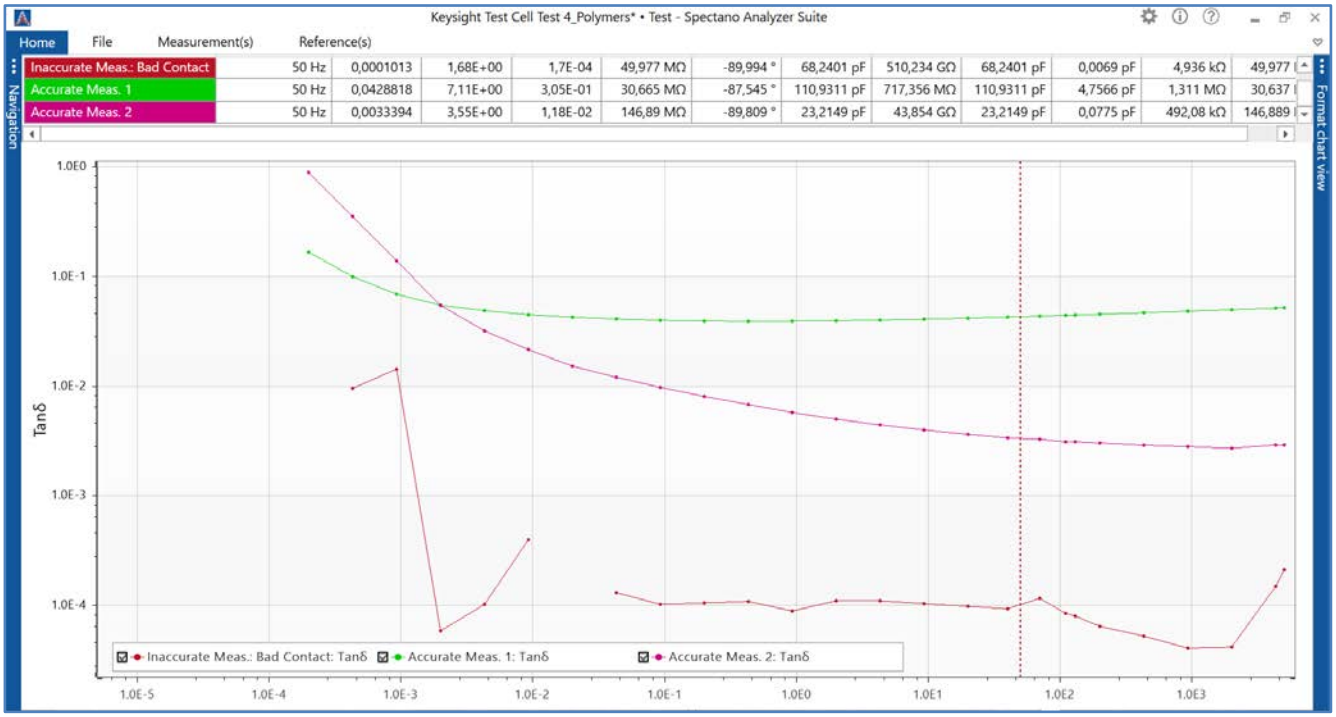
SPECTANO 100 - Application Note

Requirements to perform accurate dielectric material analysis



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Contact support@omicron-lab.com for technical support.

Table of Contents

Note: Basic procedures such as setting-up and adjusting the SPECTANO 100 are described in the SPECTANO 100 user manual. You can download the SPECTANO 100 user manual at https://www.omicron-lab.com/spectano-100/downloads.html#2

Note: All measurements in this application note have been performed with the SPECTANO Analyzer Suite V1.00. Use this version or a higher version to perform the measurements shown in this document. You can download the latest version at https://www.omicron-lab.com/spectano-100/downloads.html#1

1 About this document

In this application note we inform you about general requirements to perform accurate dielectric material analysis. Further on, the characteristics of an optimized measurement setup are outlined.

2 Operator Qualifications and Safety Standards

Testing and measuring with SPECTANO 100 and its accessories must be carried out only by personnel qualified, skilled and authorized for working with voltages up to 200 V_{peak} AC and DC. Before starting to work, clearly establish the responsibilities. Personnel receiving training, instructions, directions, or education on SPECTANO 100 must be under constant supervision of an experienced operator.

Measuring with SPECTANO 100 must comply with the relevant national and international safety standards:

- EN 50191 (VDE 0104) "Erection and Operation of Electrical Test Equipment"
- EN 50110-1 (VDE 0105 Part 100) "Operation of Electrical Installations"

Moreover, additional relevant laws and internal safety standards should be followed.

2.1 Safety Instructions

WARNING

Death or serve injury caused by high voltage or current

Before starting a measurement, read the safety rules and operation and connection instructions in the SPECTANO User Manual and observe the application specific safety instructions in this Application Note when performing measurements to protect yourself from high-voltage hazards.

3 Requirements for solid material test cells

3.1 Preparation

The measured dielectric properties can be influenced by the presence of conductive contaminations or moisture on the test cell or the material sample surface. Thus, the test cell and its electrodes or contact surfaces must be cleaned before the measurement is performed.

NOTICE

- Follow the cleaning, warning and safety instructions of the test cell user manual.
- The used solvents or cleaning agents must previously been checked to ensure that they do not contain contaminations which can influence the measurements. Ensure that the used solvent or cleaning agent has a low permittivity and dielectric losses and thus does not influence the dielectric properties. Some cleaning procedure examples can be found in international standards like ASTM D150-11 or IEC 60250.

3.2 Electrode adjustment and pressure

Parallel electrodes with a high conductivity are always very important to ensure an accurate and repeatable result. Air inclusions should be avoided. Thus, adjust the two electrodes until they are parallel to each other for accurate measurement. Moreover, ensure that also the solid test material is fully contacted on both sides. Perform these adjustments in the following cases:

- Before starting a measurement
- After changing the electrodes or the sample

NOTICE

The adjustment procedure and kind of adjustment depend on the used test cell. Read the user manual of your test cell for more information on the specific adjustment procedure for your test cell.

The following figures show examples of a correct and wrong adjustment and bad contact between the material sample surface and the electrodes.

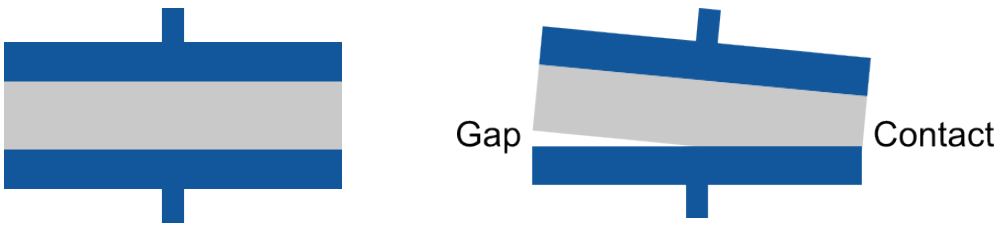

Figure 1: Correct (left picture) and wrong (right picture) adjustment of the test cell

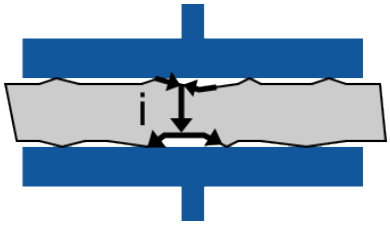

Figure 2: Bad contact between material sample surface and electrodes[1]

"Soft" material sample

In case of "soft" material samples a proper material contact with electrodes may not be an issue but the pressure of the electrodes may deform the material sample which can possibly influence the measured parameters.

"Rigid" material sample

In case of "rigid" material samples with uneven surface, a deformation of the sample under pressure may not be significant but as seen in Figure 2, areas with no sufficient contact between electrodes and the material sample surface will prevent a homogeneous current flow through the sample. This leads to measurement results which do not represent the properties corresponding to the material dimensions.

3.3 Thin film electrodes or coating

A simple solution to avoid high pressure on the material sample and to improve the contact between the sample material and the electrodes is the measurement with thin film electrodes or an additional coating surface. Thin film electrodes or a coating surface between material sample and electrodes improve the contact which increases current flow and reduces the signal-to-noise ratio especially when using low test voltages. The measurement error caused by the current flow along the material sample surface at the non-contacted areas is less than using rigid metal electrodes. There are several types of thin film electrode or coating materials, such as:

- Metal foil
- Conductive paint
- Fired on silver
- Sprayed metal
- Evaporated metal
- Metal spattering

For more details, refer to the international standards like ASTM D150-11 or IEC 60250.

[1] This image is seen in the IEEE Transactions on Dielectrics and Electrical Insulation Vol. 20, No. 3; June 2013, paper "Enhanced Accuracy in Dielectric Response Material Characterization by Air Reference Method" from Xiangdong Xu, Tord Bengtsson, Jörgen Blennow and Stanislaw M. Gubanski.

NOTICE

When attaching a thin film electrode, the gap width between the guarded thin film electrode and the guard thin film ring should be as small as practical.

3.4 Electrodes with Guard ring

When measuring the dielectric properties of solid materials without guarding, the measurement is influenced by stray capacitances at the edge of the solid test material, as shown in the following figures.

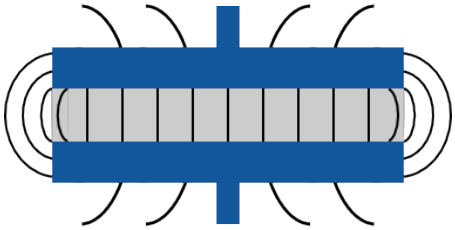

Figure 3: Lines of electric force, unguarded electrode[2]

When using a guard electrode, the stray capacitances will be guarded as shown in the following figures. With this setup, it is possible to measure the dielectric properties of the solid test material accurately, because the stray capacitances are not measured. Additionally, the influence of surface currents is eliminated by the guard electrodes. This is especially important for samples with a high-volume resistivity.

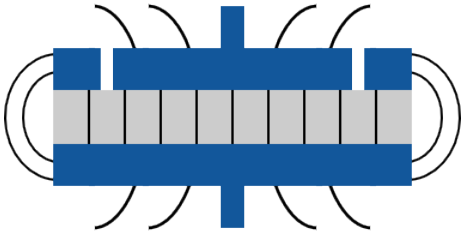

Figure 4: Lines of electric force, guarded electrode[3]

[2] Source: Own picture based on standard ASTM D150-1.

[3] Source: Own picture based on standard ASTM D150-1.

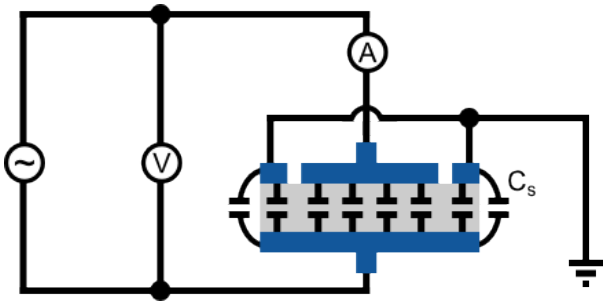

Figure 5: Measurement circuit, guarded electrode (C_s is stray capacitance)

4 Requirements for solid material test samples

The measurement error of the permittivity is not only caused by capacitance measurement error (see chapter 6.3 "Error correction"), but also by the error in the solid test material's dimensions and structure. Therefore, the test material should be accurately cut or modeled and measured so that its dimensional error will not affect the permittivity value.

NOTICE

Ensure that the sample probe surface will not be contaminated during preparation. Conductive contaminations will influence the dielectric properties.

4.1 Sample size and thickness

In general, the size of the solid material should be large enough to allow its measurement with the required accuracy. Typically, a capacitance of at least 100 pF should result from the sample's size and thickness in combination with the test cell to guarantee high accuracy. If the capacity is lower, the accuracy is limited and noise influences can prevent good measurement results, especially if the dielectric material has low losses. Therefore, usually a low sample thickness is used.

NOTICE

- For capacitances lower 100pF always shield the whole test system. For information see chapter 7.1 .
- Capacities below 10 pF will result in low accuracy and are not recommended.

4.2 Flatness

The surface of the test material must be flat at all points. When the surface of the test material is not flat, an air gap between the electrode and the solid test material causes measurement errors.

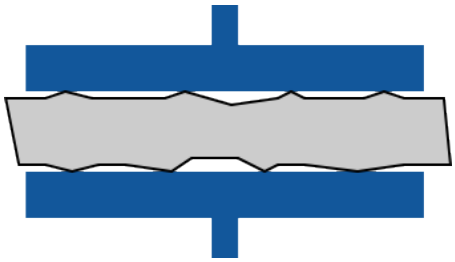

Figure 6: Example of a non-uniform solid material sample

The thickness must be determined systematically over the area of the solid material that is used in the electrical measurement and shall be uniform within ±1 % of the sample's average thickness.

NOTICE

Measurement errors caused by non-uniformity have a high influence especially when the solid test material is thin.

5 Requirements for liquid material test cells

The measured dielectric properties can be influenced by the presence of conductive contaminations or moisture on the test cell or the material sample's surface. Thus, the test cell and its electrodes or contact surfaces must be cleaned before the measurement is performed.

NOTICE

- Follow the cleaning, warning and safety instructions of the test cell user manual.
- The used solvents or cleaning agents must previously been checked to ensure that they do not contain contaminations which can influence the measurements. Ensure that the used solvent or cleaning agent has a low permittivity and dielectric losses and thus does not influence the dielectric properties. Some cleaning procedure examples can be found in international standards like ASTM D150-11 or IEC 60250.

6 Requirements for liquid material test samples

Store liquid test material in its original sealed container and protect it against light. Some liquids, such as oils of petroleum origin, change when exposed to sunlight. Allow the sealed container to stand in the room in which the test will be made for a sufficient period of time to guarantee that the liquid test material has room temperature before it is opened. When insulating liquids are heated to high temperatures, some of their dielectric characteristics may change with time. It is possible that these changes will influence the measurement results. Therefore, it is necessary to minimize the time, needed for the liquid test material to attain temperature equilibrium with the test cell, Furthermore, it is essential that the procedures described in international

standards for general and routine testing of dielectric characteristics of liquids are closely followed. In general, always rinse the test cell with a portion of the liquid test material to be tested before filling the test cell.

7 Accurate measurement of small signals

Environmental changes can influence the measurement results, especially when measuring small signals (typical for capacities < 100 pF). To ensure an accurate measurement also for small signals take the following information and instructions into account.

7.1 Shielding

To improve the signal-to-noise ratio for low current measurements, the following measures are recommended for the test setup:

- Put the test cell and/or test device into an EMC box to shield the test system from external noise.
- Increase the test voltage if possible.
- Separate guard and ground.
- Ensure that the cabling is shielded.

7.2 Stable environment

Permittivity and dielectric losses vary with temperature and humidity. Therefore, ensure measuring the sample in a stable environment. If possible, use a climate or temperature chamber to control the environment.

7.3 Error correction

To eliminate stray capacitances and unknown capacitances between the leads used to connect the test cell to SPECTANO 100 we recommend performing air reference measurements.

To do so follow the following steps:

- Depending on your test cell type, insert either a spacer between the electrodes (as shown in Figure 7) or adjust the electrodes to a defined distance, fix them into position with a locking screw (as shown in Figure 8) and measure the air gap height.
- Perform the air reference measurement(s) using the SPECTANO Analyzer Suite as described in the SPECTANO 100 user manual chapter *“Perform air reference measurements"*.

Figure 7: Adjusting the air gap height by using a spacer

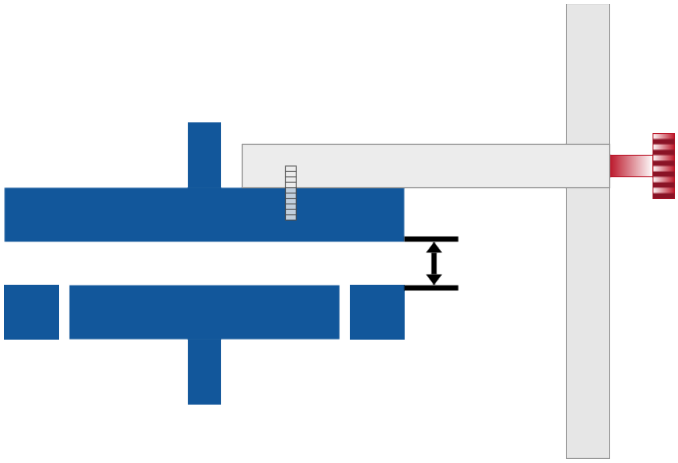

Figure 8: Adjusting the air gap height by using a locking screw

NOTICE

- Adjust the air space between the electrodes equal to the thickness of the test sample under test.
- If this is not possible, we recommend performing two air reference measurements with different air spaces. Preferably, make a first measurement with an air space higher than the sample thickness and a second measurement with an air space lower than the sample thickness.
- Always ensure that the two electrodes are parallel to each other. See chapter 3 for more information.

If you take into consideration all these rules and recommendations, there should be no obstacles to achieving accurate and repeatable measurement results. For further information feel free to contact us anytime at info@omicron-lab.com.

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