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Application Note
Radiant High Voltage Displacement Measurement Fixture
Rev B
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Introduction:
Radiant Technologies, Inc. offers four types of high voltage test fixtures. One, the High Voltage Test Fixture (HVTF), has been very popular due to its ease of use and its safety features when working with high voltage ceramic samples. Radiant has a second version of the HVTF, designated the HVDM, which allows the MTI2000 Displacement Meter to monitor the piezoelectric displacement of the sample in the HVTF during high voltage testing. The HVDM simplifies the fixturing requirements for the MTI2000 displacement sensor. As well, it decreases the effects of external vibration noise on the measurements and improves the signal-to-noise ratio of the displacement measurement.

Construction:
The HVDM is made of high-temperature Teflon and is able to withstand exposures of up to 200°C, making it ideal for both high-voltage and high-temperature testing. The HVDM breaks into two parts: the bottom half holds the sample while the top half mounts the MTI sensor wand. The sample is placed in a chamber in bottom half of the fixture. A copper electrode fixed in the bottom of the chamber contacts the electrode on the bottom of the sample. A 25KV cable connects the copper contact to an external 25KV electrical connector. The chamber is sealed so it may be filled with insulating oil to protect the sample from the arcing that may occur in "open air". The top half of the fixture fits over the bottom half, sealing the chamber. The top half of the fixture has an unclamped copper electrode that is held in place against the top sample electrode by gravity. This contact is free to move up or down to allow for varying thicknesses of sample. It will also move vertically when the sample changes size piezoelectrically. The top electrode has its own external connector. The test fixture is attached to the Precision High Voltage Interface (HVI) DRIVE and RETURN connectors. <u>IT IS IMPORTANT TO NOTE THAT THE HVI HV RETURN CONNECTION MUST ALWAYS BE MADE TO THE TOP CONNECTOR NEAR THE MTI SENSOR WAND TO PREVENT ARCING.</u> When the chamber is closed the sample is fixed and completely isolated from the external world giving a high degree of high-voltage protection to other equipment and operators. Note that when the HVDM is used in high-temperature testing, sufficient time should be allowed at the test temperature in the oven to ensure that the sample, within the chamber, has reached that same temperature as the oven.

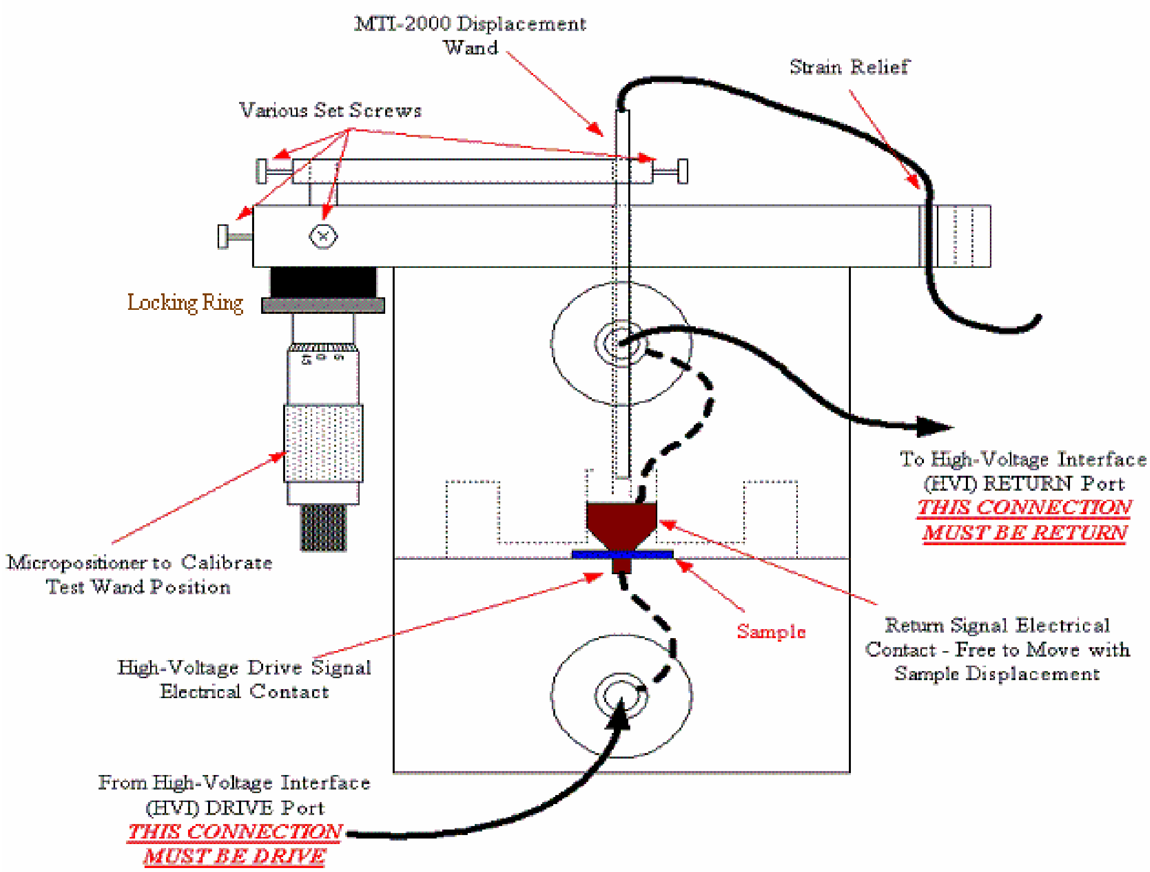

Figure 1
High Voltage Displacement Measurement Fixture

A micropositionable chuck system is built onto the top of the fixture. The chuck has an arm with a mounting hole for the MTI2000 sensor wand. The mounting hole in the chuck aligns with a similar hole in the Teflon at the top of the fixture. The wand is inserted through the two holes and slides in until it can stare at the top surface of the high voltage electrode. The electrode is copper and provides a high reflection surface for the MTI sensor wand. The strength of the reflected signal reaches 80% of the system limit, tens times higher than the 8% signal amplitude generated when looking directly at the electrodes on ceramic capacitors. Set screws in the chuck hold the wand in place. The contact is free to move with displacement of the sample and that motion is detected by the MTI-2000 displacement meter and recorded by the Vision Piezo Task.

Mounting the MTI Sensor Wand:

WARNING: DO NOT MOUNT THE SENSOR WAND BEFORE LOADING THE SAMPLE. IF THE SENSOR WAND IS SET FOR A THINNER SAMPLE, THE TOP ELECTRODE OF THE FIXTURE MAY DAMAGE THE TIP OF THE SENSOR WAND WHEN YOU LOAD THE THICKER SAMPLE.

1. Twist the Locking Ring to unlock the micrometer.

2. Using the micrometer, move the chuck to a position about 2mm to 4 mm from the top surface of the fiture.

3. Using a "+" screw driver, unscrew the set screw to allow room for the wand to fit through the mounting hole.

4. Insert the MTI sensor wand through the hole in the chuck and through the hole in the top surface of the fixture until the wand touches the electrode inside the fixture.

5. Tighten the set screw to hold the wand in place.

   WARNING: BE SURE NOT TO TIGHTEN THE SET SCREW TOO SECURELY TO AVOID BENDING OR DAMAGING THE MIT SENSOR WAND.

6. Loop the sensor cable from the wand through one of the stress relief slots on the side of the test fixture.

7. Connected the analog output of the MTI2000 control box to the SENSOR input of the Precision tester using coax cable.

8. Connect the electrical cables between the HVDM and the Precision High Voltage Interface.

   WARNING. The MTI sensor wand is clad in metal that is connected to earth ground through the power supply of the MTI control unit. The sensor wand sits only 1mm from the surface of the top electrode of the fixture when in the calibrated position. If you connect the HF DRIVE signal from the High Voltage Interface (HVI) to the top electrode, it will arc to the cladding of the MTI sensor wand. Our experience is that this arcing will not damage the MTI control unit, the HVI, or the Precision tester. However, there is no guarantee that damage will not occur. As well, data is invalidated when arcing occurs. The HV RETURN signal from the HVI is always ground potential. Therefore, ALWAYS CONNECT THE "HV RETURN" SIGNAL FROM THE HVI TO THE TOP HVDM ELECTRODE NEAR THE SENSOR WAND.

NOTES:

To use the HVDM at elevated temperature, you must verify with Radiant that your fixture has a micrometer capable of withstanding your intended test fixture.

The standard MTI sensor wand is for use only at room temperature. MTI sells a separate high temperature version of their sensor capable of reaching 200°C.

The MTI2000 sensor looks at the top electrode of the fixture. Therefore, the sample may be covered in oil without affecting the accuracy of the MTI2000 measurement.

<u>Calibrating the MTI Sensor Wand:</u>

1. Load the sample in the fixture and assemble the two halves of the fixture.

   Warning: Be sure to raise or remove the MTI sensor wand when loading a new sample to prevent damage to the top of the sensor wand.

2. Mount the sensor wand according to the instructions above.

3. Select "Range 1" in the upper left-hand corner of the control unit.

4. Set the MODE switch on the right middle portion of the front panel of the MTI2000 control unit to "CAL".

5. Press the button on the front panel of the control unit marked "Volts/EU". This will set the front display to the actual voltage level generated by the return signal to the sensor wand. The maximum is 10V.

6. Using the micrometer on the HVDM, raise or lower the sensor wand until the voltage signal indicated on the front panel of the control unit is at its maximum. This maximum should occur between 8V and 9V.

7. Once the wand height above the electrode has been set to maximize the return signal, press the "Cal Set Point" button on the front panel and wait for the calibration routine to complete. The calibration routine is complete when the "Cal in Progress" LED goes out.

8. If at this point the "Cal Error" LED is on, refer to the MTI 2000 instruction manual for the procedures to follow.

9. If there is no error in the calibration routine, set the MODE switch to "Displacement".

10. Using the micrometer, lower the wand <u>towards</u> the surface of the top electrode until the sensor voltage is around 2V to 4V.

11. Twist the Locking Ring on the micrometer to lock the micrometer and the wand into position.

    IMPORTANT: The support arm holding the sensor wand is connected directly to the shaft of the micrometer controlling the height of the wand. Micrometers have play in their rotational position. This play is called "backlash" in the specification sheets of micrometers. The backlash on the micrometer of the HVDM will cause the support arm holding the wand to have a little play laterally, allowing the wand to move laterally across the surface of the electrode. That surface will most likely not be perfectly parallel with the wand so a change in the displacement will appear on the meter from the play of the support arm. <u>You eliminate this play using the locking ring on the micrometer. After</u>

positioning the arm and the wand correctly and executing the calibration procedure, be sure to “lock” the micrometer with the locking ring.

If you have a 2032 sensor with the 3mm-diameter sensor wand, you are ready to make measurements. At this point, the unit will output to SENSOR the same reading that is on the front display, 2V to 4V. If you are using the PIEZO task, it will subtract out this bias so the first measurement point is zero. If you make the measurements using any other task, they will not subtract out the bias. You can manually adjust the bias going to sensor using the rheostat on the rear panel of the MTI control unit. The rheostat on the rear panel does not affect the front panel display. It inserts a bias into the analog signal going to SENSOR so SENSOR can see zero while the front panel shows 2V or 4V.

If you have a 2032RX sensor, it is 10 times more sensitive than the 2032 sensor if you switch to Range 2. Switch to Range 2, unlock the micrometer, and adjust the micrometer to bring the voltage display on the front panel of the control unit to within the 0V to 10V range. Then, lock the micrometer again. Finally, there is a small rheostat in the upper left-hand corner of the front panel of the control unit for the 2032RX. (The rheostat is not there for the 2032.) Adjust the Rheostat on the front panel until the front display shows 0V.

You are now ready to make measurements. When you select a measurement task, turn on the SENSOR measurement in that task to capture the output of the MTI2000. Set the “Sensor Scale” to the conversion factor for your MTI2000 unit. The calibration figure for your particular unit is located on the side of the amplifier unit for the sensor wand. You must pull that amplifier unit from the mainframe to see the calibration label.

When entering the scale factor, use a negative number. The reason is that the MTI sensor wand is seeing the distance between its tip and the top surface of the sample. When the sample expands, its surface moves towards the tip, causing the MTI output signal to decrease. If you use a positive scale factor, the measurement will be correct but upside down.

The setup menu for the SENSOR input has a “Sensor Offset” value you may input. This value is subtracted from the measured data and it is another way to zero your measurements.

The “Sensor Label” is used to label the vertical axis on the data presentation. It must match the scale factor.

NOTE: If you enter the scale factor in units of picometers instead of microns and select the “Displacement / Volts” plotting option in PIEZO, the units of the vertical axis of the data plot will be “pm/volt”, the units of d_{33}.

The final value to input is the output impedance of the MTI2000. Vision uses this number to correct the measured data from voltage division that might take place between the output of the sensor unit and the input of the Precision tester.

NOTE: The output impedance of the MTI2000 is 10,000 ohms.

You may now take data.

Example Data

Below is a photograph of the HVDM prior to loading the sample.

Figure 2
The two halves of the HVDM

Note the two electrodes of the HVDM. The top copper electrode on the portion with the micrometer is free to move vertically in its shaft.

Figure 3 shows the HVDM and MTI2000 control unit. A 2032 sensor wand is mounted on the HVDM.

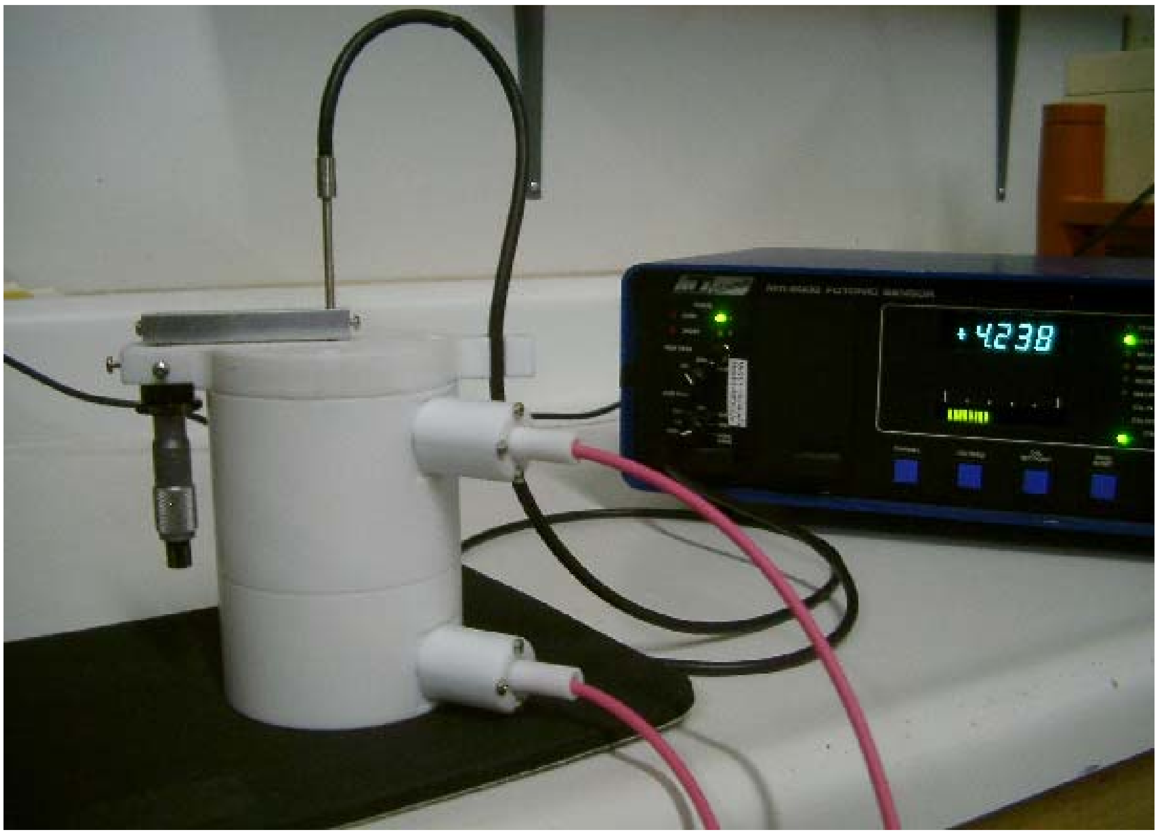

Figure 3
HVDM and MTI2000 Control Unit with 2032 Sensor Wand

The 2032 sensor wand has a resolution of less than 0.02µ. But, typical noise levels on the measurement due to external vibrations run about 0.06µ to 0.08µ. This noise level can be reduced using an air table and acoustic shielding. Therefore, in a typical laboratory arrangement like that shown above, the 2032 sensor wand is good for measuring displacements with a total throw greater than 0.5µ. Below that amplitude, signal-to-noise issues begin to affect the data. The SNR can be improved with averaging. Look in the "Filters" folder of the Vision Library for the specific filter tasks to execute averaging. Contact Radiant if you want help in setting up Vision test programs.

The 2032RX wand is ten times more sensitive than the 2032 and, because of its higher SNR, it is the best choice for measuring ceramic actuators at less than 10KV. The 2032RX is sensitive enough to see vibrations in the building imparted by the HVAC system. If you do not have an air table for isolation, put the HVDM on the floor to eliminate the table sway. Even better, go to the lowest floor in the building and place the HVDM on the concrete slab. (The lowest floor may be the basement!) It is the most stable and most quiet location in any building.

Finally, the MTI2000 control unit has a cooling fan.   For sensitive measurements, you should place the control unit on a separate bench of shelf from the HVDM so the vibrations from the fan do not affect the test. Set the Low Pass Filter on the front panel of the control unit to 100Hz and make your measurements at 1Hz (1000ms) or slower. I get my best butterfly loops using a 10-second or 20-second hysteresis period.

A close-up of the HVDM is shown in Figure 4.

Figure 4
Close-up of the loaded HVDM

Using the fixturing shown in the figures above, I measured a 300μ thick, hot-pressed 2/65/35 PNZT ceramic sample. The sample had an area of 3.8cm^2. The hysteresis of the sample is shown in Figure 5.

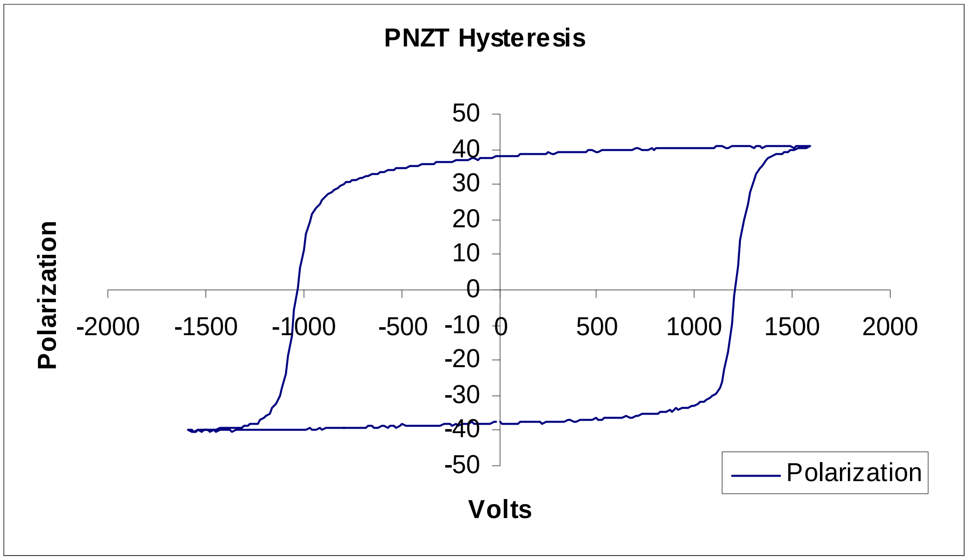

Figure 5
Hysteresis loop of the sample at 1600V

The displacement of the top electrode caused by the sample during actuation is in Figure 6.

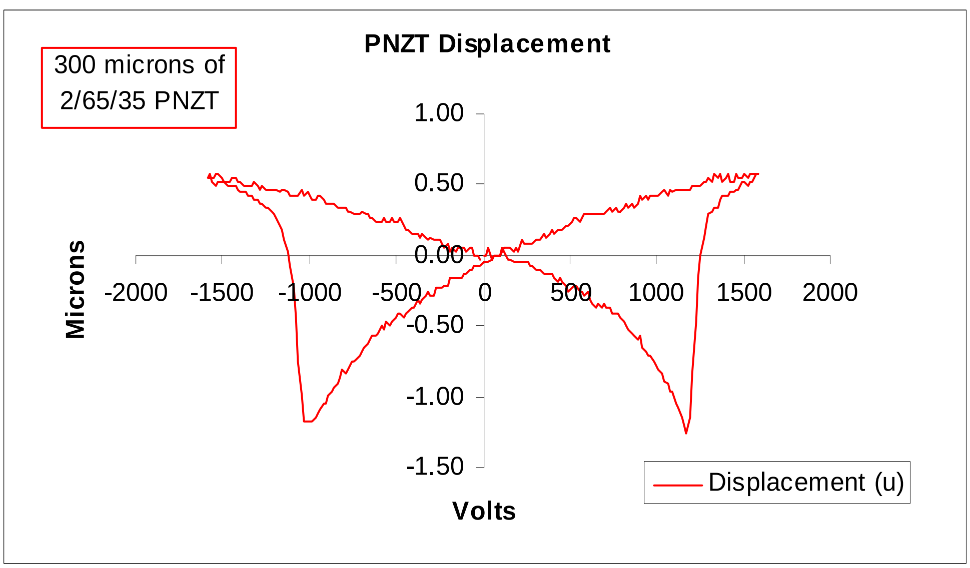

Figure 6
Displacement loop of the sample at 1600V

To verify that none of the displacement or polarization results originated from parasitics in the HVDM, I created a "capacitor" consisting of 1.3mm of 3M Sticky Pad papers. It had no electrodes. I placed the sticky pad between the electrodes of the HVDM and made a 2000-volt measurement for polarization and displacement. They are shown together in Figure 7.

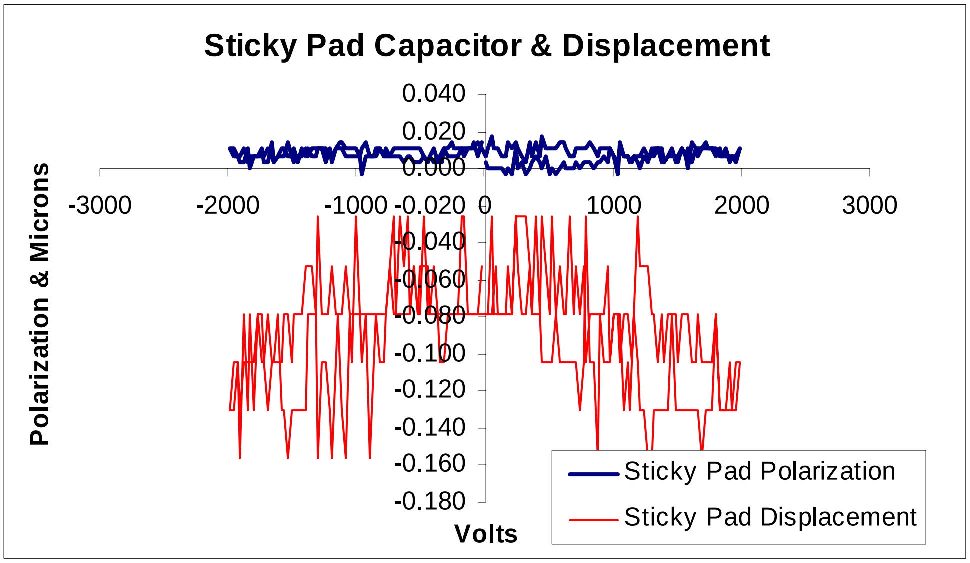

Figure 7
Polarization and Butterfly Loop of a Sticky Pad

The PNZT sample is compared to the "Sticky Pad Capacitor" below.

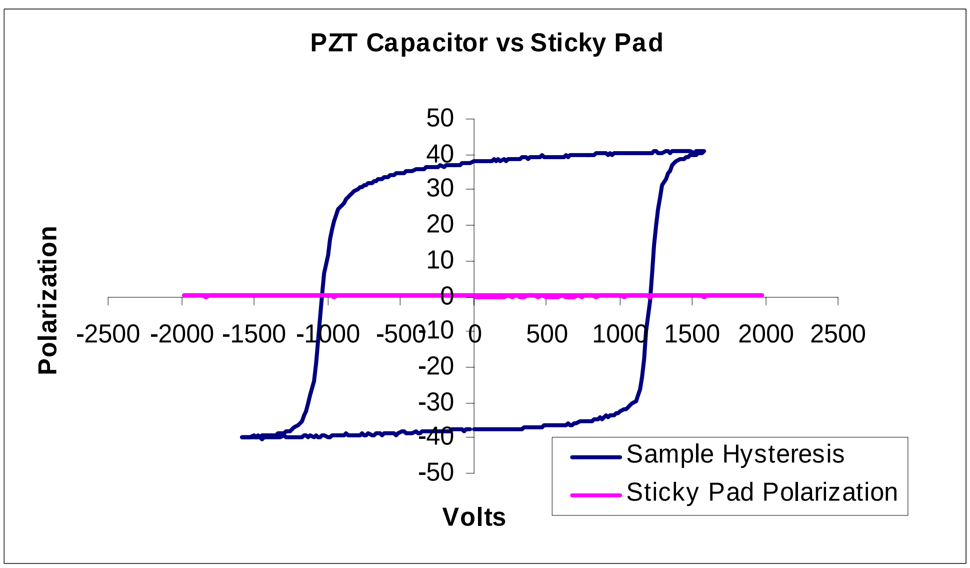

Figure 7
Polarization of a PNZT Ceramic vs a Null Capacitor

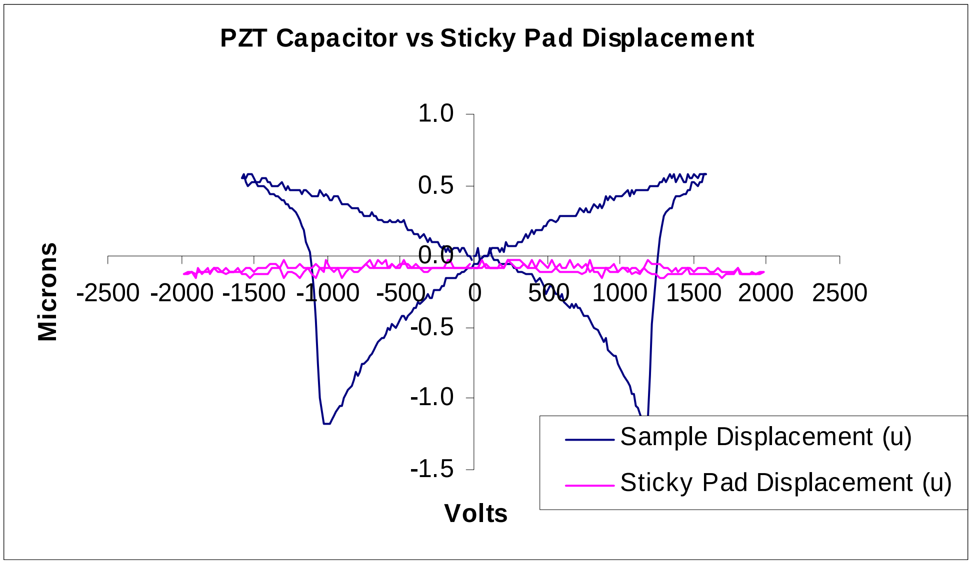

Figure 7
Displacement of a PNZT Ceramic vs a Null Capacitor

In conclusion, the HVDM adds almost no parasitics to the measurement of a typical ceramic sample.

Conclusion
The Radiant HVDM test fixture provides a stable and convenient platform for displacement measurements of ceramic capacitors. Combined with a high temperature version of the MTI2000, the HVDM allows displacement measurements up to 200°C. Finally, the HVDM is constructed of thick Teflon to provide excellent safety protection for the researcher even up to voltages as high as 10KV.