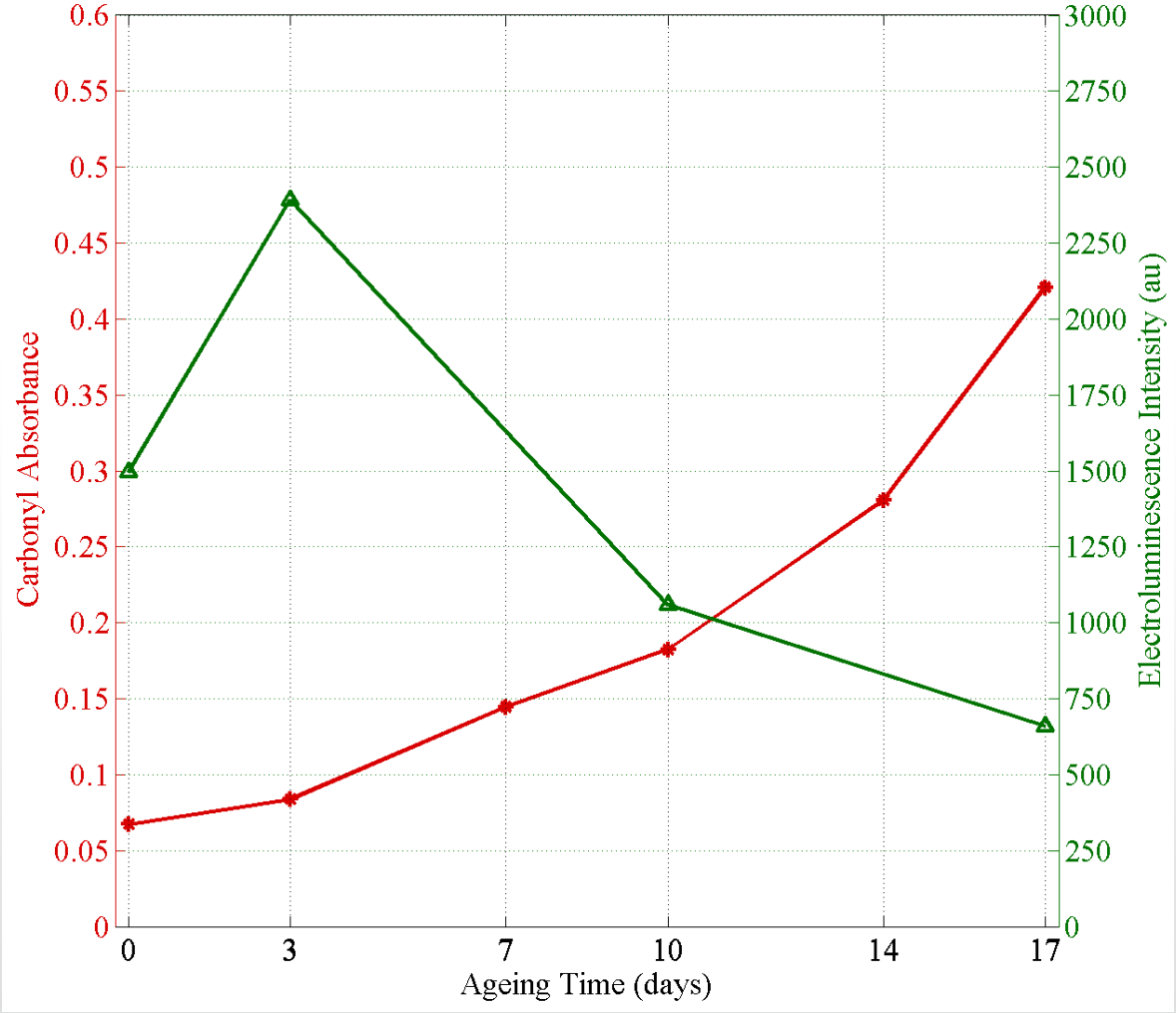
Electroluminescence Results

- Carbonyl absorbance taken at 1714 cm^{-1}
- Oxidation products are seen to increase with ageing time.



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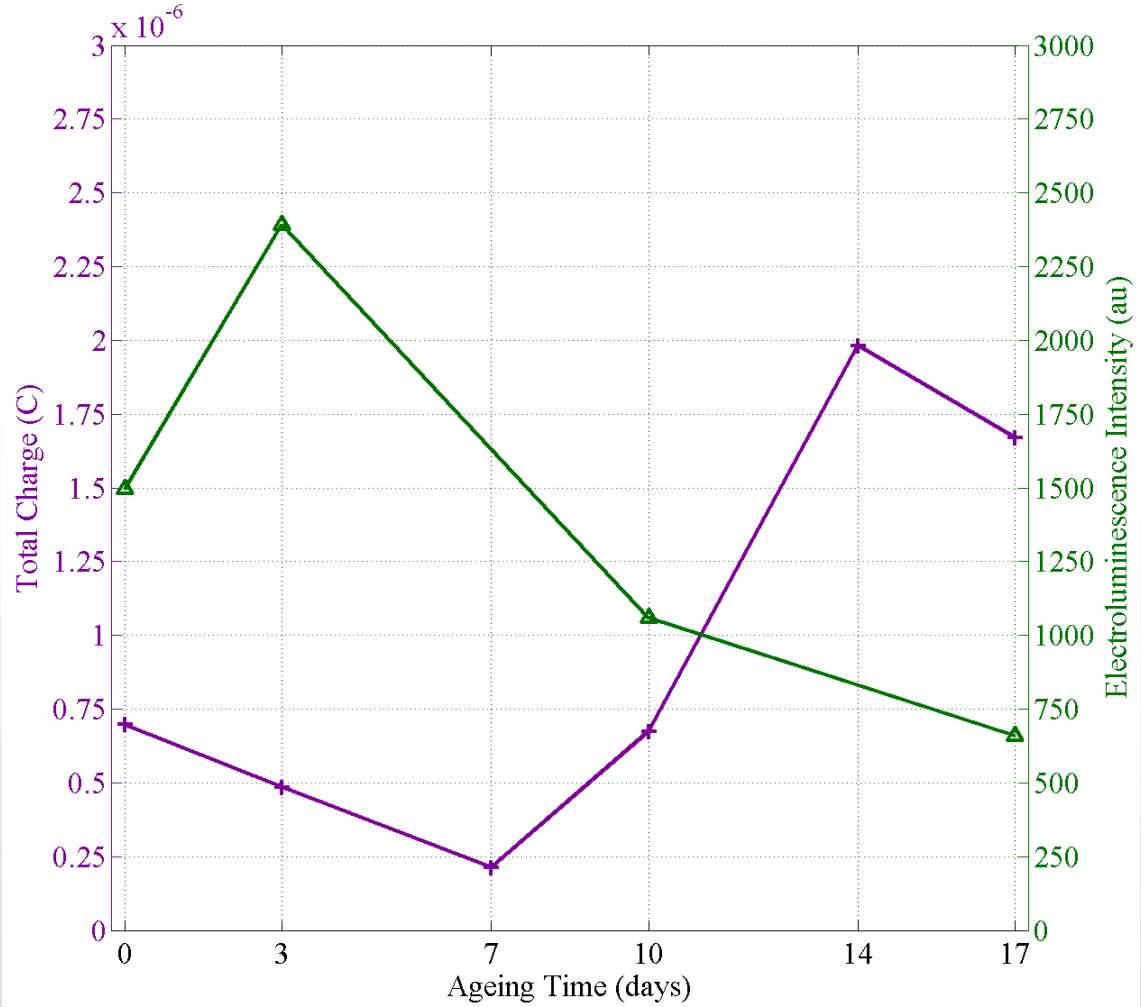
Electroluminescence Results

- Measured bulk charge after 40 minutes.
- Initially bulk charge reduces up to 7 days
- Further ageing increases bulk charge



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Conclusions

- This initial work aims to improve understanding in the role of charge movement in the ageing of high voltage insulation
- LDPE was UV aged, resulting in:
  - A reduction in dielectric strength
  - Increased cross-linking
  - Increased oxidation products

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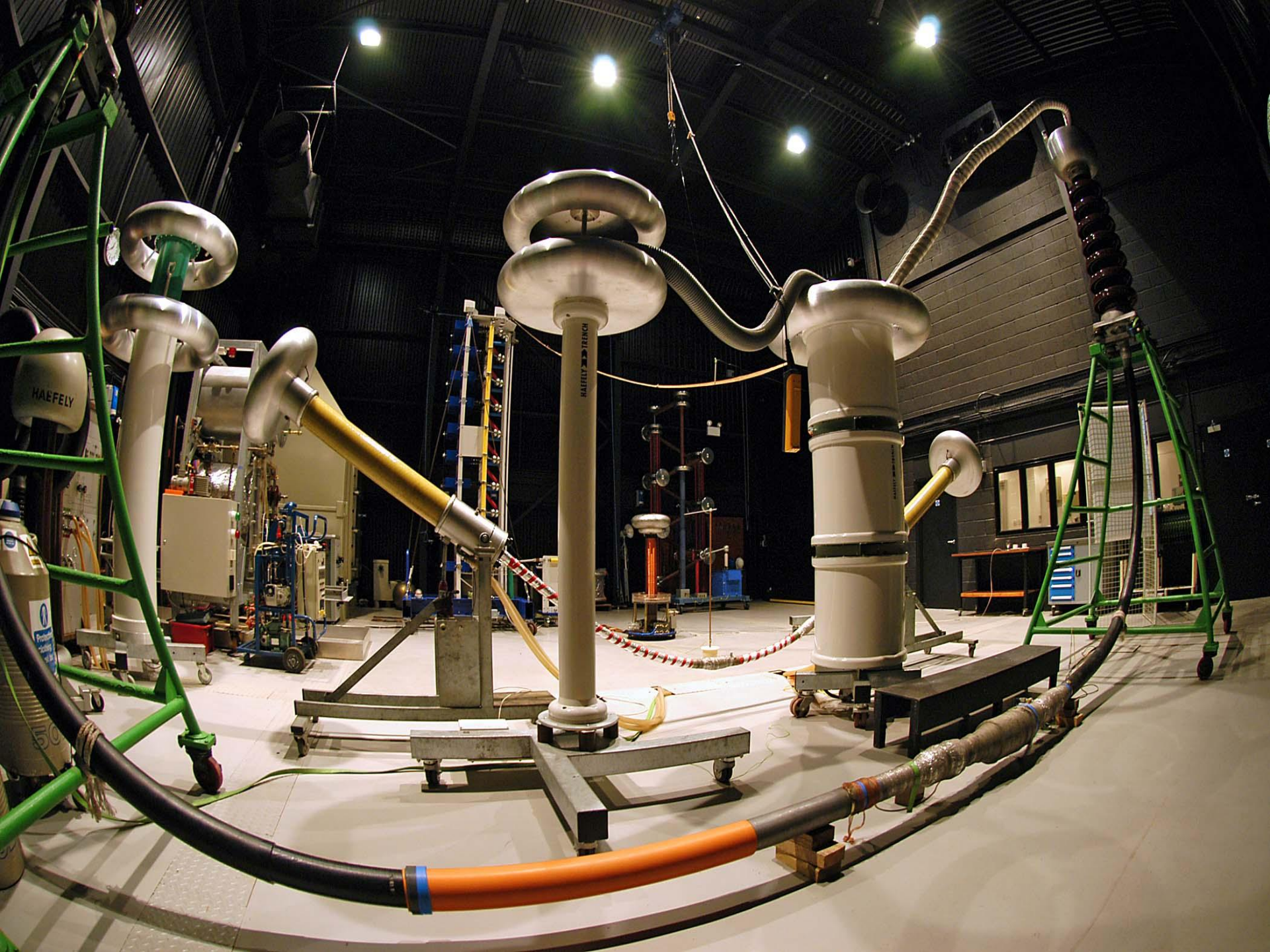
Conclusions Continued

- Experiments to investigate charge movement showed:
  - Initially less charge is trapped within the bulk but this increases with further ageing.
  - Initially stronger electroluminescence but this reduces with further ageing.
- A build up of charge traps near the electrode-polymer interface limits charge injection into the bulk. Continued ageing shows greater oxidation allowing for charge injection and trapping within the bulk of the polymer.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