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Application Note for Pyroelectric Measurements with Chamber

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The Chamber task in Vision controls a furnace or other heating element to measure the electrical properties of non-linear capacitors as a function of temperature. Chamber will measure either remanent polarization or dielectric constant. Radiant performed a measurement of the remanent polarization vs temperature for a 4% niobium doped 20/80 PZT film with platinum electrodes. The film was 0.4 thick. The remanent polarization as function of temperature is shown in Figure 1.

Radiant has a Powerpoint presentation describing this experiment. Please contact Radiant to request a copy.

When making Pyroelectric measurements, please keep in mind the following considerations.

1. The pyroelectric constant arises from the change in the size of the unit cell with a change in temperature. Any net polarization associated with that unit cell will change as the unit cell changes its size.

   If the unit cell is centro-symmetric, there is no net polarization so there will be no pyroelectric effect. There are two ways to create a net polarization:

a) Use a ferroelectric material with a strong remanent polarization. The net polarization is always present in the unit cell and it will not be centro-symmetric.

b) If the material is non-linear but has no remanent polarization, apply a DC bias to the capacitor to force the unit cell to distort into an elongated state. Now, any change in temperature will change the dimensions of the unit cell and change the "capacitance" of the device.

2. A ferroelectric material with remanent polarization will show a pyroelectric effect in its remanent polarization as well as a pyroelectric effect in its dielectric constant. So, a ferroelectric material can be measured using the dielectric constant measurement and it can also be measured with the remanent polarization measurement. The two types of measurements will give opposite results. Dielectric constant will increase with temperature. Remanent polarization will decrease with temperature.

3. A non-linear material with no remanent polarization cannot be measured in Pyro for remanent polarization changes due to temperature. It has no remanent polarization. Instead, it can only be measured for dielectric constant with or without a DC bias.

4. A ferroelectric material with remanent polarization has a naturally distorted unit cell. So, it will show a change in dielectric constant with temperature with zero DC bias during the small signal capacitance test. Some non-linear materials with no switchable remanent polarization will still have a naturally distorted unit cell. They will also show a change in dielectric constant with temperature with zero DC bias during the small signal capacitance test. Most non-linear materials with no remanent polarization do not have a distorted unit cell unless a voltage or stress is applied. In their case, they will show no pyroelectric effect unless a DC bias is applied during the small signal capacitance test.

5. If a ferroelectric material has a slim loop hysteresis, it will have a low remanent polarization value and hence will not generate much change in remanent polarization as a function of temperature.

6. The best results will occur if a large temperature range is tested for pyroelectric effect. For instance, I measured the remanent polarization of one of our 0.4µ thick 4/20/80 PNbZT films on platinum electrodes using the Chamber task. I measured it from room temperature up to 180°C. I will send you a copy of that test result in a second e-mail.

7. Some compositions of ferroelectrics have a flat pyroelectric response at room temperature and then a higher pyroelectric response at higher temperatures.

So, the following test conditions are recommended when using Chamber:

1. Make sure the hysteresis loop has plenty of remanent polarization before the test starts.

2. Choose the Remanent Polarization option for Chamber.

3. When looking at the data, first look at the Remanent Polarization vs Temperature plot to make sure that remanent polarization was measured and that the results make sense.

4. When measuring dielectric constant vs temperature, use a DC bias during the small signal capacitance measurement if the material is slim loop.

5. Use a large temperature range.

Appendix A

Opening Data Plots from the Vision Archive

1. Once you have taken test data and it is stored in a dataset, you may plot the data again by selecting the specific task you want to see and double clicking on it.

2. The original menu for the task will open so you can examine the test setup information.

3. For some tasks, there will be only one setup page. Pressing "Plot" or "Cancel" will open a second menu page. This page contains plot format options for the data. Select the format you desire, label the axes, and press "Plot" or "Cancel".

4. Other tasks will open a menu with multiple pages. The last page in these cases will be the setup page for the plotting options.

4. Vision will now plot the data. You may custom format the plot using the "Customization Dialog". See **Using the Customization Dialog in Vision Plots.**

5. Hysteresis Example:
When you double click on the Hysteresis task in the Archive, you will get the Hysteresis setup page. Pressing the "Cancel" or "Plot" button will close the first page and open a second page with plotting options. The plotting options are in the lower right-hand corner of the menu. They are:

   "None" — Raw voltages from the measurement are scaled by the sense capacitor and the amplification level to turn them into polarizations. The polarizations are plotted without any filtering.

   Note: The raw data from the "None" selection are the starting point for the other plotting options in this menu.

   Note: In the raw data, the first point is always zero so the hysteresis loop is offset up or down in the plot by the remanent polarization value.

   "Centering" — The raw data from "None" is centered vertically on the X-axis by averaging the +Pmax and –Pmax points and subtracting the average from all of the points of the loop.

   "Capacitance vs Voltage" — The polarization values of the measured loop are multiplied by the area to convert them to the measured charge values. Then, the mathematical derivative of the loop with respect to voltage is calculated and plotted. The units of charge are in microcoulombs so the units of capacitance

are in microfarads. A filter is applied to the derivative to reduce the apparent noise effects.

"Normalized Capacitance vs Voltage"
The mathematical derivative of the polarization loop is calculated and plotted. The units are microfarads per square centimeter, a measure of capacitance density. A filter is applied to the data prior to plotting to reduce the apparent noise effects.

"Time Plots" The next four selections plot the first four selections above as a function of time instead of voltage. The drive voltage vs time is also plotted.

Note: The Polarization vs Time plot is useful for examining the load on the High Voltage Amplifier during tests of bulk ceramics. Do a Hysteresis loop and select the time plot. Examine the voltage data. If the high voltage amplifier is not overloaded, the voltage data should form a perfect triangle wave. If not, then the test must be slowed down to accommodate the high voltage amplifier.

6. I/V Example:
The menu from the I/V Task gives you all of the setup pages for the I/V tests including the plot format page when you double click on the I/V task in the Archive. Go to the menu page "I/V Plot Setup". In the lower right-hand corner of the menu there are two options boxes. One lets you pick the units for the plot. The second box lets you choose in what format to plot the data: Current, Resistance, Resistivity, or Current Density. The units in the first box change to match the type of data you elect to plot.

Appendix B

Using the Customization Dialog in Vision Plots

Once you have data plotted in Vision, there is a set of powerful plotting tools available to you. Place the mouse cursor inside the plot area and press the right mouse button. You will get a pop-up menu. There are several individual selections in the pop-up menu. All of these options are also available in the "Customization Dialog" along with scaling and formatting menus.

The observations below refer to the Customization Dialog.

1. The first page, "General", allows you to add or change the title or subtitle of the plot. It will also let you set the numerical precision and turn on grid lines.

2. The third page is the "Subsets" page. If you have a plot with multiple data subsets on it, you may use this page to select which ones to show in the plot. For instance, if you have a "Pass Through Filter" with five hysteresis loops on them and one of them was a short, you can call up the Subsets page on the Customization Dialog and select only the other four for plotting. This feature is very useful.

    a) When setting up Fatigue tests, select all of the Polarizations for plotting during the test. When the data is being taken, the data plot will look like a mess because of all of the plot lines. However, when you recall the Fatigue plot from the dataset, you can use the Subsets page of the Customization Dialog to select to plot only P*, P^, -P*, and –P^ or to plot only dP.

    b) When you schmoo hysteresis speeds on the Precision Premier from 10us to 10s in length and you find that the loops at the fastest speeds do not plot well because they do not have enough points or that the loops at the slow end leak too much, you may use the Subsets page to drop them from the plot.

    NOTE: If you have multiple data subsets in a plot and you have formatted the plot to show only a few of the plots, the exact picture you have formatted will be transferred to the clip board if you export the file as a "metafile". Therefore, format it in Vision and paste the final version directly from Vision to your POWERPOINT presentation.

    However, if you have multiple data subsets in a plot and you elect to export the data as "Text", Vision will export all of the subsets no matter which ones are turned off or on in the Subsets page. You can select which subsets actually get exported in ASCII on the second page of the Export Dialog.

3. The "Axis" page allows you to change the scale and axes of the plot. Note that there is a bug in the selection of "Linear" and "Log" for the Y-axis. If "Log" is selected and you open the menu, the plot will automatically change back to "Linear" unless you specifically select "Log" again. So, when plotting the Y-axis in "Log" format, you must select "Log" every time you open the Customization Dialog no matter what the previous setting.

4. The final page is the "Style" page. This page allows you to select each subset in turn and assign it a new color and thickness.

Appendix C

How to Export Plots from Vision to Word, Excel, or Powerpoint

This appendix gives direction on how to paste plots from Vision to WORD, EXCEL, or POWERPOINT as has been done in the document above.

1. Open the data plot in Vision either from a dataset or by executing Quiklook.

2. Place the mouse cursor inside the area of the plot and press the right mouse button. You will get a pop-up menu with plotting options. Use the "Customization Dialog" to label, scale, and adjust the data format of the plot.

3. When ready to export the plot, select "Export Dialog" from the pop-up menu.

4. To export a picture of the plot, use only the first page of the Export Dialog.

5. On the Export Dialog,
   a) Leave the selection as "Metafile".
   b) At the bottom of the dialog, adjust the initial size of the plot if necessary

6. Press the "Export" button. The metafile is now on the clipboard in the Windows™ operating system.

7. Open the WORD, EXCEL, or POWERPOINT file you want to paste the plot in.

8. Place the text cursor (not mouse cursor) where you want to paste the plot. Select "Paste Special" from the pull down menu or using the right button of the mouse. Select the "metafile" format.

   Note: You may past the plot as other formats. However, a "Picture" takes a lot of memory space, making the file very large in size and difficult to send via e-mail. A "Bitmap" has a fixed physical size on the page that cannot be changed. The "metafile" has size boxes so you can adjust the size of the pasted plot to fit the allotted space. A metafile has the unique feature that the letters of the wording inside the plot will adjust as you change the size of the plot to maintain the proper visual perspective for the words.

9. Press OK. The plot will be pasted.
   a) You can select the plot by putting the mouse cursor inside the plot area and pressing the left mouse key. Size boxes will appear.
   b) You may change the size of the plot by "grabbing" a size box with the mouse cursor and dragging it to the appropriate size.
   c) You may move the entire plot by placing the mouse cursor inside the area of the plot, pressing the left mouse key, and holding it down while you move the mouse. Letting go of the left mouse key lets go of the plot.

10. Once the plot is in the proper position on the document, you can lock it in place with respect to the words, etc. Put the mouse cursor inside the plot area and press the right mouse button. You will get a pop-up menu. From that menu, select "Format Picture" at the bottom. In the Format menu, go to the page labeled "Position". Check the boxes labeled "Moved Object with Text" and "Lock Position".

Appendix D

How to Export ASCII Data from Vision to Word, Excel, or Powerpoint

This appendix gives direction on how to copy ASCII data from Vision to WORD, EXCEL, or POWERPOINT.

1. Open the data plot in Vision either from a dataset or by executing Quiklook.

2. Place the mouse cursor inside the area of the plot and press the right mouse button. You will get a pop-up menu with plotting options. Select "Export Dialog" from the pop-up menu.

3. At the top of the page on the right hand side, select "Text/Data Only" and then the "Export" button. You will get a format menu.

4. There are several options available to you on the Data Format menu page. They are covered individually below:

5. <u>Export of a single data plot</u>:
   If you export from a plot with a single data plot on it, you will get one column of X:Y pairs.
   a) Select "Data", not "Data and Labels"
   b) Select "Maximum Precision"
   c) Press the "Export" Button
   d) Go to the file you want to paste the data in, place the mouse cursor into the location that you want to paste the data, press the right mouse key, and select "Paste".
      1) If you are in WORD, POWERPOINT, WORD PAD, NOTE PAD, etc, place the text cursor (not the mouse cursor) where you want the data to go and paste the data. The data will be pasted one X:Y pair to a line.
      2) If you are in EXCEL, select the box that is the upper left-hand box of the column where you want to the data to go and paste the data. It will automatically align into two vertical columns. Note that the data will remain highlighted after the paste. This is an excellent time to press "CNTL F1" to get the format menu for the selected data and adjust the data format to your liking.

6. <u>Export of a multiple data plots</u>:
   If you export from a file with multiple data plots on it, for instance a "Pass Through Filter" with five hysteresis plots, you will by default export all of the data plots as lists of X:Y pairs. You must tell Vision how you want that data formatted before exporting the ASCII.
   a) In the upper left-hand corner of the menu, choose "Select Data" if you do not want to export all of the individual plots. The box below will become active and will list the different subsets of data available for export. Highlight the ones you want to export.
   b) In the upper right hand corner, select "Data", not "Data and Labels"
   c) For spreadsheets like EXCEL only, go to the middle of the right-hand side of the menu, select "Table" and "Points/Subsets". This will format the multiple plots in columns of X0:Y0:X1:Y1… Do not use this format for other types of programs.
   d) Select "Maximum Precision" at the bottom of the menu.
   c) Press the "Export" Button
   d) Go to the file you want to paste the data in, place the mouse cursor into the location that you want to paste the data, press the right mouse key, and select "Paste".

1) If you are in WORD, POWERPOINT, WORD PAD, NOTE PAD, etc, you left the data in the "List" format. Place the text cursor (not the mouse cursor) where you want the data to go and paste the data. The data will be pasted one X:Y pair to a line. Each subset will follow the previous one in the list vertically.

2) If you are in EXCEL, the paste function for the "Points/Subsets" format can get rather complicated. First, select the box that is the upper left-hand box of the column where you want to the data to go and paste the data.

   a. If you have preset the conditions of EXCEL so to paste one column of text in one column of the spreadsheet, all of the columns will automatically align into individual vertical columns.

   b. If the multiple columns of data do not properly paste into individual columns, follow the instructions below:

      1. Select the box in the upper left-hand corner of the pasted data.
      2. Go to the "Data" pull down menu at the top of EXCEL. Select the option "Text to Columns…". Press the "Next" button.
      3. On the next page, check the "Comma" box and "Finish"
      4. Excel will separate the one selected box from one pair in one box to one pair in two boxes. Now, EXCEL has been set to automatically split the data correctly for pasting multiple columns of ASCII data.
      5. Select the upper left box again. Paste the original data. It is still on the clipboard. This time, it will overwrite the original data paste and put one column of ASCII data each into one column of the spreadsheet. As long as EXCEL remains open, it will continue to paste multiple columns properly.