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Determining Probe's Maximum Allowable Current

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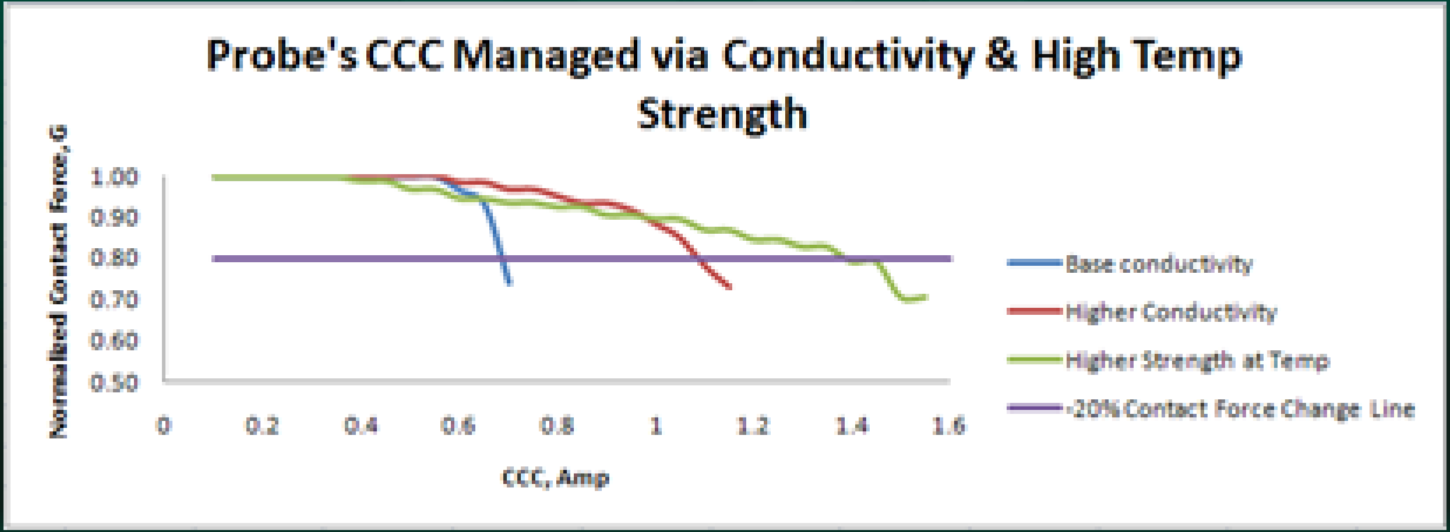
Overview

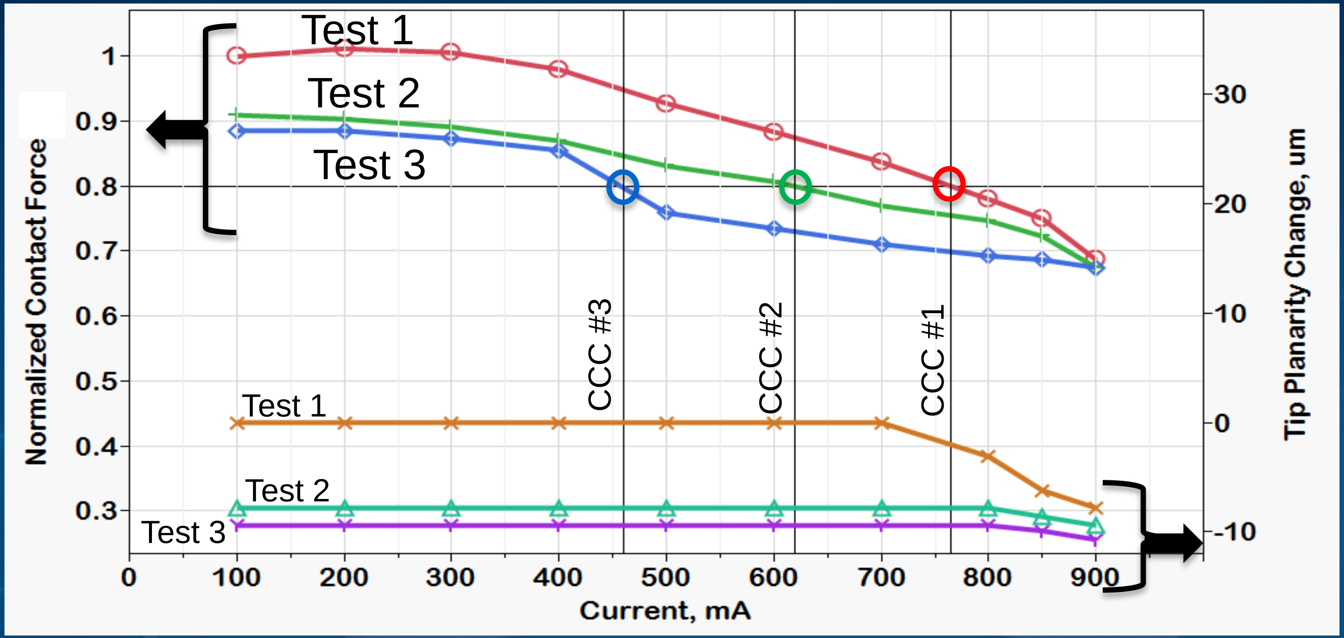
- ISMI CCC Spec vs. what wafer test engineer needs to know
- Introducing Maximum Allowable Current (MAC) concept
- Method for finding singular MAC value
- Confirmation of MAC performance in repeatable loading
- Relationship between MAC and CCC
- MAC vs. current pulse width
- Ways to minimize transient currents in wafer test
- Conclusions

Definition of CCC

- CCC = Current which results in a 20% contact force reduction
  - Below plot typical of SEMI-defined methodology
- CCC modulated by several variables
  - Here, improvement achieved through probe material conductivity (electrical and thermal) and high temperature strength increase



CCC-level Current Damages Probes

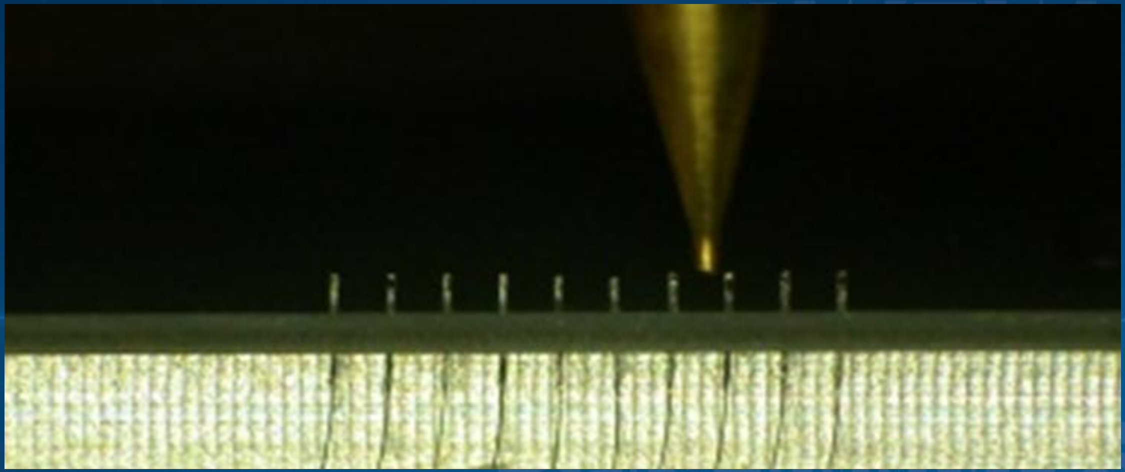


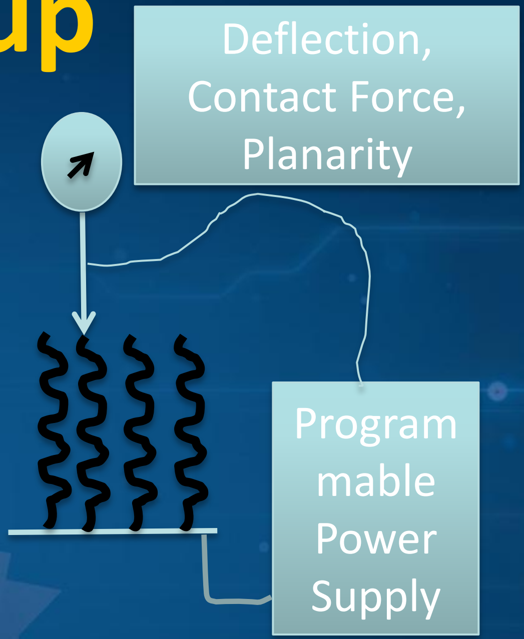
- **The same probe tested for CCC three times shows diminishing actual CCC and Tip planarity, ~150mA reduction per test**
- **Probes cannot sustain CCC-level current due to loss of planarity and contact force**
- **CCC spec causes many misunderstandings between users and probe card suppliers**
  - Why can't I use CCC spec for current clamp setting?
  - Why does probe card contact performance degrade over time after exposure to CCC?

Probe ISMI-CCC Spec Does not Define Current that Probe Could Carry After Multiple Exposure in Production

- **Disparity between what test engineer needs to know about the probe and what ISMI-CCC spec defines:**
  - Test engineer asks for maximum current that can be carried by the probe thousands of times without changing probe's performance (planarity, alignment, contact force, CRES)
  - ISMI-CCC test itself causes a permanent damage to the probe - probe is deformed and contact force lowered by 20% after one current event
- **Methodology is needed to measure <u>M</u>aximum <u>A</u>llowable <u>C</u>urrent that can be applied over and over throughout product life time**
  - To help with setting power supply current clamp in tester program

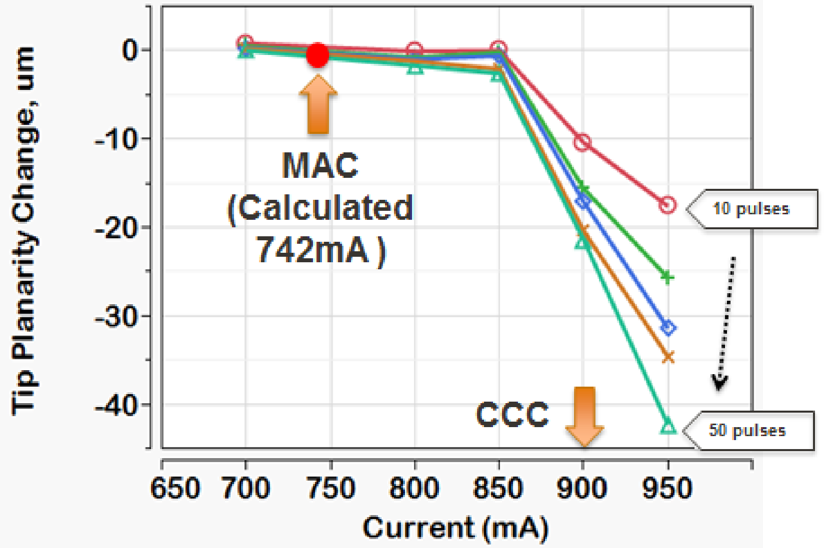
Maximum Allowable Current Measurement Setup

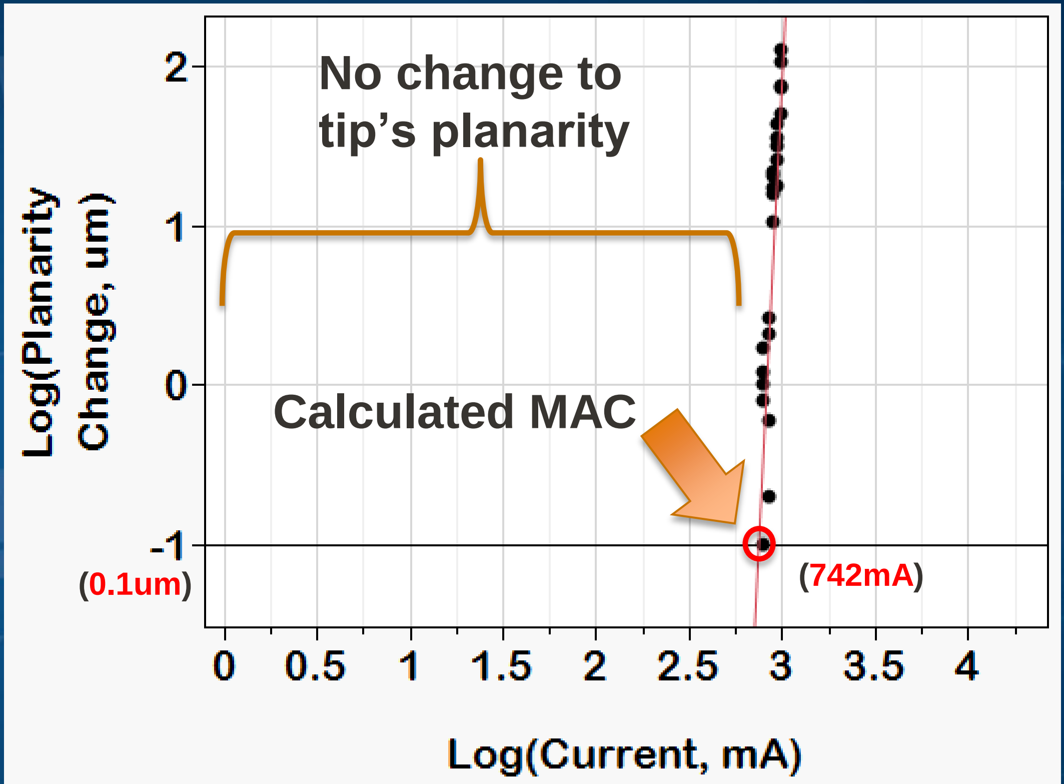




- **Use probe tip's planarity change in response to current pulses as a proxy for defining probe's Maximum Allowable Current (MAC)**
- **Each probe is tested at a unique current level in increasing number of pulses, (1 min On /1sec off) representing real life test scenario**

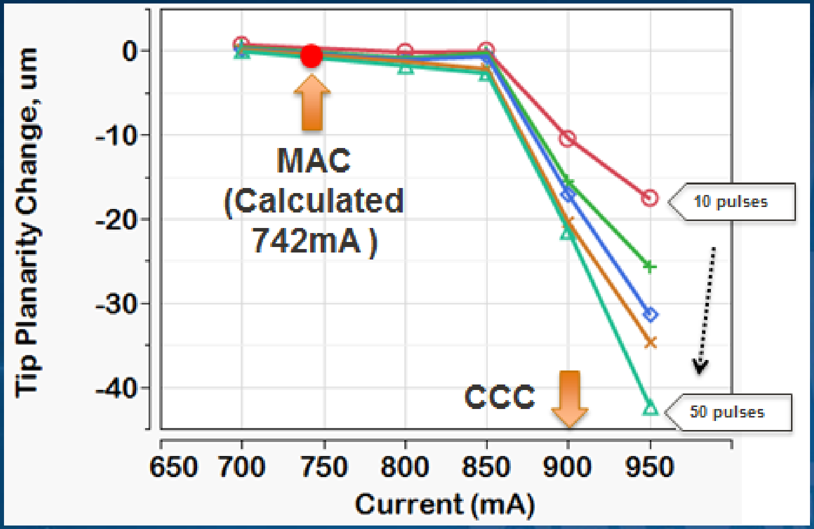
Maximum Allowable Current Calculation of MAC value

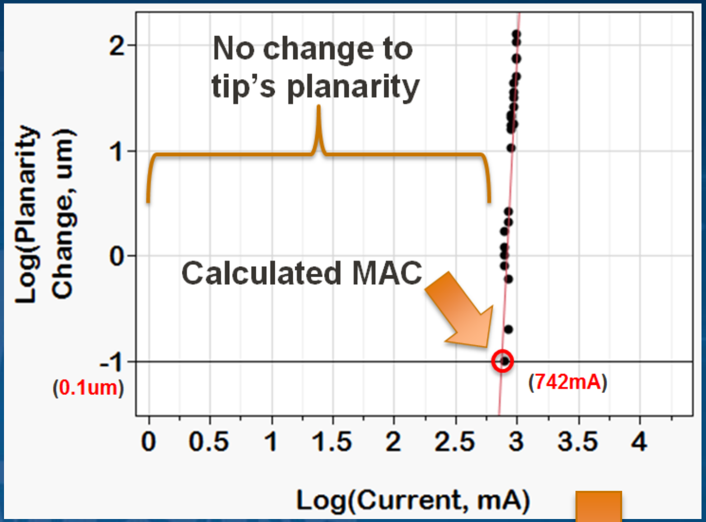




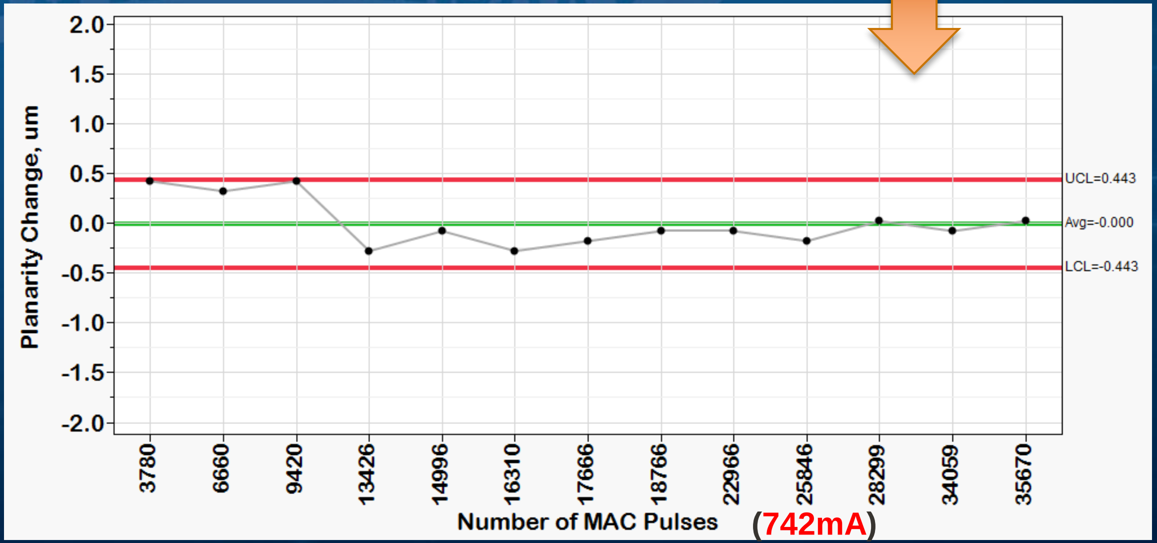
- Plotting Log of planarity change vs. Log of current (use linear scale) allows for linearization of otherwise asymptotic curve
- Finding best-fit line equation to the data is easy and used to calculate MAC, in this case MAC=10^(2.8705)=742 mA for planarity change =0.1um

Confirmation of MAC concept, Stable Probe Tip Planarity after 35k MAC pulses

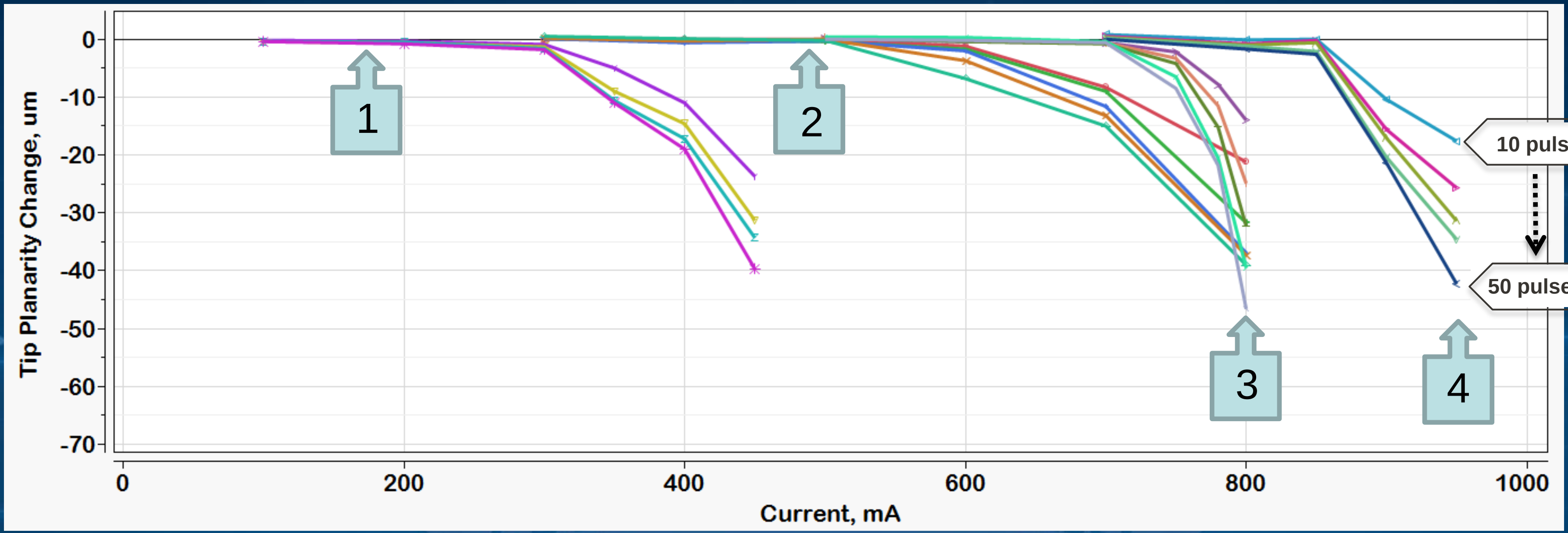




- No change to probe tip's planarity during the performed 35k MAC (742mA) pulses
- Each pulse 1min-on/1sec-off
- 75um probe deflection



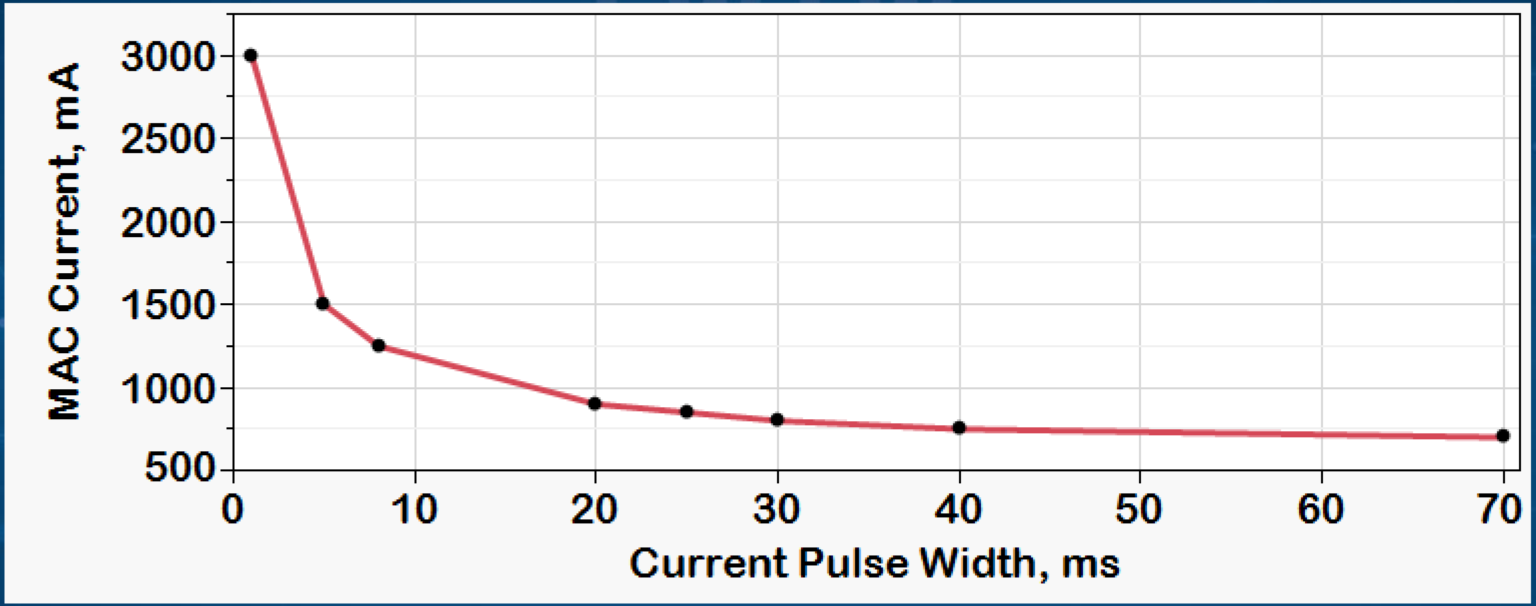
MAC vs. CCC for a Range of Probes



- MAC/CCC Ratio is not a constant, is probe architecture dependent

Probe	ISMI CCC, mA	MAC, mA	MAC/CCC
1	450	278	~0.6
2	800	478	~0.6
3	800	637	~0.8
4	900	742	~0.8

MAC vs. Current Pulse Width for a 900mA CCC/742mA MAC probe



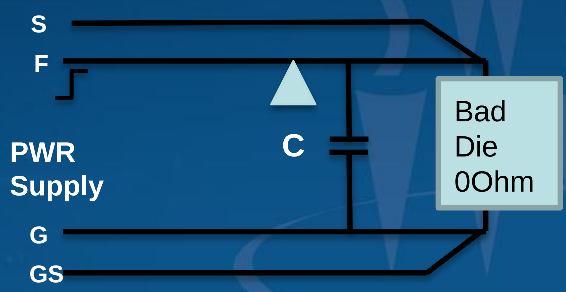
- For current pulse >=70mS the MAC value does not change
- Practical current pulses used in wafer tests exceed 70mS, therefore, shorter pulses cannot be used to “increase” MAC
- Ultra short pulses (<1 msec) can help “transient current” management

Impact of Test and Power Supply on Probes

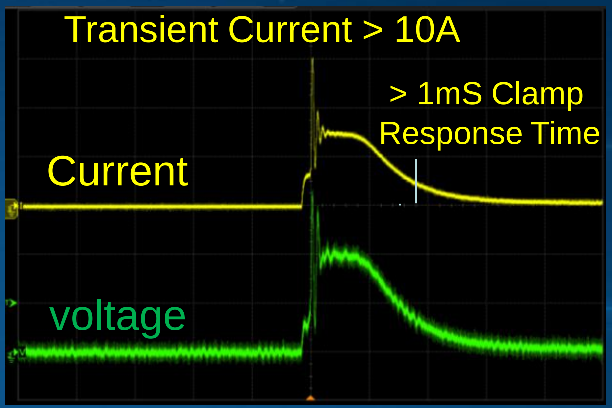
- Significant static and transient currents can happen during wafer test due to electric shorts in faulty chips
  - >2A current have been experienced
- Faulty devices must be screened out at lower voltage setting with current clamp limits set <=MAC at the begining of the wafer test
  - Full voltage and higher clamp limits are applied only to confirmed good die
- Management of power supply is needed in the test program to protect probes:
  - Current range, clamp limits and the response time -> example 1
  - Power supply slew rate (dv/dt) and transient current magnitude -> example 2

Example 1: Current Profile and Clamp Response Time

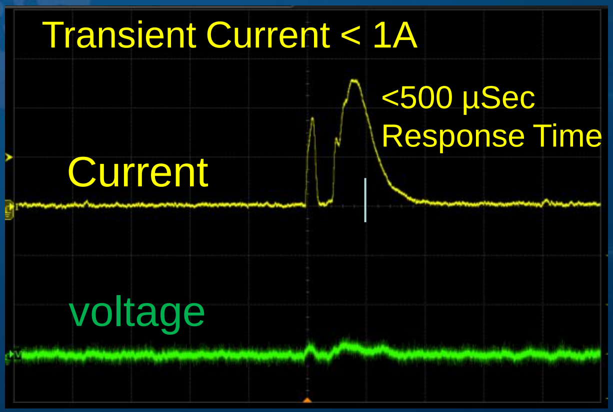
- **Test Case: Clamp response time for the same power supply under 100mV step into a shorted device (Vdd shorted to Vss) at different current range**



Higher Current Range



Lower Current Range

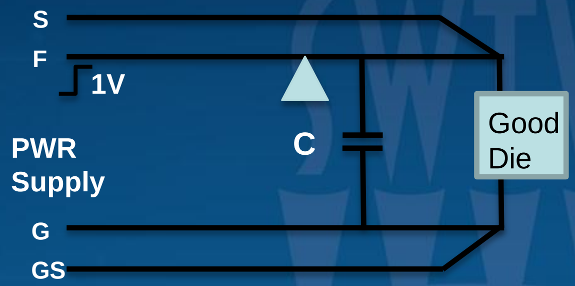


- **Current clamp is effective in limiting static current; however, its response time is not fast enough to completely limit the transient current**
- **To protect probes from damage, transient current magnitude and duration must be limited**
  - Select lower current range of the power supply to reduce transient current spikes
  - Reduce clamp response time by switching off large capacitance

Example 2: Slew Rate Effect on Transient Currents

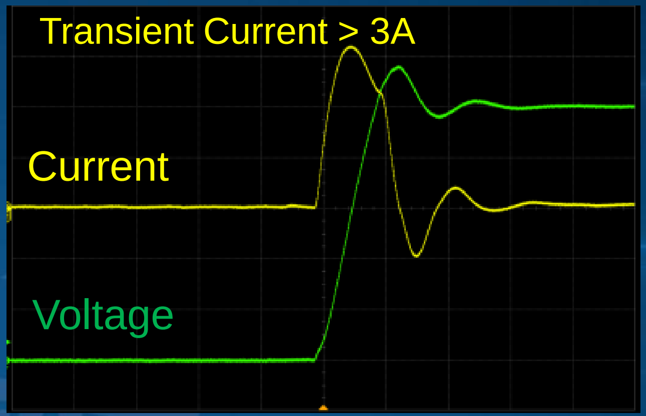
- Test Case: Transient current response versus Voltage slew rate. Same power supply.

No current clamp



- Case 1 :
  - Fast Slew Rate 50 x
  - > 3A peak current within 1 milli-second
- Case 2 :
  - Slow slew rate 1x (digitally controlled in steps)
  - < 200mA peak current
- Slower slew rate minimizes magnitude of current surge to protect probes; however, it can have a small impact on test time
- Actual current going through the probes depends on device and capacitor impedance

Case 1: 50x slew rate



Case 2: 1x slew rate

Conclusions

- The Maximum Allowable Current (MAC) represents actual current that probe can safely deliver, a more reliable specification than CCC
- MAC is defined as current level at which probe will not change its planarity or cause permanent damage in repeated use
  - Duty cycle representative of test time and prober indexing time
- MAC is lower than CCC, however the MAC/CCC ratio is not a constant number – varies based on probe architecture
- For current pulse shorter than 1 millisecond, a probe can sustain significantly higher current than MAC without damage
- Current clamp is effective in limiting static current; however, its response time is not fast enough to completely limit the transient current
- Slower power supply slew rate minimizes magnitude of transient current to protect probes