

Determination of Threshold Electric Field for PPLP Specimen in Liquid Nitrogen Based on the Measurement of Electrical Conductivity

Ik-Soo Kwon, Jin-Yong Na, Ho-Young Lee and Bang-Wook Lee

HVDC Electric Power Laboratory, Hanyang University, Hanyangdeahak-ro, Sangnok-gu, Ansan, Gyeonggi-do, 15588, Korea

Background

- The externally applied electric field causing sudden increase in electrical conductivity is called the threshold electric field. In addition, this threshold electric field is very important for reliable insulation design of a dc power apparatus such as HTS power cable because the electric field distribution is governed by electrical conductivity of the insulating material.
- There are some research reports on threshold electric field of XLPE and polymeric materials used for dc power cables, operated under room temperature conditions. However, there is no previous works on the threshold electric field of cryogenic insulating materials, which is necessary for the reliable insulation design of superconducting dc cable.
- The Investigation the threshold electric field of PPLP is important for the reliable insulation design of a variety of dc cryogenic power apparatuses. Designing an insulation system for an electrical stress below the threshold field would assure long life and high reliability.

Objectives

- For determination of the threshold electric field of PPLP specimen in LN₂ considering the number of PPLP layers.
- For comparison of the electrical conductivity considering externally applied electric field of PPLP test specimen in LN₂ according to the number of PPLP layers

Experimental Set-up and Test

- The electrical conductivity can be derived by measuring the leakage current through the volume of the insulating material, which can be expressed as below equation:

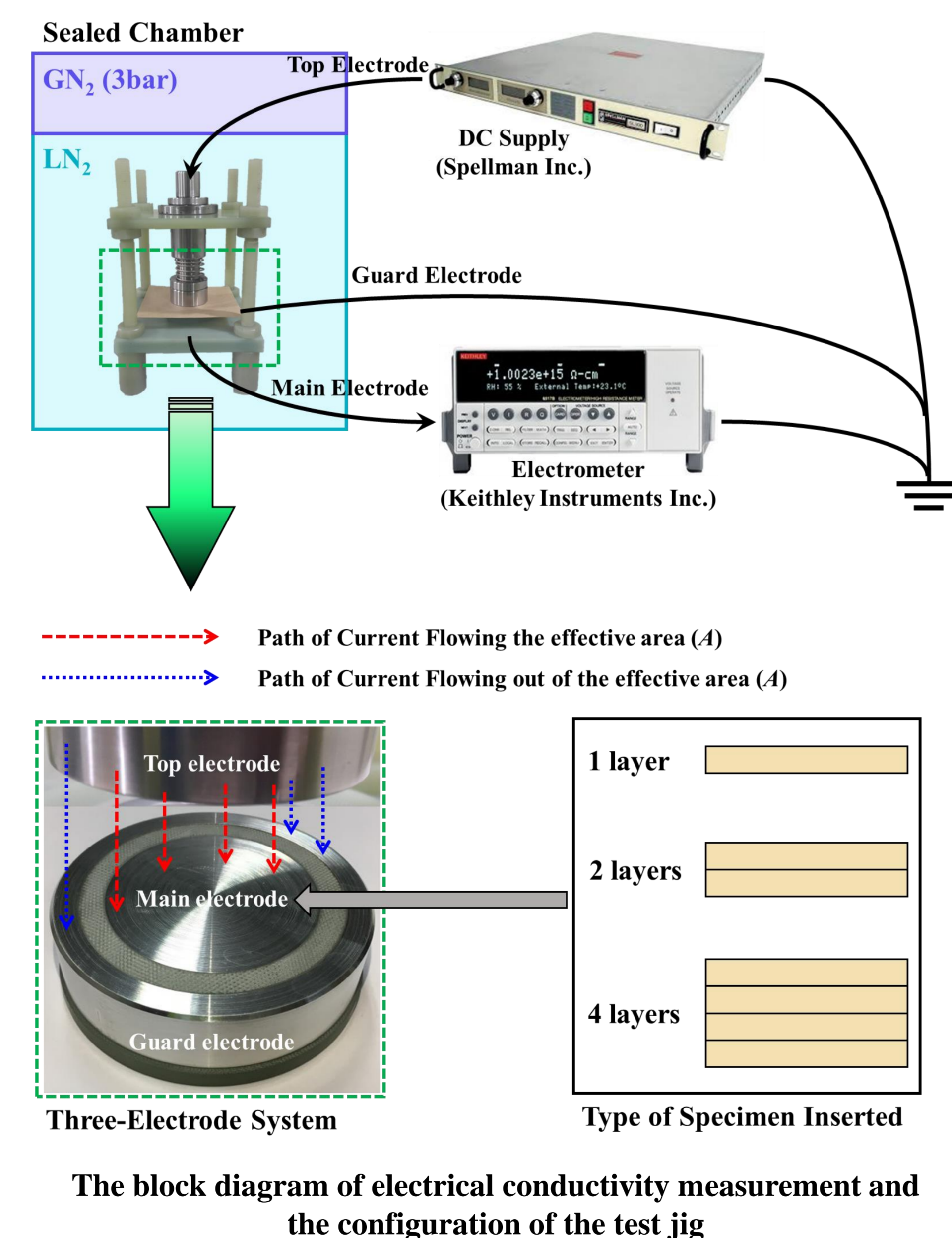
$$\sigma = \frac{Il}{VA} = \frac{I}{EA}$$

- Figure 1 shows the block diagram of electrical conductivity measurement and the configuration of the test jig for leakage current measurement based on IEC 60093 document.

- A highvoltage is applied to the top electrode. The main electrode is used for measuring the leakage current flowing through the effective area (A) of the test specimen and is connected to the electrometer where the leakage current (I) is measured.

- Red dashed line and blue dotted line represent the path of the leakage current flowing through effective area (A) and the path of the current flowing out of the effective area (A) of the test specimen, respectively.

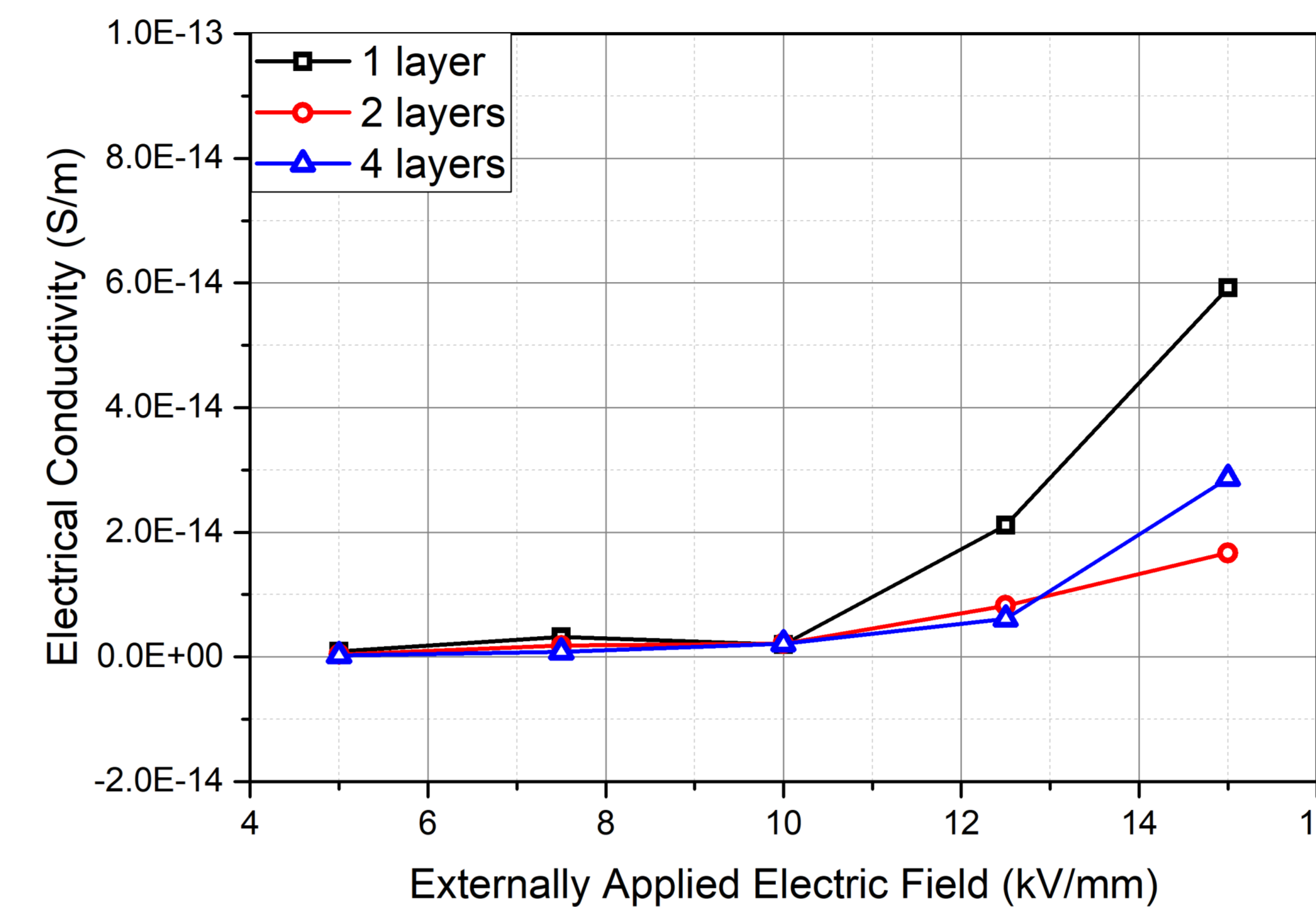
- The electrical conductivity was measured for single-, double-, and quadruple-layered specimens under five different external dc stresses from 5 to 15 kV/mm at 2.5 kV/mm intervals.



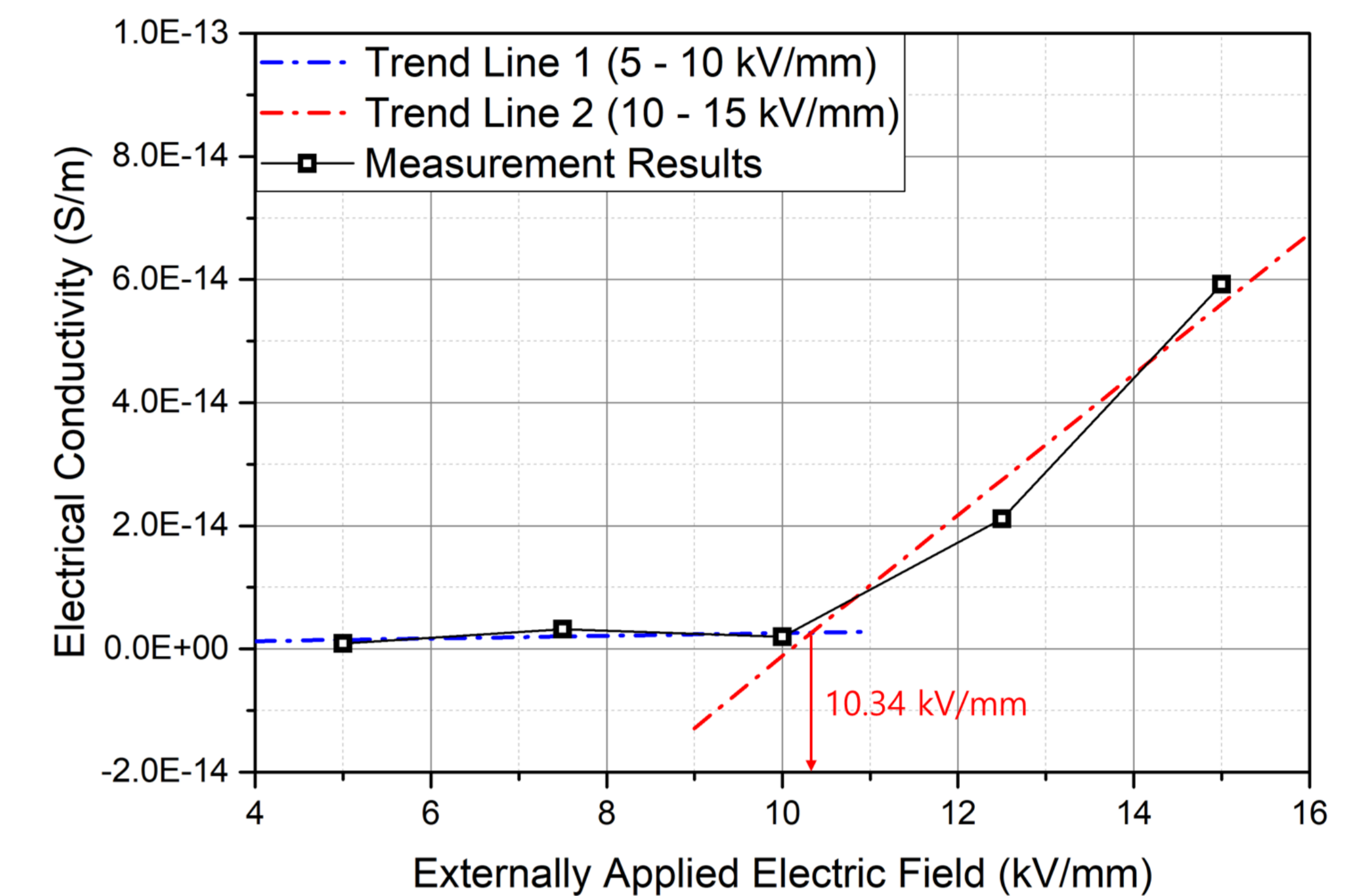
Conclusion

- we could observe that there exists the threshold electric field of PPLP in a cryogenic environment
- It was found that there was no difference in threshold electric field based on the number of PPLP layers.
- When the electrical stress exceeds the threshold electric field on the PPLP specimen, the electrical conductivity can be varied according to the number of PPLP layers.

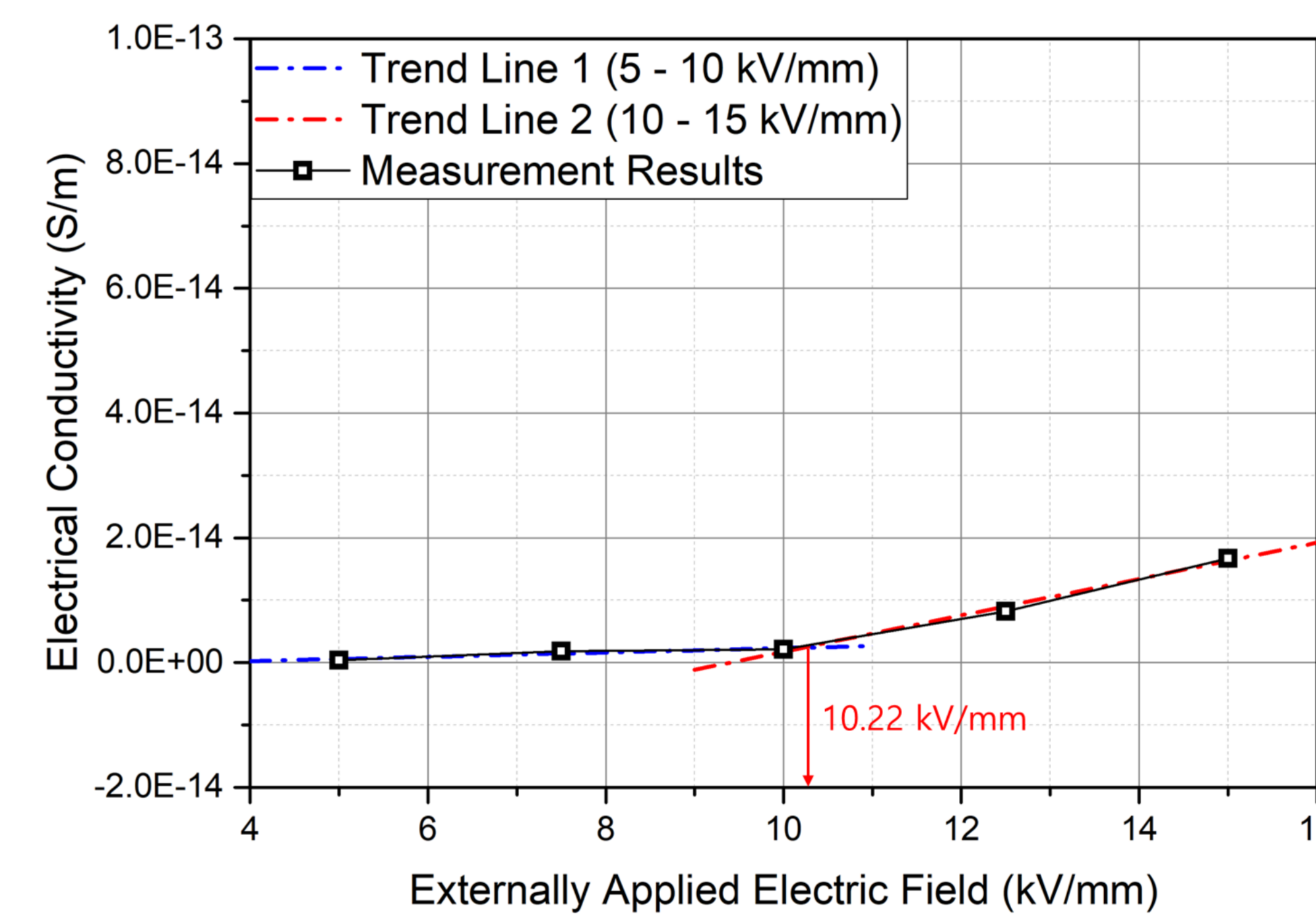
Experimental Results and Discussions



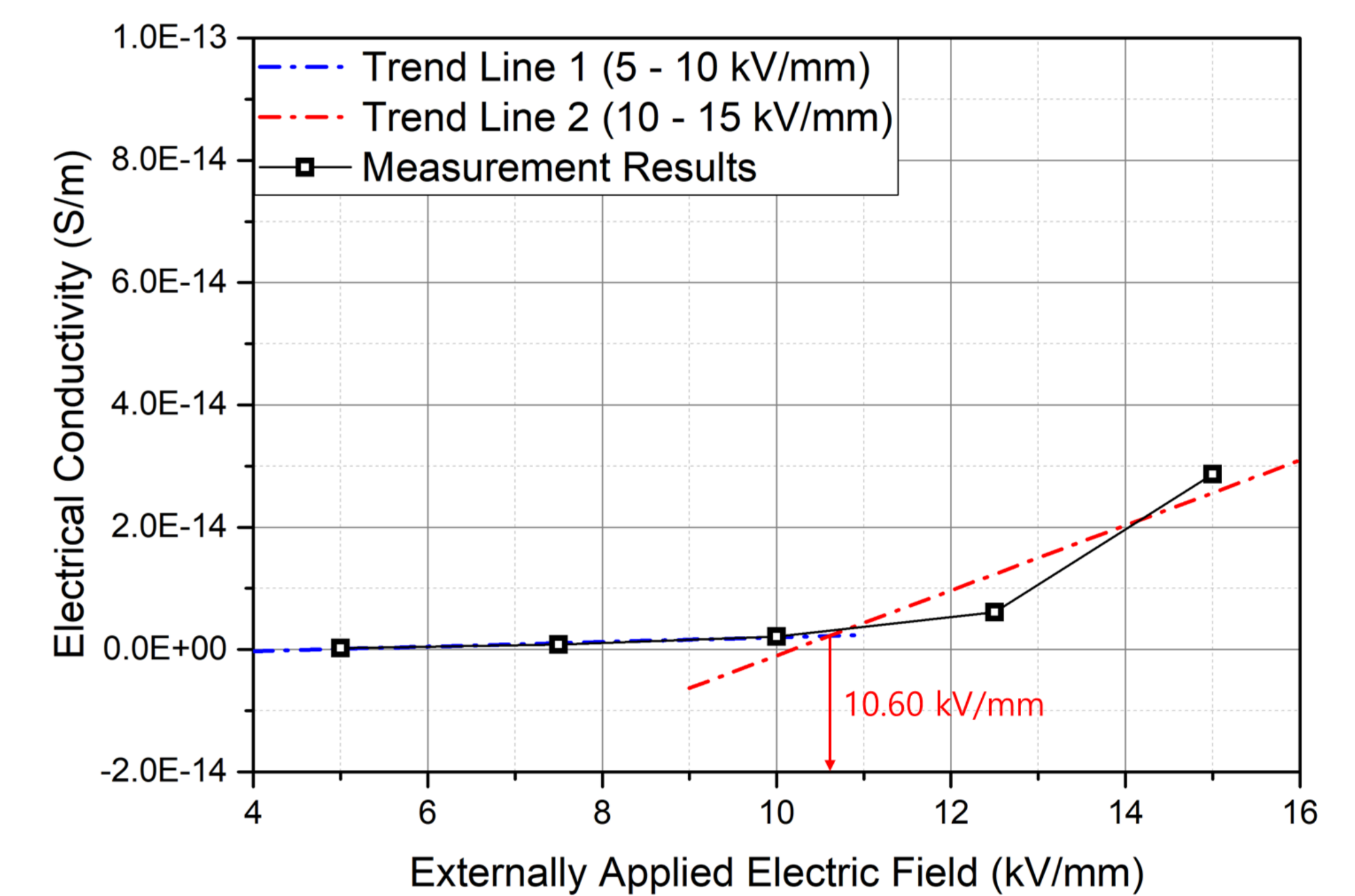
Electrical conductivity comparison based on the number of PPLP specimen layers



Determining of the threshold field based on the 1 layer of PPLP specimen



Determining of the threshold field based on the 2 layers of PPLP specimen



Determining of the threshold field based on the 4 layers of PPLP specimen

A. Measurement of Electrical Conductivity of PPLP Considering External Electric Field

- When the external electric field was applied at 10 kV/mm or below, there was no difference in conductivity depending on the number of layers. On the other hand, when the externally applied electric field was 12.5 and 15 kV/mm, a difference in the electrical conductivity according to the number of layers is observed, and the electrical conductivity for one PPLP specimen layer was the highest. It is considered that the flow of the conduction current is disturbed by the space charge accumulated between layers.

B. Determination of Threshold Electric Field of PPLP in LN₂

- The threshold electric fields in LN₂ were found to be 10.34, 10.22, 10.60 kV/mm for the one, two, and four layer PPLP specimens, respectively. As a result, there is no difference in the threshold electric field according to the number of layers.

C. Application of Threshold Electric Field in Insulation Design of DC HTS Cable

- When an external electric field exceeding the threshold electric field is applied, a difference in the electrical conductivity is observed depending on the number of layers. However, it can be confirmed that this phenomenon does not affect the determination of the threshold electric field for the PPLP specimen in LN₂. The threshold electric field of PPLP in a cryogenic environment can be utilized as useful data for long-term performance evaluation, such as space charge accumulation and deterioration.
- Furthermore, it is essential to derive a threshold electric field for various insulating materials such as HVDC power cable joints, cable terminations, and accessories, employing a composite insulation structure. This information is also valuable for the insulation design of various dc power apparatuses.