Q&A

Tesla On-Wafer Power Device Characterization System

Why is this announcement important?

For years, Cascade Microtech has heard requests from the power semiconductor device industry to provide a means of on-wafer probing for their devices. Up until now, power device manufacturers were forced to package their devices prior to testing due to a lack of support for higher voltage and current testing from probe station manufacturers. This was a problem because it adds time and cost to the development schedule and gives them no real option for KGD sort. Cascade Microtech's Tesla on-wafer characterization system for power devices is the solution to this challenge. Unlike existing methods that require high voltage or high current testing be performed in package, the Tesla System opens the door for on-wafer characterization of power devices thus saving huge amounts of time, cost and in the end enabling a faster time to market.

The world market for power semiconductors has grown from $4.94 billion in 1996 to in excess of $20 billion in 2006 and is expected to continue to experience double digit growth for the next few years. This strong growth is largely driven from traditional power semiconductor device applications such as power transmission and traction appliances like trains. However, in the past few years increasing requirements for more efficient power utilization in the automotive and electronics industry has created a stronger demand for power semiconductor devices. Today power semiconductor devices are manufactured by all of the world's major fabs. Some fabs, like International Rectifier and Fairchild Semiconductor have based their entire business on the production of power semiconductor devices.

What is a power semiconductor device?

Power semiconductor devices belong to a separate segment of the mass semiconductor application market, differing both in production technology and in end-user applications. Power devices are typically characterized by their ability to accommodate higher current density, higher power dissipation and/or higher reverse breakdown voltage. A power device can be defined as any device that can switch at least 1 A (with power dissipation of > 1W @ 25°C). The most common types of power devices are the power MOSFET, BJT, Rectifier, Thyristor, and IGBT.

Power devices are sold in either discrete or module form. Discrete devices are stand-alone components for example one PowerMOSFET. IPM or intelligent power modules are integrations of discretes and/or modules with logic in a single package.

What is the probing challenge?

The power device industry is always striving to develop the "ideal switch" - a device that blocks high voltages in the off state, exhibits zero resistance in the on state, and has unlimited switching speeds, low cost and other desirable characteristics. Though the ideal is unattainable, the pursuit of ideal performance has driven the industry towards an optimization of these parameters.

Current-generation probe station configurations are designed for low voltage and current, limiting their ability to be used in conjunction with the full capabilities of power device instrumentation (curve tracer, Keithley 237/238). When power device manufacturers run measurements on-wafer they are only able to utilize a subset of the instrument capabilities with current probe and probe station equipment.

Safety is another big challenge for power device developers. With power devices requiring anywhere from a 20V to 300V measurement condition, this becomes a dangerous task for the operator.

In addition, the wafer has decreased in thickness over time. Average wafers today are between 100 and 150 microns thick. This adds an additional layer of complexity in on-wafer device characterization as thin wafers are very difficult to hold down on a standard wafer chuck. These thin wafers will curl at the ends or "potato-chip". This is very problematic for wafer probing and in particular in order to get low contact resistance between the wafer and the chuck.

As engineers drive the ON state resistance to lower and lower levels in pursuit of this ideal power device, the Rds(on) measurement becomes tougher to attain and next to impossible to perform on-wafer. This measurement measures the resistance of the drain in the ON state. The on-state resistance is an important spec to differentiate one manufacturer's chip as superior to other solutions and thus command a premium.

Engineers are also trying to increase the amount of voltage a switch can block in the off-state. Currently on-wafer probe station equipment can only handle up to 500V. Test technicians need to characterize the power device at up to 5 times this in order to get an accurate blocking voltage curve. Although there are instruments that can support up to 1100V on-wafer, the probes and probe stations do not.

How do test engineers perform their test today?

Today, power device developers are shackled with the requirement to test their devices in-package as opposed to on-wafer. This translates into longer development times and higher cost of production. Typical semiconductor device development follows a process where the device is designed, characterized on-wafer, models are extracted, and then it heads off to production to be processed for mass manufacturing.

With power devices this process is slightly different. Power devices require higher voltages and currents to characterize their parameters. Existing probe station equipment does not provide the capability to test devices at these high currents and voltages. In addition, there is a lack of commercially available test instrumentation for on-wafer device characterization. Thus the power device is forced to follow a different path of development.

Power devices must be sent out for packaging prior to characterization and model extraction. This is an extra and often time-consuming step to add to the schedule. This means that the devices for characterization need to compete with the devices for sale, and sensibly usually get a lower priority on the production line. According to one engineer this process has delayed him up to one year.

Some device characterization labs have designed their own system by piecing together several components. This approach presents a problem in safety among other things. Test technicians are consumed by building a test system instead of performing their primary role, testing devices. Too add to it, this time-consuming process not only consumes tester time, it tacks on unnecessary time to the schedule. And it comes at a risk that 1) the development may not meet the device technical needs, and 2) it may not have the required safety protocols in place.

What is the Tesla system?

The Tesla system bundle for on-wafer probing of power semiconductor devices is a turnkey system that includes everything you need to make power device measurements on-wafer.

System includes:

- Summit 12K Semiautomatic probe station with low noise performance package (microchamber, attoguard)
- Power device thermal chuck optimized for minimal chuck to wafer contact resistance and thin wafer mounting
- High performance thermal controller and chiller system
- Safety interlock system
- Probe station control package including system controller and software
- Hands-free digital imaging system featuring eVue™ digital imaging system 40X remote focus and motorized microscope bridge-mount with 2x2 programmable focus
- Three high voltage probes, probe positioners, and replacement tips
- Two high current probes, probe positioners, and replacement tips
- High voltage/current triaxial cable package including probe-to-panel and panel-to-instrument cables
- Cable interface panels

Why should I buy a Tesla system from Cascade Microtech?

As the leading provider of on-wafer measurement probe stations and probes, Cascade Microtech is a natural to provide these capabilities to the power device industry. As with all Cascade Microtech products, a focus on the measurement has produced a system that anticipates the needs of the test technician and provides a solution to those needs. Careful attention has been given to providing the utmost electrical performance while enabling this long awaited capability in a user-safe system.

How does the Tesla system handle such high currents?

The break-through high current probe has been developed to reduce probe and/or device destruction at high currents. The probe can support an amazing 10A of current in continuous mode and up to 60A of current in pulsed mode. This is no small feat considering that the probe tip is designed for pad sizes as small as 850um2.

Typically, when a high current is applied to a device the device will heat up. This device heating is often referred to as an isothermal effect. In order to reduce the amount of heating in a device, the test technician will often use a pulsed current measurement. Even in this case, at very high currents, on the order of 10A or greater, the device will experience some level of heating. This device heating causes a build up of residual capacitance that can impact the measurement accuracy. In order to reduce device heating, the probe tip has been designed to minimize contact resistance at the wafer to probe interface. In addition, the probe also has a means of distributing the current over a multiple contact points that are joined with a relatively massive hunk of metal that is used to pull heat from the probe tip.

For added convenience, the probe features a replaceable tip design that can be interchanged as residues build at the tip, ensuring a low contact resistance at the tip.

Can I make a low leakage measurement at high voltage?

The Tesla system also features a high voltage probe that ensures operator safety and a high performance electrical measurement path. The high voltage probe provides the capability to make a coaxial measurement up to 3000V and triaxial measurements up to 1100V. In addition, the probe features a replaceable tip that can be easily interchanged as contaminates build at the tip affecting the accuracy of the measurement. This never before available functionality makes it possible for device engineers to understand more of the characteristics of their device in the off state, enabling a premium price sort for devices with superior leakage handling capabilities.

Will the Tesla chuck properly hold down my thin wafers?

The Tesla chuck provides state of the art handling for thin wafers. We call this technology our Vacuchannel™ chuck. An innovative vacuum pattern provides the right amount of vacuum in a delicate method that protects against wafer breakage and probe damage. With a highly polished gold top surface, its design supports a low contact resistance between the wafer and chuck enabling the most accurate backside connections. In keeping with the market for power devices, the chuck supports 3", 4" 6" and 8" wafer diameters. As with all Cascade Microtech products, the wafer chuck is designed with superior performance in mind and provides a low-noise, environment for low-level triaxial measurements.

Do I need to build custom cables to connect with the Tesla system?

To complete the solution, Cascade Microtech Tesla system provides an end-to-end answer to the high voltage and high current measurement needs. The Tesla system takes care of the cabling from the instrument to the probe; providing highly insulated and electrically guarded and shielded cable assemblies that provide both triaxial performance and high current / high voltage handling capabilities. In addition to the system's cable assemblies, Tesla provides the necessary interface panels that offer ease of measurement in a convenient and intuitive design. Each and every component in the measurement path and measurement environment has been designed and tested to comply with up to 3000V. Layers of safety interlocks are provided to ensure operator safety.

What are the available instruments for power device characterization?

- Keithley 237/238
- Keithley 2400 Series
- Keithley 2600 Series
- Tektronix CurveTracer model 370/371
- Agilent 4142

What factors affect contact resistance?

There are two major factors to consider when looking at contact resistance for on-wafer power device measurements; first is the wafer to chuck contact resistance. In order to make a good Rds(on) measurement, it's required to keep this value as low as possible. The Tesla system minimizes wafer to chuck contact resistance in two ways; first by providing highly polished gold chuck top surface and second through a superior vacuum pattern that provides the optimal wafer hold-down even for today's thinnest wafers.

The second factor to consider is the probe to pad contact resistance. This value can be affected by pad material, pad thickness, probe tip shape, and probe scrub. The Tesla system has a multi-finger flat shape tip that creates only an insignificant amount of contact resistance when applied to typical aluminum pads; thus providing a more accurate data value.

How does Tesla improve productivity of the test engineering staff?

Today, power device engineers are required to test their devices in package. This means that they have to add additional steps to their development process. These additional steps add time and costs. One engineer describes this frustration by explaining that what he could complete in one day with an on-wafer probe station, can take up to forty days in package.

In addition, the test equipment and jigs are not always readily available that meet the specific needs of their device. In this case, test engineers are required to develop custom solutions. This can lead to a diversion of manpower from testing and an added expense both of which have a significant impact on the test group's ability to be productive.

The Tesla system eliminates the added step of packaging, allowing test engineers to make their measurements on flexible on-wafer probe stations that can adapt to various device types and sizes. Thus, giving power device engineers the ability to improve their productivity as much as forty times.

What is the range of configurations for Tesla?	The Tesla system is provided as a complete system bundle. The system is available in two forms; one that has a complete temperature range of -55 to 200 degrees and a hot only option that provides a fixed ambient to 200 degrees range. The complete system includes probes and positioners, as well as eVue™ digital imaging system. Additional accessories, such as positioner, cables, probes, and probe tip replacements can be ordered separately on shop.cmicro.com. All of the components in the systems bundle are available as single line items. Please note however that the Tesla probe station comes pre-configured with the high power chuck and safety interlock systems.
What kind of companies can benefit from this solution?	The Tesla system provides a benefit for fabs producing discrete power devices on 3", 4", 6", or 8" wafers. These customers currently have no good/safe way to characterize these devices up to 3KV and/or 10A DC. They have a need for ESD/margin testing. They desire capability to obtain Rds(on) measurements and have problems making these kinds of measurements on wafers – particularly thin wafers. Additionally they may have invested a lot of time, money and effort in trying to design their own approach with largely unsatisfactory results. The Tesla system also is of value for companies who are looking for ways to sort KGD prior to packaging. Lastly, companies looking at 3-5 wafers will find value in the Tesla system's ability to pass power through the chuck.
Can Tesla be used to probe other kinds of devices?	Yes; the Tesla system is a multipurpose probe station that provides a triax probing environment for all types of ICs on wafer. Since the system is based on the Summit 12 K platform, it can be fitted with a variety of RF and DC probes and positioners.
When should I recommend the Tesla system as opposed to a standard Summit 12K?	The Tesla system should be recommended any time customer needs to probe power devices. If your customer needs to probe their devices higher than 500 volts, they are required to use the Tesla systems. The Tesla system also provides value for customers who are working on any type of power device and have plans in the future that require this kind of test capability.
What is the thinnest wafer I can use with the Tesla system?	The Tesla chuck has a superior vacuum capability that supports wafers as thin as 80um.
What kind of Rds(on) performance can I expect?	Tesla system has been designed from the ground up to reduce the amount of erroneous data that can affect your Rds(on) measurements. This enables engineers to measure values lower than ever measured before on a probe station. This capability is primarily enabled by the Tesla chuck which has a highly polished gold surface that can provide very low wafer to chuck contact resistance and allows you to measure the resistance of the drain at very high current.
What is the maximum current that the Tesla system offers?	Tesla system can handle up to 60A pulsed and 10A DC or continuous. This covers the full range of capability for today's on-wafer test instrumentation.

What is the maximum voltage I can test at?	The Tesla system provides 2 modes of voltage capability. For an unguarded or coax measurement, it provides support for voltages up to 3000V. For guarded or triax measurements, the system supports a measurement up to 1100V. This capability mirrors that of available test equipment in the market today.
Is it safe to test at that voltage?	The Tesla system provides a complete safety solution with a safety light curtain that connects into your instrument interlock interface and provides automatic shut-down the voltage if the light curtain is penetrated. In addition to this, all electrical connections and cables are fully guarded and shielded to insulate up to the maximum system voltage. By bundling the eVue system, Tesla system provides a hands-free digital imaging system for your on-wafer probing.
Does the Tesla system connect to my Keithley 237?	Yes, the Tesla system comes with a cable that plugs directly into your Keithley 237 series instruments and it supports the full capability of low leakage high voltage measurements that the 237 provides. In addition, the Tesla system also supports the Ketihley 2400 series and 2600 series high voltage/high current SMUs.
Will the micro grooves on the chuck affect my measurement?	Tesla system features a vacuum pattern that provides optimal handling for wafers as thin as 80um. In order to do this, Cascade Microtech has developed a revolutionary vacuum pattern that employs our proprietary Vacuchannel™ technology. Vacuchannel technology enables the lowest possible chuck to wafer contact resistance value. Although the Vacuchannel technology may add an insignificant amount of contact resistance to your measurement, as proven in testing, the superior vacuum hold-down that they provide far outweighs any risk of additional contact resistance that the Vacuchannel technology may add.
What are the wafer sizes that the Tesla system supports?	Tesla system can support wafer sizes from 3", 4", 6", and 8" wafers.
What is the maximum power that the Tesla system can dissipate through the chuck?	The Tesla system can handle up to 40 watts through an active chuck terminal providing more than ample support for available power devices in today's marketplace.
Is there a Pureline™ version?	The Tesla system is optimized for power devices. This means that we have optimized the system for higher voltages and higher currents. Both the Pureline and Tesla systems have many specialized capabilities optimized around the target device they are intended for. Whereas Pureline has been optimized for low-noise measurements, meaning that very low leakage measurements can be made on it, the Tesla system has been optimized for power device measurements, such as Rds(on). The Tesla system is capable of 1pA at 1100V.
If my probes fail, what is the cost of replacement?	The Tesla system features a high current probe and a high voltage probe, both with a replaceable probe tip. This is especially beneficial for power device probing where as contaminants build-up on tip of your probe your contact resistance increases. With your Tesla probe, only the damaged or contaminated portion of the probe needs to be replaced, reducing the total cost of ownership over time. High current tips are available for $1K for a 4/pack; high voltage probe use the standard PTT needle probe tip replacement, also available from shop.cmicro.com.

Can I make a Kelvin measurement with this system?	Of course! Cascade Microtech understands that your high current testing requires a Kelvin sense probe. Therefore, the Tesla system fully supports a Kelvin measurement and includes a Kelvin probe with the system bundle.
Is the Tesla system CE marked?	Yes; the Tesla system has completed a full suite of safety certification and has both a TUV and CE mark. It is also RoHs compliant.
Can I add these probes and positioners to my existing Summit 12K?	Customers who would like to add high current probes and positioners to their Summit 12K setup may do so by ordering these parts separately. However, they should note that high current probing can produce device heating therefore the Tesla Probe station is always recommended for power device characterization.
Can I add the Tesla chuck to a standard Summit 12K?	The Tesla probe station has been engineered with many power device-specific components in order to support higher voltage and higher currents. Cascade Microtech offers a trade-in program for customers who wish to trade-in their existing Summit 12K for a Tesla power device system.
Who is Cascade Microtech?	Cascade Microtech is renowned throughout the semiconductor industry as the leader in precision electrical metrology. Cascade Microtech's advanced electrical metrology systems and production probes enable successful design and production of complex semiconductors to achieve faster time to revenue and lower cost of test. The semiconductor industry has relied upon Cascade Microtech's probing systems for more than 20 years for reliable process development, device characterization and modeling, and failure analysis of devices such as semiconductor wafers, printed circuit boards, and micro electro-mechanical systems (MEMS). Cascade Microtech's Tesla System expands upon the company's traditional markets, by extending expertise in electrical and mechanical metrology to power semiconductor device test.

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