Contact Resistance: Kelvin Probes vs. Osmium Tip Probes. 9/14/2015

Misunderstandings exist in the semiconductor industry in regards to the measurement accuracy in TLP and VFTLP systems using 2 wire vs. 4 wire (Kelvin) DUT connections. The following information provides some history on the subject, and is our attempt to provide meaningful information regarding correct application, and hopefully eliminate this widespread confusion.

The semiconductor industry has used tungsten tip needles because its extreme hardness maintains tip sharpness longer than softer metals. A few ohms of contact resistance are acceptable for high resistance leakage current or IC circuit operation measurements. While we were developing the first commercial TLP system for wafers the contact resistance problem inherent with tungsten needles immediately became obvious. We found that cleaning the oxide from the tungsten shank and tip eliminated the contact resistance problem for a few hours. However less than six hours later an objectionable surface oxide returned that added its resistance to the pad contact and added errors to the TLP data.

The added contact resistance prevented our using tungsten needles, because it simply could not achieve the accuracy we require in our TLP Systems. A simple search for a better metal found that osmium tip needles did not have resistive surface oxides and produced zero metal to metal contact resistance. We have supplied osmium tip needles with our TLP system since then and have told anyone interested how well they work. Not only does Osmium have no resistive surface oxides, it is harder than tungsten and holds its tip shape longer.

The simplistic 2014 ESO/ESD paper on added contact resistance caused by tungsten surface oxides outlined the basic problem of using two "tungsten" needles in TLP test systems, while promoting 4 needle Kelvin probing.

Achieving low needle contact resistance to pads on wafer determines how well TLP and VFTLP system can measurements the low resistance of circuit operation. Low contact resistance is needed for accurate low resistance measurements in ESD protection circuits where contact resistance must be much less than 1/10 ohm. The contact resistance added by oxides on the tungsten needle surface adds resistance to metal to metal contacts is a well known fact in many electrical industries. The surface oxide can add a fraction of an ohm, to two ohms of nonlinear contact resistance to measurements.

Four tungsten needles in a Kelvin probe configuration reduces contact resistance to pads. However putting two needles on each pad typically requires larger pads. A single osmium tip needle provides low contact resistance to standard bond-wire sized pads.

This recently published paper discounted the use of 2 "tungsten" needles setup for TLP measurements in favor of 4 wire Kelvin probing which eliminates the tungsten tip oxide problem. Unfortunately, the author's did not describe any attempt to find or test other needles that do not have oxide problems. Their lack of investigation did not identify the needle alternative many in the industry have used since TLP testing began. A complete and more useful paper would have included the osmium tip needles that Barth has supplied with its systems since producing the first commercial TLP system 15 years ago. Osmium tip needles have been used successfully and continue to be used for low resistance probing with just two needles in many TLP measurement systems.

The ESDA Working Group on TLP, during the TLP standard writing process, added the description of using four Kelvin needles as a solution to achieve acceptable contact resistance to the circuit's pads; but unfortunately it is the only method identified in the TLP and VFTLP standard. Simple two osmium tip needle connections are in widespread use. They are effective and accurate alternatives to the more complex four needle Kelvin probes, and their use should be added to the TLP standard. The standard should also specify that Kelvin probes must be used with tungsten needles; but they are not needed with osmium tip needles.

The need to eliminate needle contact resistance is just as important in VFTLP testing. Because VFTLP has the additional requirement for higher speed measurements, the connection method requires that needles are designed specifically for high speed, 50 ohm connections.

Our VFTLP system uses 40 GHz fixed needle spacing test heads with metals that have no surface oxides. They exhibit less than 0.03 ohm contact resistance while providing extremely high speed pulse delivery and measurement. These needles have faster response than is possible with oversize pads needed to accept 4 needle Kelvin probes. The more complex four needles on two pads required by Kelvin probes will have a limited test pulse risetime in VFTLP testing. It has yet to be demonstrated that Kelvin probes can provide 6 GHz bandwidth scope speed used in VFTLP testing. Trying to obtain this 6 GHz bandwidth with four needles is probably impractical at best and may not be achievable.

Building special test circuits with larger pads for Kelvin probes can delay TLP testing ESD protection circuits. Our TLP system provides accurate data with absolutely minimum contact resistance with just one osmium tip needle on each pad. The use of high speed connections to CDM protection circuits is another issue that should be addressed in the standard.

Osmium tip needles have been used by many people with excellent results for over 15 years and because of their simpler operation is often the connection method of choice. There are many other factors in TLP/VFTLP instrumentation systems that determine measurement accuracy, watch for information from us on these topics in the future.

Jon Barth