INTERFACING MICROMANIPULATOR PROBER TO HP4284A LCR METER

Application Note

Abstract

This Application Note discusses recommended connections for the Hewlett Packard 4284 LCR meter to insure accurate and consistent C-V measurement results with Micromanipulator probing equipment. Two-point wafer surface to surface measurements will be discussed as well as measurements that incorporate the prober chuck for stations with and without Kelvin wiring. In each case, recommended probe/chuck connection to the HP4284 LCR meter will be explained in detail. In addition, general setup considerations will be discussed. This Application Note assumes that the reader is familiar with the concepts of C-V measurements and the operations and features of the HP4284 LCR meter.

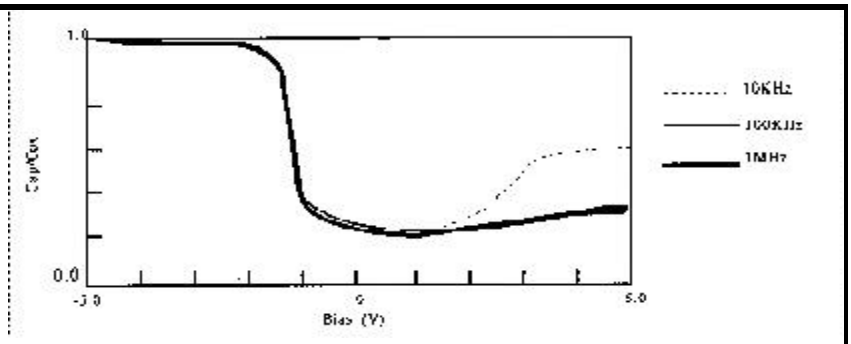

Figure 1; Multi-frequency C-V characteristics of a typical MOS type semiconductor

Introduction

A very common application for probe stations is *Capacitance* versus *Voltage* measurements of MOS devices. Typically referred to as C-V measurements, they are used to see how the Capacitance of a device varies with changes in Voltage. C-V data can include information about composition, process quality, and material interaction. Accuracy of C-V measurements is crucial for product design and process control in production environments. Figure 1 is a graphical presentation of an example C-V measurement through a broad frequency range and of the cleanliness of C-V measurements that can be made with Micromanipulator equipment if the proper setup and techniques are employed.

General Setup Considerations

When setting up your C-V system, the following items should be considered to insure the accuracy and consistency of C-V data.

1. Shunt LCR meter common connections in close proximity to the DUT. Shunting the LCR meter commons as close to the DUT as possible actually brings the vector ammeter in series with the DUT and connects the shields of the LCR meter high and low terminals "across" the DUT preventing "dead legs" in which unwanted currents may be induced.

2. Insure that the substrate of your DUT is ALWAYS connected to the bias (high) terminals of the 4284 LCR meter when performing surface to substrate measurements.

Insuring that the substrate of your sample is connected to the high terminals of the 4284 is essential for insuring clean and accurate C-V data. Figure 2 shows a general DUT construction for a capacitive element.

The connection of the substrate to the high terminals is important because the low terminal of the 4284 is the current vector ammeter for the HP4284. The high terminals are the bias source. The substrate is much larger in area and therefore will carry more stray noise. By connecting the bias (high) terminals to the substrate, and the ammeter (low) terminal to the DUT, the noise injected into the substrate will not be detected by the ammeter and therefore will not result in noisy data. This is illustrated by figure 3B.

3. When performing surface to surface measurements that do not incorporate the probe station chuck, insure that the chuck surface is referenced to the single-point ground discussed in General Setup Consideration number 4. The chuck should be tied to ground to prevent erroneous readings that include the back oxide to chuck "capacitor" that is formed when making surface to surface measurements. By grounding the chuck surface, you insure that any capacitance formed between the chuck surface and the wafer does not effect measurement data. If the chuck surface is left floating, stray capacitance will be allowed to effect measured data. This is illustrated in figure 3A.

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4. Always insure that the probe station, chuck, light tight enclosure (if being used), and LCR meter are referenced to a single-point ground. 8000 series Micromanipulator probe stations are equipped with a single-point ground access point. In addition, Micromanipulator light tight enclosures (LTE) are equipped with a single-point ground connection that may itself be referenced to the probe station ground. The HP4284 meter also provides a chassis ground connection on the front panel. It is recommended that all of these ground points are referenced to a single location to avoid common ground loops.

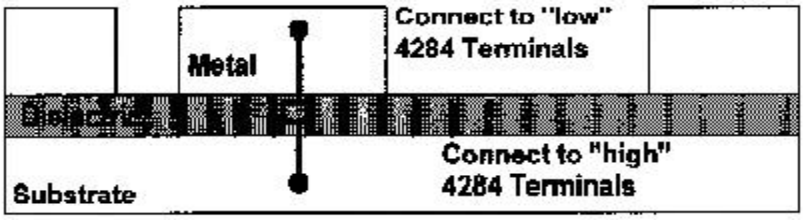
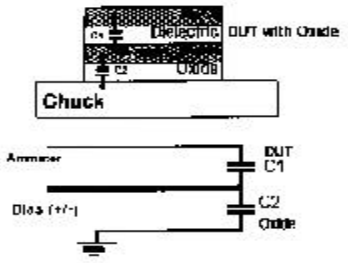
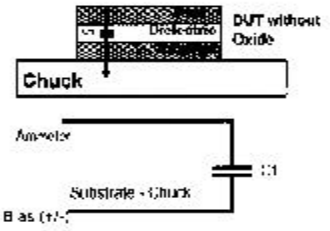


Figure 2; General DUT construction



Results in increased capacitance if chuck is not grounded and floats

Figure 3A



Results in less noise, ammeter sees smaller area probr current, not larger chuck with possible stray or induced noise

Figure 3B

Again, it is also recommended that if the chuck surface is not an active part of the measurement (i.e., as in figure 3A) that it too be grounded to a single-point ground. The grounding of the chuck surface is important if it is not an active part of the measurement because a capacitor will be formed by the substrate, the oxide that exists on the bottom of the wafer and the chuck surface (see figure 3A). This represents a parallel capacitance attached to the DUT circuit, and if the chuck floats above the bias voltage, the 4284 will see an increase in capacitance levels. By insuring that the chuck does not float and is properly grounded, the effects of this parallel capacitance will not effect measured capacitance levels.

5. Exploit the OPEN/SHORT/ LOAD compensation functions of the HP4284 LCR meter.
The OPEN/SHORT/LOAD functions of the LCR meter minimize errors that may be introduced by the probe station or cabling by canceling their effects. For more information about using these functions, refer to the HP4284 users manual supplied with the LCR meter.

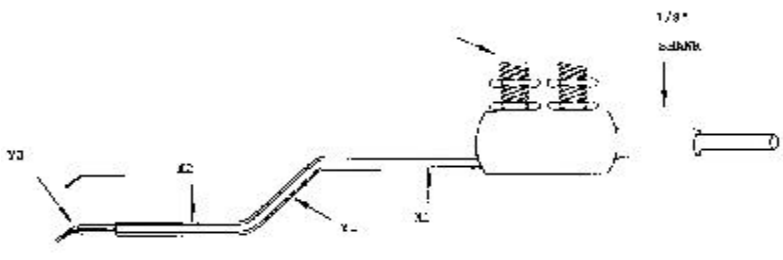
Two-Point Wafer Surface Measurement

Two-point wafer surface setups are usually the easiest setup for C-V measurements. Two-point surface measurements allow an engineer to connect two Kelvin style probes directly to the HP4284 LCR meter front panel connections.

An example of a two-point wafer surface measurement is a measurement made on a PWell device, where both the N and P material are accessible from the top side of the wafer. These types of measurements do not use the chuck surface to make connections to the device as there is usually an insulating oxide on the back side of the wafer. With such a setup, however, as discussed in the special setup considerations section of this application note (see General Setup Consideration number 3 and figure 3), the chuck can still effect the measurement data taken by the LCR meter. Therefore, as shown in figure 5, the chuck, chuck surface, probe station, LTE, and LCR chassis connection should be referenced to a single-point ground for surface to surface measurements.

Micromanipulator recommends using model 44-J probe holders for two-point wafer surface measurements. The model 44-J probe is constructed using a single-point with two external female UMC

Figure 4; Coaxial model 4-J probe holder



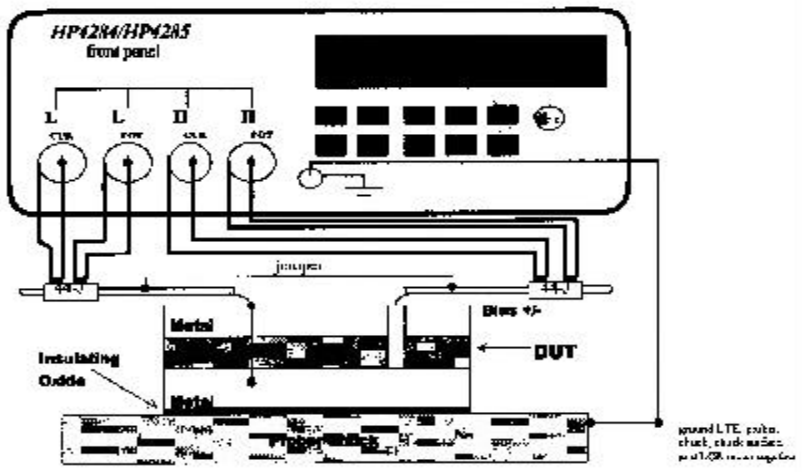


Figure 5; Two-point wafer surface CF measurment with model 44-J coaxial probes.

coaxial connections. Figure 4 is an illustration of a model 44-J holder.

Figure 5 illustrates the recommended hookup for two-point wafer surface measurements with model 44-J probes. Notice that figure 5 shows the substrate of the wafer is isolated from the prober chuck surface. Two UMC to BNC patch cables (Micromanipulator p/n 49-30) are used to connect each probe to the LCR meter. In addition to the "high" and "low" terminal connections, a small jumper wire has been connected between the two model 44-J probe bodies. The jumper wire shunts the LCR meter shields as close to the DUT as possible.

To connect the HP4284 using the Micromanipulator model 79-D holder (constructed using a single probe tip and two external BNC cables), the same setup illustrated in figure 5 would be used with a few minor changes. To use the 79-D holder, the engineer would not be required to use the model 49-30 UMC to BNC patch cables. The 79-D has BNC coaxial cables hard wired directly to the probe holder, as illustrated by figure 6. Also, the 79-D probe holders are equipped with small alligator clip grounding wires that can be connected together to allow shunting of the LCR meter shields.

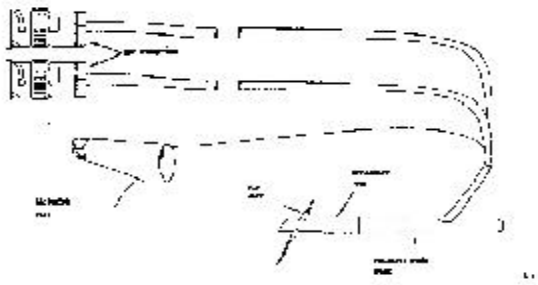


Figure 6; Coaxial model 79-D probe holder.

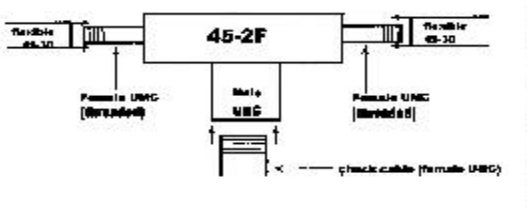
C-V Measurements through the Prober Chuck

C-V measurements from the top of a wafer through the prober chuck are also fairly easy to setup. There are two possibilities for this type of C-V measurement that are dependent on the probe station setup. The probe stations can be either 1) configured with Kelvin wiring, or 2) not drive configured with Kelvin wiring. "Kelvin" refers to a system with both force and sense connections for the probe station chuck.

If you have a probe station that has been configured with Kelvin wiring, figure 8 illustrates the recommended 4284 hookup. A key point to figure 8 is the connections to the thermal chuck. In figure 8 the chuck is not isolated from the DUT and is therefore an active part of the measurement circuit. The thermal chuck Kelvin connections are connected to the "high" terminals of the LCR meter. Additionally, a jumper wire from the chuck connection and the probe holder has been connected to shunt the LCR meter shields in close proximity to the DUT.

Figure 9 shows the recommended hookup for probe stations that are not configured with Kelvin wiring (force and sense connections). Figure 9 also shows the use of Micromanipulator part number "45-2F". 45-2F is an adapter that has two (2) female UMC connections and one (1) male UMC connection as illustrated by figure 7. Micromanipulator thermal chucks are equipped with a female UMC connection. Once the thermal chuck female connection is connected to the male UMC connection of the 45-2F adapter, two (2) model 49-30 patch cables are required to connect to the "high" terminals of the LCR meter. Also notice that a small jumper wire has been connected between the 45-2F adapter and the probe holder to shunt the LCR meter

Figure 7; 42 2F adapter.



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commons as close to the DUT as possible. If your are using the model 79 probe holder, the jumper wire is not required because the model 79 holders are equipped with small alligator clip grounding wires that can be connected to the 45-2F body.

Summary

This Application Note has discussed how to use Micromanipulator probing equipment in conjunction with the HP4284 LCR meter to measure Capacitance versus Voltage characteristics of semiconductor devices.

Two-point wafer surface measurements have been discussed as well as measurements through the prober chuck for stations with and without Kelvin wiring. In addition, this Application Note has explained general setup considerations for C-V measurements.

What should you look for if you are experiencing problems?

- Is your DUT substrate connection connected to the 4284 "high" terminals if you are performing surface to substrate measurements?
- Is your probe station chuck surface and chuck grounded if you are making surface to surface measurements?
- Do you have ground loops in your system (i.e., are you conforming to a single-point ground scheme)? Your probe station, LTE, and test equipment should be referenced to the same ground location.
- Are you using Kelvin style probes and are the shields of the 4284 shunted as close to the DUT as possible?
- If your chuck is not active in the measurement setup, has it been grounded?

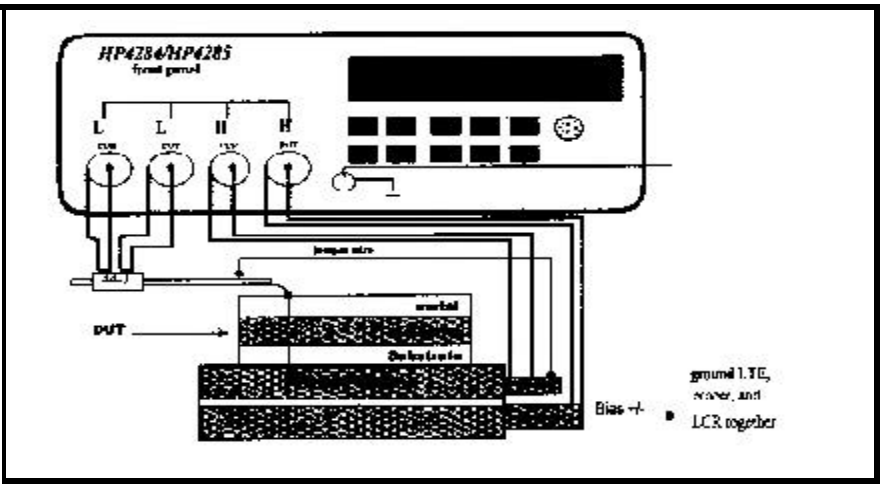

Figure 8; Hook-up for probe station with Kelvin wiring.

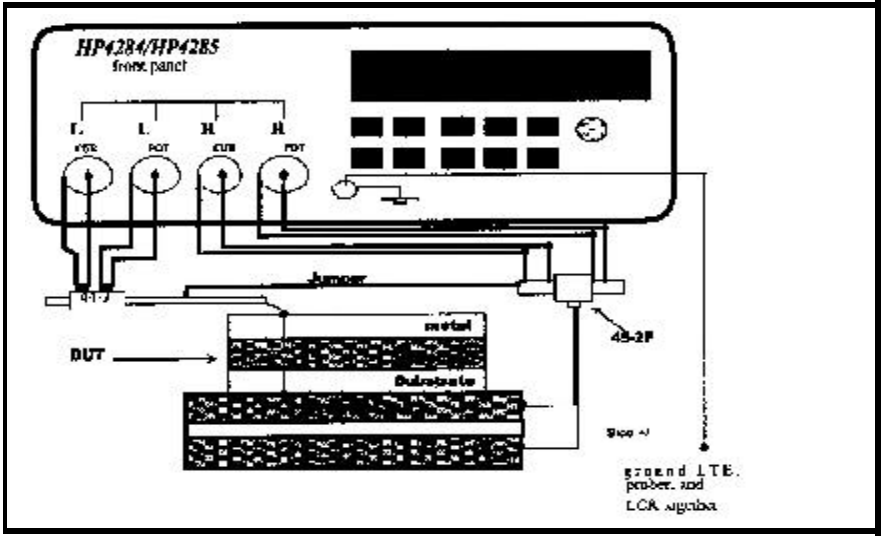

Figure 9; Hook-up for probe station without Kelvin wiring.

- Are you making the mistake of turning off the drive motors or thermal chuck controller to make clean measurements? Turning off themotors on a Micromanipulator semi-automatic or motorized station is not required in order to obtain clean measurements. Turning off the thermal chuck is also not required. If you need to turn off the motors on the probe station in order to lower the noise levels seen in you measurement, your station and measurement equipment have not been properly setup. Turning off drive motors or thermal chuck controllers actually increases noise levels because the internal filtering functions of probe station and thermal chuck controllers are disabled.

Further Reading

- Application Note 369-5: *Multi-frequency C-V Measurements of Semiconductors.*
- *HP4284A Precision LCR Meter*, Hewlett Packard Corp.
- *Hewlett Packard 4284A Operators Reference Manual* (HP part number 042084-90020).
- *Probe Tips and Probe Holders Reference Manual* (Part number A1009784). The Micromanipulator Co., Inc.

Acknowledgments

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