MEASUREMENT PRINCIPLE AND BASIC CRITERIA TO ASSESS THE SPACE CHARGE DISTRIBUTION IN SILICONE ELASTOMERS

TECHNISCHE UNIVERSITÄT DARMSTADT

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OUTLINE

1 motivation

2 functionality of the PEA

3 experimental Setup of PEA system

4 overview of the assessment concept

5 assessment concept of four samples

6 summary/outlook

MOTIVATION

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- energy transition:
  - electricity generation increasingly from renewable energies by 2050 (80%)
  - expansion of the HVDC transmission system
  - cable systems for voltages of up to 525 kV
  - space charge inspections have become increasingly important
    - integrated the determination of the space charge distribution into their prequalification (PQ) test procedure

Investigation of the insulations for their space charge behavior

[1]

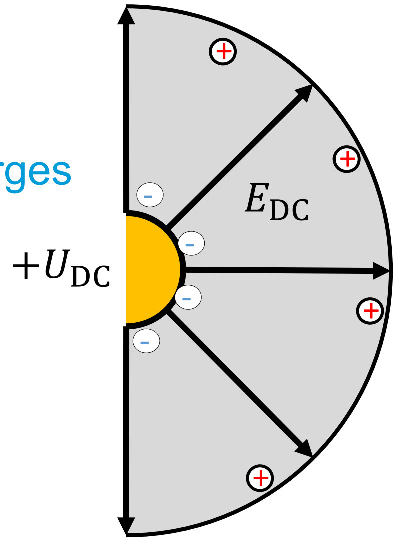
MOTIVATION

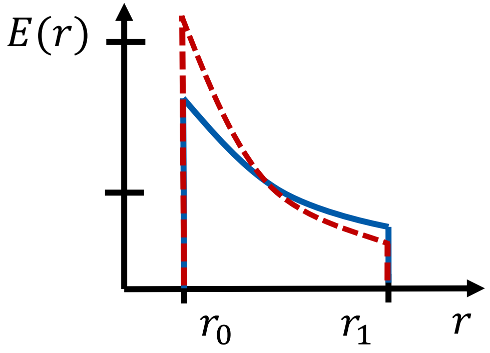
- issues with DC load
  - creation of space charge in the insulating material
  - hetero- or homocharges

- reduction of the electrical strength in the insulation
- possible early damage or breakdown of the insulation material

- various measuring methods for space charge measurement available:
  - difference between destructive or non-destructive measurement
  - Piezoelectrically Induced Pressure Wave Propagation
  - Lacer Induced Pressure Pulse

Pulsed Electroacoustic Methode (PEA)





FUNCTIONALITY OF THE PEA

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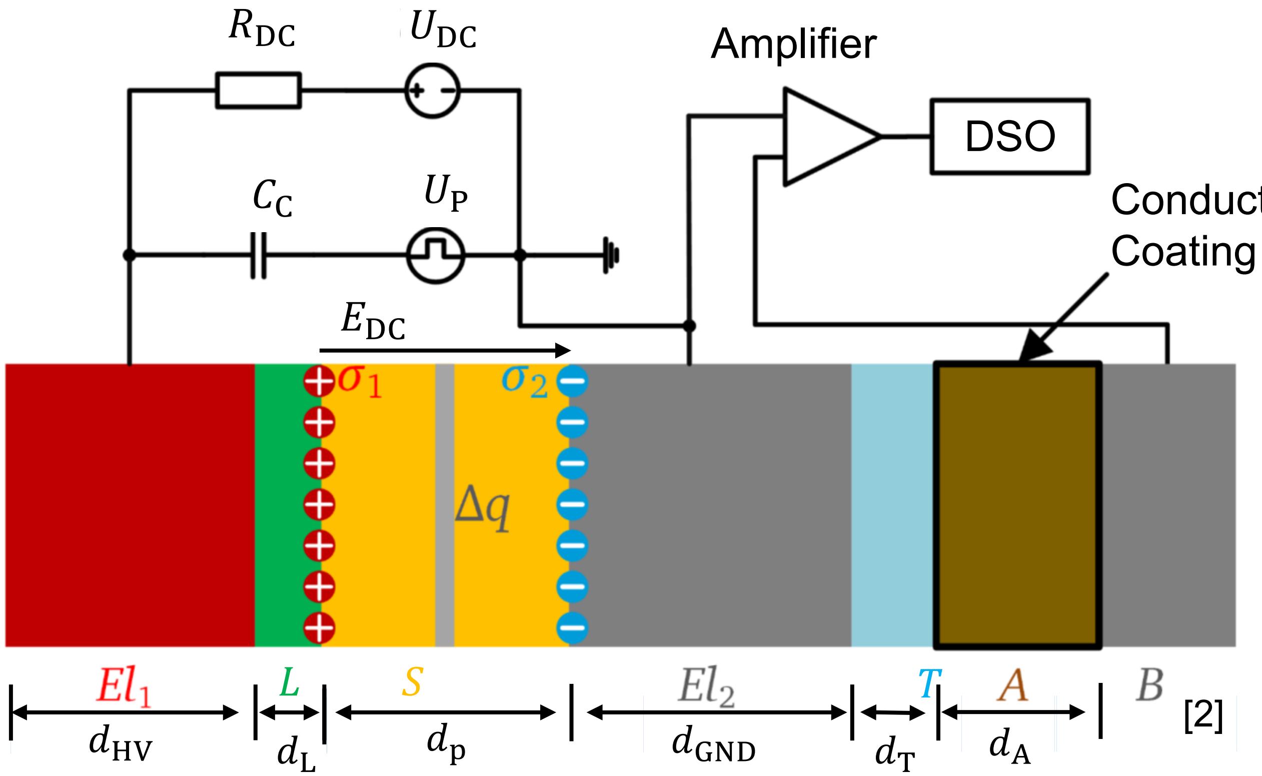
process steps

1) polarization
2) generation of acoustic waves
3) propagation of acoustic waves
4) reflection of acoustic waves
5) deconvolution of the signal



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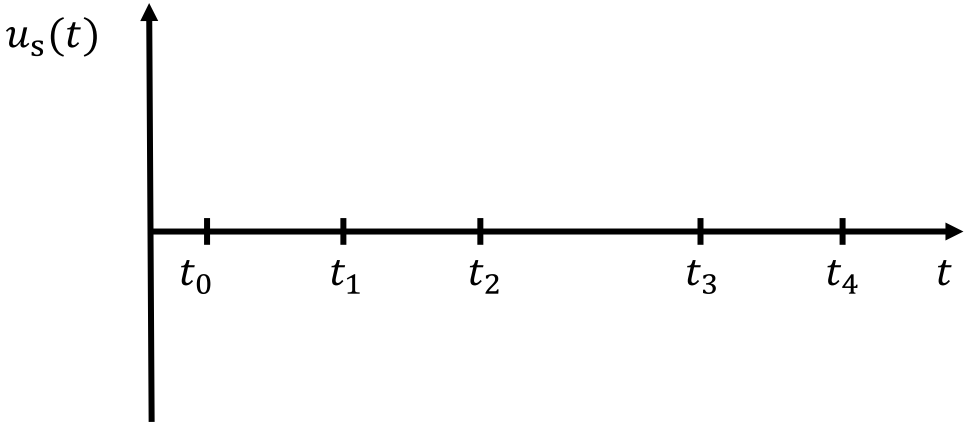

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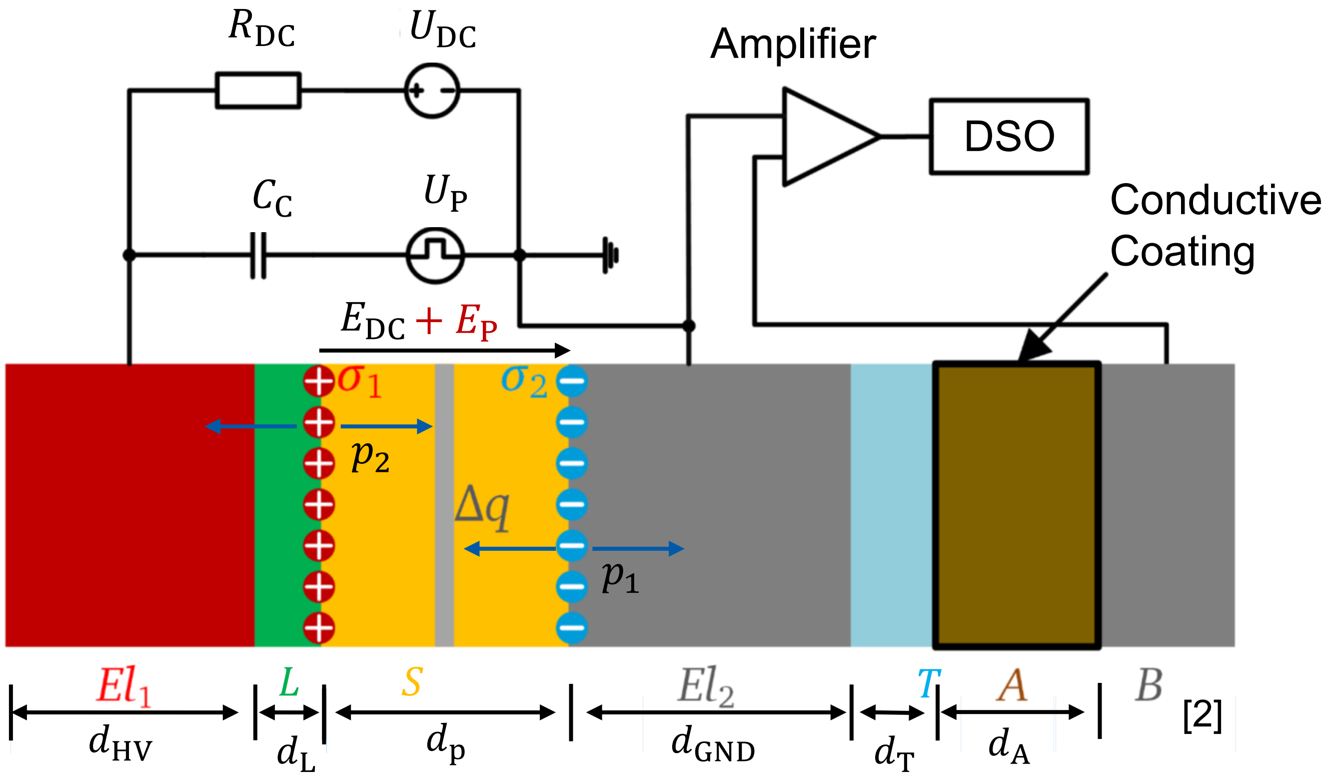

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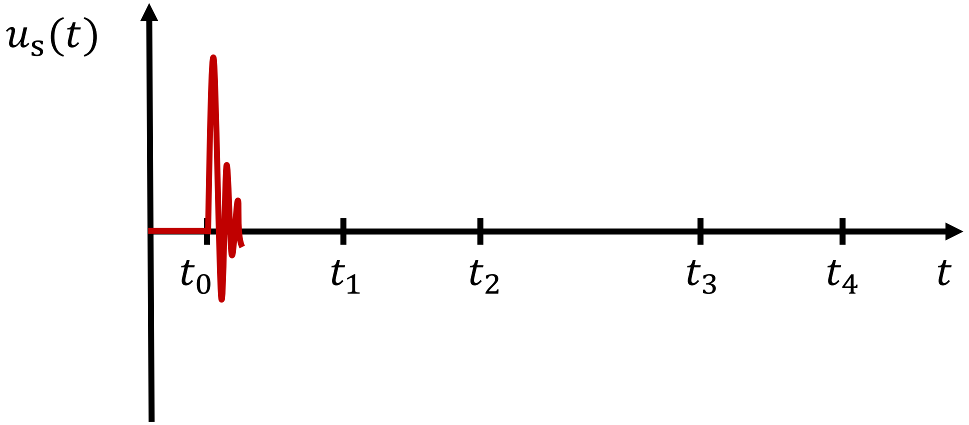

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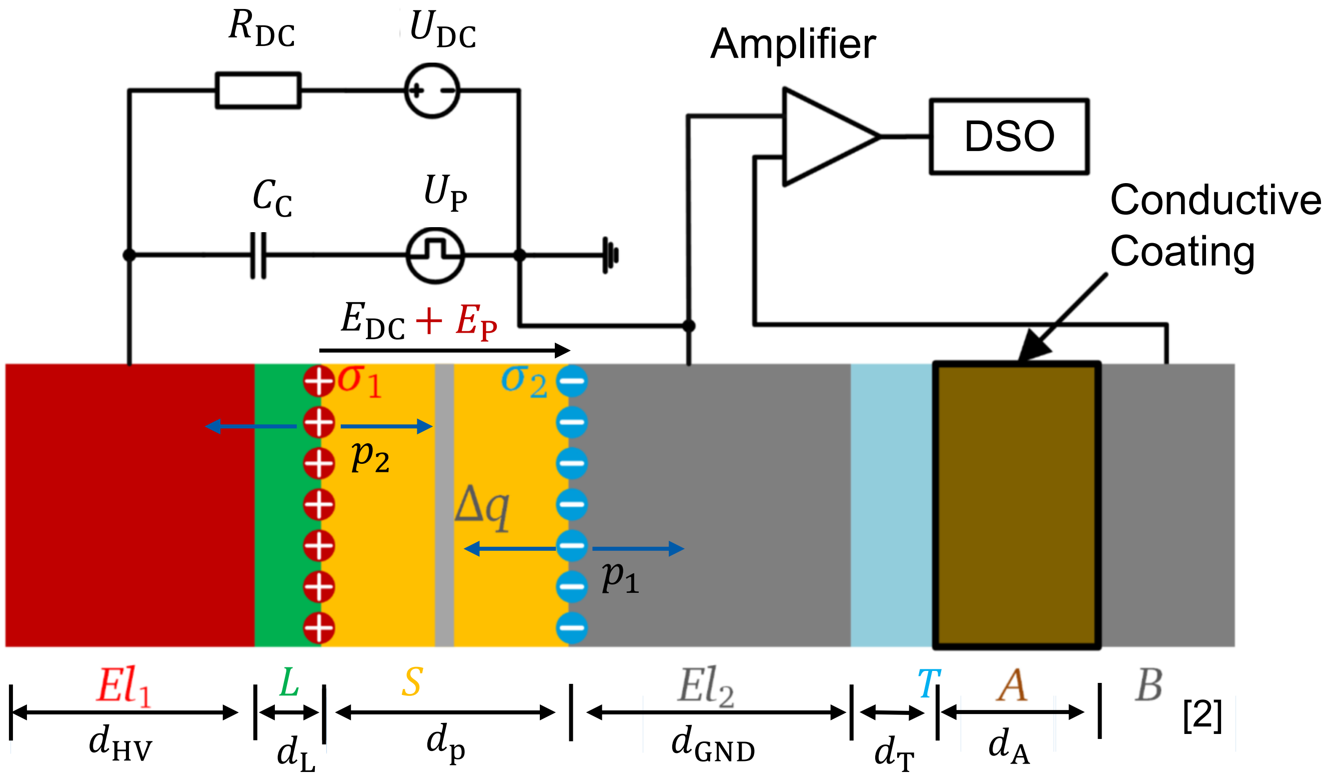

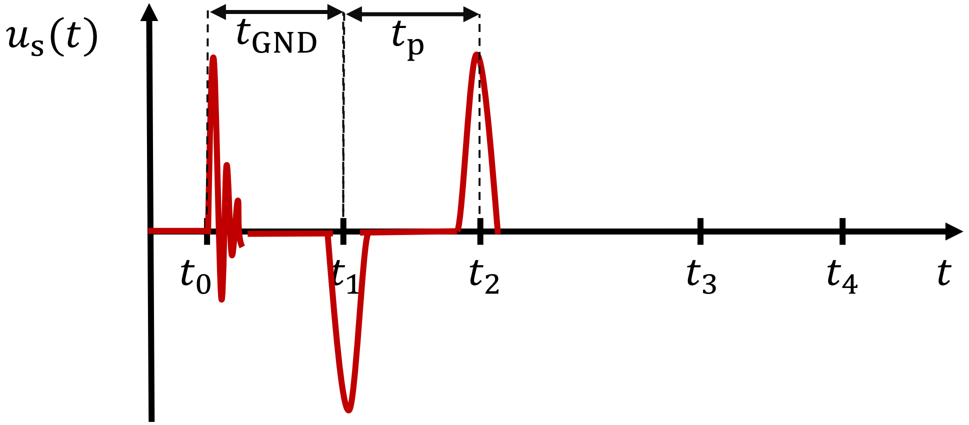

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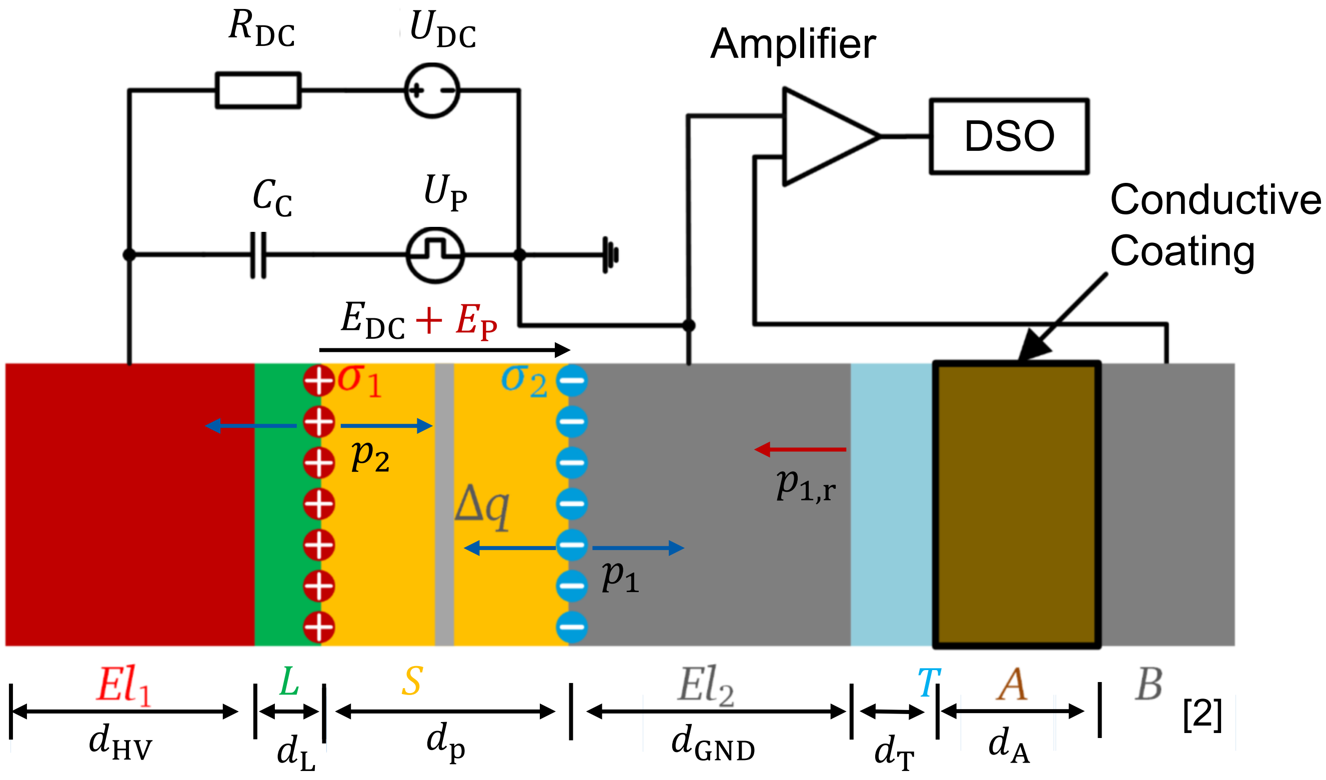

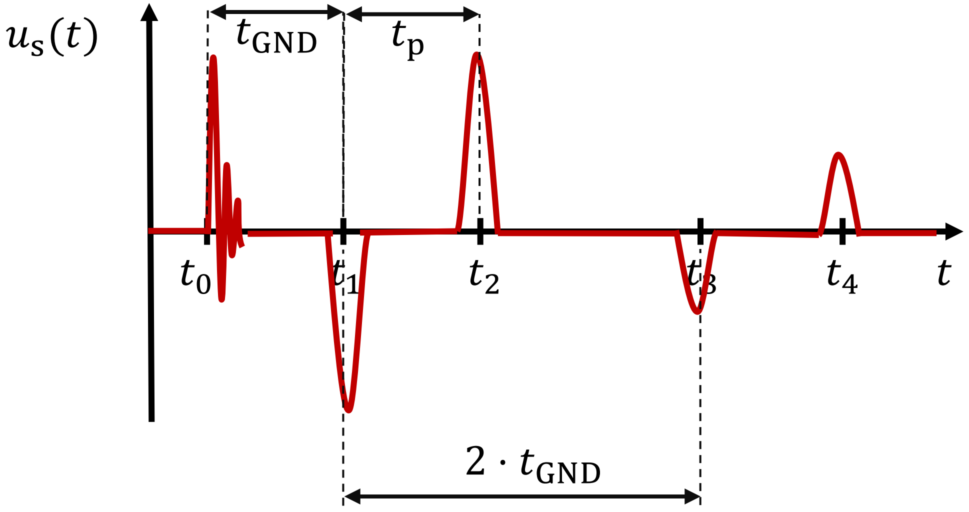

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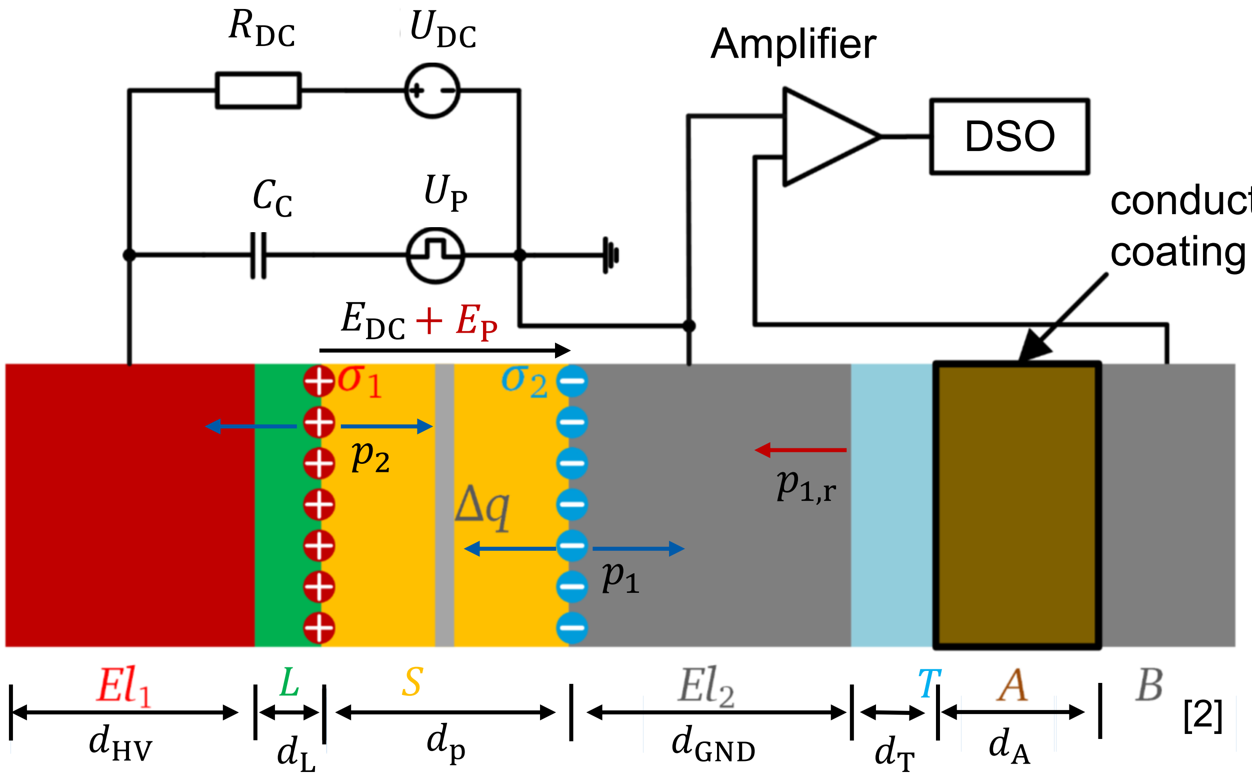

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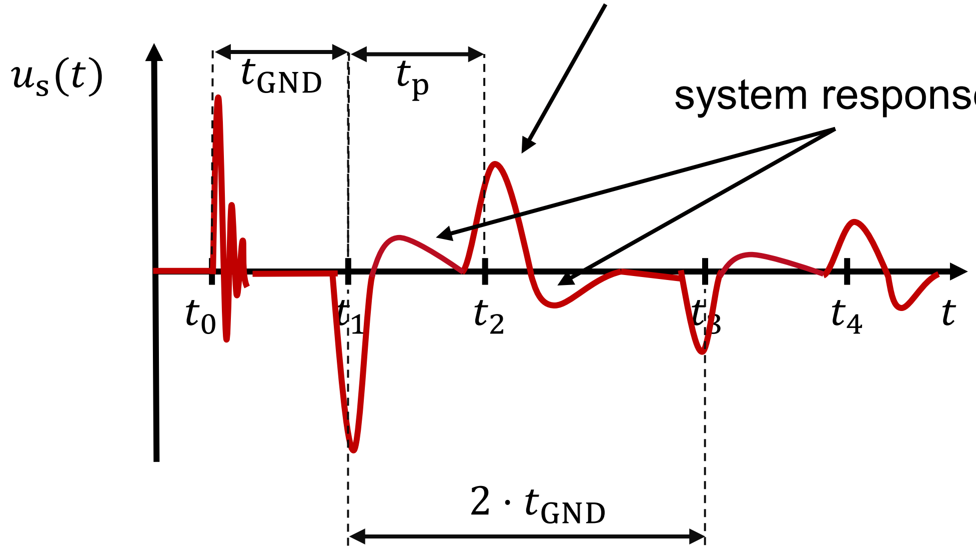

- influence of the system response of the PEA cell
- frequency-dependent attenuation and dispersion of the material

EXPERIMENTAL SETUP OF PEA SYSTEM

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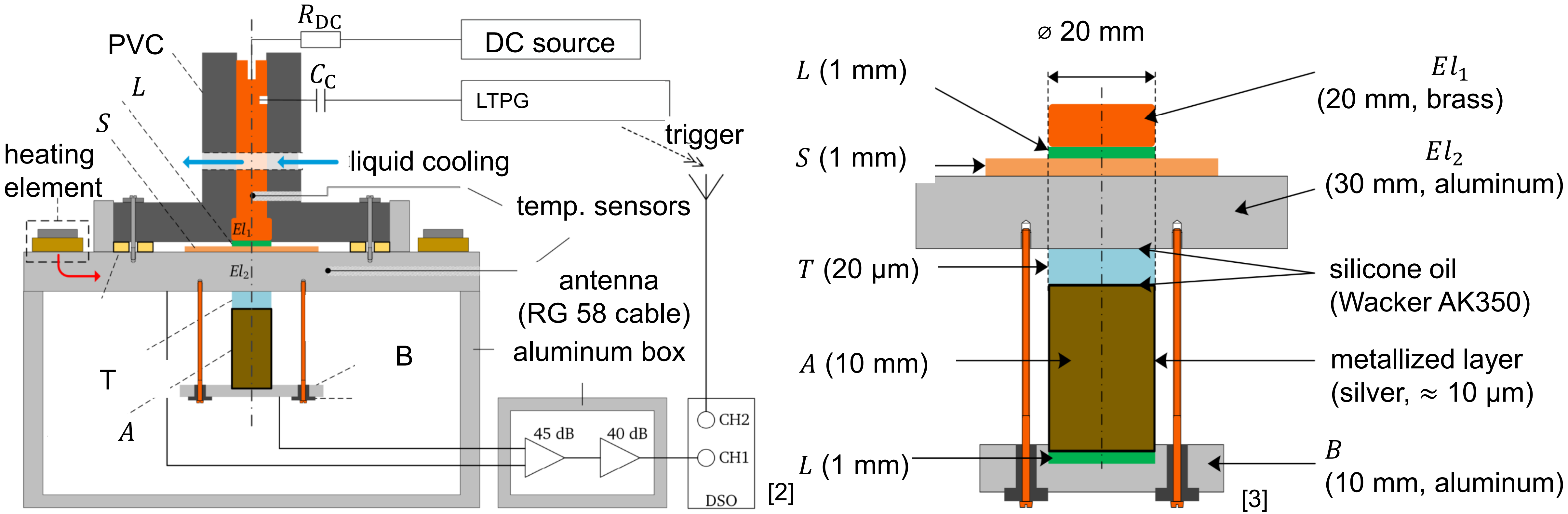
- schematic structure of PEA setup & acoustic detection unit



OVERVIEW OF THE BASIC CRITERIA

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basic criteria to assess the reduction of space charges

- **first criteria:** average increase of the charge density & rise time of the average charge density

$$\rho_{\text{mean}}(t_i) = \frac{1}{x_2 - x_1} \int_{x_1}^{x_2} |\rho(x, t_i)| \mathrm{d}x$$

$$v_{\text{mean}} = \frac{\Delta\rho}{\Delta t} = \frac{\rho_{\text{mean}}(t_{i+1}) - \rho_{\text{mean}}(t_i)}{t_{i+1} - t_i}$$

- **second criteria:** Electric field enhancement factor *FEF*

$$FEF = \left| \frac{E_{\max}(t_i) - E_0}{E_0} \right| \cdot 100\%$$

- **Third criteria:** reproducibility of the measurements

assessment concept of four samples with different filler concentration at $E = 10\ \mathrm{kV/mm}$ at $T = 60°\mathrm{C}$

ASSESSMENT CONCEPT OF FOUR SAMPLES

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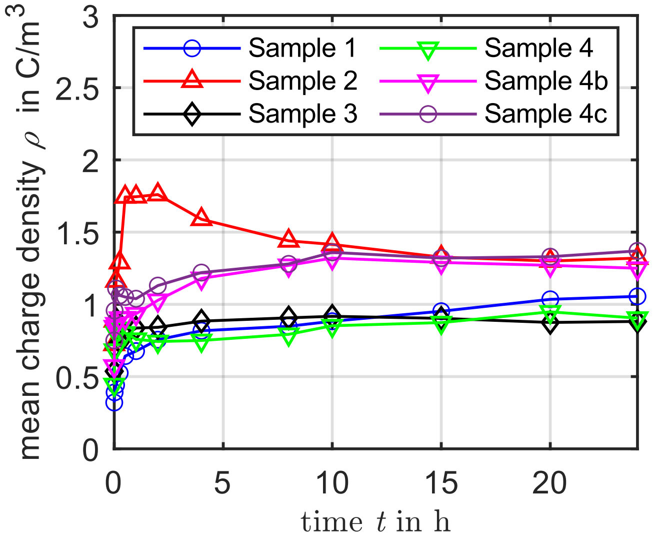
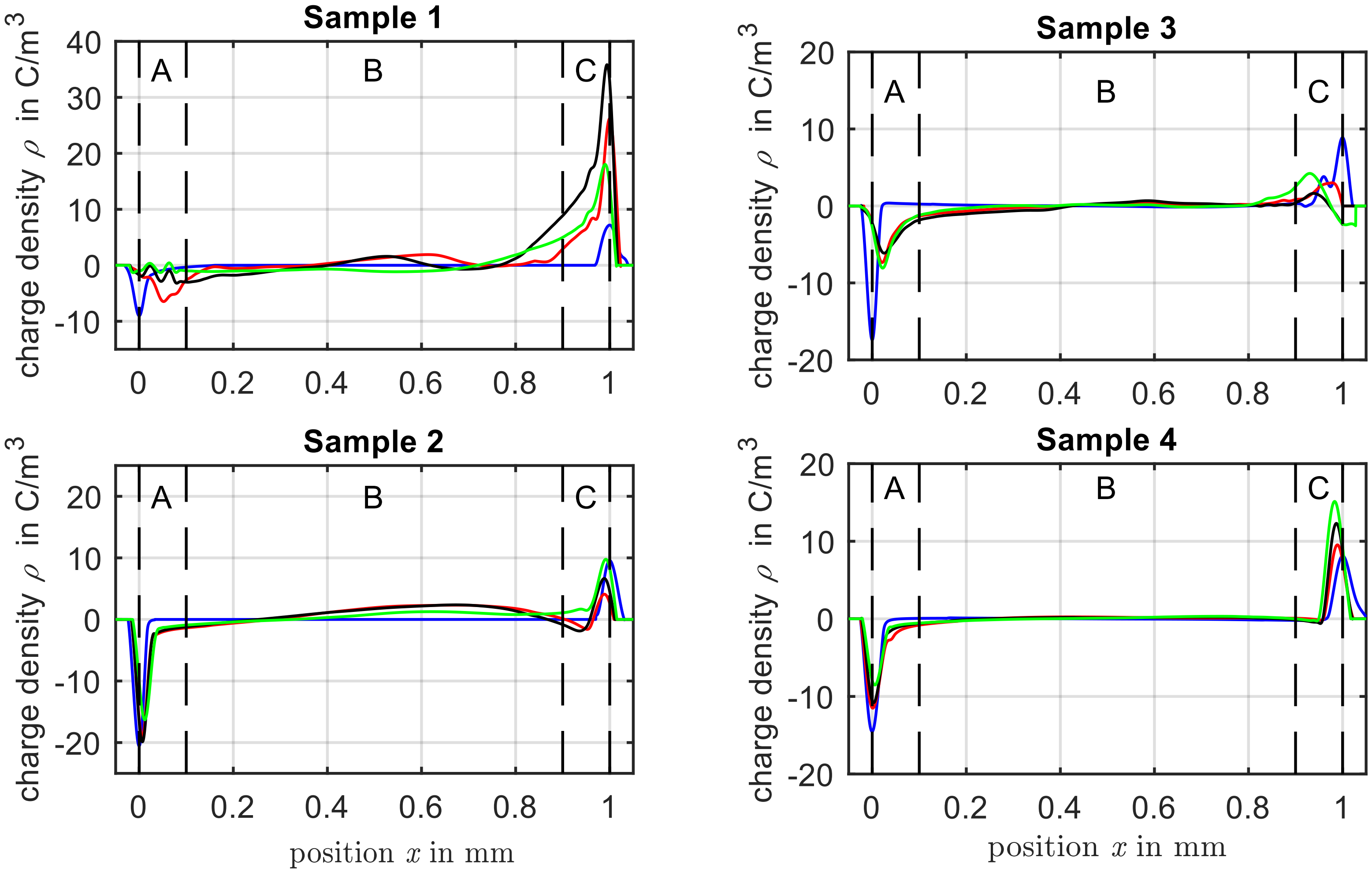
<u>evaluation according to first criteria</u>

- ➢ sample 1 & 2 show high increases in space charges
- ➢ sample 3 & 4 → higher filler concentration



Sample 3 & 4 accepted



ASSESSMENT CONCEPT OF FOUR SAMPLES

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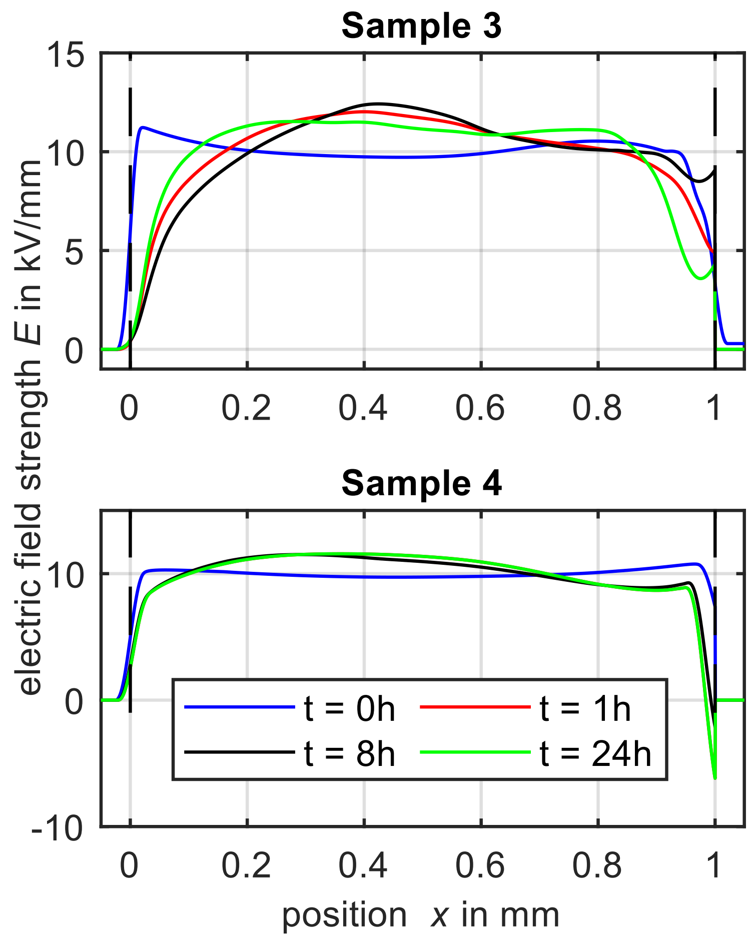
evaluation according to second and third criteria

- *FEF* of sample 1 & 2 too high
- *FEF* of sample 3& 4 perfect
- two additional batches of sample 4

Material	ρ_{24h}/ρ_{0h}	v_{mean} in C/m^3h	FEF in %
Sample1	3.29	Not stable	50
Sample 2	1.82	0.039	47
Sample 3	1.64	0.038	16
Sample 4	2.03	0.035	15
Sample 4b	2.18	0.074	39
Sample 4c	1.82	0.061	45

third basic criterion is not fulfilled for sample 4



SUMMARY/OUTLOOK

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- overview of the different measurement methods and the experimental test setup
- description of the functionality of the PEA method
- presentation of the main criteria of an evaluation concept for assessing the different material compositions of silicones.
  - average increase of the charge density
  - Electric field enhancement factor *FEF*
  - reproducibility of the measurements
- to explain this evaluation concept, four different carbon black-filled silicone elastomers were measured and evaluated at an electrical field stress of 10 kV/mm at a temperature of 60 C°
- it was possible to show how the spectrum of the different material compositions of the samples could be placed in a suitable research orientation with the help of the three criteria

THANK YOU FOR YOUR ATTENTION!

[1] https://www.egeplast.de/2020/12/kabelschutzrohre-energiewende/
[2] R. Hussain, “Electrical Characterization of Liquid Silicone Rubber with Carbon Black Nanofiller for HVDC Cable Accessories”. Dissertation, 2021, DOI: 10.26083/tuprints-00018585
[3] R. Hussain and V. Hinrichsen, “Development and Optimization of a Pulsed Electroacoustic System with Temperature Controlled Electrodes,” Nordic Insul. Symp. Mat. Comp. Diagnostics, 2019.