A Fundamental Study on Electrical Properties of Reactor-made Thermoplastic Olefin for the Eco-friendly Power Cable. (case study of on-going research)

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Backgrounds

XLPE

- Excellent properties in electrical and mechanical
- Difficult to recycle
- Thermosetting

Non-cross linked polymer

Thermoplastic

Easy to recycle

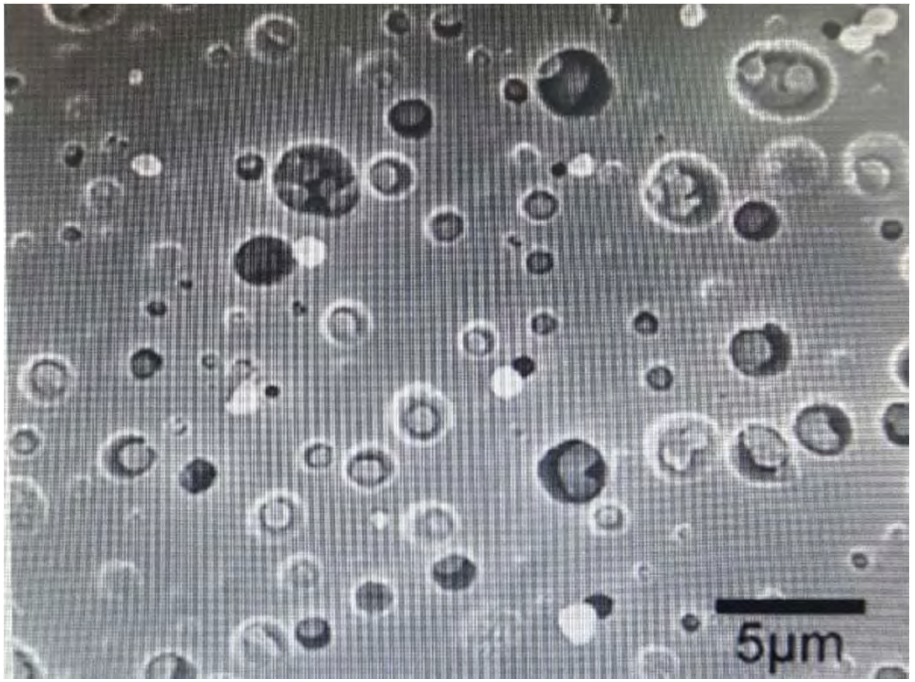
Eco-friendly

In this work

- Thermoplastic olefin samples containing the polypropylene(PP) and ethylene-propylene copolymer which were made in the reactor simultaneously were prepared to test.
  - AC Breakdown (ACBD) Test
  - Accelerated Life Test (ALT)
  - Water Tree Test
  - Space Charge Distribution Test

Samples

The process of reactor-made thermoplastic olefin(RTPO) can make the size of EPR smaller and control the size distributions of EPRs effectively.

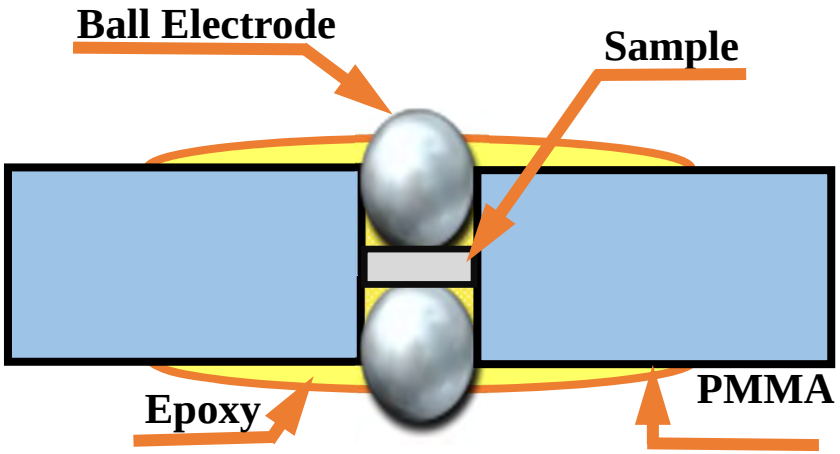


SEM of a sample tested

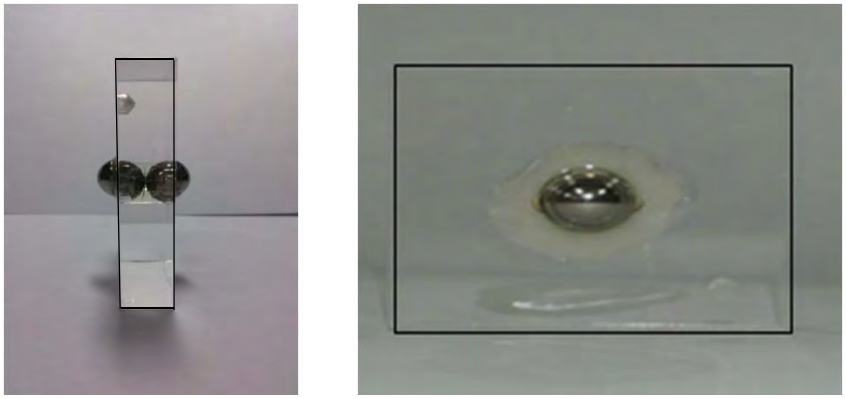
Samples	Thickness			
	ACBD	ALT	Water Tree	Space Charge
XLPE (reference)	210±20[μm]		850±10[μm]	800±10[μm]
Eco-friendly polymer Group N2				

※ McKeown electrode used

McKeown electrode



<Structure of McKeown electrode>



<Actual picture of McKeown electrode>

Electrodes for breakdown test

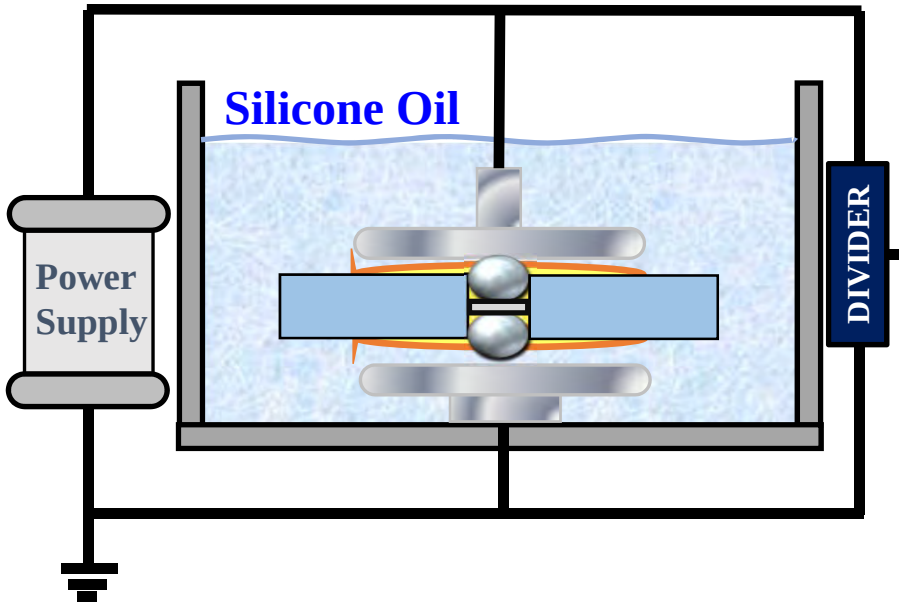
- **McKeown electrode (feasibility and easiness for application)**
- **Molded electrode**
- **Recess electrode**

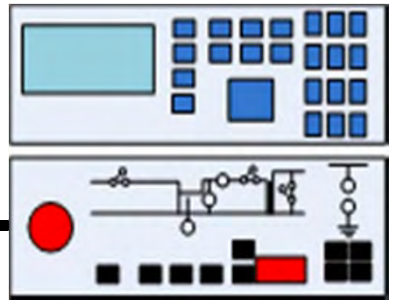
Advantages of McKeown electrode

- **Improve the accuracy of the sample thickness measurement.**
- **Receive only little effect by interface and surrounding mediums.**
- **Calculate the exact breakdown field.**
- **Remove air bubbles in the epoxy into a vacuum treatment.**

AC Breakdown test

ACBD test





Digital Measuring Instrument
: DMI 551

Operating Terminal
: OT 276

- Statistical data analysis
  - selection of suitable distribution function (ReliaSoft Weibull++7)

1. Preparation of McKeown electrode

2. Fixing the McKeown electrode

3. Applying the AC high voltage

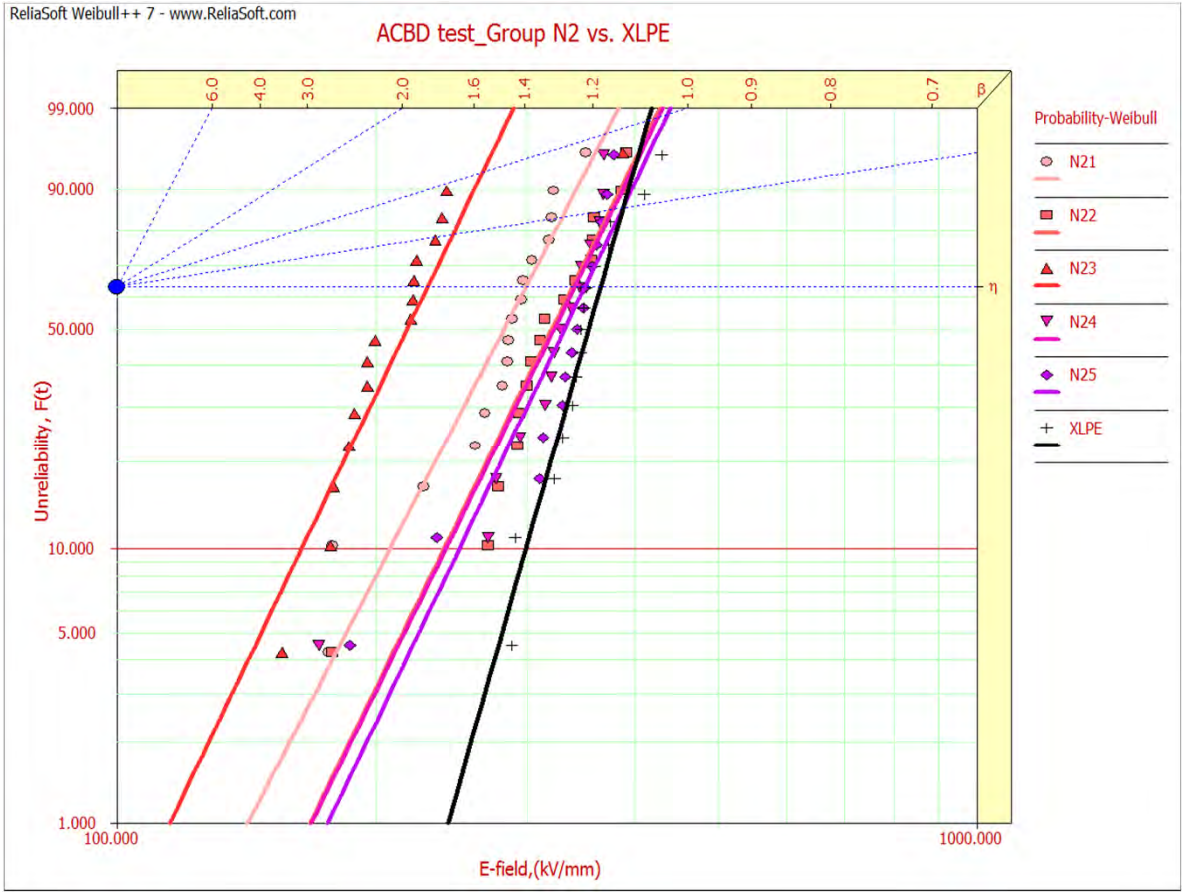
15 units per sample tested

4. Measurement of breakdown voltage

5. Analysis of results

Results of AC breakdown test

Group N2 vs. XLPE

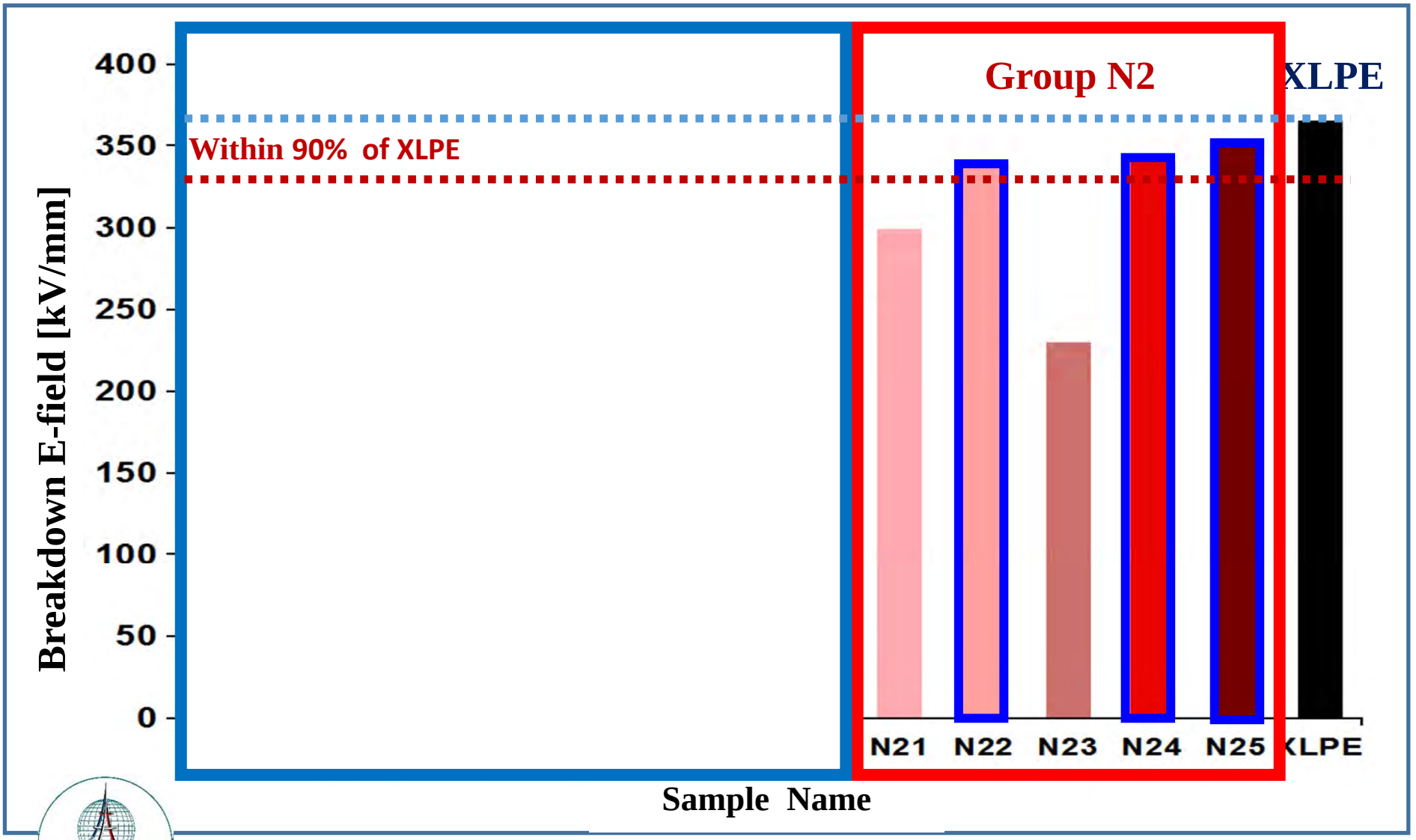


sample		
N21	6.2	298
N22	6.5	338
N23	6.7	229
N24	6.5	340
N25	6.7	349
XLPE	11.2	364

η : scale parameter
- Characteristics electrical field

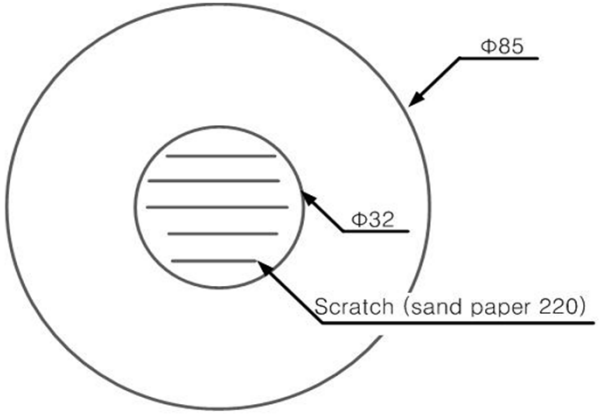
β : shape parameter
- Slope of the line

Results of AC breakdown test

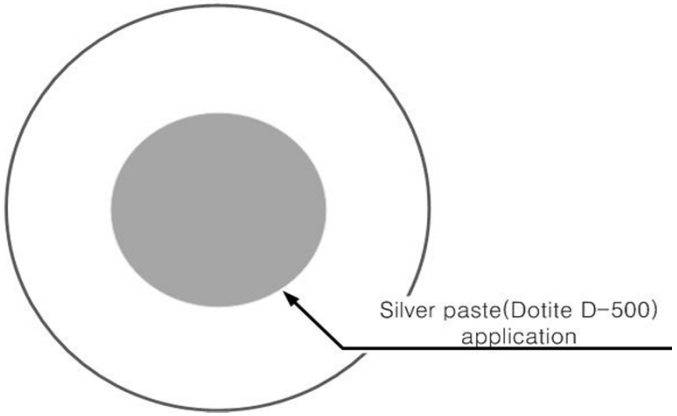


Accelerated water treeing test

Water Tree test cell



<One side of the sample>



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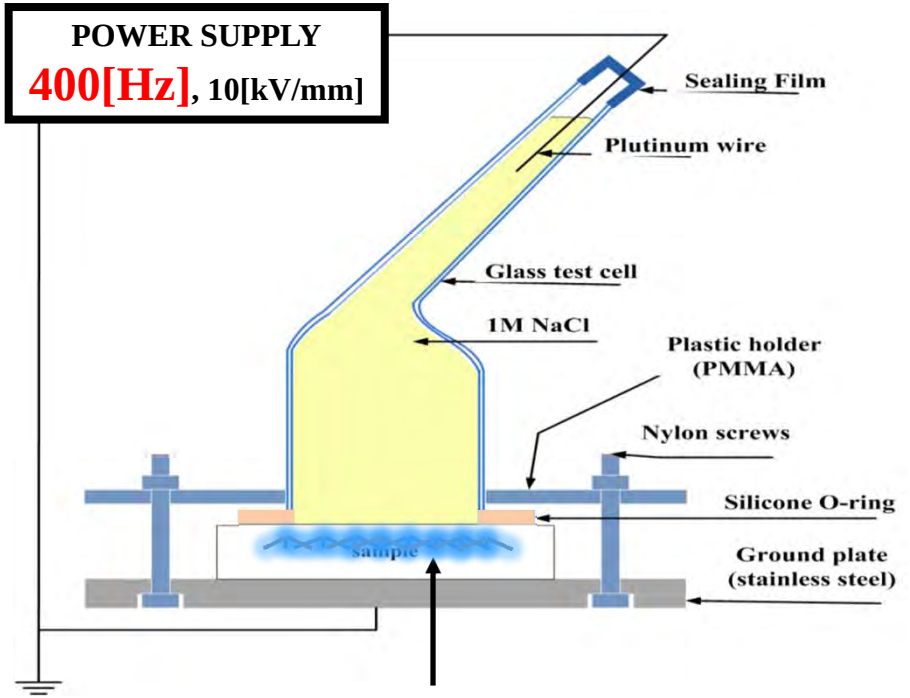
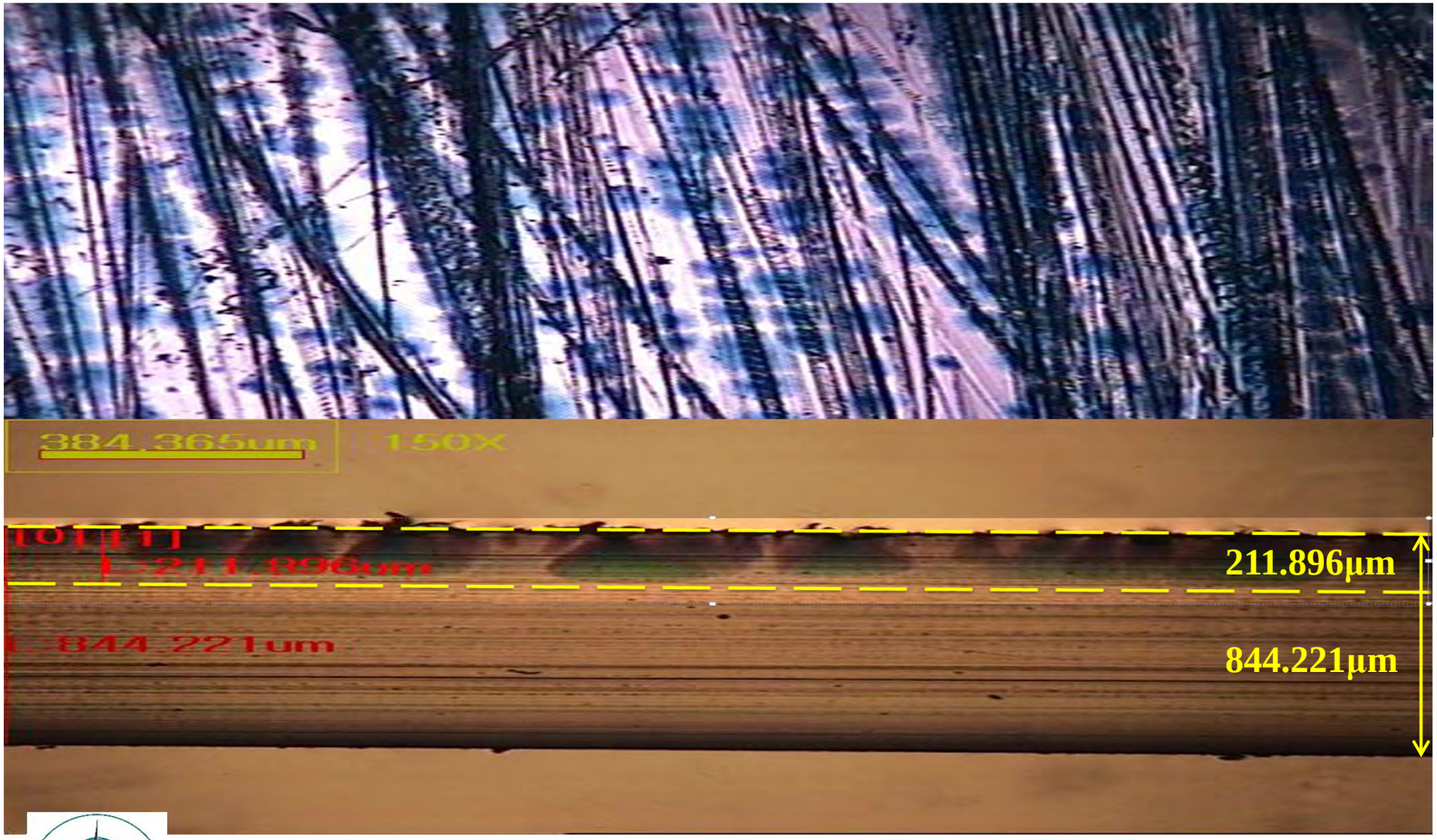


Sample	XLPE Group N1 Group N2	Time	300[hr]
Aqueous solution	NaCl	Pretreatment	20[torr]
E-field	10[kV/mm]	Frequency	400[Hz]

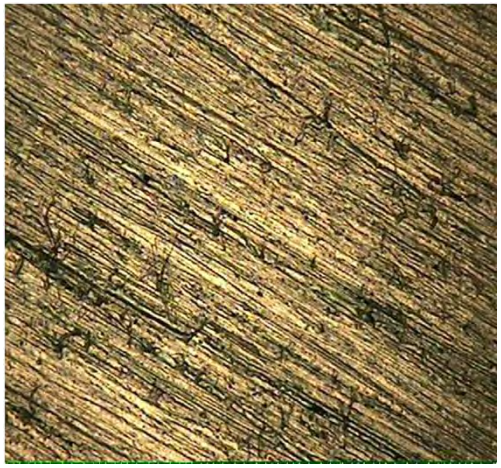
case of 400[Hz], the accelerating factor of 6.67 than 60[Hz].

Results of water tree test (XLPE)

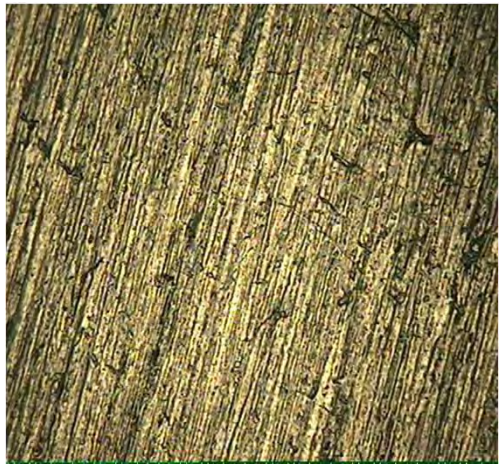


< Water Tree degraded XLPE >

Top view of water treed samples (Group N2)



< N21 >



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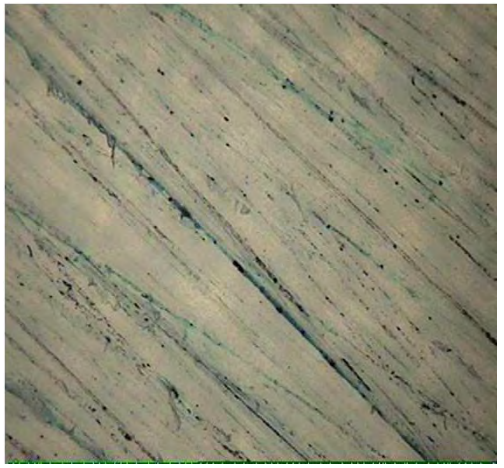
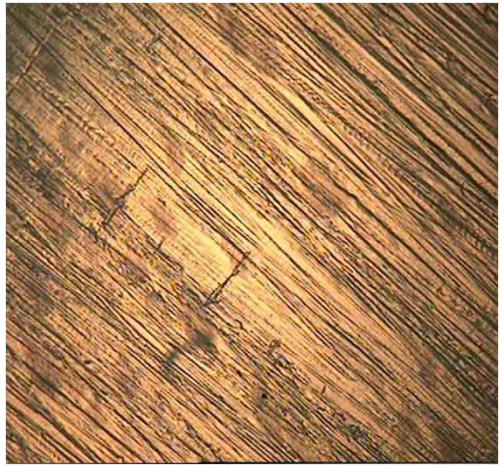


< N23 >

< N24 >



< N25 >

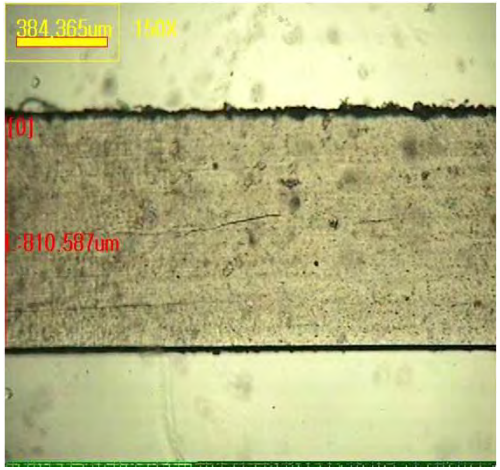
Group N2

Water Tree

was not observed

on surface

Cross section of water treed samples (Group N2)



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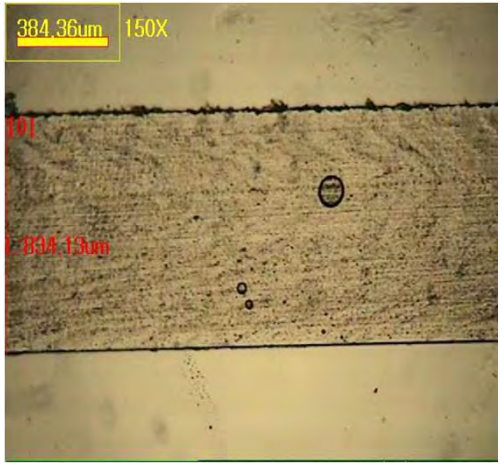
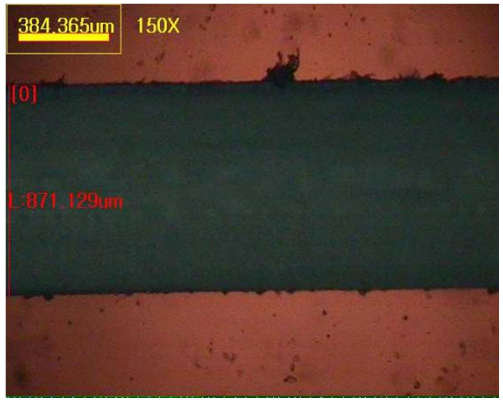
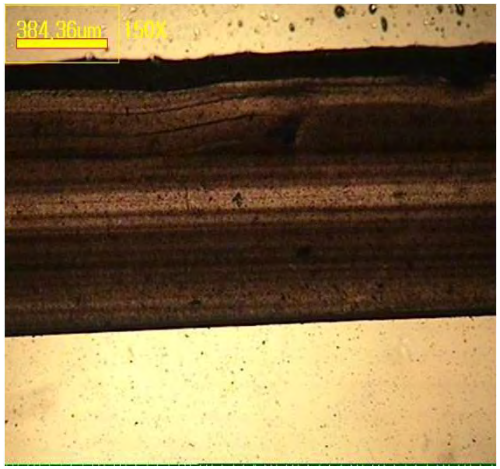


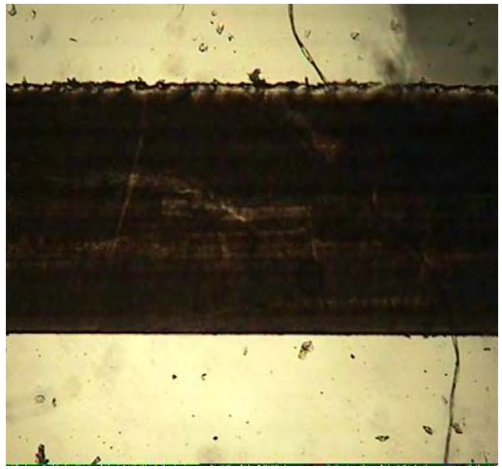
< N22 >

In case of N23,
the sample cross section was so opaque that we could not the check water tree was grown or not.





< N24 >



< N25 >

Group N2

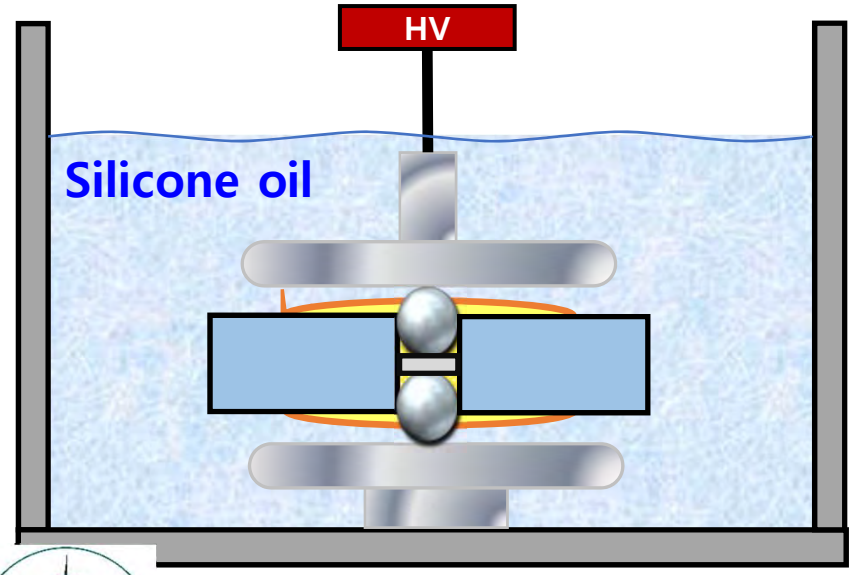
Water Tree
was not observed
on the cross section

Accerelated Life Test (ALT)

Accelerated Life Test

1. Preparation of McKeown electrode
2. Fixing the McKeown electrode
3. Constant voltage application
4. Measurement of breakdown time
5. Analysis of results

12~15 units per sample tested



Experimental condition of the ALT

- Constant applied voltages : AC 22[kV], 26[kV]

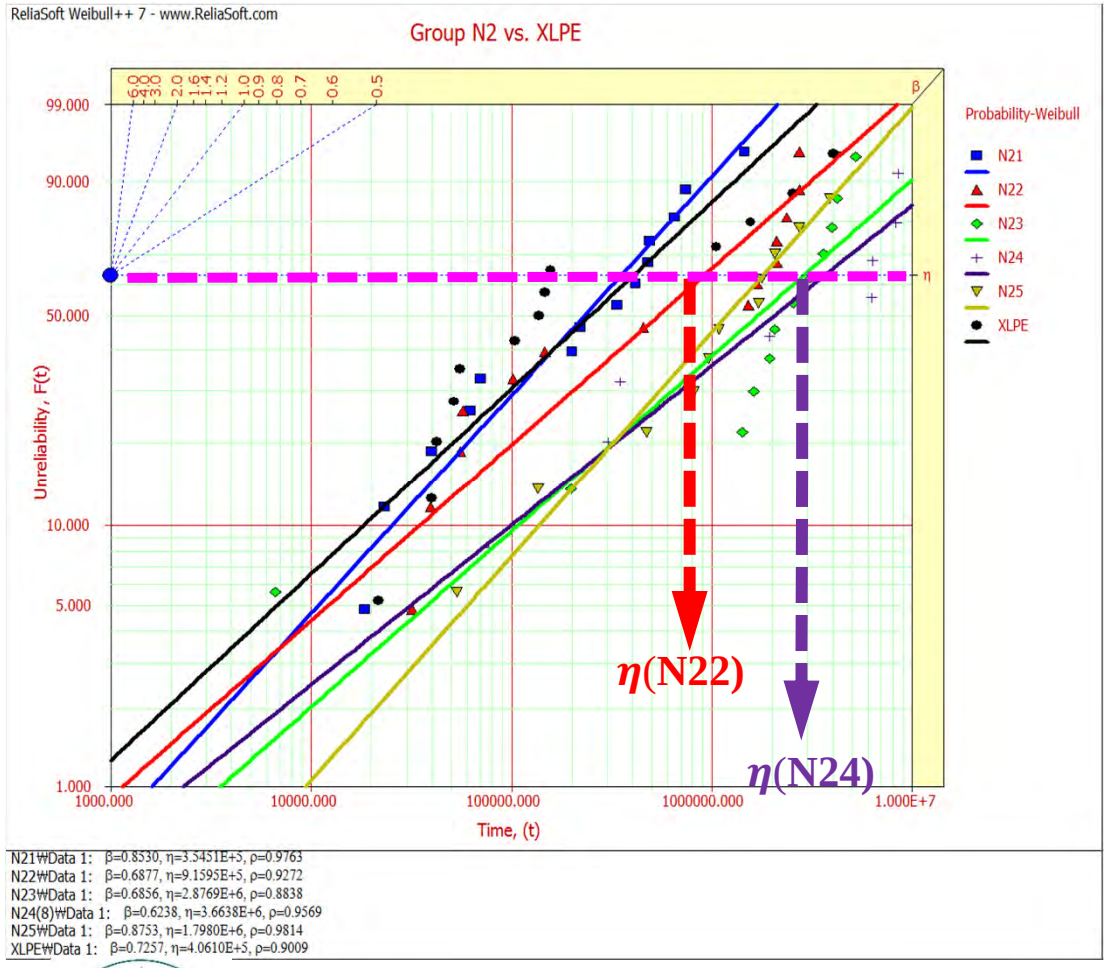
Purpose of the ALT

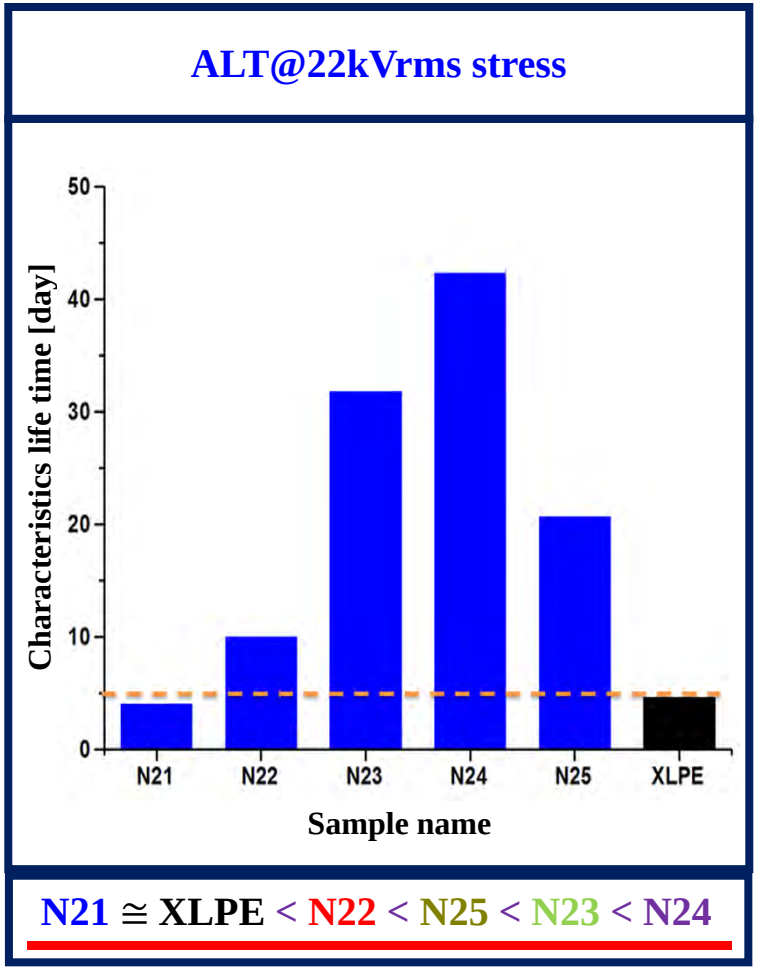
- ALT : Mid or Long-term life expectancy of systems.

※ Ex) Longest breakdown time of some sample : 2,380 hours (100 days)

Results of the ALT

At 22kVrms stress

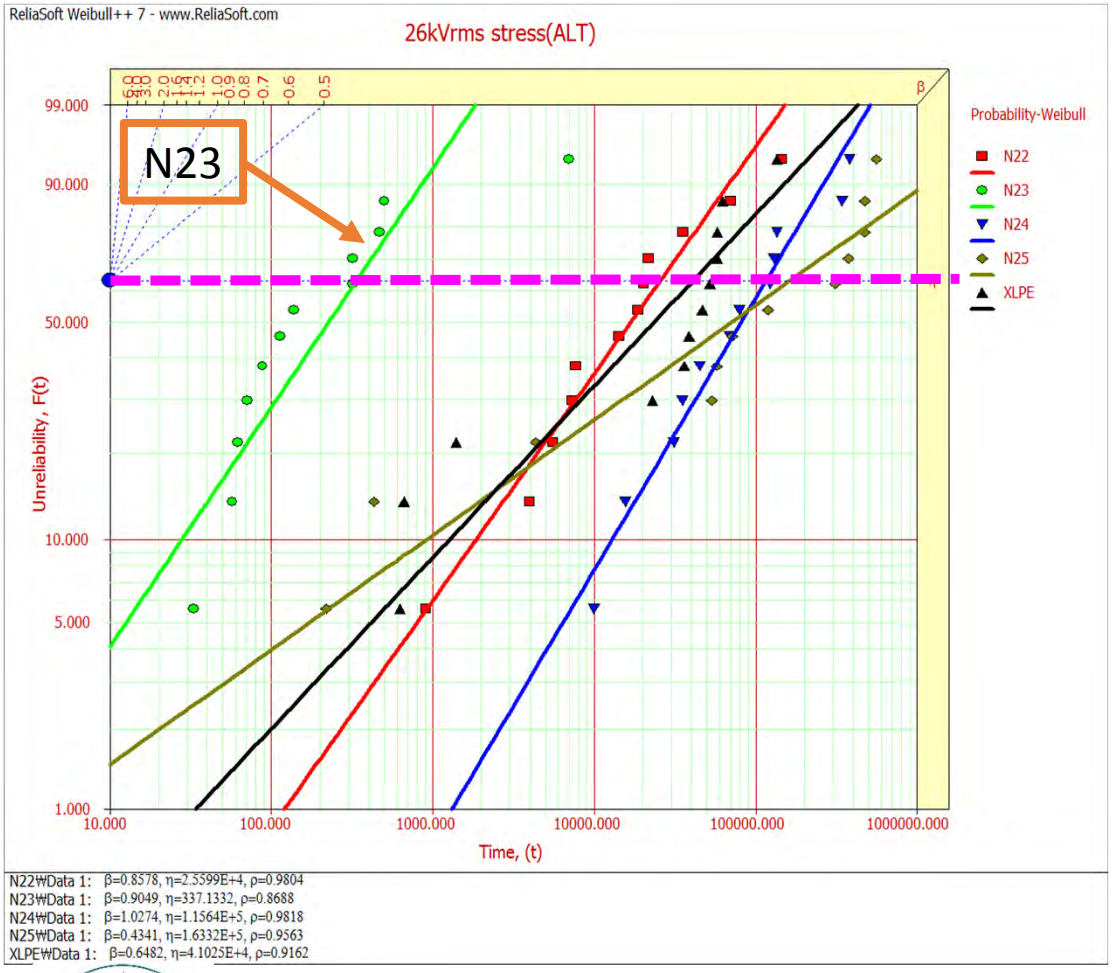


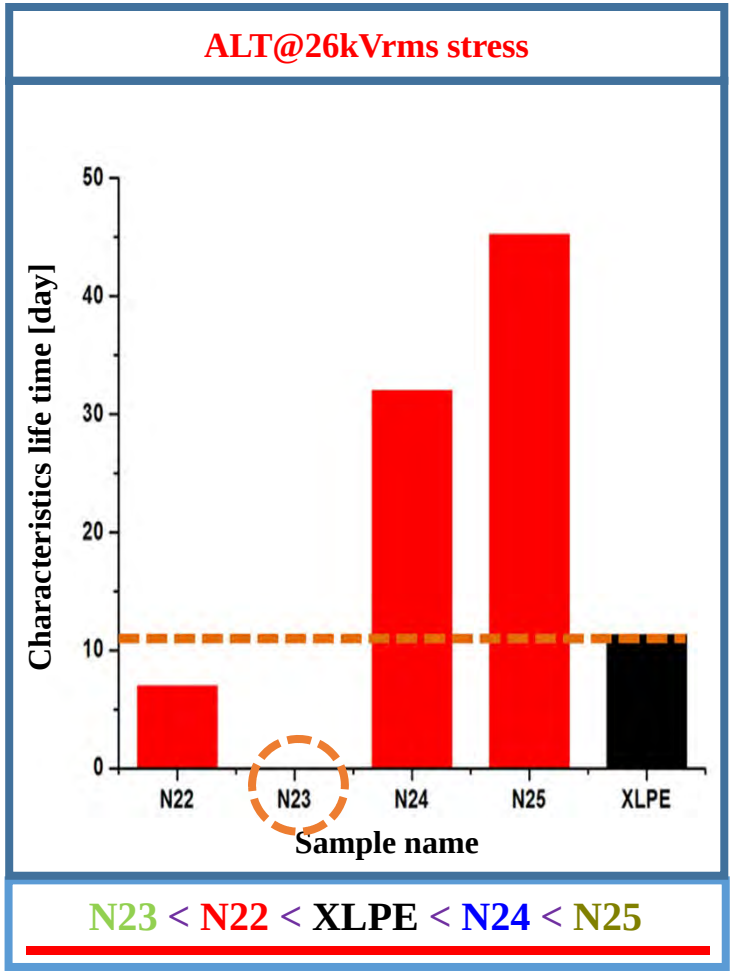


η : Characteristics life time

Results of the ALT

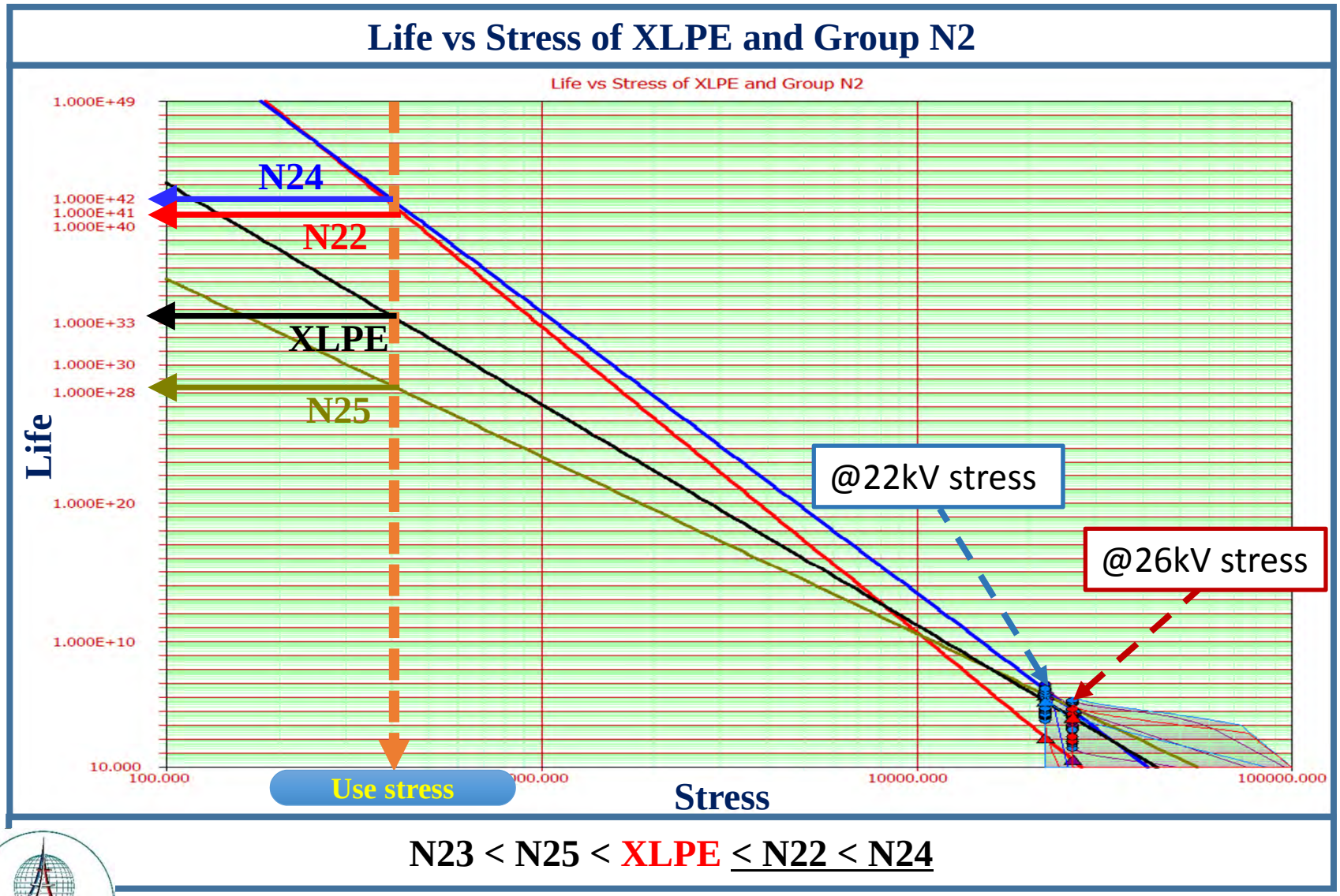
At 26kVrms stress





η : Characteristics life time

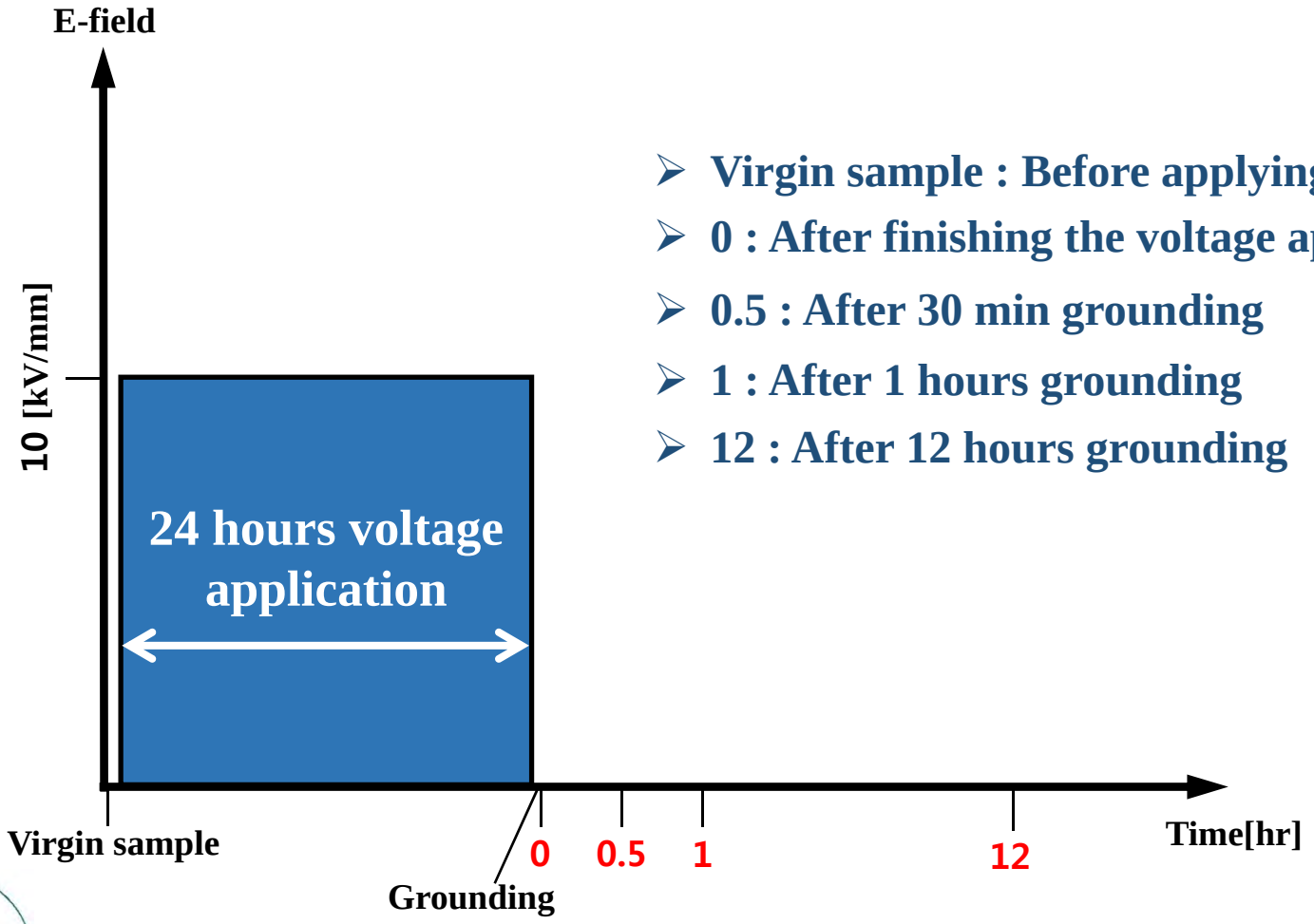
Results of the ALT



Space Charge Distributions
(by PEA method)

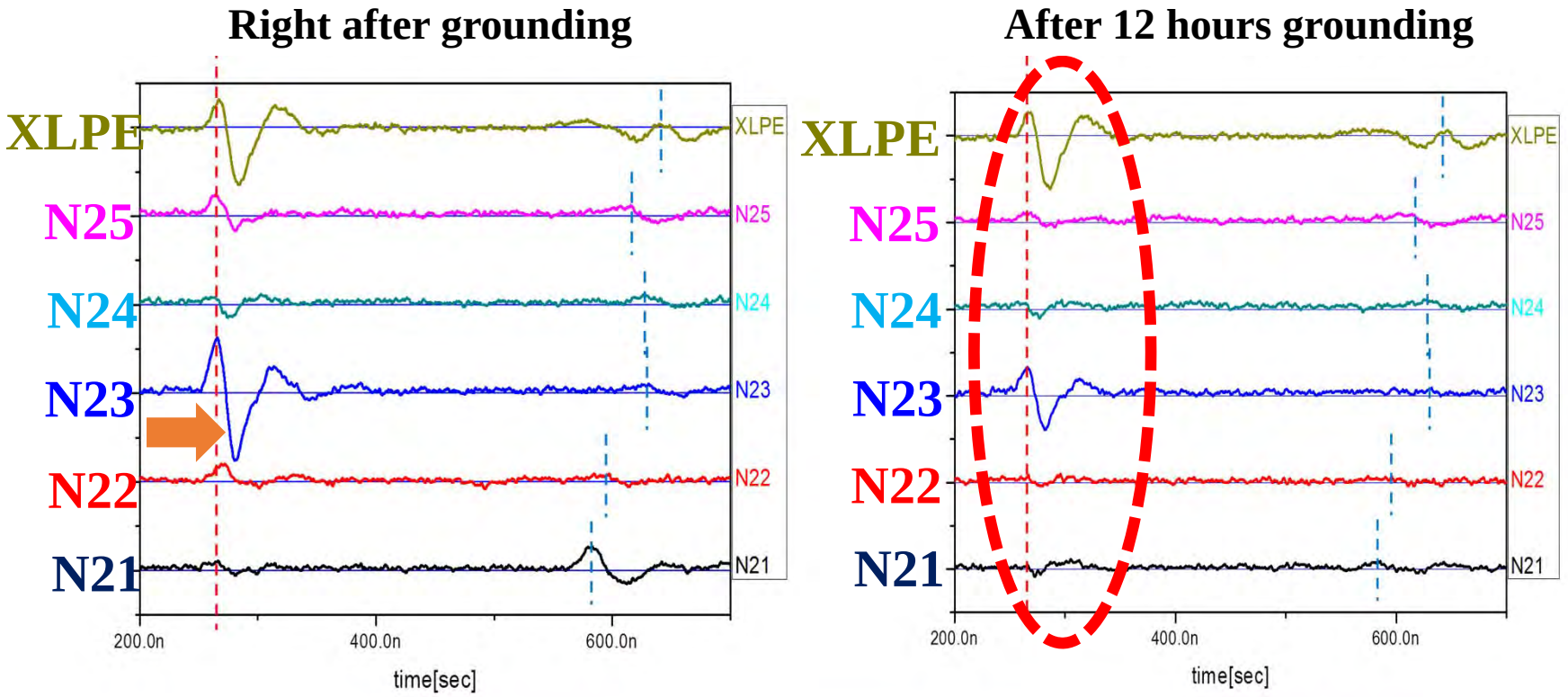
Results of space charge distribution

DC E-field profile for space charge test



- Virgin sample : Before applying the E-field
- 0 : After finishing the voltage application
- 0.5 : After 30 min grounding
- 1 : After 1 hours grounding
- 12 : After 12 hours grounding

Results of space charge distribution



- **Right after grounding, the space charge distributions from all the samples of group N2 except N23 was smaller than that of XLPE.**
- **After 12 hours grounding, the accumulated space charge in group N2 disappeared rapidly in contrast to the XLPE.**
- **Samples in the group N2 showed better space charge distribution properties than that of XLPE.**

Summaries and Questions

Based on basic measurements of electrical properties

For the reliable application of recyclable polymers to the power cable

- **Deeper understanding based on the fundamental research is needed**

Mechanism of treeing initiation and growth(water treeing/ electrical treeing)

- **Why the water treeing is not observed in recyclable polymers?**
- **Staining method? Too fine channel? Water treeing retarded?**

The *ALT* might be a second-best way to give a statistical results to evaluate the long-term performance of new materials

What makes the difference of spacecharge among the samples?

- **Size of copolymers/ size distributions/ catalysis of process**
- **Heat treatment/ Anti-oxidants/ etc.**

Thanks for your kind attention