Organic Light-Emitting Diode Testing

Standard Operating Procedure

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Purpose:

This document will introduce the testing procedure for OLEDs. Equipment for this testing is located in Amundson 419

Equipment:

Agilent 4155c Semiconductor Parameter Analyzer
Larger-Area Silicon Photodiode
Probes (with tips)
Ocean Optics HR4000 Spectrometer
Fiber Optic cable (1000μm, .600um, UV/VIW, VIS/NIR)
SpectraSuite software

Overview:

Organic light-emitting diodes (OLEDs) are primarily characterized by measuring the device current density (J, mA/cm^2) versus voltage (V), the brightness (B, cd/m^2) versus voltage, and the spectral distribution of emitted light. The J-V and B-V data will be taken using the Agilent semiconductor parameter analyzer (PA) and large-area silicon photodiode (photodiode from here on). Devices are contacted via probes with tungsten tips. A bare probe tip is used to contact the anode (the "hard probe", labeled "1"); a gold wire wrapped onto a tungsten tip and covered with silver paste is used to contact the cathode (the "soft probe", labeled "3"). A typical J-V, B-V measurement will consist of a voltage sweep by the PA, while simultaneously recording device current (IF), and photodiode current (PI). A typical spectra measurement consists of a constant current being applied to the device, while the spectrometer measures the emitted intensity per wavelength.

J-V, B-V Testing Procedure:

Initial Equipment Setup:

The photodiode can be found in the top drawer, to the right of the sink in Amundson 419. A BNC cable, paper aperture, and tweezers can also be found in this drawer.

1) Place the photodiode in the empty post on the optics table, connect the BNC from the photodiode to the BNC cable labeled "2" near the solar testing setup (remove any connected cables, if necessary).

2) Place the paper aperture and OLED device on the photodiode surface; ensure that the OLED is centered on the aperture such that the edges of the device are not within line-of-sight of the photodiode. Take care to not scratch the surface of the photodiode, it is delicate and scratches may render data and the detector useless.
3) With probes sitting on the optics stand near the photodiode, make contact through organic layers to the ITO anode with the hard probe; carefully make delicate contact with the soft probe to the cathode. The device is now ready for testing.

Parameter Analyzer Setup:

To setup the parameter analyzer, turn it on and wait for it to initialize. Once the PA is ready it will show the default screen, "CHANNELS: CHANNEL DEFINITION". This screen will show which inputs relate to which channels, for OLEDs, a basic setting as been programmed.

1) To select the standard OLED setting, push the 'more' button near the bottom right of the screen, then select the "MEM4 DIODE VF-IF" setting using the adjacent button.
2) The photodiode input (BNC cable "2") must be added manually, to do this use the arrow buttons to highlight row 2, column "VNAME;" name the new variable "P" by using the alphanumeric key pad (the blue key will toggle between numbers and letters), pressing the enter button will confirm the name and move the curse down the row. Enter "PI" as the INAME (for photodiode current), enter "V" as the mode, using the buttons adjacent to the screen, and enter the FCTN as CONST similarly. The channels and inputs have now been defined.
3) Using the "Page Control" buttons, move to the "Meas" (Measurement) page. Here the desired voltage sweep is defined. Parameters that must be modified are the "Start", "Stop", "Step", and "Compliance". For an initial scan, to verify proper contact to the OLED, a 0v (start) to 5v (stop) scan in 50mv steps is used; compliance is always set to 10mA. To select a proper power (i.e. milli-, micro-, nano-, etc.) use the buttons on the right side of the alphanumeric pad (m, μ, n, p, f).
4) Use the page control buttons to navigate to the "Display" page. Here the graphic output of the PA will be defined. Using the arrow keys, highlight the Y2Axis column, and "Name" row; using the buttons adjacent to the screen, select PI. A range will automatically be set.
5) Navigate, using the page control buttons, to the "Graph/List" by pressing the button once, here is where device current and photodiode current will be displayed, versus voltage.
6) Press the Graph/List button; this will display a numeric list of the data.

7) Press the page control button “Display”. This will bring up a list of columns displayed on the graph: list page. On this page, arrow down to row No. 3, add PI to the list using the screen adjacent buttons.

8) Press the Graph/List button, this will display the numeric list of data, now including the PI column. Double check that all required columns are listed.

9) Press the Graph/List button, this will display the graphic window. The PA is now ready to scan for diode contact. See the Fig. 1 below for the typical settings described above.

CHANNELS: CHANNEL DEFINITION					STBY
MEASURE					
UNIT	VNAME	INAME	MODE	FCTN	
SMU1:MP	VF	IF	V	VAR1	
SMU2:MP	P	PI	V	CONST	
SMU3:MP	V	I	COMMON	CONST	

Standard channel and input settings

MEASURE: SWEEP SETUP		
VARIABLE	VAR1	VAR2
UNIT	SMU1:mp	
NAME	VF	
SWEEP MODE	SINGLE	
LIN/LOG	LINEAR	
START	0V	
STOP	5V	
STEP	50mV	
NO OF STEP	101	
COMPLIANCE	10mA	
POWER COMP	OFF	
HOLD TIME	0.000 s	
DELAY TIME	0.000 s	

Standard measurement settings

DISPLAY: DISPLAY SET\UP			
	Xaxis	Y1axis	Y2axis
NAME	VF	IF	PI
SCALE	LINEAR	LINEAR	LINEAR
MIN	-500.000mV	-10.000mA	-100.000mA
MAX	2.0000 /V	40.000mA	100.000mA

Standard display settings

DISPLAY: DISPLAY SETUP	
No.	Name
1	VF

2	IF
3	PI

Standard display: list settings

Figure 1: Typical PA settings for J-V, B-V measurement

Data Acquisition:

Once the PA, photodiode, and OLED have been setup, a measurement may be performed using the "Measurement" buttons on the PA:

1) Set the integration time ("Integ Time") to "Medium" for a standard scan.
2) Close all doors, curtains, etc. such that there is as little possible light in the testing enclosure as possible. Room lights, flashlights and computer monitors should be turned off. Cover the PA and computer tower with the black sheet.
3) Begin a single scan by pressing the "Single" button.
4) To scale the X and Y1 axes to include measured data post-measurement, press the "Scaling" button below the PA screen. Using the buttons adjacent to the screen press "Auto Scaling"
5) To Scale the Y2 axis push the "Axis Y1" button below the screen. This will make the Y2 axis the active axis. Press the "Auto Scaling" button again to scale the Y2 axis. A properly contacted diode scan curve will appear as:

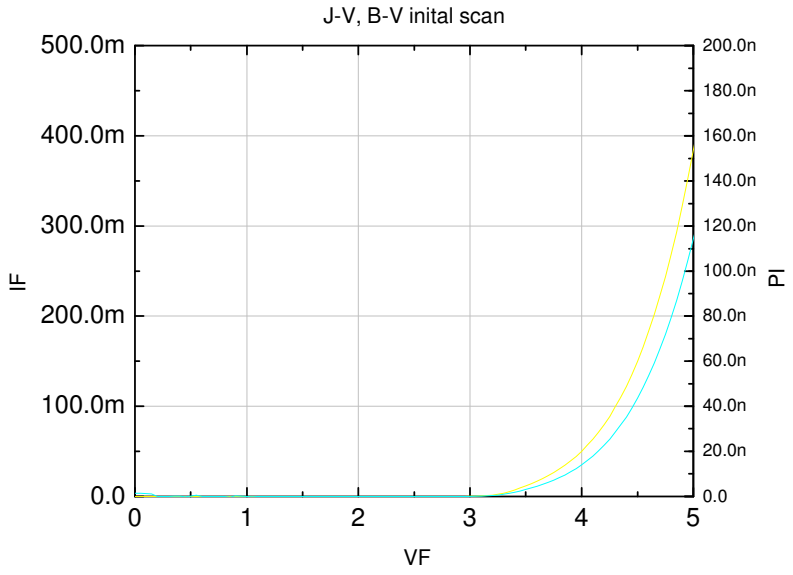

Figure 2: Properly contacted diode curve. Yellow curve represents device current, blue curve the photodiode current.

6) When a proper contact has been established a full scan may be done by changing the "stop" voltage on the measurement screen. A full scan may sweep from 0V to 10V or higher depending on device characteristics.

7) To display measured data in a log-log form, starting on the graphic display screen, press “Display”.
8) Using the arrow buttons and the buttons adjacent to the PA screen, select “Scale: Log” for each column (Xaxis, Y1axis, and Y2axis).
9) Display ranges may also be set on this screen, typically a useful Xaxis scaling will be from .1V to 10V (or 100V depending on “stop” voltage). A full scan on a log-log scale is shown below:

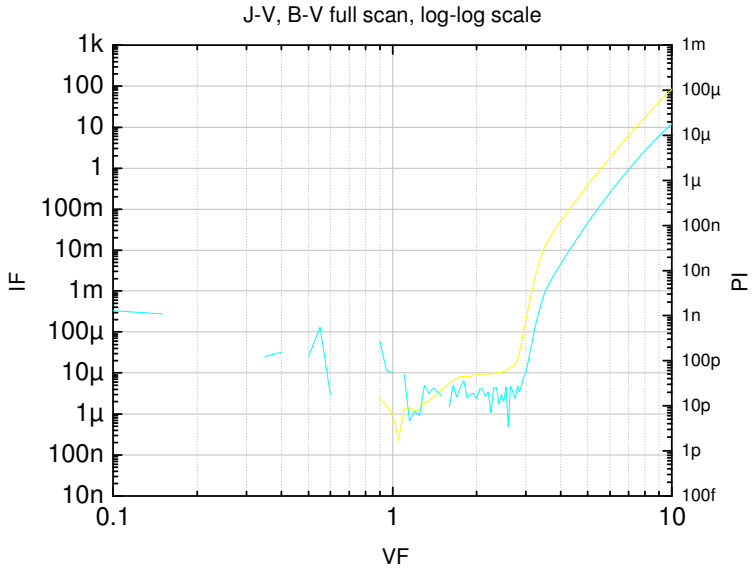

Figure 3: Typical full scan on a log-log scale. Yellow curve represents device current, blue curve the photodiode current

Saving Data:

1) Insert a floppy disc into the PA
2) With the graphic window active, press the “Graph/List” page button to bring up the “List” window.
3) Press the “Spreadsheet” button below the PA screen.
4) Name the file using the alphanumeric key pad. Using the arrow keys and buttons adjacent to the screen, select “Delimiter: Tab.”
5) Press the “Execute” button below the screen to complete the save.

Spectrum Measurement Procedure:

Initial Equipment Setup:

To measure the spectrum emitted by an OLED, a fiber optic cable connected to the Ocean Optics spectrometer is required. Cables are usually in place, though additional fibers are located in the tall cabinet at the back of Rm 419. Take care not to damage the exposed ends of the cable when

connecting them. Place an OLED on top of the fiber optic assembly on the optics bench, center a single device above the fiber, and make contact using the hard and soft probes. Test contact using procedure previously described.

1) With the computer on, start the SpectraSuite software.
2) End the current, active (default) measurement by clicking the "x" on the window tab.
3) Use the  button to begin a new "absolute irradiance" measurment.
4) Select "New spectra acquisition" and click "next".
5) Click "next" on the following page.
6) Slect "get calibration from file", click next.
7) Select the most recent calibration file, located on the desktop. Click "next".
8) Select a fiber diamater of 1000 or 600 micron depending on fiber, this value is printed on a white strip at one end of the fiber. Click "next"
9) Set the integration time to 250 milliseconds. Set the number of scans to average to 5. Click "next".
10) With the room darkened as previously described, set mouse pointer on top of the image of the black light bulb. Turn off monitor and click mouse to take baseline spectrum. Wait ~3 seconds. Turn monitor on. Click "Finish". Using the buttons above the graph, hit the  button to pause the scan. The spectrometer and software are ready.

Parameter Analyzer Setup:

To measure the spectrum of an OLED, a constant current must be supplied. To do this the PA must be set to provide current, instead of voltage:

1) With the PA on and set up as described previously, go to the "Chan" page.
2) Using the arrow keys, highlight row "SMU1:MP" and column: "MODE". Change setting from "V" to "I".
3) Next go to "Measurement" page. Change the "start" current to .785µA. Set the stop current to +5µA larger (i.e. 5.785µA). The "start" current represents .1mA/cm^2 on a standard size OLED (1mm diameter cathode).
4) Arrow down to "Hold Time" and change this to 100 s. This will force the PA to hold the "start" current level for 100 seconds and will allow plenty of time to measure the device spectrum.
5) Go the "display:" graphics page. The PA is now ready to supply .785µA for 100 seconds. The setup for the spectral measurement is now complete.

Spectrum Acquisition:

1) With the testing room darkened, set the mouse pointer over the  button.

2) Turn the monitor off.
3) Click mouse to take a “dark scan”. (PA and OLED are still off).
4) Either turn the monitor on and click the  button to save the dark scan, or press Ctrl-D to store dark scan. Repeat this procedure a total of 3 times to ensure even spectral baseline. Note: establishing a baseline in this manner is required whenever the integration time is changed on the SpectraSuite software.
5) With a baseline established, set the mouse pointer over the  button and turn off the monitor.
6) Cover the PA and computer tower, such that no light is reaching the fiber optic cable. Using one hand, push the “single” button on the PA (same button used to start the J-V, B-V scan).
7) With the OLED now on, begin the spectral measurement by clicking the mouse.
8) After ~ 3seconds (i.e. integration time x number of scans) turn on the monitor, turn off the PA.
9) To autoscale the spectrum, push the  button. The Y-axis units should be in $\mu W/cm^2/nm$, the X-axis in nm.
10) To save a spectrum, press the  button. Select the file type : “Tab Delimited”
11) Push the “Browse” button. Save the file in the desired location on the computer. To see previously saved files, change “Files of type: …” to “All files”.
12) Repeat the above steps, changing the PA start and stop values to the desired current levels. Consequently, as current density is stepped up, intensity will also increase. If the spectrometer becomes saturated, scale down the integration time, being sure to establish a new baseline.

When testing is complete, turn off the PA by pushing the ON/OFF button, remove floppy disk. Return photodiode, BNC cable, and paper aperture to drawer.