Ultra High Voltage High Current Probe for Power Device Testing

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Abstract

On-wafer power device probing is a very challenging task [1], which requires probes that can endure high-current and high-voltage conditions, minimize pad damage and contact resistance on the DUT pads, and achieve over-temperature probing. Cascade Microtech recently developed a 10 kV / 300 A probe for on-wafer power device probing.

1. Introduction

In 2007, Cascade Microtech introduced the Tesla probing system [2] for on-wafer power device characterization. Our first-generation high-current probe was designed to handle only 100 A and 500 V, since the maximum test voltage of the high-current test instruments was 100 V, requiring probes to handle only high-current.

After the Tesla system was introduced, test instrument manufacturers released new power device analyzers with the switching capability between High Voltage (HV) and High Current (HC) tests [3], requiring a single probe touchdown to handle both HV and HC at 3 kV / 500 A. To meet this requirement, Cascade Microtech developed a new Ultra-High Power probe (UHP).

2. Requirements for the UHP probe

The target devices were built with the following test conditions.

2.1. Test Conditions and Assumptions:

1. The test devices are MOSFET, IGBT and diode wafers.
2. The test devices have 3 µm-thick AlSiCu and/or AlSi pads.
3. A majority of the test devices has 3 µm-thick pad layers.
4. The device pad materials are mainly AlSiCu and AlSi.
5. The device pad size varies from 2 mm x 2 mm to 12 mm x 12 mm.
6. The device wafer is thicker than 50 µm.

   - The thickness of a thin wafer does not directly affect the UHP probe design, however, the size of vacuum holes and/or groove design on the chuck and probe finger shape must be taken into consideration to protect thin wafers.
7. The device structures include both vertical and lateral.
8. The maximum test temperature is 300°C.

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2.2. DC Parametric Test Conditions and Assumptions:

1. The maximum pulsed test current is 300 A.
2. The maximum pulse width is 1 ms.
3. The maximum pulse duty cycle is 1%.
4. The maximum test voltage is 3 kV DC.
5. Agilent Technologies B1505A/N1265A is used for DC parametric test.
6. Some of IGBT require voltage higher than 3 kV.

3. Target Performance of the UHP Probe

Based on the target device and test conditions listed above, the target performance of the UHP probe was defined as follows:

1. The UHP probes are used by power device R&D engineers.
2. Cascade Microtech Tesla system is used.
3. The UHP probe is compatible with Cascade Microtech RF positioners.
4. The targeted handling current is 300 A pulse or higher.
5. The targeted pulse width is 1 ms or less.
6. The targeted pulse duty cycle is 1% or less.
7. The targeted HC pulse rise/fall time is 10 µs or slower.
8. The targeted handling voltage is 6 kV with a stretched target of 10 kV.
9. The insulation resistance of the UHP probe is;
    a. 1 TΩ at 25℃ and the leakage current is 3 nA at 3000 V.
    b. 100 GΩ at 200℃ and the leakage current is 30 nA at 3000 V.
    c. 10 GΩ at 300℃ and the leakage current is 300 nA at 3000 V.
10. Maximum operating temperature is 300℃.
11. The targeted contact resistance (Rc) between the pad and probe is 5 mΩ or less, to minimize the heat generated while probing.
12. The value of probe tip skate is from 150 µm to 250 µm.
13. A probe tip has multiple fingers, covering wide pad area.
14. A probe tip should be replaceable by the users.
15. A probe tip, as well as the device pad size, is configurable as a custom product.
16. Two probes can be used in parallel for large vertical structures, to double the current capacity on one pad.

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17. The maximum drain current for vertical devices is 2 x 300 A = 600 A.
18. The maximum drain current for lateral devices is 300 A.
19. Tip life is more than 100k contacts on AlSiCu pads.

4. Design of the UHP Probe

Based on the target performance, the requirements on the probe body and tip designs were identified as follows:

1. A probe tip is made of Tungsten with Au plating to achieve consistent Rc over a high number of touchdowns on AlSiCu and AlSi pads.
2. The angle of a probe tip on wafer is 45°.
3. One probe tip consists of maximum 12 fingers and covers 7 mm to 12 mm wide area on the pad, depending on the finger pitch:
   - 12 fingers with 650 µm pitch cover approximately 7.5 mm-wide area.
   - 12 fingers with 900 µm pitch cover approximately 10.2 mm-wide area.
4. A probe body is made of high temperature engineered plastics.
5. A probe uses a 10 AWG (= 5 mm^2) high-voltage silicone wire.
6. Probe wire length is 1 m.
7. A probe connector is an insulated Au-plated Banana plug.

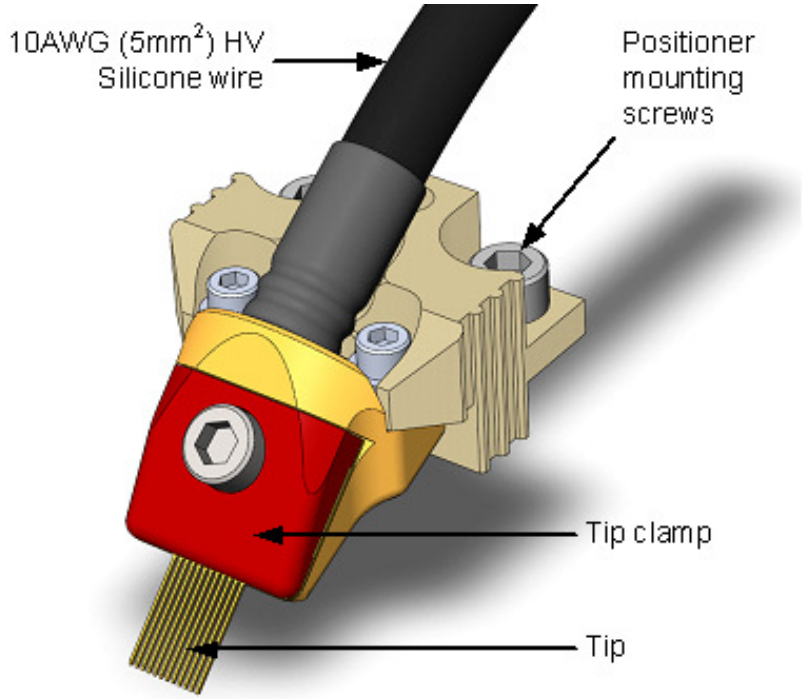

Figure 1. CAD model of the UHP probe.

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5. Performance of the UHP Probe

5.1. Probe resistance (Residual resistance + Contact resistance)

a. The residual resistance of the UHP probe is about 3.5 mΩ, which is mainly from the residual resistance of a 1 meter-long 10 AWG high-voltage silicone wire.

b. The initial Rc on a 3 µm-thick AlSiCu layer on Si wafer is typically 2 mΩ.

c. Total probe resistance is about 5.5 mΩ.

5.2. High-current handling performance

Figure 2 shows the Rc measured by forcing the current from 0 A to 300 A and from 300 A down to 0 A. The Rc is reasonably stable up to 300 A and there is about 400 µΩ hysteresis between up current and down current. This measurement was made with Agilent Technologies B1505A / N1265A (UHCE).

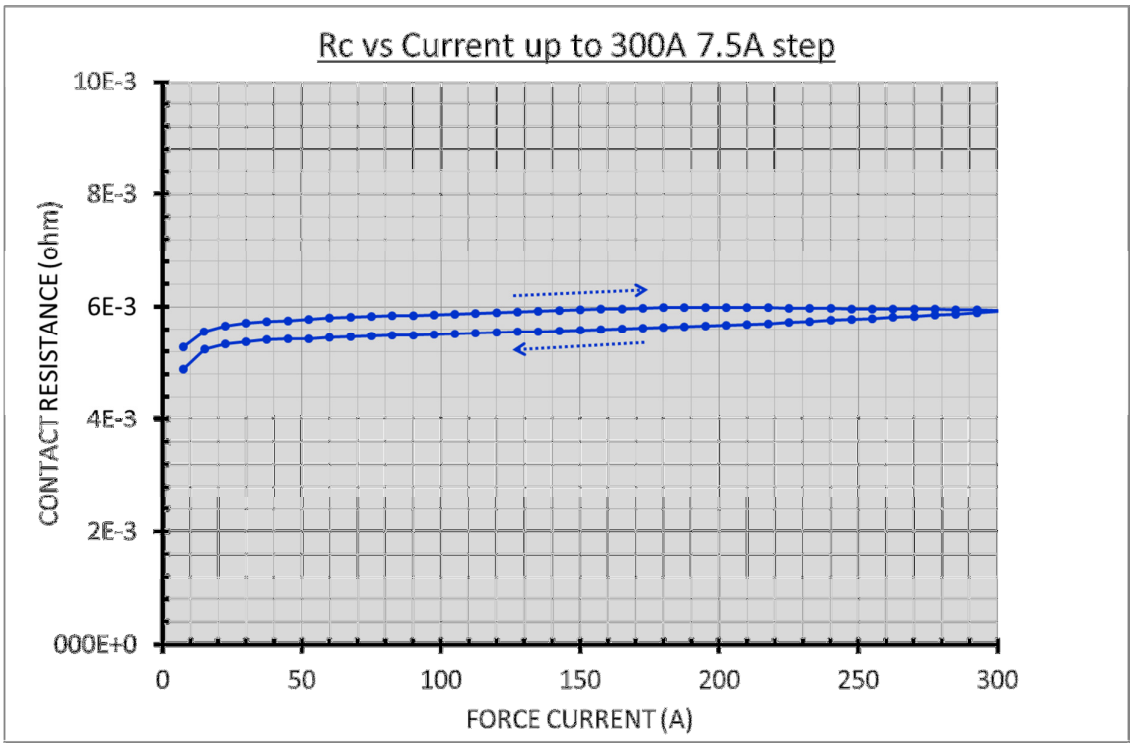

Figure 2. Contact resistance of the UHP probe.

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5.3. Insulation Resistance (Mounted on RF positioner)

B1505A/B1513A (HVSMU)

Temperature	Voltage	Time from test start	Insulation resistance	Leakage current
(℃)	(V)	(sec)	(Ω)	(A)
25	3,000	10	22.4T	134 p
25	3,000	60	51.5T	58.3 p
200	3,000	10	5.7T	525 p
200	3,000	60	12.9T	233 p

KEW3128 (HV insulation tester) [4]

25	6,000	60	> 6.0T	< 1.0n
25	10,000	60	24.2T	420 p
200	6,000	60	> 6.0T	< 1.0 n
200	10,000	60	3.71T	2.74 n

5.4. Contact Resistance over 100k Touchdowns

The test conditions are as follows;

1. The UHP probe applies five of 200 A / 1 ms pulses with 0.2 s pulse period each per touchdown.
2. The Rc is measured at the first, third and fifth sites.
3. The skate of the UHP probe tip is about 150 µm.
4. The chuck temperature is 200℃.
5. A probe tip makes about 14,600 touchdowns per 200 mm wafer.
6. A 3 µm-thick AlSiCu layer on 200 mm Si wafer is probed.
7. Two UHP probes are used to probe a wafer– one probe applies current to a wafer, while the other is used as a “Probe Under Test” to measure its Rc.

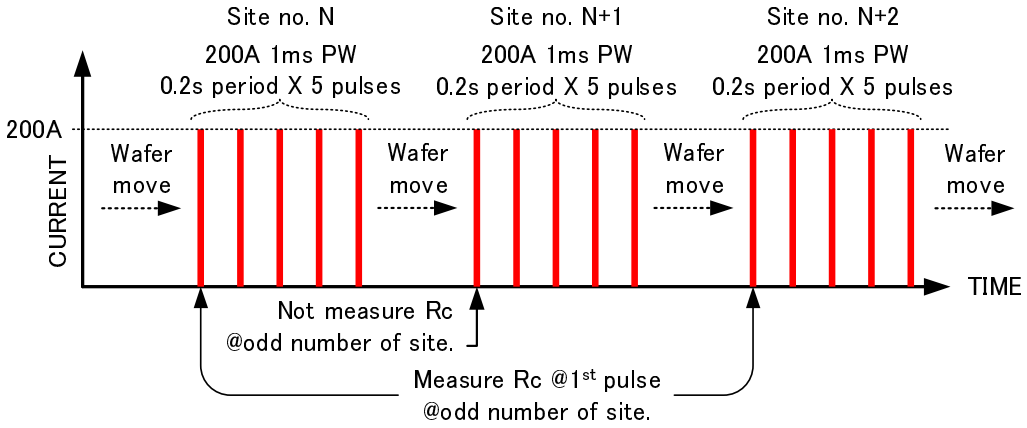

Figure 3. Applying current with 200 A 1 ms pulse.

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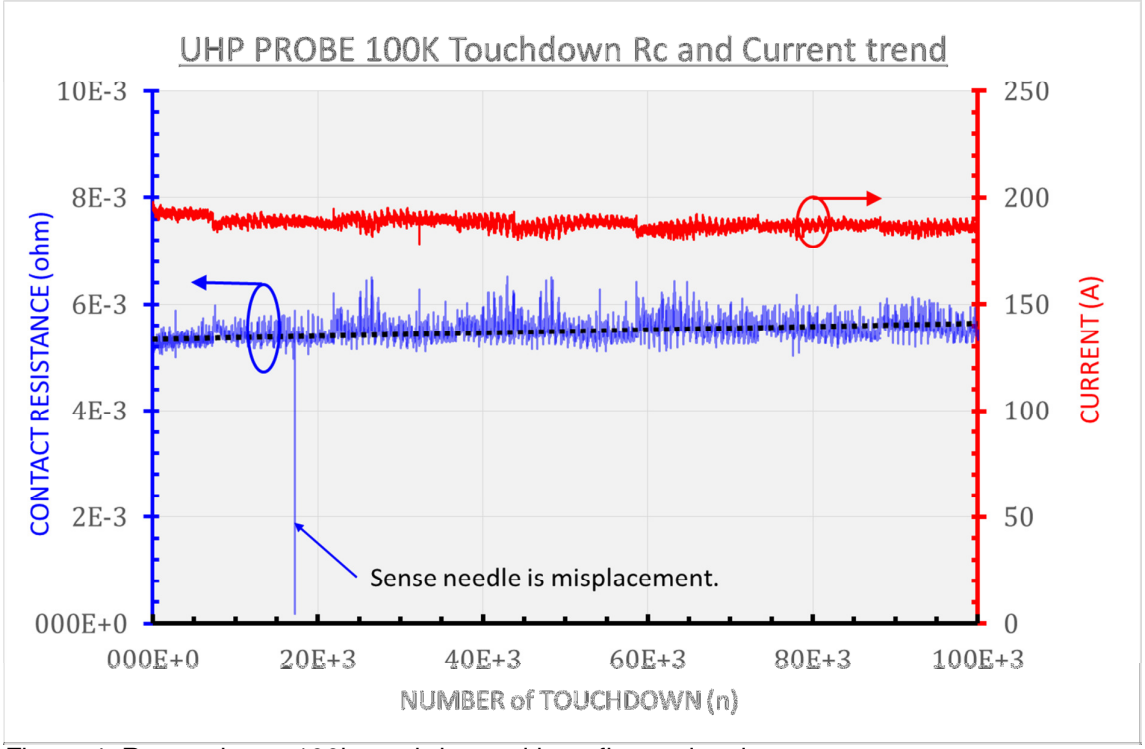

Figure 4. Rc trend over 100k touchdown without finger cleaning.

5.5. Probe mark and pad damage

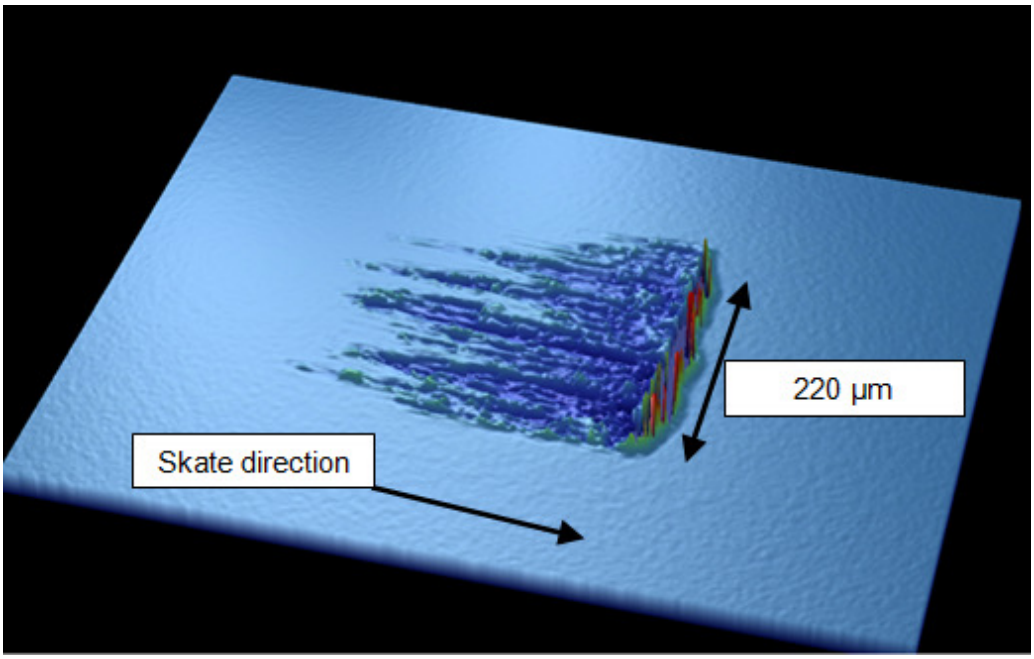

Figure 5. Probe mark made by one finger on a probe tip.

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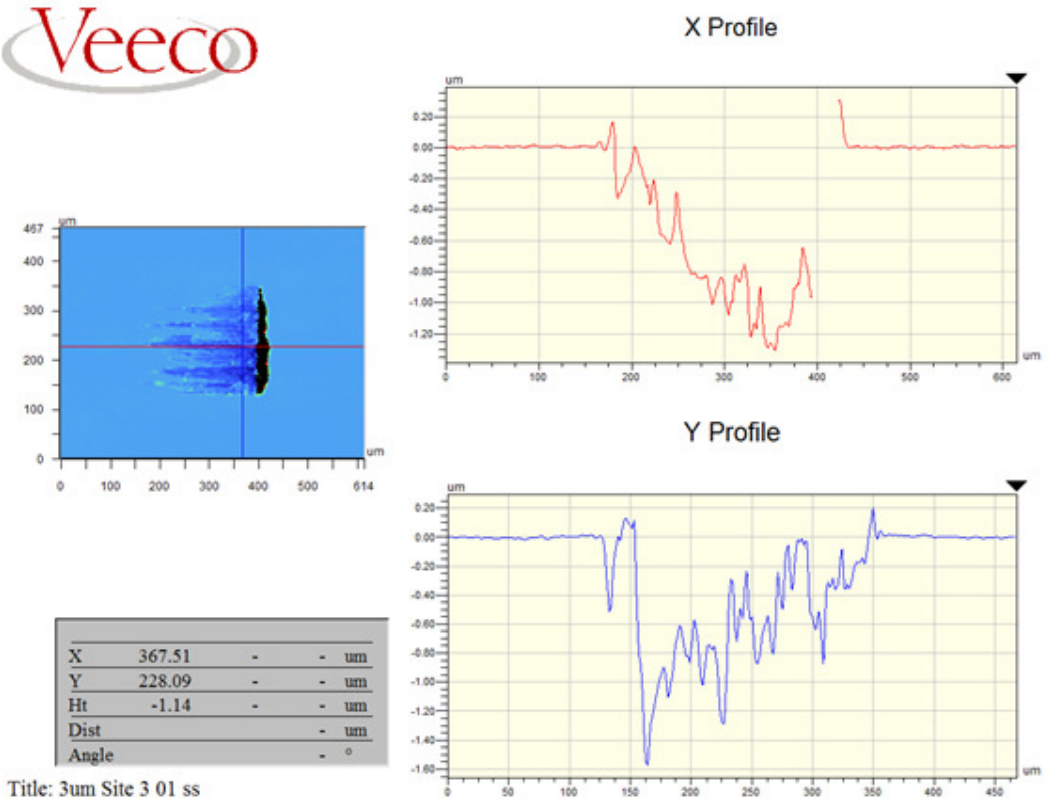

Figure 6. Probe mark profile (maximum. depth of X axis is 1.3 µm and Y axis is 1.6 µm).

6. Conclusions

The new UHP probe developed for on-wafer power device probing achieves:

- Residual resistance of about 6 mΩ (typical), which is included in Rc.
- Maximum handling current of 300 A.
- Maximum handling voltage of 10 kV at 200℃.
- Stable Rc on a 3 µm-thick AlSiCu layer over 100k touchdown without tip cleaning.
- Less than 3 mΩ Rc between the UHP probe tip and a 3 µm-thick AlSiCu layer, with adequate probe over travel.
- Less than 2 µm-deep pad mark on a 3 µm-thick AlSiCu pad layer.

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7. Acknowledgements

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