DCP-HTR

Parametric DC Probing of Small Pads

APPLICATION NOTE

Overview

Following the trend of Moore's Law, semiconductor sizes continue to shrink, as do device pad sizes. Many advantages come from using smaller pads , not the least of which is the reduced space required. Smaller pads allows both test structures to be placed in narrow scribe streets, and lower capacitance parasitics of the pads. However, driving to smaller pad geometries causes problems in terms of accurate and repeatable probing with a low contact resistance. Unless the probes can contact the pads and scrub through the oxide to make a low-resistance contact (all before any excess overtravel causes the probe to skate off the pad), measurement reliability and confidence will suffer.

Large pads of 100 µm x 100 µm are generally not a problem to probe with the most basic probe stations and probes, and generally no attention is paid to the type of DC parametric probe tip used other than for electrical performance, as any contact issues can be overcome with excessive overtravel. However, as we move to smaller pads such as 40 µm and less, the room for excessive overtravel to overcome poor contact to the pads is no longer possible. As excessive overtravel is applied, the probe simply skates out of room on the pad and either skates off the pad or catches the edge of the passivation and bends the probe tip. Repeated excessive overtravel will lead to unrepeatable measurements or damage (often called 'hooking') of the probe, leaving it unusable (see Fig. 1).

Figure 1 – A 'hooked' probe tip after excessive overtravel.

Attributes of the probe tips such as tip material, shape and diameter will have different effects on the contact resistance with regards to the amount of overtravel. The pad material, construction and even the environment the wafer is stored in will also affect how well contact is made. Tungsten is generally considered to be the preferred material for probing aluminum pads. The tungsten tip is hard and rugged enough to break through the oxide on the aluminum pads. The choice of tip shapes includes a flat tip or round radius tip, and offers different means of penetrating the oxide and contacting the pad material. Finally, options for tip diameters may be the most obvious variables to change when it comes to probing smaller pads. Logically one would assume a smaller tip will be more capable of probing smaller pads, but other factors may work against this assumption.

There is a real challenge today as scribe street widths are moving from 100 µm with 80 µm pads to 60 µm with 40 µm pads, and a 38 µm probe area after taking the passivation overlap into account. Recent semiconductor roadmaps also call for pad probing of 30 µm with a probe area of 28 µm as early as 2013.

In order to recommend the best choice of probe tips for smaller pads, experiments were conducted to measure contact resistance of various tip options while increasing the amount of overtravel in a controlled and measurable manner. It should be noted that these measurements were made using one sample of an aluminum-coated substrate. All other wafers may have different thicknesses of oxide that may change the amount of overtravel needed.

Measurement Set-Up

In order to measure contact resistance versus overtravel we used a Cascade Microtech's Tesla semi-automatic probe station with DC parametric positioners, DCP-HTR probes and the Agilent B1505A Semiconductor Parameter Analyzer, and used one SMU to force a 10 mA current and measured voltage difference between ground potential (aluminum plate) and the Kelvin sensing point of the DCP-HTR probe. With its precise semi-automatic control, the Tesla probe station allowed an increase in the Z overtravel in known precise steps while measuring contact resistance (Fig. 2 and 3).

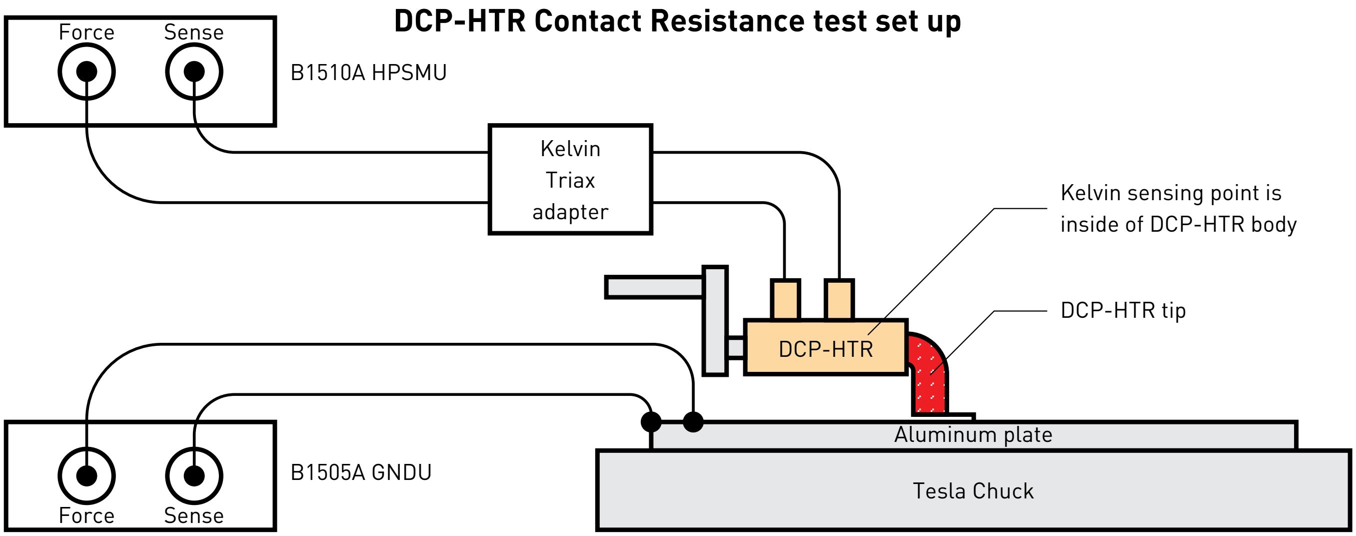

Figure 2. Electrical set-up used to measure contact resistance.

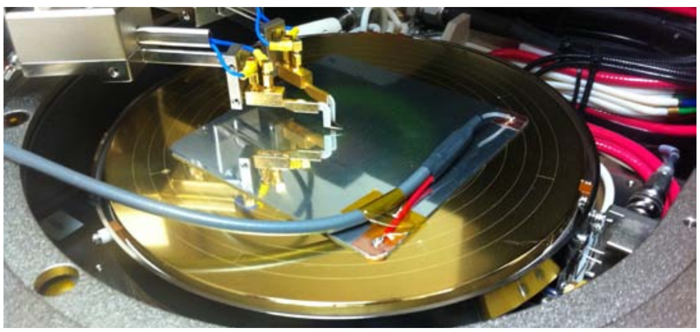

Figure 3. Test substrate with Kelvin connection and two probes tested simultaneously.

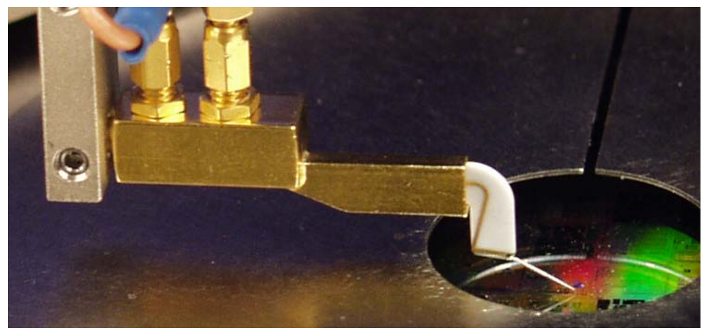

Figure 4. A DCP-HTR probe with probe needle.

It should be noted that the 'Kelvin' point of the measurement was at the probe body, so the defined measured resistance (hereafter called the R_{pt}) includes the contact resistance and the series resistance of the probe needle and interface to the probe body. The only varying resistance in the measurement was the contact resistance, as the resistance of the probe needle and interface to the body remained constant (Fig. 4).

In this experiment we measured five different types of DCP-HTR probe tips including different tip diameters and shapes (Table 1 and Fig. 5).

Table 1. DCP-HTR probe tip shapes with five corresponding diameters.

Part Number	Tip Shape	Tip Ø [µm]	Depth	Beam Angle
154-007	Flat	19	0.358	7°
154-009		13		
154-011		7.5		
154-001	Radius	19		
154-003		10		

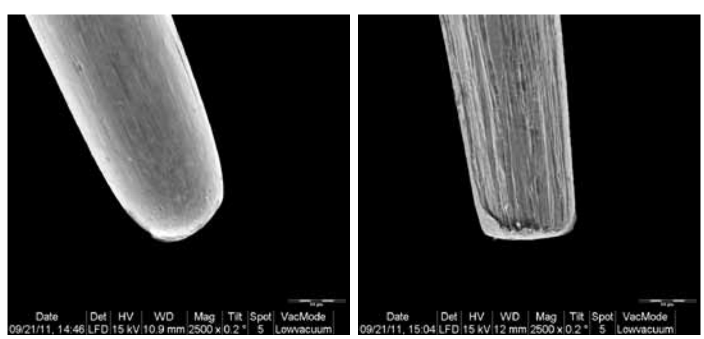

Figure 5. SEM Images showing the radius and flat probe tip shapes respectivley.

Results

Within the limited range of the experiment it was found that all probes except the 19 µm flat tip had made a contact where the R_{pt} was less than 1 Ω in less than 50 µm of overtravel. Since these probe tips have a overtravel-to-skate ratios of 2.5:1, then 50 µm of overtravel would result in 20 µm of lateral probe skate across the pad (Fig. 6).

The sum of the probe skate and the diameter of the probe tip provides the amount of pad budget required to land the probe successfully on the pad. For example, the 19 µm tip radius probe required 24 µm of overtravel to reach an R_{pt} resistance of less than 1 Ω, which is 9.6 µm of laterial skate. Since the tip diameter is 19 µm, this would use up a total of 28.6 µm of the pad budget. (Fig. 7)

The observations from this work show that the flat tips required more overtravel to reach lower levels of contact resistance, and the radius tips gave a more defined point of overtravel where the desired low contact resistance was achieved. Another observation was that the smaller 7.5 µm tip probe would bend with excessive overtravel, at which point the contact resistance would increase. This was observed again when repeating the test.

To determine the recommended probe tip to use for smaller pads, a chart was constructed that took into account the required overtravel for different desired R_{pt} (Table 2). The resulting skate from the required overtravel is added to the diameter of the probe to give the required pad budget. This pad budget can be used to recommend minimum pad dimensions for each probe type at each goal of R_{pt}.

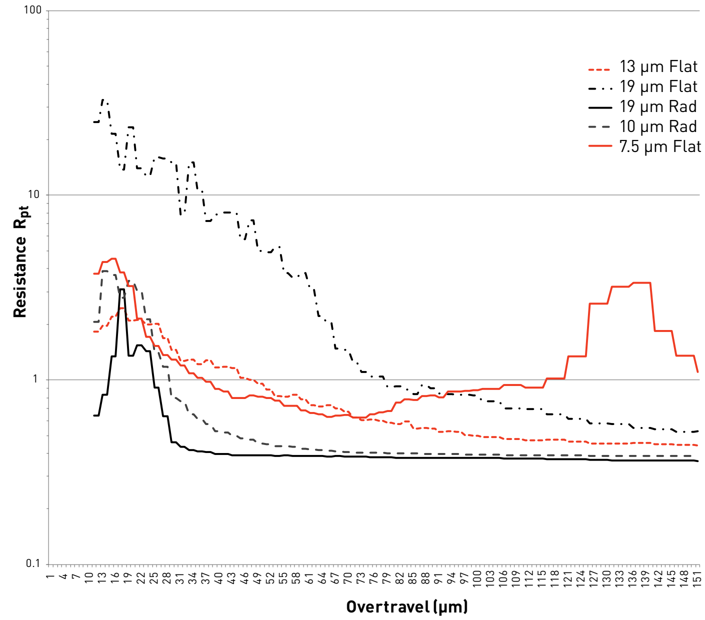

Figure 6. Results of probe resistance (probe tip + contact resistance).

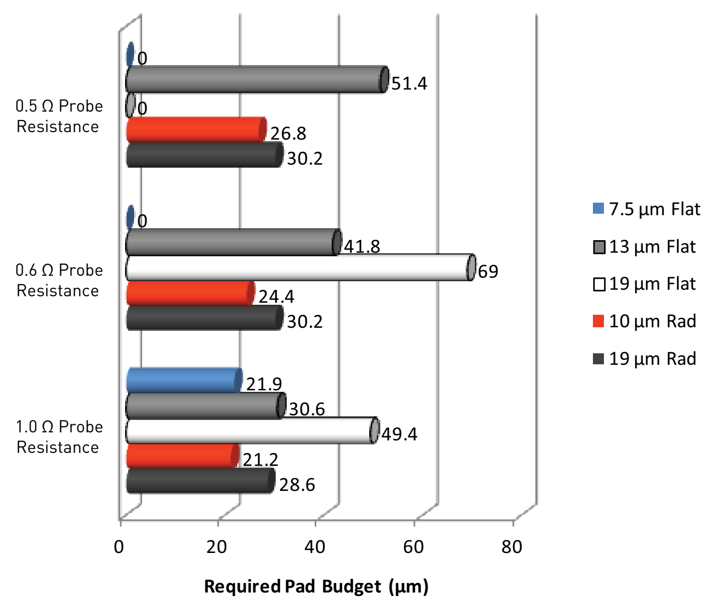

Figure 7. Amount of pad budget required to achieve lower Rpt (Note in case of '0', the goal Rpt was not achievable).

Table 2: Tips and the resulting amount of overtravel, skate and pad budget.

Part Number	Tip	Tip Diameter (µm)	Skate Ratio	Overtravel (µm) Required for:			Skate (µm) Required for:			Total Pad Budget (µm) for:		
				1 Ω R_C	0.6 Ω R_C	0.5 Ω R_C	1 Ω R_C	0.6 Ω R_C	0.5 Ω R_C	1 Ω R_C	0.6 Ω R_C	0.5 Ω R_C
154-001	19 µm Rad	19	2.5	24	28	28	9.6	11.2	11.2	28.6	30.2	30.2
154-003	10 µm Rad	10	2.5	28	36	42	11.2	14.4	16.8	21.2	24.4	26.8
154-007	19 µm Flat	19	2.5	76	125	NA	30.4	50	NA	49.4	69	NA
154-009	13 µm Flat	13	2.5	44	72	96	17.6	28.8	38.4	30.6	41.8	51.4
154-011	7.5 µm Flat	7.5	2.5	36	NA	NA	14.4	NA	NA	21.9	NA	NA

Conclusion

In general, best results for low contact resistance were found with the radius-tip probes. For probing small pads, the probes with a 10 µm radius tip used the least amount of pad budget. For the probes with a 10 µm radius tip, 1 Ω of R_{pt} was achieved in 11.2 µm of skate and less than 0.5 Ω in 16.8 µm of skate. Pads as small as 30 µm could be probed when using a probe with a 10 µm radius tip, and a R_{pt} of <0.5 Ω was achieved using a high-precision probe station.

Table 3. Recommended probe tips.

Pad Size (µm)	Recommended Probe Tip	Overtravel	Skate
28 - 35	154 - 003 (10 µm radius)	40 µm	16 µm
36 - 50	154 - 003 (10 µm radius)	50 µm	20 µm
51 - 100	154 - 001 (19 µm radius)	40 µm	16 µm
> 100	154 - 001 (19 µm radius)	50 µm	20 µm

Recommendations

When using the DCP-HTR probe on silicon wafers with aluminum pads, Cascade Microtech generally recommends the following probe tips for the best performance on the different pad dimensions (see Table 3).

Other tips may be better suited to applications outside the scope of this application note.

To reiterate, this work describes an example of probing one substrate with Al coating. Other substrates with Al and other pad materials may vary in success using these recommendations due to materials, thicknesses and storage conditions.

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DCPHTR-AN-0412

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