Addressing the Challenges of Small Pad Probing

TECHNICAL BRIEF

InfinityQuad™ Solves Small Pad Probing Challenges

True to the theory of Moore's Law, leading semiconductor manufacturers' roadmaps include shrinking devices and much smaller pads. Numerous advantages come from laying out devices with small pads. Smaller pads not only utilize less device real estate space, they also allow sacrificial test structures to be placed in scribe lines, meaning process control monitoring and device characterization can be performed without using valuable space for sellable circuits (see Figures 1 and 2). In addition, the parasitic capacitance of pads decreases with physical size, which means device performance is less likely influenced by the pad's capacitance.

Probing pads with dimensions of 100 µm x 100 µm or 80 µm x 80 µm is no real challenge with most conventional probe technologies. However, trying to probe pad sizes of 50 µm x 50 µm or less becomes a challenge and a source of frustration when reliable and repeatable contact is not made on all the pads.

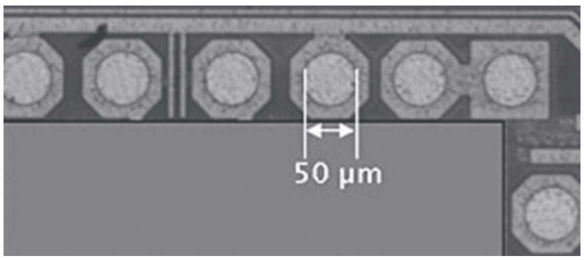

Figure 1. Small 50 µm pads of a semiconductor IC.

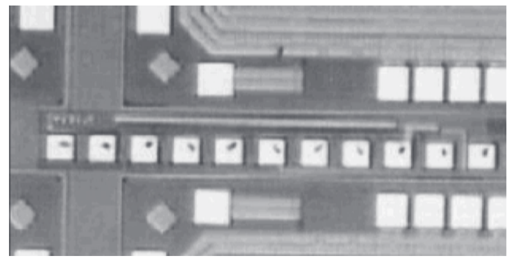

Figure 2. Probe pad structures within scribe street.

There are many factors when probing small pads that can lead to probes not making good contact and poor measurement results. The following are some of the main causes of errors when probing small pads.

Large Probe Tip Contact Area

Depending upon the type of contact such as DC or RF, the probe tip of a mixed-signal probe may be relatively large compared to the area it needs to contact. It is common for a Tungsten needle probe to have a tip diameter of ~20 µm (see Fig. 3) and for a RF contact to have a diameter of 40 µm. In order to probe small pads the tip contact area needs to be significantly smaller than the pad.

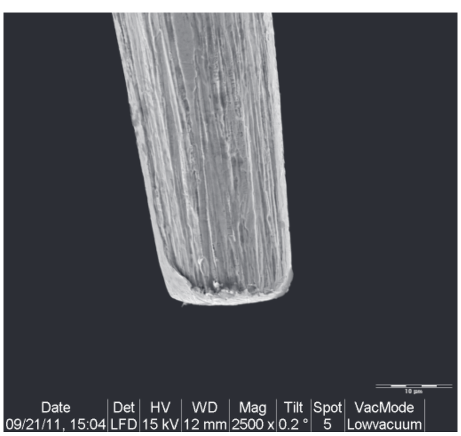

Figure 3. SEM image of a conventional DC probe contact area with a diameter of 19 µm.

Poor Tip Planarity

When a multi-contact probe has poor tip planarity the amount of overtravel needed to make contact with all needles, including the last one to touchdown, results in excessive skate across the pads of the needles that contact before it. Poor planarity can result in the first contacting probe to skate off the pad before the last one has touched down. The better the planarity, the less unnecessary skate is encountered (Fig. 4).

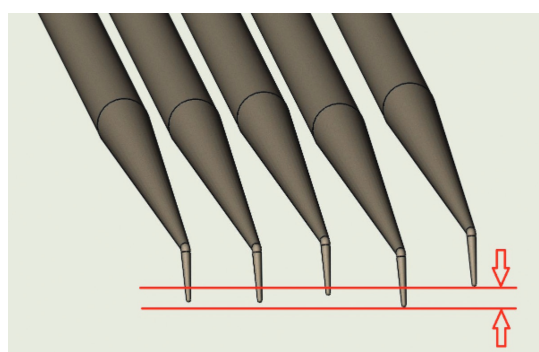

Figure 4. The planarity (first-to-last contact) can cause the first probe to skate off the pad by the time all probes have made contact.

Overtravel-to-Skate Ratio

The aforementioned problem is amplified when the overtravel-to-skate ratio is too small. If a probe has a 1:1 skate ratio then each additional micron of overtravel needed to bring all tips into contact will result in an extra micron of skate across the pad (Fig. 5). However, if a probe has a 4:1 skate ratio then that same micron of overtravel only results in 0.25 µm of skate.

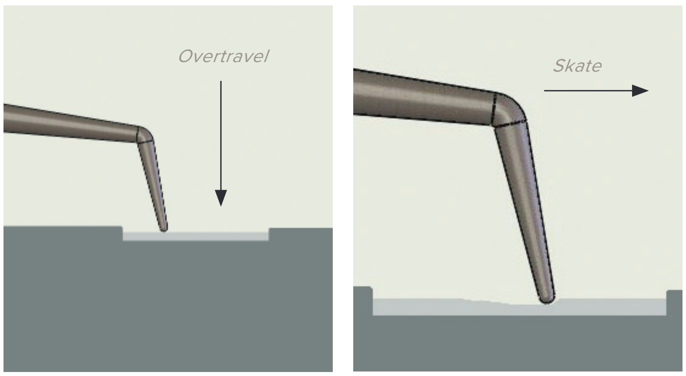

Figure 5. The more over travel applied the more skate occurs. The smaller the ratio, the more skating effect is suffered by excessive overtravel.

Relative Tip Accuracy

Conventional probes will have mechanical errors in positioning of each tip relative to each other. These errors can be in the X, Y and Z axis (Z-axis error is essentially tip planarity error) and will lead to missing or skating off a pad, if too extreme (Fig. 6). The better the accuracy of the tip position, the greater the chance of hitting small pads.

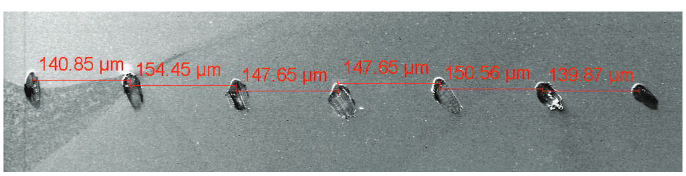

Figure 6. A good conventional probe will have up to 10 µm of tip-to-tip inaccuracy even at ambient temperature. This probe should have 150 µm even pitch between tips.

High Contact Resistance on Aluminum Pads

Aluminum pads grow a layer of oxide when exposed to the oxygen in the air. This layer of Aluminum Oxide needs to be penetrated by the probe in order to make a low contact resistance measurement. In order to break through this oxide layer, probes require additional skate to scrub down to the Aluminum metal below the oxide. Again, the more scrub the greater the chance of skating off the pad and losing contact altogether.

Side-Skating Probes

When a conventional multi-contact probe has many contacts, the needles need to be routed in the shape of a fan in order to bring all the tips into the tight pitch arrangement of the device under test. This configuration means that the needles mounted in the center will skate forward in the direction of the probe, and the probes on the outer ends enter from an angle and will skate to the side as well as forward when brought into contact (Fig. 7). This is known as 'side skate.' Side skate limits pad size and pitch.

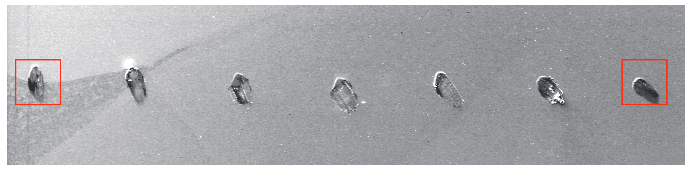

Figure 7. Side-skate causes the outer probe tips to skate inwards, leaving a wider probe mark and also changing the pitch as extra overtravel is used.

Yaw-Axis Error

Considering the multi-contact probe may have up to 25 contacts and pitches as wide as 250 µm, the overall length of the probe contact area can be as much as 6 mm. Unless the probe is aligned perfectly in the yaw-axis (probe rotation), then the probe tips at the outer ends of the probe will not be in-line with each other. This needs to be mechanically corrected by loosening the screws and manually aligning the yaw-axis by sight, before tightening the probe mount screws. This method is problematic and time-consuming, and if not done correctly the probes will not align with small pads.

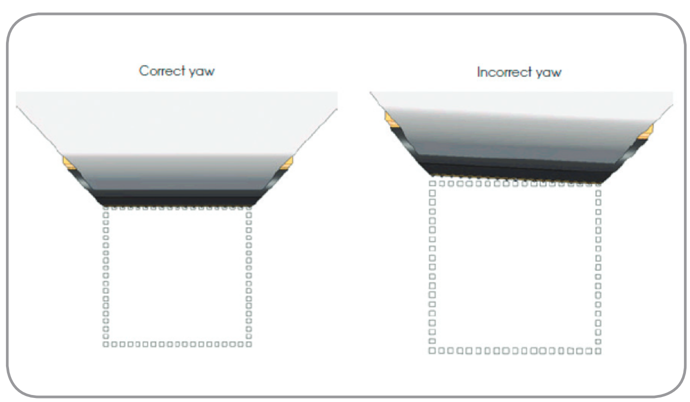

Fig 8. Effect of incorrect yaw alignment

Net Result of Probe Errors

In effect, each pad has a probing 'budget.' Each of the above errors decreases that budget relative to the size of the error. For example, if a probe has contact diameter of 20 µm, a first-to-last of 10 µm (with a 1:1 skate ratio), has an X & Y accuracy of 10 µm, requires a minimum skate of 20 µm to break through the oxide and has a side skate of 45 deg – then the minimum pad size needed to make repeatable contact with this probe would be 70 µm long x 65 µm wide, and that is before adding non-probe related errors of the user, thermal expansion and automatic probe station accuracies. In this case, a minimum pad size of 90 µm x 85 µm would be recommended (Fig. 9).

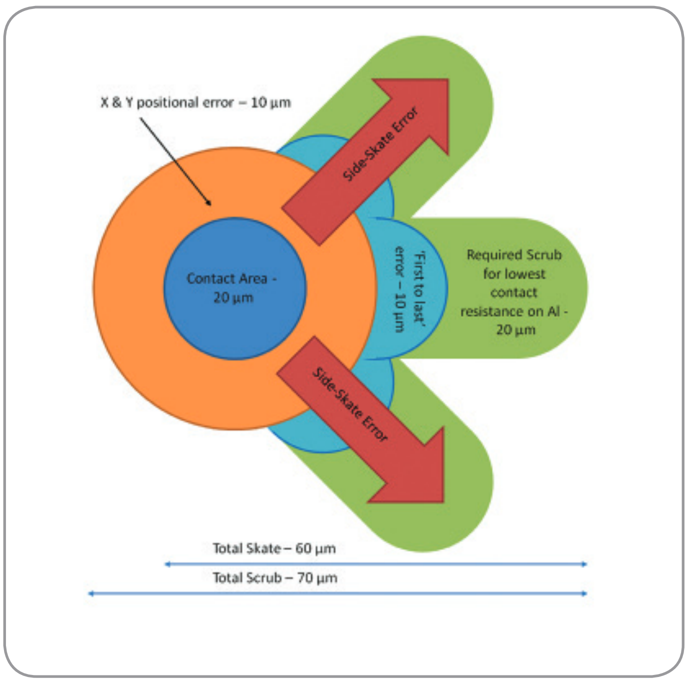

Figure 9. Footprint of a probing budget when taking into account errors when using a conventional multi-contact probe.

InfinityQuad Lithographically-Fabricated Tip Technology

A new multi-contact probe is available from FormFactor with the introduction of InfinityQuad. InfinityQuad is the first and only multi-contact probe that uses lithographically-fabricated set of tips specifically designed for probing multiple small pads with mixed signals. The probe can be configured with up to 25 contacts that are defined as ground, power (with integrated tip de-coupling), logic, 20 GHz RF or a premium mmWave signal up to 110 GHz (Fig. 10).

Figure 10. InfinityQuad probe configured with mixed DC, 20 GHz RF and 110 GHz mm-wave channels.

Because of how the tips are fabricated there is an extremely small yet durable contact area of 8 µm (long) x 12 µm (wide) (Fig. 11), very accurate X & Y positional errors of less than 1 µm (Fig. 12) and first-to-last planarity of <10 µm (with a 2.5:1 scrub ratio).

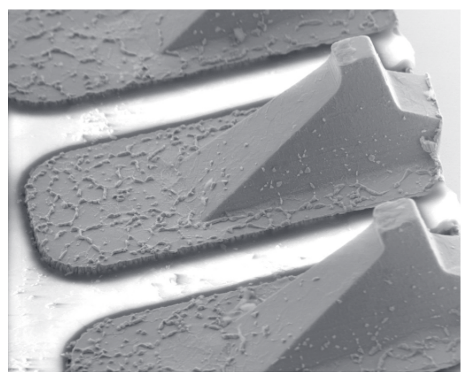

Figure11. Small lithographically-fabricated contacts of InfinityQuad with a width of 12 µm and a contacting length of ~ 8 µm.

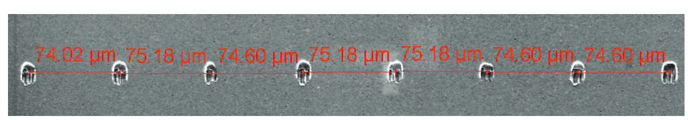

Figure 12. Probe marks of InfinityQuad showing X & Y errors of less than 1 µm at ambient temperature.

The small contact area of the InfinityQuad tip, along with the hard non-oxidizing Nickel alloy material, provide a typical contact resistance of less than 50 mΩ with a skate of less than 16 µm (at 40 µm overtravel). Because the tips are all skating in parallel to each other, there is zero side skate.

The InfinityQuad enhanced probe mount includes a method to accurately adjust the yaw-axis to ensure the probe correctly aligns to the pads. This method is more simple and precise to set up, saving time and improving probing accuracy.

Addressing the Challenges of Small Pad Probing

TECHNICAL BRIEF

Save Probe Pad 'Budget'

Taking the above into account, the calculated probing budget is only 14 µm wide and 30 µm long. Including a conservative allowance for user error, thermal effects and automatic probing of 10 µm on each side would mean that the smallest pad InfinityQuad can probe is 30 µm wide and 50 µm long, much smaller than the 90 µm pad budget with conventional probes (Fig. 13). Manual probing, probing at ambient temperature only or using advanced unattended over-temperature probe station software such as VueTrack™ from FormFactor, could potentially allow a pad budget as small as ~20 µm x 30 µm.

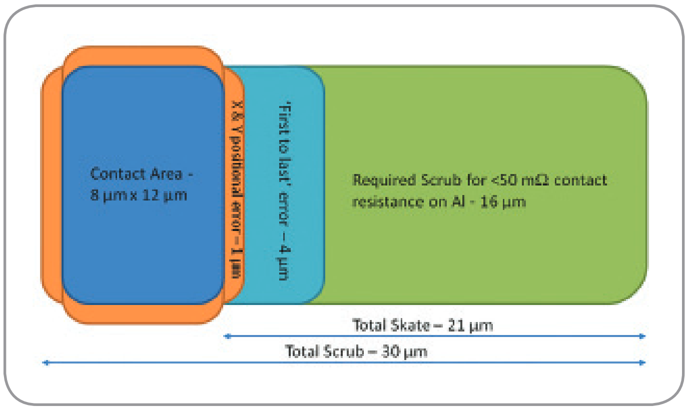

Figure 13. Footprint of the InfinityQuad probing budget uses 1/10 of the surface area compared to a conventional probe.

Measurements Over Full Thermal Range

The thermal repeatability of InfinityQuad is superior to other conventional probe technologies, however, tolerances of probe tip accuracy at different temperatures does have an effect. The magnitude of the effect depends on the number of contacts and the pitch (which determines the physical width of the whole probe) and the thermal range. When probing over the full specified range of InfinityQuad from -40°C to +125°C, the minimum recommended pad sizes for the number of tips and pitch are shown in Table 1. It should be noted that these recommendations take into account all the error margins of measuring over the full thermal range when used in an automatic mode on a FormFactor semi-automatic probe station. Results may vary with other manual, semi-automatic and fully automatic probe stations.

# of Contacts (include X)	75 um pitch	80 um pitch	100 um pitch	125 um pitch	150 um pitch	200 um pitch	250 um pitch
4	25 x 45	26 x 46	26 x 46	26 x 46	26 x 46	27 x 47	28 x 48
5	26 x 46	26 x 46	26 x 46	26 x 46	27 x 47	28 x 48	28 x 48
6	26 x 46	26 x 46	26 x 46	27 x 47	27 x 47	28 x 48	29 x 49
7	26 x 46	26 x 46	27 x 47	27 x 47	28 x 48	29 x 49	30 x 50
8	26 x 46	27 x 47	27 x 47	28 x 48	28 x 48	30 x 50	31 x 51
9	27 x 47	27 x 47	27 x 47	28 x 48	29 x 49	30 x 50	32 x 52
10	27 x 47	27 x 47	28 x 48	28 x 48	29 x 49	31 x 51	32 x 52
11	27 x 47	27 x 47	28 x 48	29 x 49	30 x 50	32 x 52	33 x 53
12	27 x 47	28 x 48	28 x 48	29 x 49	30 x 50	32 x 52	34 x 54
13	28 x 48	28 x 48	29 x 49	30 x 50	31 x 51	33 x 53	35 x 55
14	28 x 48	28 x 48	29 x 49	30 x 50	31 x 51	33 x 53	36 x 56
15	28 x 48	28 x 48	29 x 49	30 x 50	32 x 52	34 x 54	36 x 56
16	28 x 48	29 x 49	30 x 50	31 x 51	32 x 52	35 x 55	37 x 57
17	29 x 49	29 x 49	30 x 50	31 x 51	33 x 53	35 x 55	38 x 58
18	29 x 49	29 x 49	30 x 50	32 x 52	33 x 53	36 x 56	39 x 59
19	29 x 49	29 x 49	31 x 51	32 x 52	34 x 54	37 x 57	40 x 60
20	29 x 49	30 x 50	31 x 51	32 x 52	34 x 54	37 x 57	40 x 60
21	30 x 50	30 x 50	31 x 51	33 x 53	35 x 55	38 x 58	41 x 61
22	30 x 50	30 x 50	32 x 52	33 x 53	35 x 55	39 x 59	42 x 62
23	30 x 50	30 x 50	32 x 52	34 x 54	36 x 56	39 x 59	43 x 63
24	30 x 50	31 x 51	32 x 52	34 x 54	36 x 56	40 x 60	44 x 64
25	30 x 50	31 x 51	32 x 52	34 x 54	36 x 56	40 x 60	44 x 64

Table 1. Recommended minimum pad sizes dependent upon number of contacts and pitch. Numbers are inclusive of probing budget and an error window representative of user error, auto-prober error and thermal effects.

Conclusion

InfinityQuad technology reduces the minimum size of the pad that can be used with a multi-contact, mixed-signal probe (Fig. 14). Pads as small as 30 µm x 50 µm become a reality in automated over-temperature probing applications. This allows the user to reduce pad sizes, saves device real estate space (Fig. 15) and lowers pad parasitics – both saving money and improving measurement accuracy. And for customers already using small pads, InfinityQuad will allow confidence in making contact with the pad repeatedly – reducing the amount of time needed to manually test or eliminating the need to repeat automatic tests due to probes skating off the pads.

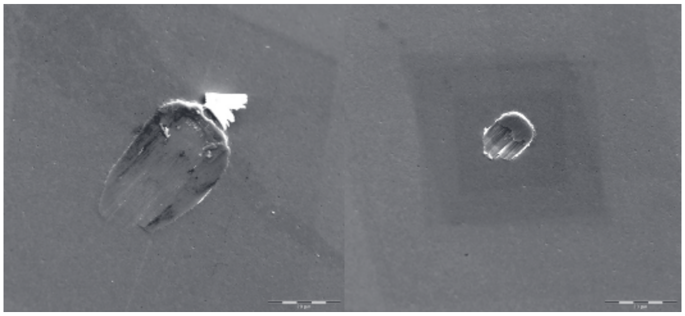

Figure 14. A good example of a conventional probe mark compared to an InfinityQuad probe mark using a similar scale.

InfinityQuad is the only multi-contact probe technology that allows automatic measurements of small pads over temperature.

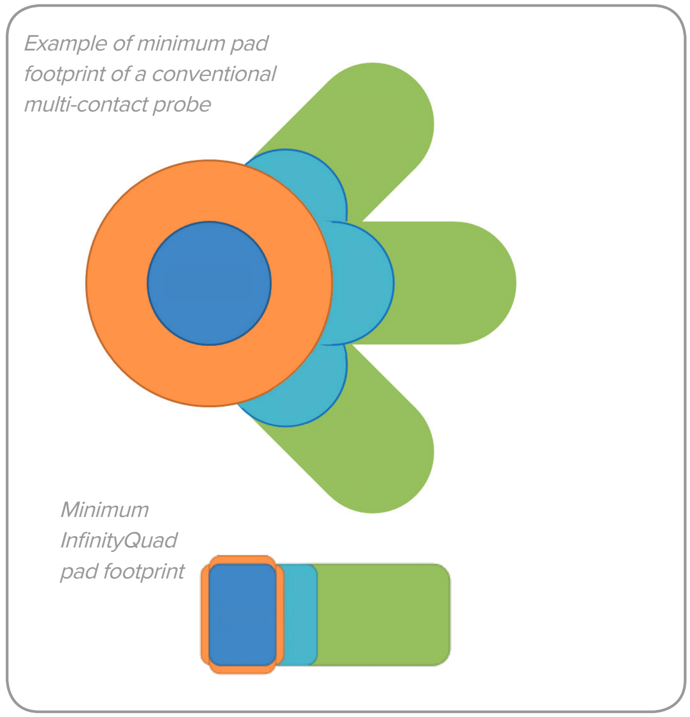

Figure 15. Including an error margin for automatic probing over temperature, the recommended pad area for InfinityQuad is five times less than conventional probes.

Corporate Headquarters

7005 Southfront Road
Livermore, CA 94551
Phone: 925-290-4000
www.formfactor.com

SmallPadProbing_InfQuad_0520