Standard Operating Procedure	
Coral Name: IV-probe (TRL)	
Model: Micromanipulator 6" Probe Station, Cascade DCM-210 Positioners with DCP-150 Coaxial Probes, HP-4156A Parameter Analyzer	
Location: TRL 4th Floor, next to cleaving area, near SAMCO and Acid-hood	

INTRODUCTION

The IV-prober is a DC probe station for device characterization. The system currently uses two probe positioners and a chuck bias can be used to run electrical measurements using an HP4156A parameter analyzer, with up to ±40 V and 100 mA. The analyzer is operated from the associated PC via MATLAB scripts.

This SOP and the associated training on the tool only cover the very basic operation. For any problems, more complex measurements, any extra probes, wires, probe tips, etc. – please contact the staff for further assistance or training.

For training or help, please contact Bernard Alamariu (first name @ mtl.mit.edu), or Jorg Scholvin (last name @ mit.edu).

SAFETY

Probe tips are sharp. If moving the positioners around or lifting them off the platen, do not place them where you can collide with the probe tips – i.e. don't have the tips face you. The HP4156A can set output voltages up to 100V at significant current levels. **DC voltages above 40V are dangerous** and in addition to electric shock can cause blood electrolysis. Above 40V the HP4156A is interlocked. If you need to run measurements in excess of 40V please talk to the staff for additional training, and do not defeat the tool's safety interlock. If high voltages are active, it is indicated by a rectangular light in the top right area of the HP4156A panel.

PROCEDURE

During your training session, you will create a copy of the MATLAB scripts in your home directory. This procedure is outlined in the appendix at the end. There are four scripts for 1) diodes and resistors, 2) BJTs, 3) MOSFETs, 4) Four-point probe measurements. The photo below shows some of the names and locations for the probe station parts. A more detailed view of the positioners and microscope controls will be on the next page.
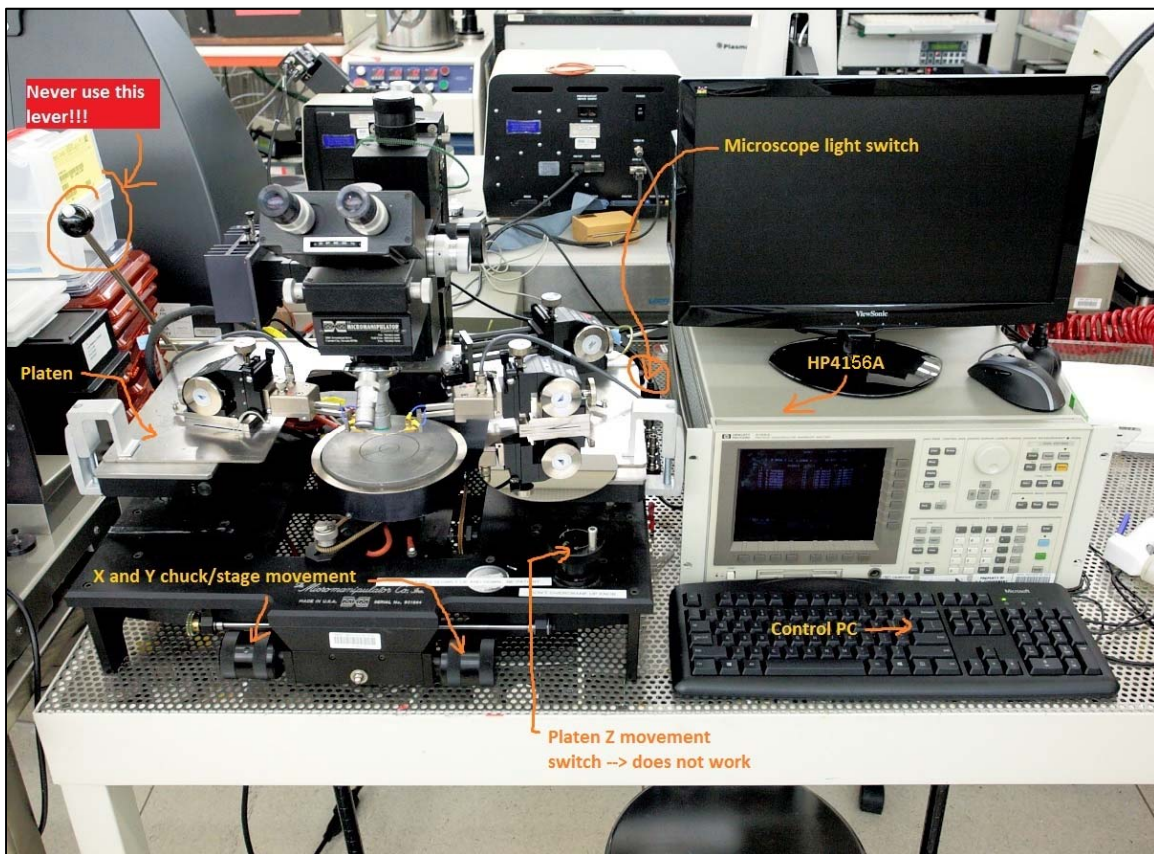
0. Check reservations in CORAL to insure that you reserved the correct machine in the correct facility for the correct date. Another user may have reservations; it is your responsibility to honor them, if this is the case

1. **"Engage"** the machine in CORAL. This enables power to the microscope light. Turn **on the microscope light**. Check that the **HP4156A is turned on**. Please do not program the HP4156A directly, because the unit's display is too weak for effective use. The MATLAB scrips are designed to program the necessary functions on the instrument instead, and allow you to acquire, plot, and save your data more comfortably.
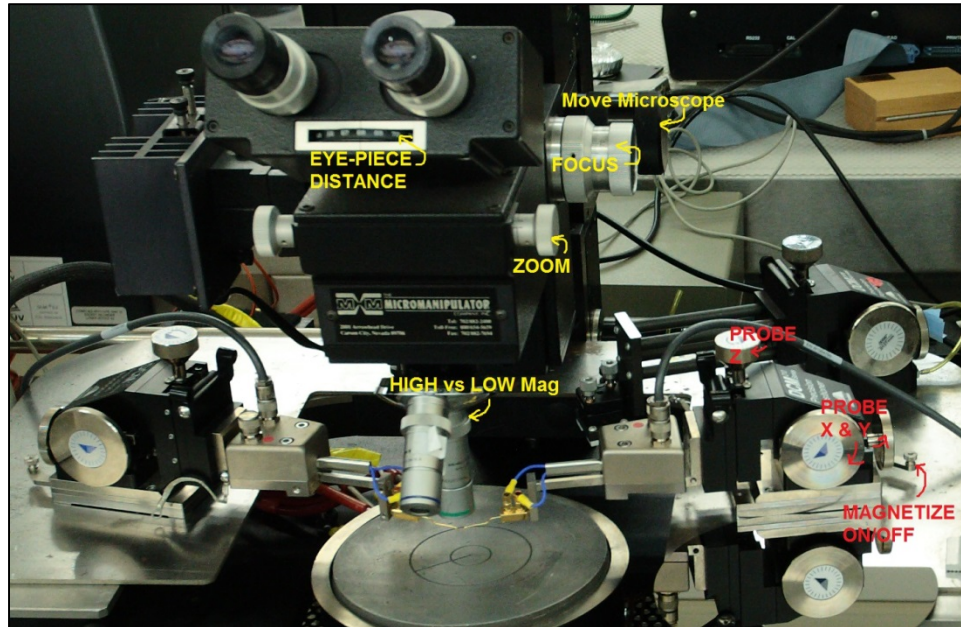
2. Make sure the **positioners are moved up** (e.g. 2 mm above the chuck), to prevent damaging them or your substrate when you load and adjust your sample. The photo below shows some of the detailed microscope mechanisms that we will refer to.

    Note: We have disabled the platen Z movement mechanism, because the movement belt frequently breaks when not used properly, and because incorrect platen movement often results in damage to the probe tips.

    > **CAUTION:** Never use the platen lift lever (see photo on previous page). This lever coarsely lifts up the entire platen, but it does not stay up, and it is a sure way to accidentally damage the probe tips. Always only use the positioner's Z-micrometers to move probe tips up and down.

3. Log onto the PC and **start MATLAB**. In MATLAB (see screenshot on next page), navigate to the path that contains your test program, and open the appropriate command file (1). Edit the test program(s) that you will need: In the editor (2), adjust any start/stop sweep values, following the commented instructions in the file. If you mix up the windows (e.g. accidentally close some) in MATLAB, use the "Layout" tab (3) to revert back to the "Default" arrangement (4). To start a test program, type the filename in the command window (5). You can do a dry run now to see that the GPIB bus communication with the HP4145 is working. **The left probe is SMU1, the right probe SMU2**.

    > **Please:** Do not change the cabling on the system (e.g. the SMU-to-probe wiring). It will cause problems and confusion for all other users. The choice of the SMUs can be configured in the MATLAB scripts instead. Note that the SMU number is also written on a sticker attached to the cables coming from the HP4156A.

4. Set up the probe station and load your sample: Check and if needed **zero the X- and Y-axes** on the positioners. Adjust their location on the platen so that probe tips are close enough (e.g. **2-3 mm apart**) together to reach your device when adjusting X and Y. Often they are already in a good place and no action is needed, but some users may have moved them to accommodate larger devices. Be careful not to place the tips too close together by hand, since it can result in accidental crashing of the tips into each other. Fine adjustments will be done with the micrometers, and not by moving the positioners around on the platen. When moving the positioners, make sure to unlock the **magnetic fasteners** (by flipping the "magnetize on/off" lever identified in the photo above) and then gently move the positioners around – otherwise they are hard to move and the excess force you will apply can
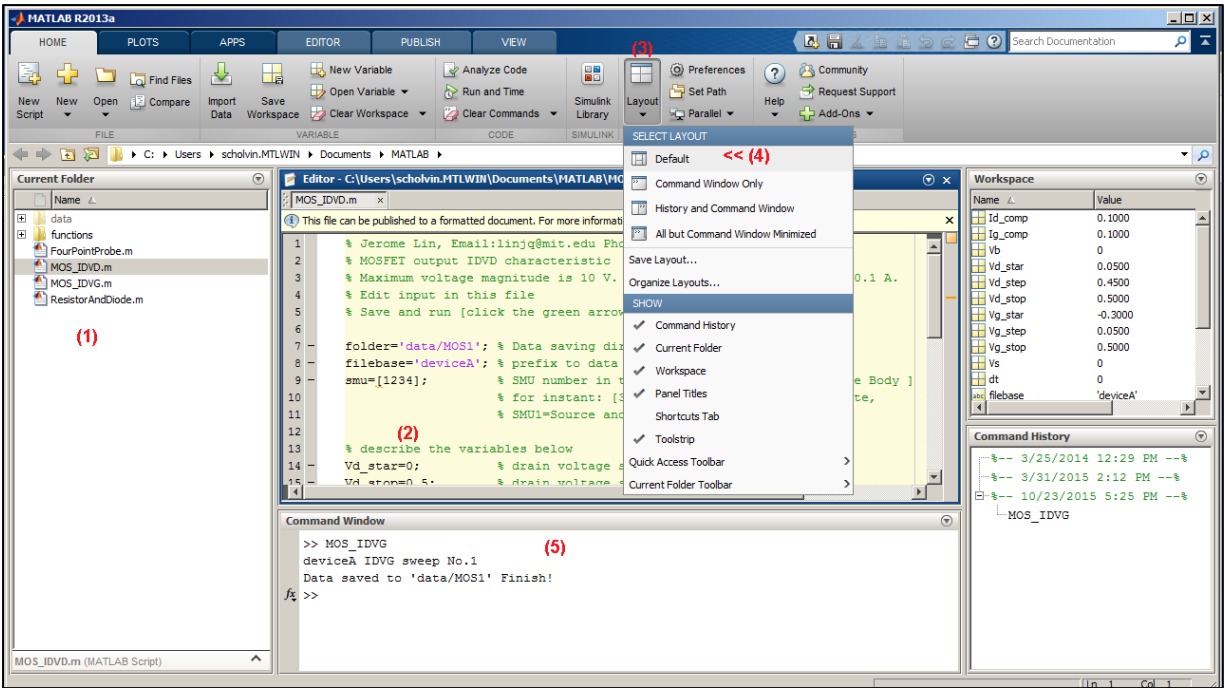
damage the micrometers. Also remember that the microscope can be moved in X and Y. Check that the **microscope position is centered in X**, and moved **back in Y** (away from you). See the above system photo for the microscope movement knobs. The reason for this position is to allow the probe tips to reach the sample, and to allow you to later switch the objective if necessary.

5. Check again that the probe tips are sufficiently high up, and then **load your sample**. Place sample on chuck and adjust the sample and the move the chuck as needed. Always pay attention to the probe tips so that you don't accidentally run the tips into your sample (which can scratch up and damage your devices and the probe tips). Please do not use the probes when there is photoresist or other organics near the test sites, because the residues quickly clog up the probe tips.

> **CAUTION:** While the chuck can rotate, the associated tubing for temperature control can be easily damaged when it is rotated out of position. Therefore, please check that the chuck is rotated the right way before. See left photo below marked (A), and adjust your sample's orientation manually – leaving the chuck rotation for minute adjustments only.
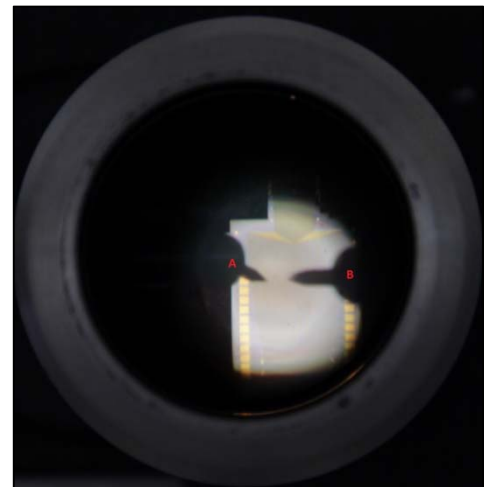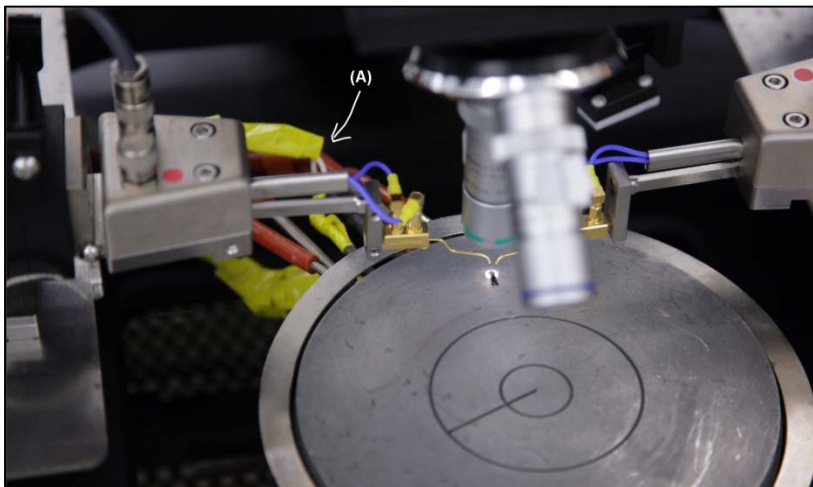
6. Focus the microscope on your sample, find a device to test, and then **lower the probe tips** one at a time, and adjust their X and Y position. **If you can't see the tips** (initially as dark shadows that move into focus as you lower them), then stop - you need to first adjust the X and Y to be in the field of view. Otherwise you won't easily notice if you lower them too far. Typically, you will do 1) move the tips so they show up as diffuse shadows in the field of view, 2) start lowering them until they almost touch the sample, 3) move them into position above your test pads, 4) lower them to touch the device (next step). The right photo above shows the left tip in focus

(labeled A), while the right tip is still higher up and out of focus (labeled B). If you use the high magnification, that diffuse shadow will be a lot weaker than what you see in the photo.

> **HINT:** To switch the microscope objective, **do not** rotate the turret while the objective is between the probe tips. There will not be enough room to rotate, even if you move the microscope zoom up, and you will bump into the probes causing damage to them and your device. Instead, use the microscope movement knobs to move the microscope towards you. Now, with the objective out of the way of the probe tips, you will be able to rotate the turret without problems.

7. Lower the probe tips to **contact your device**. The probe tips should be in focus with your device, and you should see the tips move forward slightly (called "overdrive"). The overdrive should be very small: you are looking for just a very tiny movement of the probe tip, and it should not "skate" along the pad. Also note that for small samples, the first probe tip to contact the sample can push it forward. Again, lower the probe tips one at a time, and stop as soon as you see either the probe skate on the sample or the sample move from the probe pressing on it.

> **CAUTION:** Once the probe tips are contacting the sample, be very careful not to bump into the system. Vibrations and shocks are bad news for the contact quality, and can also damage the tips. Moving the chuck is particularly bad, because the tips will scratch your sample and also get bent.

To move to a new device always raise the probes with the Z micrometers, and then either move the probes with their X- and Y-micrometers (if the new device is nearby in the current field of view), or use the chuck movement for adjusting the sample for larger movements.

> **Design Hint:** A brand-new probe has a 5 µm diameter tip. But that does not translate into the ability to measure pads of that size. Wear-and-tear or improper use can also dull the tips. Therefore, for test pads to your device, a 100 µm sized square or larger provides a very comfortable space to land the probe on – and it gives you extra room in case you wear down the pad from repeated probing. You can use smaller pads if necessary, and pads down to 50 µm can still be probed. But even smaller pads become increasingly challenging to measure. We recommend pads of 100 µm or larger, so that you have an easy time to probe and are tolerant to different probe tip conditions.

8. **Run your measurement**. See step 3 above for details on MATLAB. After you start a command, you should see some activity on the HP4145 screen while the MATLAB script is configuring the system and begins the data acquisition. Once measurements are complete, the command prompt will tell you, and a plot window with the results will show up – depending on which program you ran. All **raw data and the plots will be saved** automatically in your "data" subdirectory, with the filename prefix that you specified in the MATLAB script. This allows you to come back to it later, and use the data for further processing and analysis. The saved plot image is not of publication quality, but is intended for you to have a thumbnail view of the measurement data. We suggest you clean up your directory before any important measurements and set a good filename prefix, so that later you will remember what the data was about.
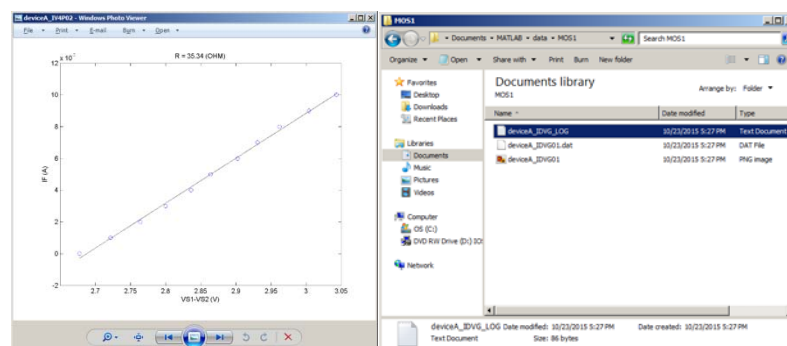
9. To measure a different device, use the Z micrometers to **lift the probe tips**, and **reposition** the stage to the new device. The tips should be lifted enough to avoid accidental scratching of your If the device is already in view, you can just use the X- and Y- micrometers instead. The stage positioning may not be accurate enough to exactly land the probe tips over your pads. Use the X- and Y-micrometers to do the fine positioning. Then **lower the probe tips** (i.e. step 7) and continue with a new measurement.

10. Once you are done, or when moving to a far out wafer location, use the Z micrometers **to raise the probe tips** to 2-3 mm above your sample, and then unload your sample. Move the chuck towards you if needed and then slide

the sample out. Be careful with wafers, and avoid tilting it as you lift since that may crash your wafer into the probe tips.

11. **Turn off** the microscope light. You do not need to turn off the HP4156A.

12. **"Disengage"** the machine in CORAL. In the comment field, please **describe the probe tip condition**. This helps us track the state of the tips and when to replace them. Please be specific: e.g. if the tip was not in great shape, if dirt had accumulated on then, if you had difficulties measuring with both tips on a gold pad, if you noticed that you accidentally jammed or scratched it across your substrate, etc.
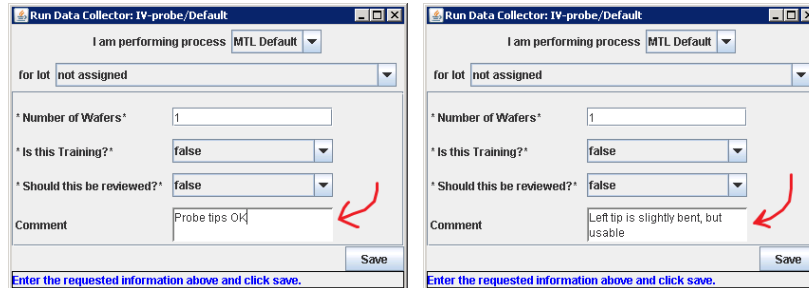
13. **If the probe tips are damaged**, please report that as a "Report Problem" in Coral. If you are not sure if the tips are in good shape or not, please report this as a "Comment" in Coral (not the comment field when you disengage, but the "Equipment Action" menu, "Make Comment" entry). Because of the many different ways in which people use the system, do not use the "Shutdown" to report a problem with the probe tips.

APPENDIX: SETUP OF MATLAB SCRIPTS

The first time you log into the PC with your MTL windows account, you will need to copy the MATLAB scripts to your own folder, so that you can make modifications as necessary. For this, copy the contents of the folder called "c:\ScriptsReadOnly" to your own directory. You can, for example, create a folder on your desktop for this. After copying the file, you can start MATLAB by opening one of the scripts in that folder. The files are initially set as read-only, and you may want to save them under a different name, or remove their read-only attribute in your own folder.

OTHER NOTES:

1. Please do not install any software on the PC. The PC is for probe station use only, and not a general purpose PC. Please use the other lab PCs for that.
2. Not all metals are easy to probe. Gold is great since it's soft and the probe can dig in easily. Aluminum is a good choice, but is more vibration sensitive (as it oxidizes and accumulates on the tungsten probe tips) – and the contact resistance can increase over time (e.g. after a few minutes or after you rattle the table). Whether this matters depends on your device. If you see such an increase, don't just dig the probe tips in deeper (not great for the probes), but instead move them up in Z, and then adjust slightly to a new position and lower them down again. In those cases, be prepared – get ready to run the measurement program, then lower the probe tips, and start the measurement. If you're really worried about this, run a second identical measurement and compare the data.
3. Depending on the pad material, the metal thickness sufficient for probe pads can be made quite thin. A good thickness for gold pads is 100 nm, although we have probed resistor structures with gold films of 50 nm and less. Especially if the pads are large (e.g. >100 µm), you can use thinner films because the pad will be large enough to offer places to probe even when repeated probing causes some wear.
4. The Cascade part number for replacement probe tips is 107-158.

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