

Study of the charge profile of thermally poled electrets

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Research question

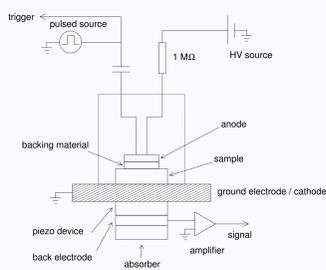
Can we study the charge profile of thermally poled electrets with acoustic pulse methods?

Rationale and background

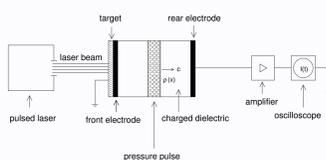
The aim of this work is to explore new tools to study thermally poled electrets.

Acoustic methods for determination of charge profile:

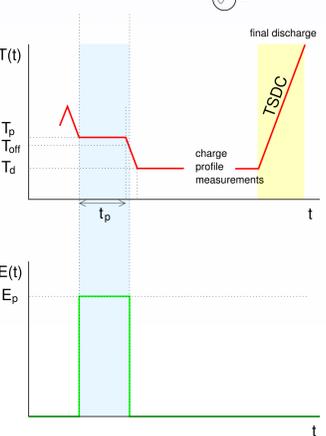
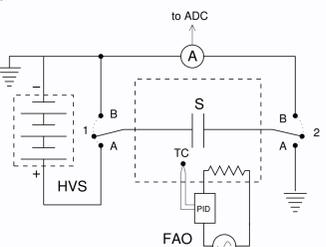
Electroacoustic pulse (PEA)



Laser induced pressure pulse (LIPP)



Acoustic methods have seldom been employed to study thermally poled electrets. Usually their polarization is studied with thermally stimulated depolarization currents (TSDC), that does not give information about space distribution.



Objectives

- Relate the charge profile with the relaxations that are activated in the material.
- Find out the role of the different mechanisms that take part in thermal poling (especially charge injection).
- Relate charge injection with the type of electrode.
- Find a way to use acoustic charge profile methods (PEA, LIPP, ...) when the sample is poled outside of the setup.
- Test a deconvolution procedure apt for thin samples.
- Validate PEA results with LIPP and assess the performance of these methods.

Samples

- Two PET materials have been used for the samples:
- Autobar PET (industrial provider) 320 μm thickness.
- Goodfellow (science provider) PET 240 μm thickness.
- Sample size: 2.5 × 2.5 m². Vacuum deposited aluminum electrodes of 2 cm diameter on one (M1 sample) or both sides (M2 sample)

Experiments

- LIPP, PEA, TSDC: PEA is used to check LIPP measurement.
- Charge sample with TSDC setup
- Measure charge profile in LIPP setup
- Measure charge profile in PEA setup
- Discharge and register thermally stimulated current in TSDC setup
- LIPP, PEA, TSDC: PEA measurement. Activated mechanisms are checked with TSDC.
- Charge sample with TSDC setup
- Measure charge profile in PEA setup
- Discharge and register thermally stimulated current in TSDC setup
- TSDC only: Relaxational study of the samples.
- Charge sample with TSDC setup
- Discharge and register thermally stimulated current in TSDC setup
- TSDC charge parameters

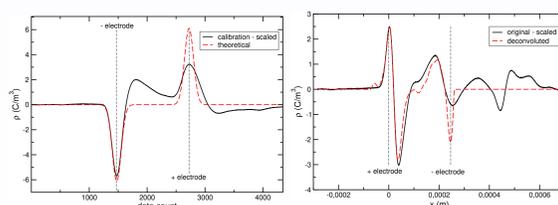
Experiment/sample	At electrode side	T ₀ (°C)	T _p (°C)	t _p (s)	T _{off} (°C)	T _d (°C)
A	Both	95	65	600	55	25
B	Both	140	95	0	80	25
C	Both	95	80	1200	75	25
D	Minus	95	80	1200	75	25
E	Plus	95	80	1200	75	25

Data processing

- LIPP and TSDC data do not need to be processed.
- PEA data requires deconvolution. Samples are measured in an ideal capacitor configuration. Transfer function is found from these data.

$$V_{cal} = H_{pea} \rho c$$

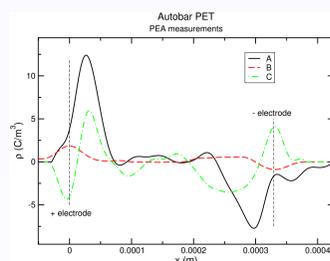
$$\rho = H_{pea}^{-1} V$$



M2 samples

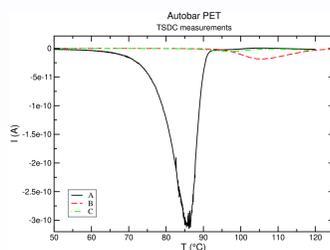
Results for AB PET samples with vacuum deposited aluminum electrodes on both sides

PEA



- A experiment: image or injected charge not cancelled by induced charge.
- B experiment: macroscopic dipole and image charges.
- C experiment: profile dominated by charge injection at both electrodes.

TSDC

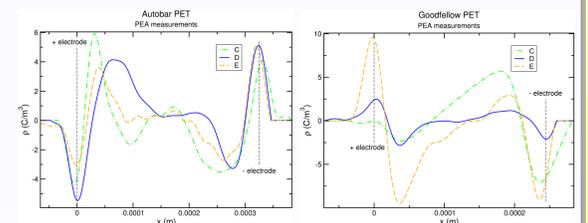


- A experiment has dipolar charge activated and B experiment has space charge activated. C experiment presents a mix of both mechanisms.
- GF PET gives qualitatively similar results for A and B experiments. No charge injection in C.

Injection

Same injection-oriented poling history with different electrode configuration.

PEA



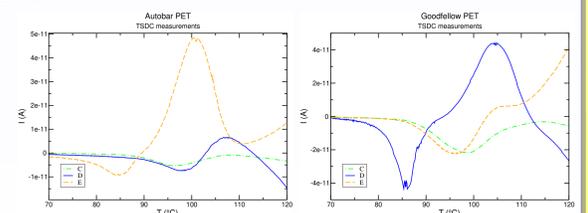
AB PET

- Increased hole injection when air gap faces positive electrode (D experiment).
- Electron injection similar regardless of electrode type.

GF PET

- No charge injection.
- Formation of space charge macrodipole, strongest for experiment C.

TSDC

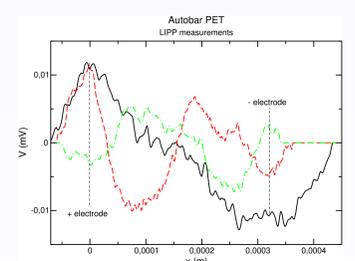


- Homocurrent ρ peak in experiment E for AB PET and in experiment D for GF PET.
- According to charge profiles, in experiment D recombination takes place at the electrodes while in experiment E recombination takes place in the bulk.
- Hypothesis: Diode effect due to asymmetry of the electrodes is of opposite direction in AB PET and GF PET due to differences in surface states.
- In C experiment heterocurrent always prevails.

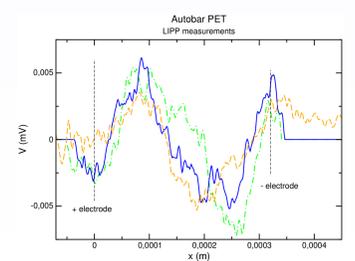
LIPP results

LIPP method yields results compatible with PEA.

M2 samples



Injection



Conclusions

- Induced charge created by dipolar space charge mechanisms can only be detected indirectly.
- Microscopic dipoles with heterocharge orientation are formed when a space charge relaxation is activated.
- Industrial add-ons, such as anti-static treatments can modify surface energy levels and affect injection and diode-like behavior of M1 samples.
- Charge injection can take place even in M2 samples.
- Agreement between PEA and LIPP methods. Both yield similar qualitative profiles.
- There is room for more robust yet simple PEA deconvolution schemes.
- Charge profile methods are most useful for the study of charge injection and less able for strictly superficial charge distributions such as injected charge, probably due to slow response of the piezoelectric sensor.

REFERENCES

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