Long term stability

New insulating materials for next generation of HVDC cables - methods for evaluation of degradation phenomena by electrical treeing

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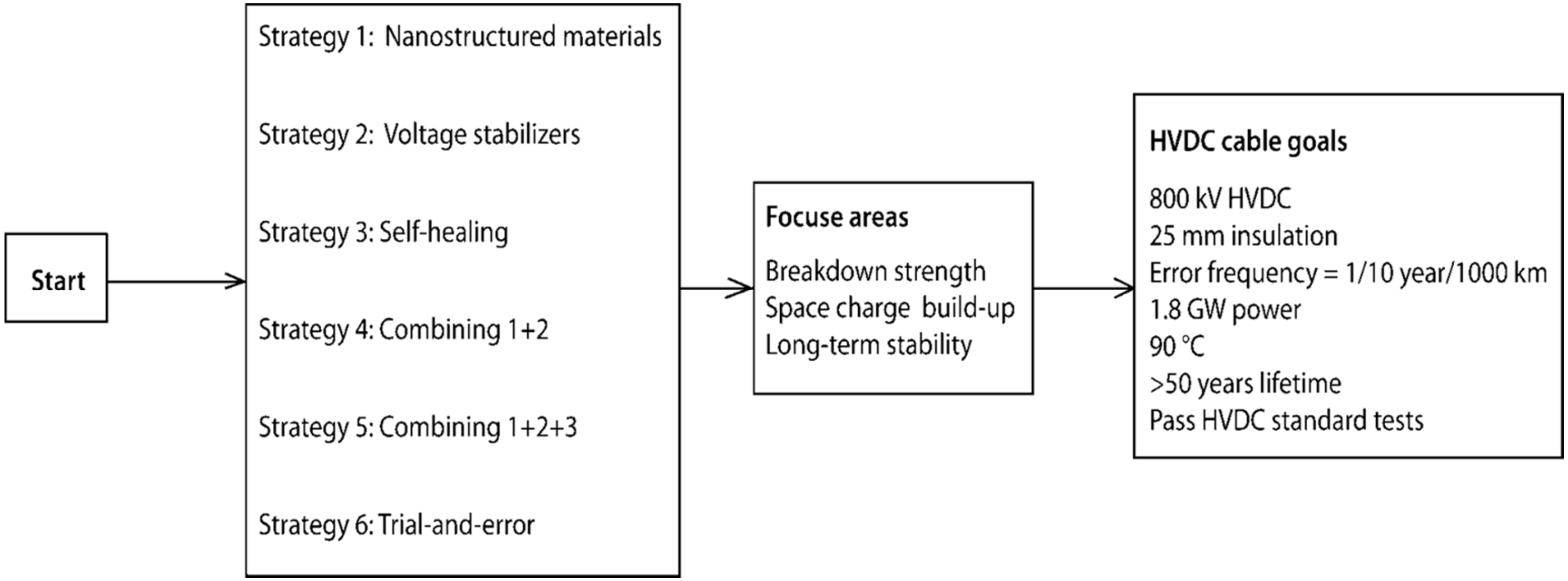

- Which of the proposed strategies will become most suitable for HVDC cable applications?
- Is testing of the resistance to electrical treeing suitable for evaluation of the material long term stability? If so, what methodology should be adopted for the evaluation?
- Are there similarities and cross-correlations in the development of electrical treeing phenomena under DC and AC stresses?

Characteristics of breakdown, degradation and ageing processes

	Breakdown	***Degradation***	***Ageing***
Effect	**Catastrophic:** insulation cannot be used afterwards	**Leads to breakdown:** reduces breakdown voltage	**May lead to degradation:** may not reduce breakdown voltage
Speed	**Fast:** occurs in << 1s	**Less than required service life:** ~hours – years	**Continuous process:** whole service life
Evidence	**Direct observation:** normally by eye - hole through insulation	**Observable directly:** may require microscopic or chemical techniques	**Difficult to observe:** may even be difficult to prove existence
Place	**Continuous filament:** bridges electrodes	**Occurs in weak parts:** may form fractal structures	**Assumed to occur throughout whole insulation**
Size	**> mm:** dependent on energy of event	**> µm:** may form larger structures	**> nm:** molecular scale
Examples	Thermal Electromechanical Mixed mode Avalanche Intrinsic	Electrical trees Water trees Partial discharges	Bond scission Nano-voids Trap formation Non-electrical changes (oxidation etc.)

J.C. Fothergill, "Ageing, space charge and nanodielectrics: ten things we don't know about dielectrics", Proc. IEEE Int. Conf. Sol. Diel., Winchester UK, 2007, pp. 1- 10.

Thermal ageing of XLPE cable insulation under operational temperatures – does it exist?

R. Olsen, J. Holboell M. Henriksen, J.Z. Hansen, in Proc. of 23rd Nordic Insulation Symposium (NordIs-13), Trondheim Norway, 2013, pp. 49 - 52.

"Based on the literature found, or to be more precise, on the literature not found it seems to be very difficult to determine that thermal ageing should be problematic for operational power cables at all, in particular as compared to laboratory investigations at very high temperatures, where thermal ageing clearly takes place."

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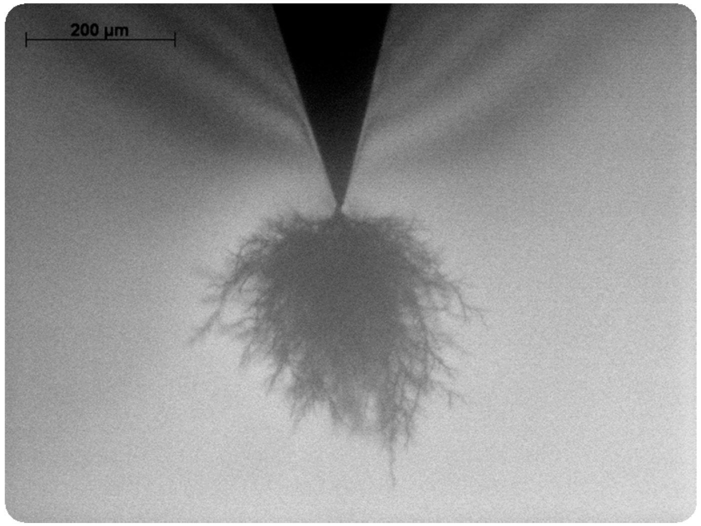
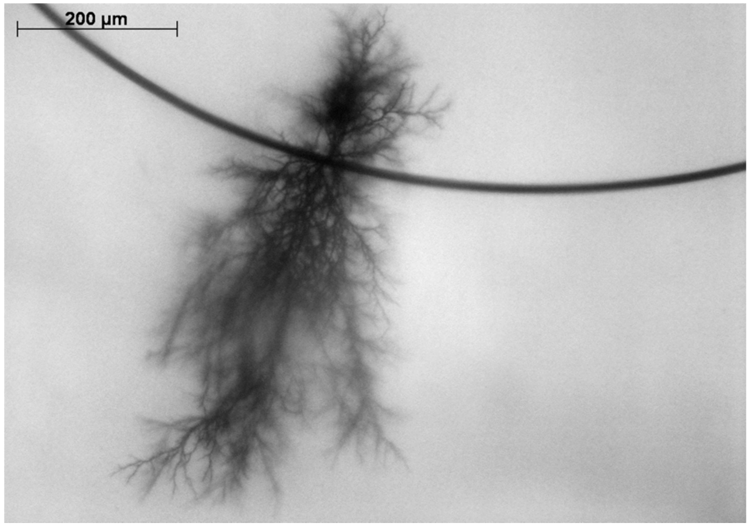
Close and Return

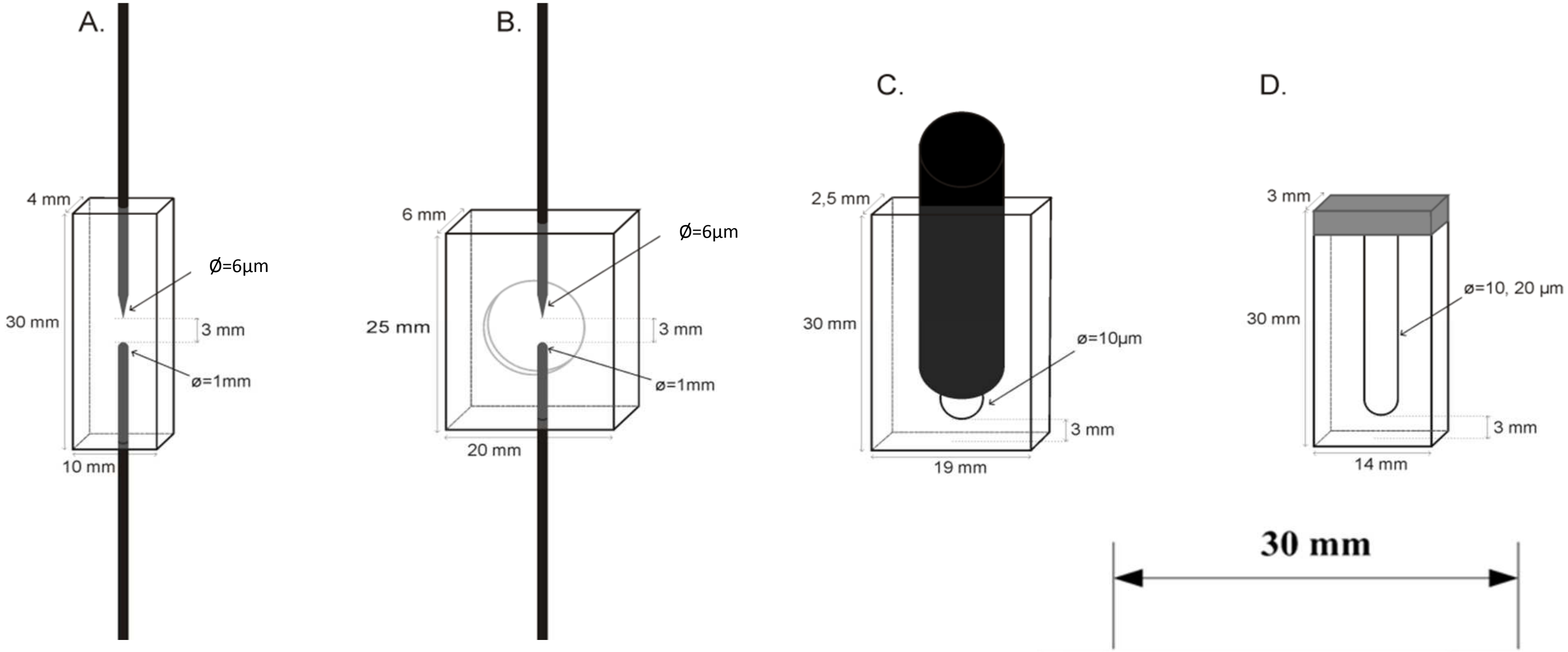
Content

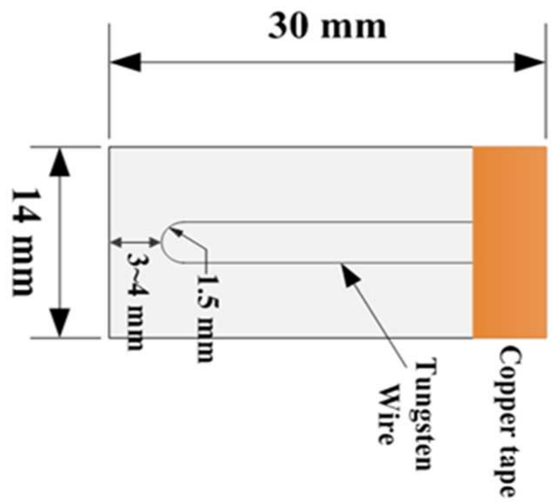
- **test objects**
- **AC and DC electrical treeing**
- **Effects of electro-thermal treatment**





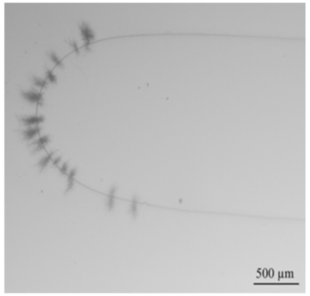
Test object geometry

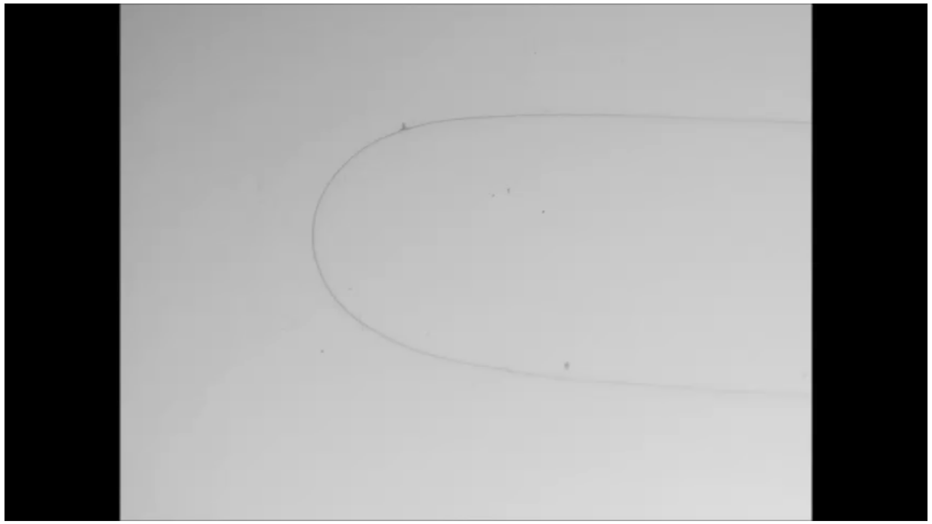




M. Jarvid, A. Johansson, J. Blennow, M. Andersson and S.M. Gubanski, Evaluation of the Performance of Several Object Types for Electrical Treeing Experiments, IEEE Trans. on DEI, 2013, vol. 5, pp. 1712 - 1719.

Many trees - more data…

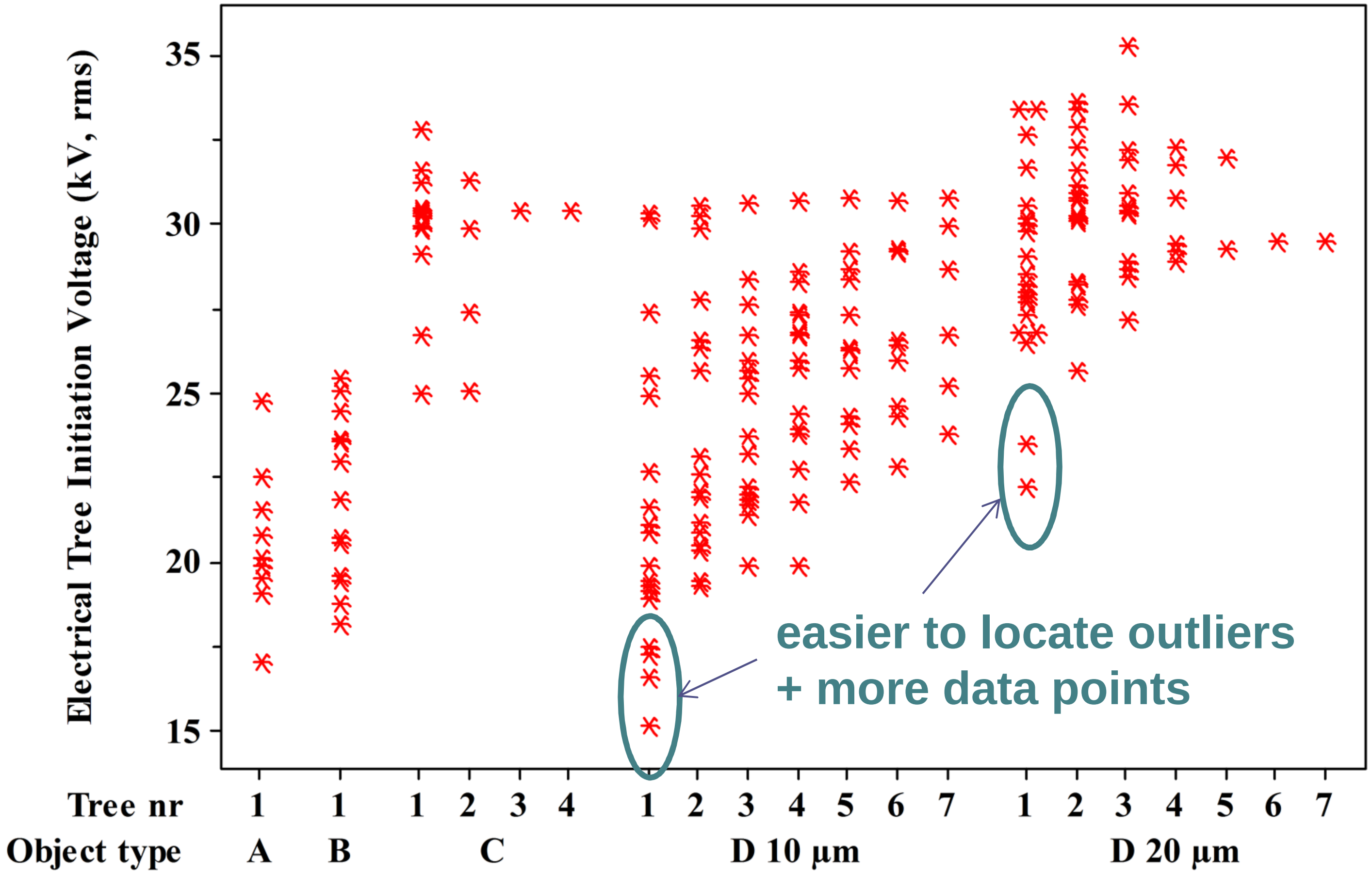




Click to activate the video

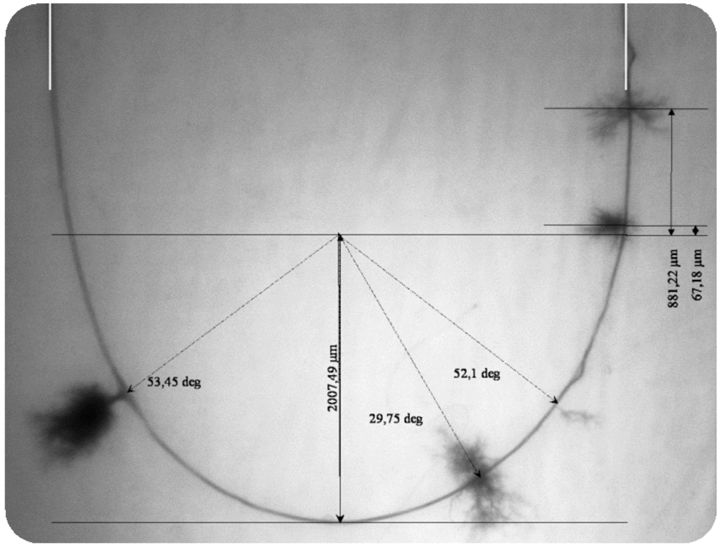
- tree initiation in a relatively large volume of material - tree inception is not forced at one specific location but at naturally created defect points
- several data points are generated in each test object
- possibility of adopting to other dielectric systems

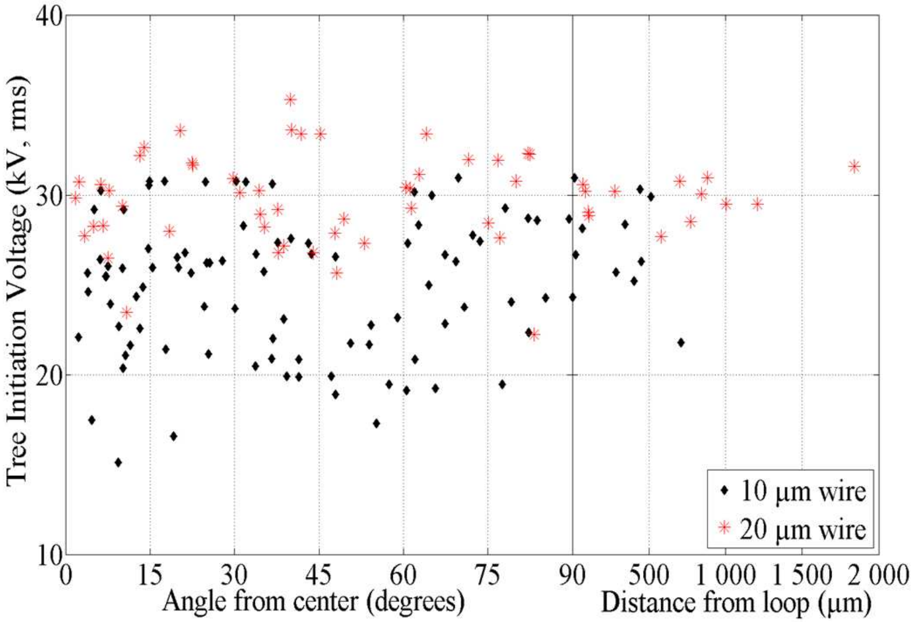
Many trees - more data...

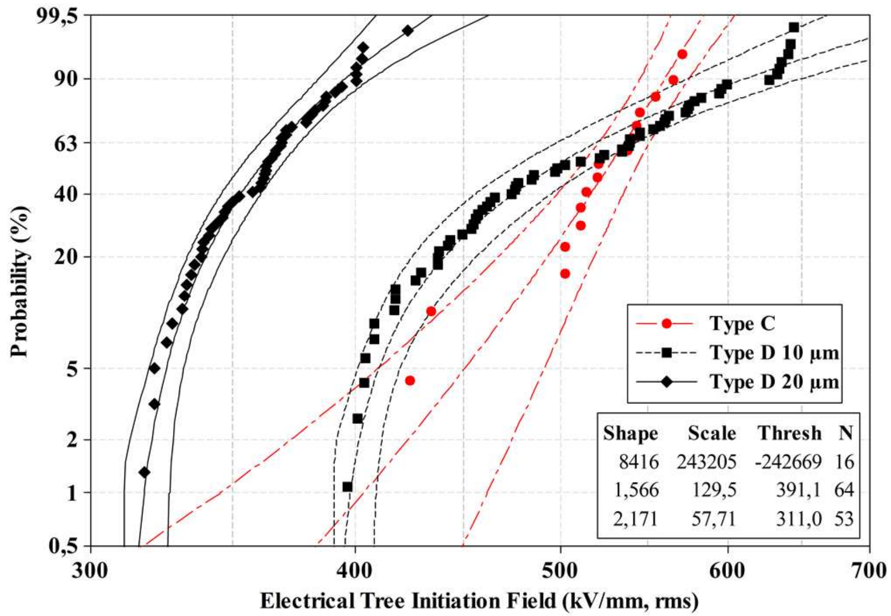


Influence of position on wire - distribution

- samples with 10 and 20 µm wire
- trees growing from defects excluded

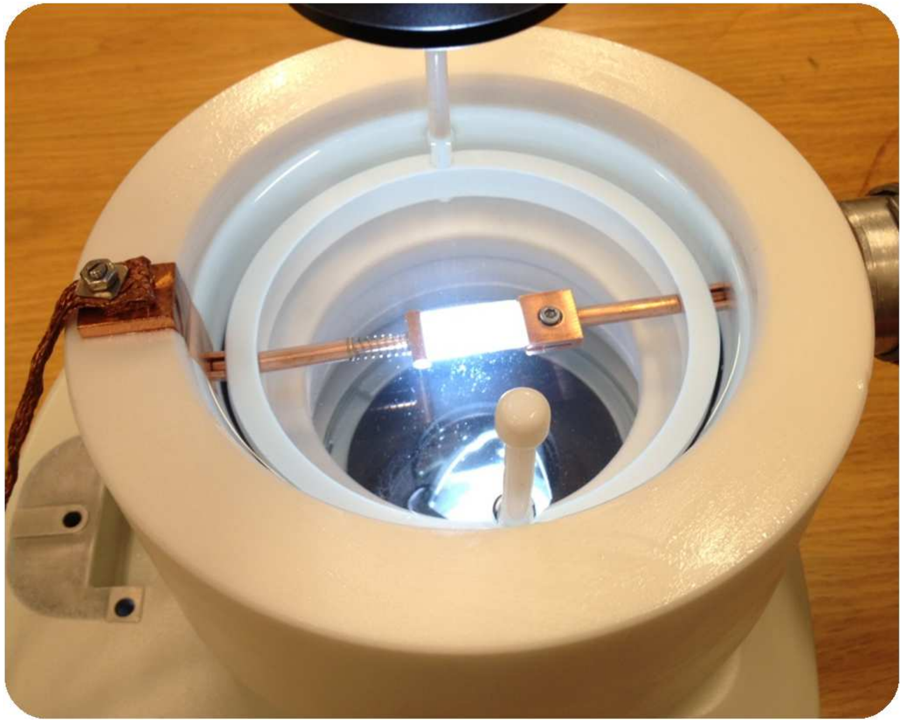




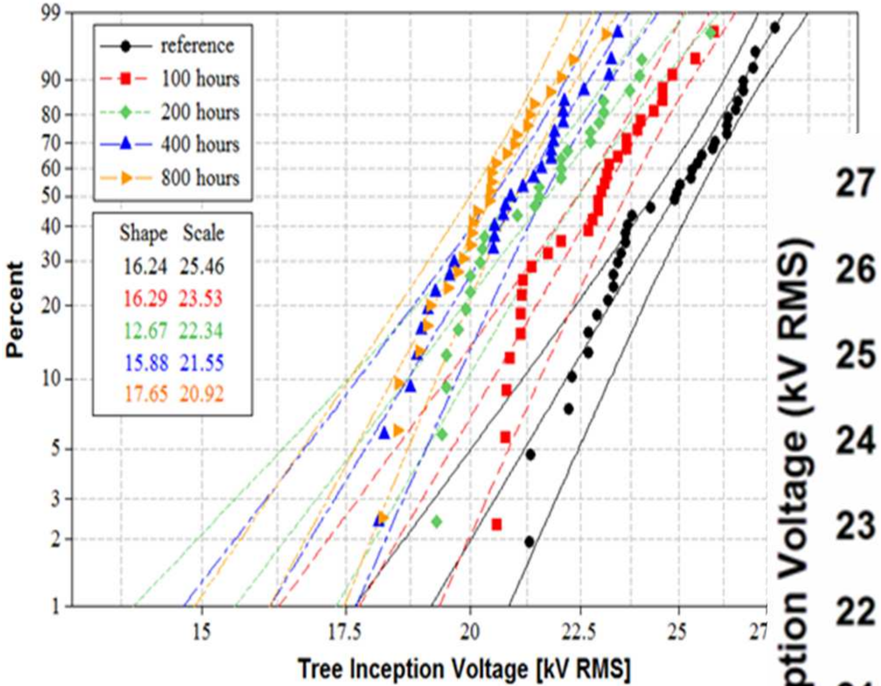


Resistance to electrical tree inception under DC and AC stress

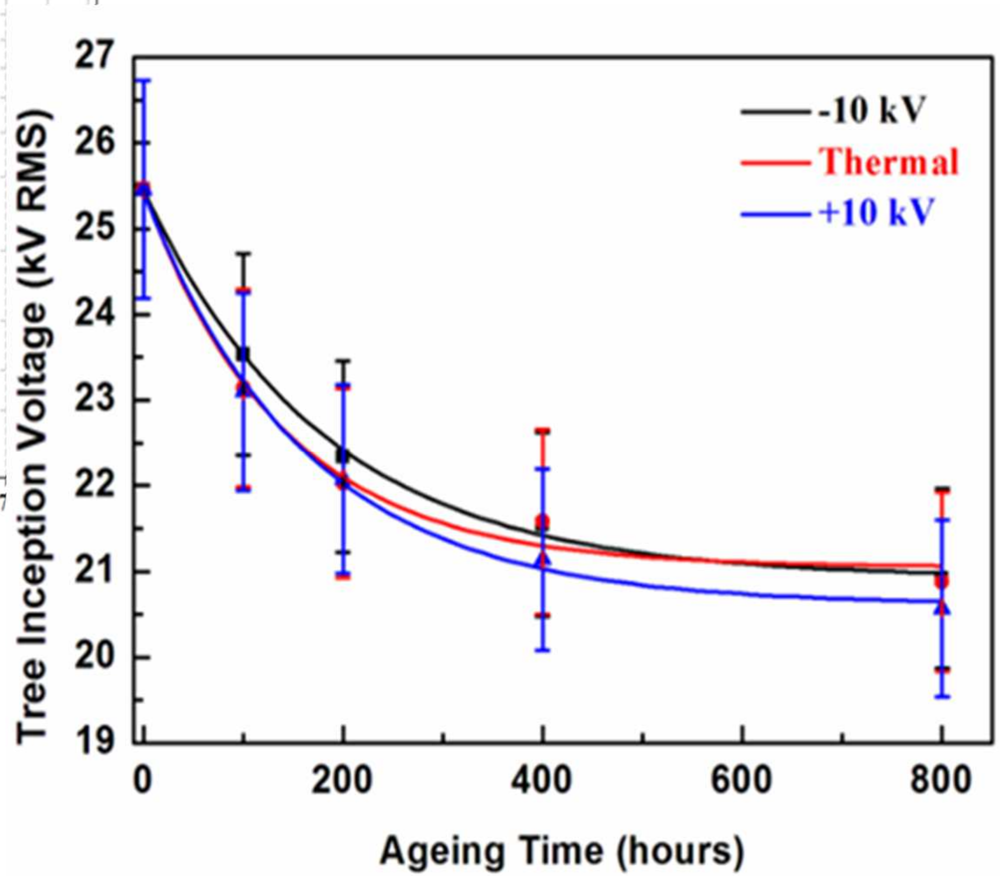
- effects of electro-thermal treatment (DC stress ±10 kV and 80 ºC)
- LDPE and XLPE materials
- AC ramp testing
- DC pre-stress plus impulse testing
- Microscopic observations and pd activity measurements during the treeing process



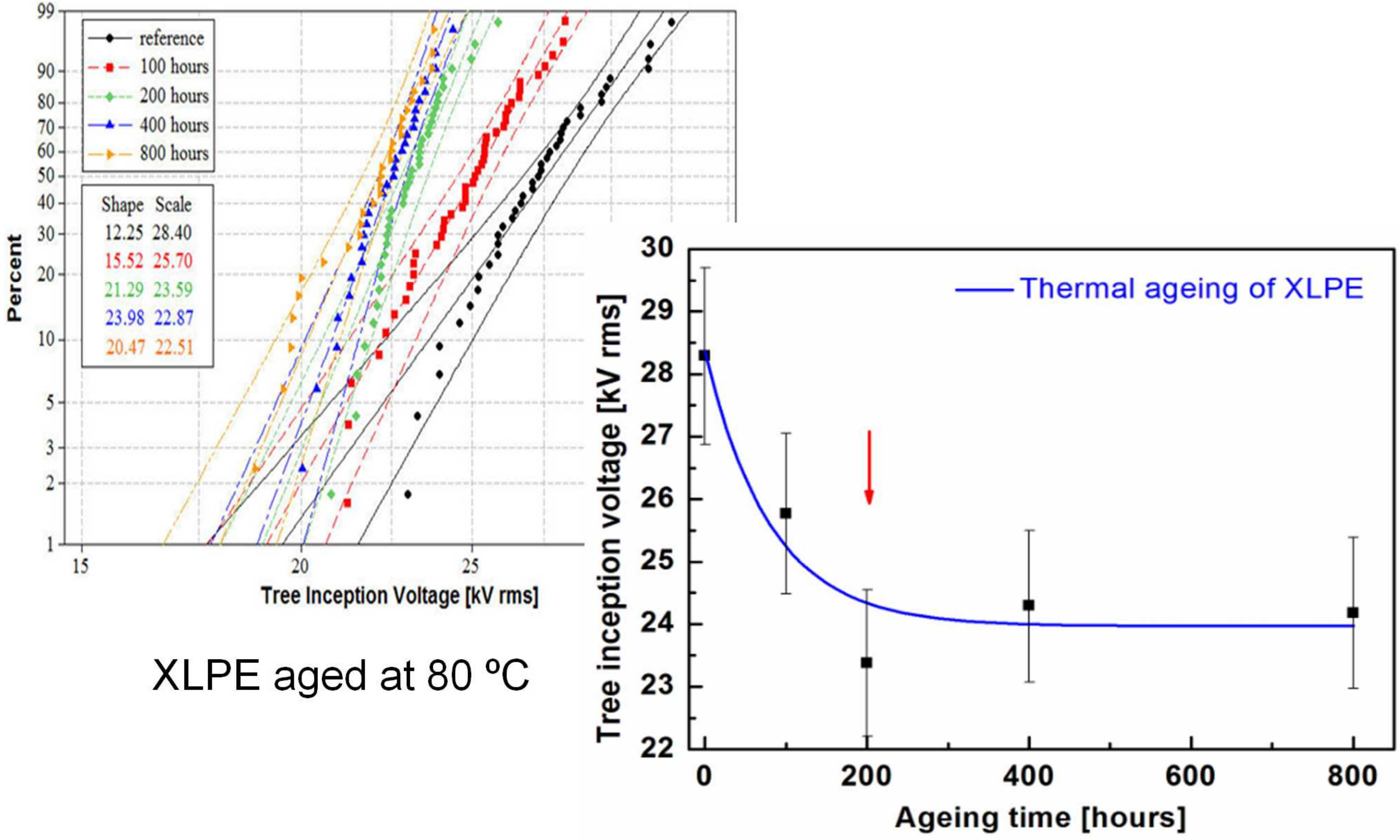
AC treeing test



LDPE aged at 80 ºC
and -10 kV DC



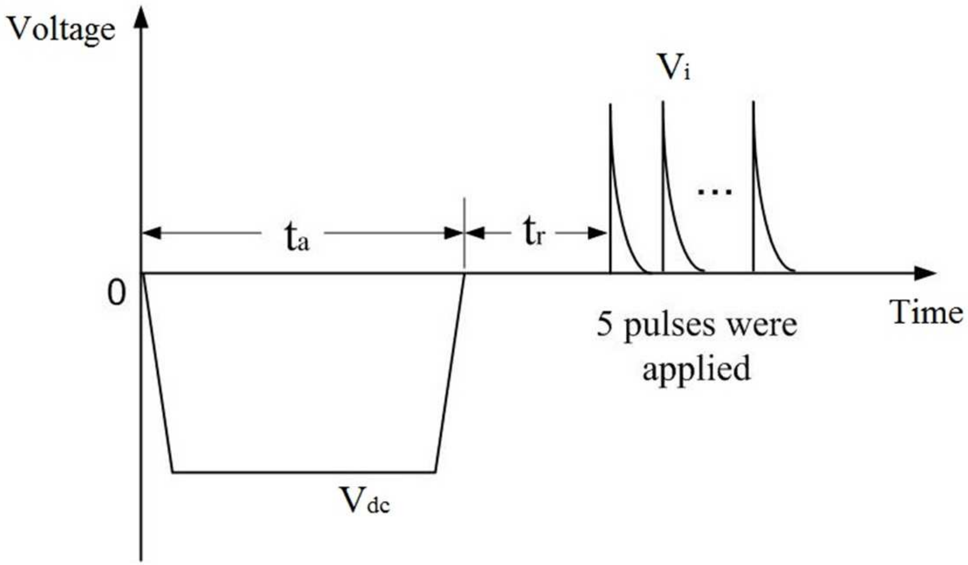
…. and for comparison XLPE material



DC tree inception experimental procedures

1. Ramping DC voltage
2. Short circuiting after DC pre-stress
3. DC with superimposed impulse
4. DC pre-stress plus impulse

Application of negative DC pre-stress in combination with positive impulses appeared to be most successful among the applied methods.



V_{dc} = 45 kV

t_a = 40 min

t_r = 2 min

V_i = 40 kV

Pulse front time = 1.5 ms

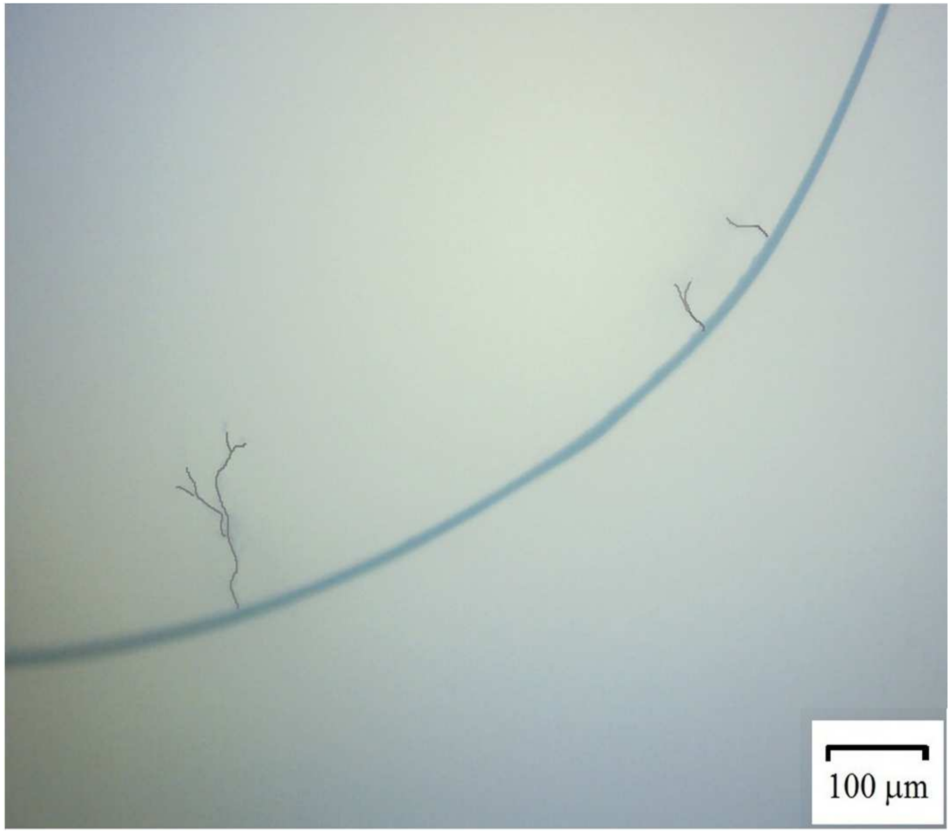
Pulse tail time = 70 ms

Time interval = 5 s

Applied at room temperature to **10 in parallel connected samples** immersed in transformer oil bath.

Time needed for testing and analyzing 20 samples : 3 h

Appearance of DC trees



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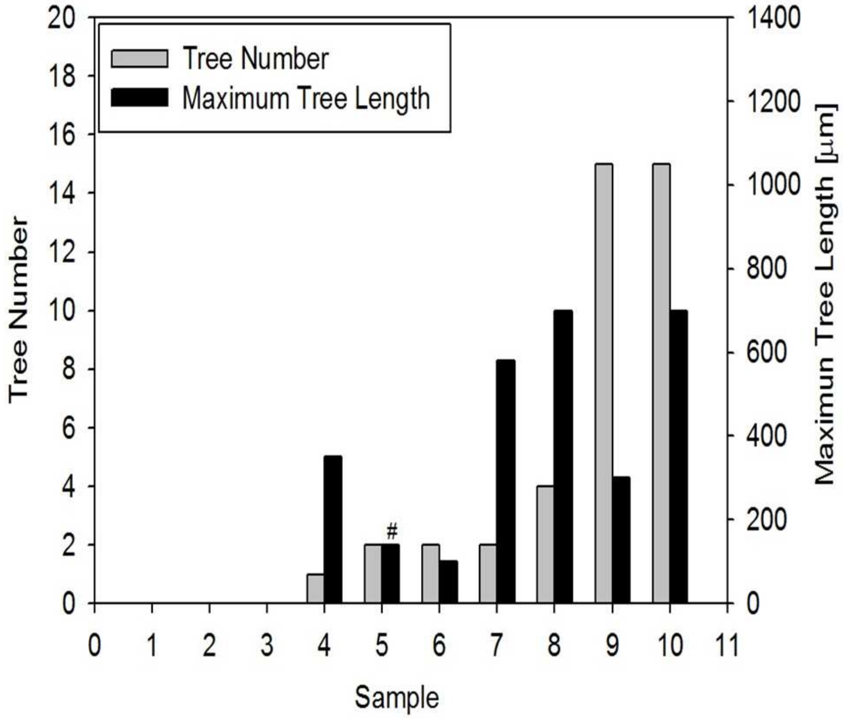
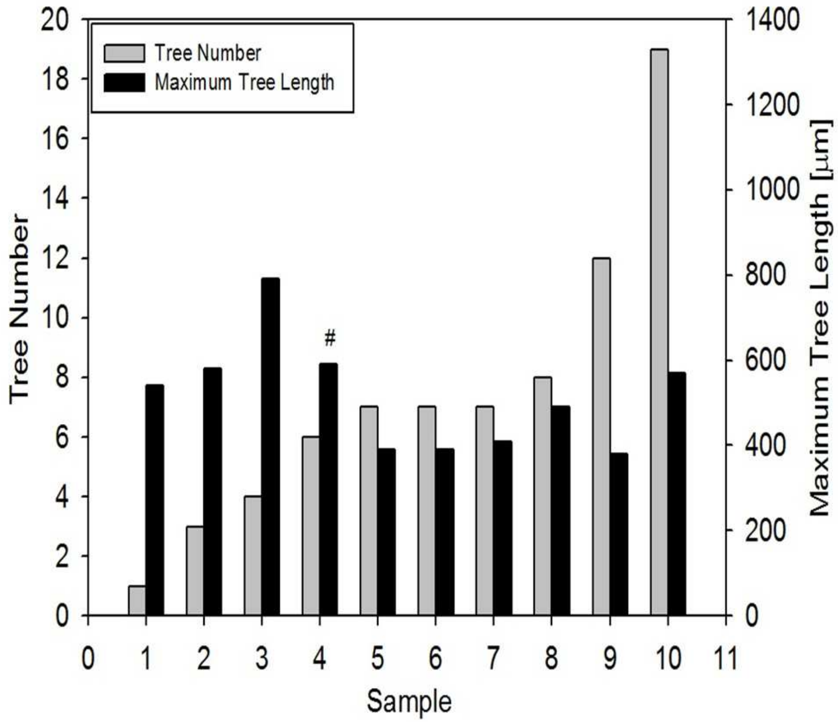
DC treeing characteristics



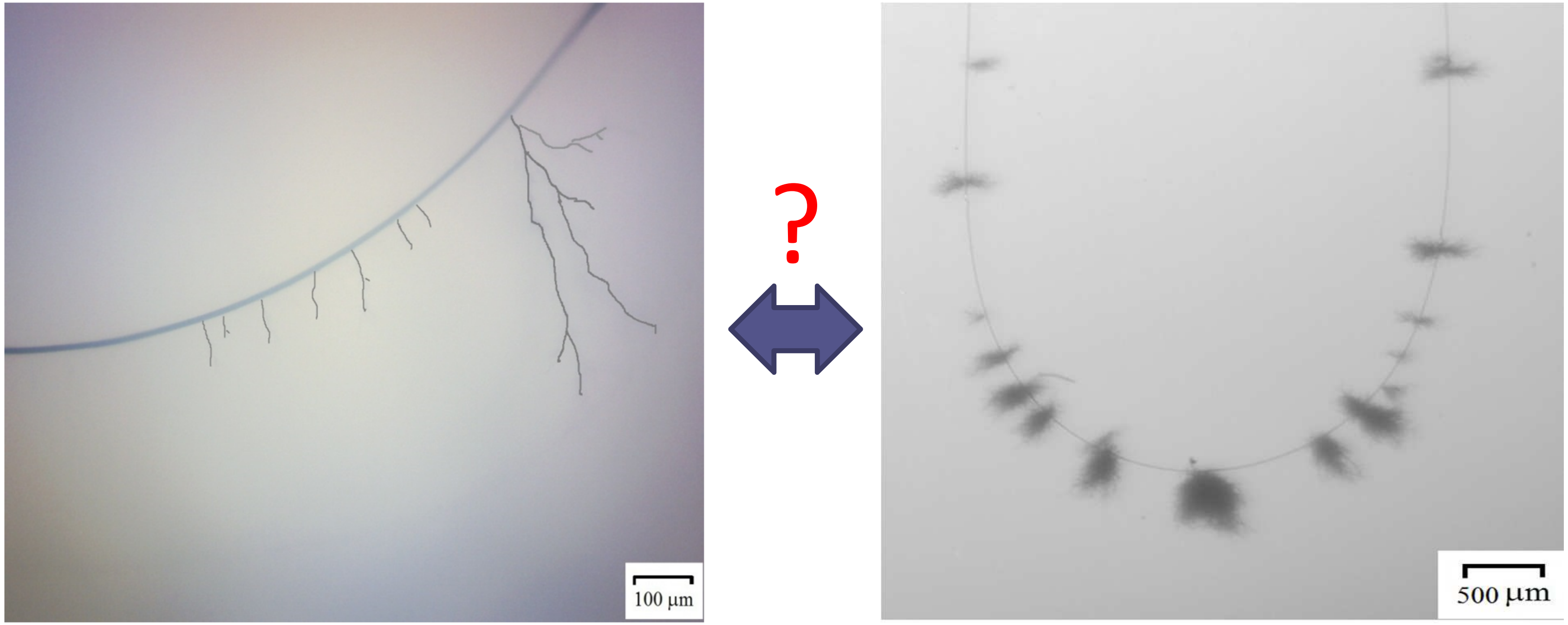
XLPE reference



XLPE aged at 80 ºC

DC tree filaments were found in all the thermally treated objects, while thy were found in only 7 reference objects. The largest number of trees was detected in one of the aged samples , where 19 trees incepted; 17 of them were single-branched short trees (40 µm to 100 µm long).

Is there any correlation between DC and AC treeing process?



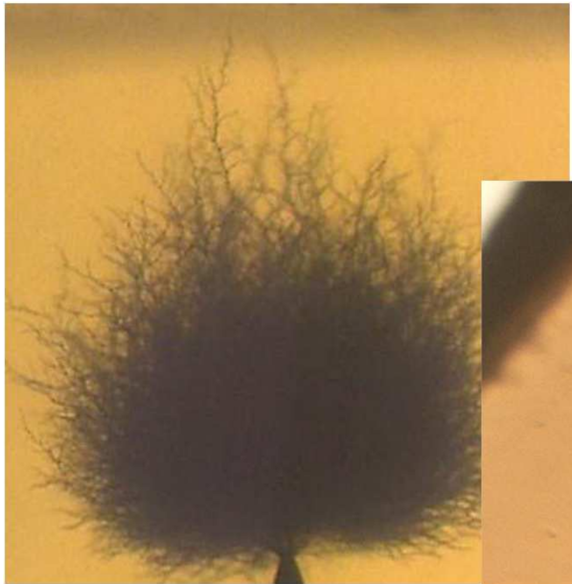
DC trees

AC trees

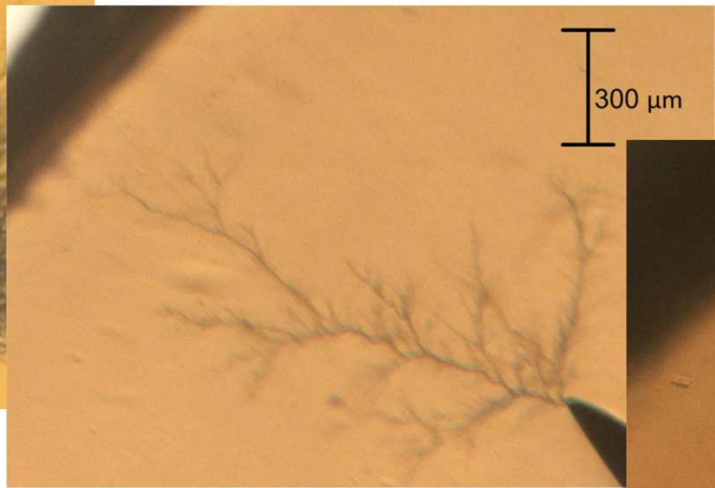
Tree appearance v. voltage frequency

E. Ildstad, K. Fauskanger, J. Hølto, "Electrical treeing of XLPE cable insulation at low frequencies", Proc. IEEE Int. Conf. Sol. Diel., Bologna Italy, 20013, pp. 800 - 803.

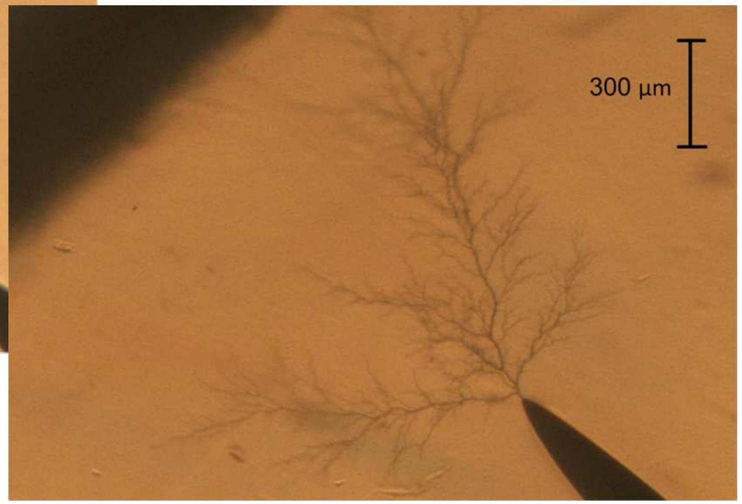
point-plane electrode system



50 Hz, 10 kV



1 Hz, 14 kV



0.1 Hz, 14 kV

Summary and discussion points

- DC and AC tree inception tests show qualitatively similar results (.
- Thermal treatment of LDPE and XLPE materials tends to stabilize their ability to resist DC treeing, similarly as found in the results of AC tree inception tests.
- AC ramping test can be used as a robust screening methodology when ranking the resistance to degradation (long term stability) of materials for application in HVDC cable insulation.

Ongoing and future activities

1. Morphological and chemical analyses for elucidating the condition of tree initiation in wire electrode test objects.

2. Investigations of electric properties of the new material compositions for ranking their applicability as HVDC insulation:
   - DC treeing
   - AC treeing
   - DC conductivity

3. Evaluation of long term stability in service-like conditions (humidity and oxygen free atmosphere as well as a presence of elevated temperature and DC voltage stress) by the elaborated testing methodology.

4. Up-scaling of experimental activities with the best material alternatives.

Thanks to all contributing coworkers

Anette

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Le

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Carl-Olof