Standardized Direct Charge Device ESD Test For Magnetoresistive Recording Heads II

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Abstract **-** The well-known Human Body Model is not the most relevant ESD mechanisms along today's production lines. Damage will most likely occur from metal contact rather than from bare fingers. Discharge waveforms from metal-to-metal contact are of the order of 1 ns, while HBM is 150ns. As there is no standard for Direct-Charged Device Model in the literature yet, the purpose of this work is to propose and define the first standard for D-CDM testing. This standard is based on manual discharge data. We further investigate if existing D-CDM tools meet this standard: ISI D-CDM and T.E.T ESD/CDM tools are reviewed.

I. Introduction

As the areal density increases dramatically in the magnetic recording industry, so does the sensitivity to ESD. The Human Body Model is not the most relevant model any longer, as ESD will mostly occur from direct metal-to-metal contact discharge events that occur as a charged component discharges to another object at a different electrostatic potential. In this case, the discharge waveform is very different from the HBM one. The discharge is much faster (1ns versus 150ns for HBM).

Metal-to-metal contact discharge has been a concern in IC technology for some time. The ESD Association released a technical report this year on Socket Device Model tester [1] for integrated circuits, but the discharge waveforms are not reproducible for different sockets or testers [2].

In the literature, there is no standard for Direct-Charged Device Model (D-CDM), but there is a need for test Standards and calibration procedures.

There is a standard for field induced CDM [3], but it is not appropriate for D-CDM and the voltages used are at least one order of magnitude higher than failure voltages for magnetic recording technology.

Here, we will limit ourselves to voltages in the range that is relevant for readback sensors in heads for magnetic recording (0-50V). The standard defined here is based on manual and Spice model data [4]. We'll define a waveform for known calibration capacitors of values close to the usual value of HGAs capacitance (between 5 and 15 pF, depending on the flexible interconnect and head designs). For D-CDM discharges on current areal density heads, voltages of 5 to 10V will cause irreversible damage.

II. Experimental Results

In order to define the ideal waveform for metal-to-metal discharge, we use manual charge and discharge a capacitor, as described in [4]. The value of the capacitor is chosen from 2 pF to 20pF to slightly extend beyond the capacitance values an HGA is expected to have.

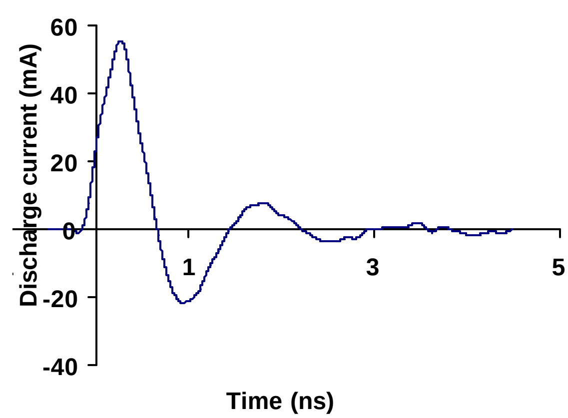

Figure 1: Manual Discharge waveform for a 4.4pF capacitor at charging voltage 4V.

Figure 1 shows an example of waveform for a capacitor of 4.4 pF and voltage of 4V from [4]. In summary, a voltage source provides voltage to the top plate of the capacitor. The bottom plate of the capacitor lays on a grounded gold plate. The discharge of the top plate of the capacitor to this ground is done manually using a short wire. A CT6 current probe is placed around this short wire, very close to the discharge contact. The manual contact must be very fast and precise and the discharge wire length is small enough to minimize the inductance from the short wire. Contacting the wire and the top capacitor will create a spark, with added resistance (Rspark). Waveforms have been monitored with a CT6 current probe and the oscilloscope was a Tektronix TDS 694C 3GHz and 10GS/s. The current of the first peak reaches 55 mA and the width of the pulse is about 0.5 ns. Note that after the first peak, there is a second peak of opposite polarity or undershoot. Waveforms obtained in the same manner for the same capacitor and the same charging voltage (V_DCDM) are mostly reproducible, i.e. peak currents and pulse width values are within +-10%. Waveforms were captured for a range of capacitor values and charging voltage values.

In fact, the manual D-CDM setup corresponds to a simple RLC circuit. The only uncertainty lies in the spark resistance. The spark resistance issue was addressed in [4]. From [4], we will assume that values of spark range from 20 to 60 Ohms. Therefore, in the range of capacitance and inductance considered here, the response of the circuit is underdamped, as can be seen in Fig.1. Our purpose here is to establish a standard for testing. In production or testing lines, the discharge can be very different than the one shown here, depending on R, L and C. However, it is likely that the discharge will be less severe than the manual discharge described here, as we minimized L and R. More inductance or resistance will broaden the peak and reduce the peak current. Therefore we consider here what we call "a worst case scenario".
It will allow to set a safe voltage specification for manufacturing.

III. Defining a Standard

To define a standard, the notations as indicated in Fig.2 will be used. tr is the rise time and is defined as the time from 10% to 90% of full amplitude. t_d is the width at half amplitude, I_{p1} is the maximum current of the first peak and I_{p2} is the maximum current of the second peak.

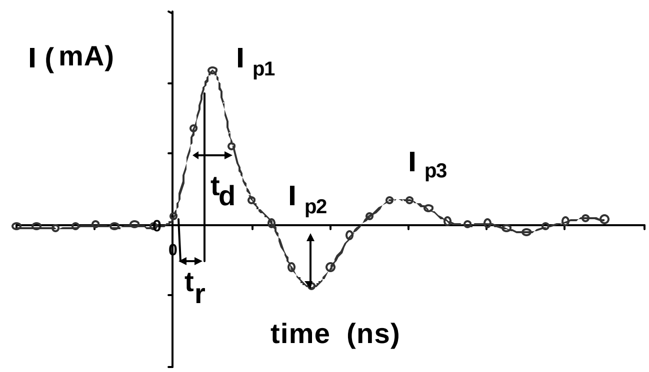

Figure 2: typical D-CDM manual discharge waveform.

Measurements should be performed with an oscilloscope with a single shot bandwidth of at least 2GHz and 10GS/s such as LeCroy DDA260 and an inductive current transducer or coaxial resistive probe of at least 2 GHz bandwidth (CT6 for example). Standard values are given in table 1 for 2 disk capacitors of values 5 and 12 pF.
Values for peak currents are slightly lower than the ones reported in [4]. The reason is that a 3GHz oscilloscope was used in this article while standards should apply also for the use of a 2GHz oscilloscope. Hence, current values will be lower and width higher than the ones reported below.

Parameter	symbol	2 GHz/5pF	2GHz/12pF
Rise Time (ns)	t_r	< 0.4	< 0.5
Width at half Height	t_d	0.65 ns	1 ns
Max 2nd peak	Ip_2	<50% Ip_1	<50% Ip_1
Max 3rd peak	Ip_3	<25% Ip_1	<25% Ip_1
Ip1 per charging voltage (mA/V)		11	16

Table1: D-CDM standard for 5pF and 12 pF Disk capacitors.

IV. Calibration Procedure

Based on the above, we can now define a calibration for D-CDM tools:

1- Required Equipment

- D-CDM ESD tester: Equipment capable of meeting the discharge waveforms for the chosen discharge method.
- For full bandwidth waveform measurement: oscilloscope with a single shot bandwidth of at least 2GHz and 10GS/s such as Tektronix TDS 694C or LeCroy.
- For full bandwidth waveform measurement: An inductive current transducer or coaxial resistive probe of at least 2 GHz bandwidth.
- Two gold-plated etched copper disk on one side and ground plane on the other side on 0.8 mm thick FR-4 circuit board material, with a capacitance to the ground plane of 5 pF +/- 5% and 12 pF +/- 5% at 1 MHz.
- Capacitance meter with a resolution of 0.1 pF, a measurement accuracy of 1%, and a measurement frequency of 1 MHz.

2- Calibration

- Both positive and negative waveforms shall be recorded during the tester qualification and calibration procedures. Clean the disk capacitor modules for 20 seconds in an ultrasonic cleaner using IPA. Avoid further skin contact with the modules prior to and during testing.
- Place the capacitor on the ground plane; ensure intimate contact between the module and the ground plane.
- Set the horizontal time scale of the oscilloscope to 0.5 ns per division, and the vertical sensitivity appropriately. Make sure waveforms are repeatable. Record waveforms of discharge current for 5 and 12 pF in mA/V at 1, 10 and 20V charge levels
- Plot the sensitivity curve using Ip vs. V-DCDM at 5 pF and 12 pF
- All parameters shall be within the limits specified in table 1 within 10%

All waveform records shall be kept for future waveform verification purposes.

V. Evaluation of D-CDM Tools

1- I.S.I. ESD/CDM Tool

We also evaluated an automatic D-CDM tester from Integral Solutions International. It is used for measuring the D-CDM failure threshold for magnetic sensors in recording heads. Typically, a Head Gimbal Assembly (HGA) is mounted and the tool outputs automatically all Quasi-Static parameters, such as amplitude and resistance, as a function of charging voltage. Capacitors can be mounted instead of HGAs for calibration purpose.

The D-CDM module comes with a CT6 placed very close to the pogo pins that contact the capacitors. We measured the current waveforms with the CT6 for several capacitors. One side of the capacitors is on the plate connected to ground, and the other side is in contact with the probe for charge and discharge.

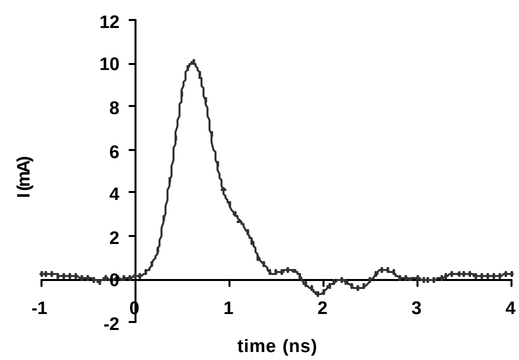

Figure 3: ISI ESD/CDM waveform for 5pF and 1V.

Fig.3 shows that the peak current (10mA), is close to the standard (11mA) as well as the width of the peak (0.5ns) and the rise time (0.3ns) for 5pF. However there is almost no undershoot. No undershoot was observed at other voltage or capacitance values.

The same experiment as manual discharge described above was done with ISI D-CDM module. Fig. 4 and 5 show peak current and width versus voltage. Width of peak seems to saturate for higher capacitance values (>10pF or so).

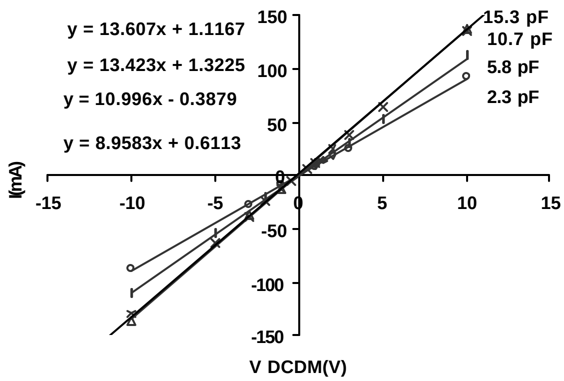

Figure 4: ISI ESD/CDM results: current of first peak versus charging voltage.

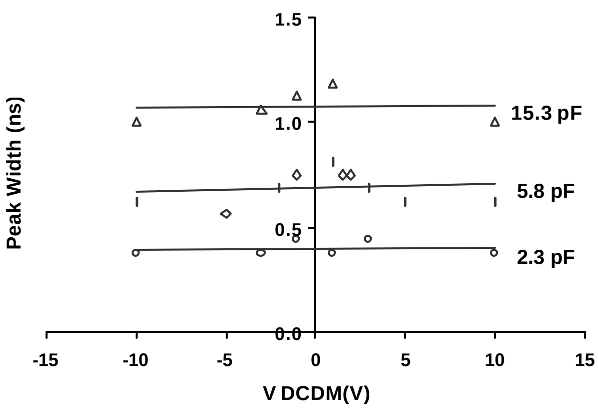

Figure 5: ISI ESD/CDM results: Width of first peak versus charging voltage.

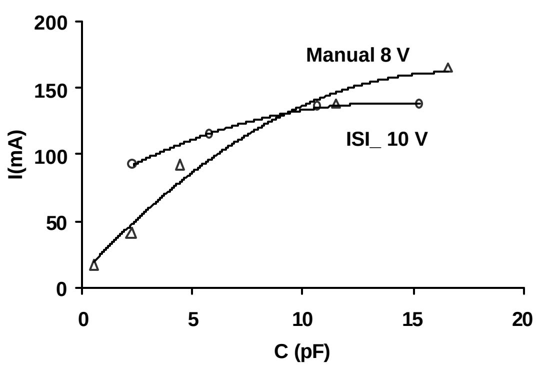

Figure 6: Peak current as a function of capacitance values for ISI tool at 10V compared with manual data at 8V.

The width of first peak is reasonably close to standard ones. However the peak current is high for lower capacitance, compared to standards. Figure 6 shows a comparison of peak current as a function of capacitance value for ISI tool and manual data.

The slope of I versus C is lower for ISI tool than for our standards. From manual or Pspice data, the slope of Imax versus C is expected to decrease with increasing capacitance. Figure 7 illustrates the fact that manual data is close to Pspice data.

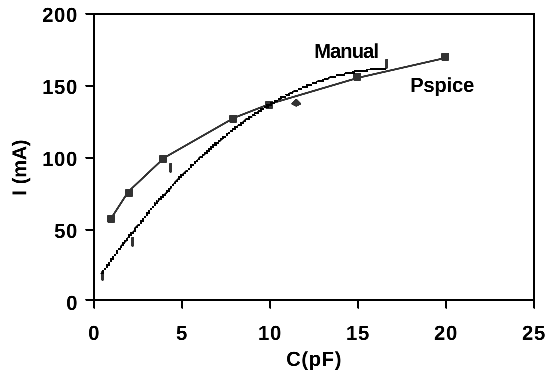

Figure 7: Peak current as a function of capacitance values for manual data at 8V compared with Pspice data at 8V, L=15nH, Spark=24 Ohm.

It is surprising that in the ISI tester, a clear saturation is reached around C=10pF.

When using an HGA instead of a capacitor, the waveform looks different. Ref. 4 gives the equivalent circuit of an HGA, which is much more complicated than a single capacitor.

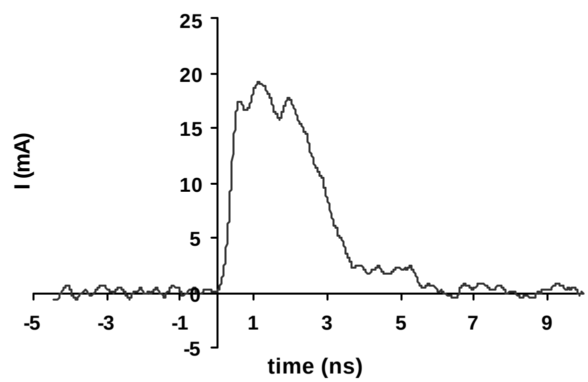

Figure 8: Current as a function of time obtained with CT6 for an HGA with a current technology GMR head obtained with ISI D-CDM tester at 2V.

An advantage of the ISI D-CDM tester is that devices are directly charged and discharged through a mercury relay and QST parameters are automatically measured after each D-CDM discharge. A study of degradation of GMR and TMR heads using this tester has been reported previously [5].

2- T.E.T. ESD/CDM Tool

We evaluated a semi-manual D-CDM tester from Tokyo Electronics Trading Co., Ltd. (ECDM 100E; http://www.tet.co.jp/English/home-eg.html). We used the capacitors described above and replaced the T.E.T built-in probe with a current probe CT6 located right where the TET pin contacts the capacitor.
A waveform for 5pF capacitor and 2V is shown Fig.9.

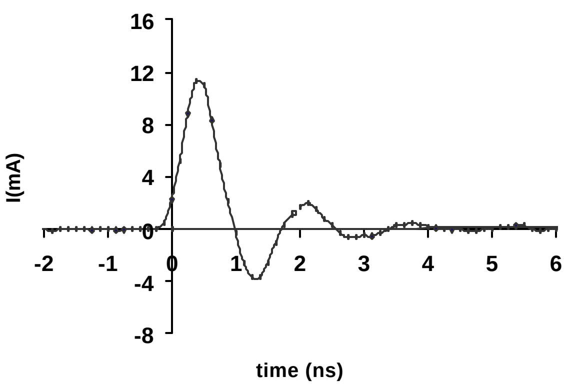

Figure 9: TET ESD/CDM waveform for 5pF and 2V.

Fig.9 shows that the peak current (11mA) is close to the standard (11mA) as well as the width of the peak (0.6ns) and the rise time (0.4ns) for 5pF.
The undershoot is also within limitations (<50% of first peak).

The same set of data as taken with ISI was taken with TET tool and is reported Fig. 10 and 11.
As well as with ISI tool, the current saturates for higher capacitance.
This tool also lacks a calibration procedure. However, for low capacitance, results are close to manual results.

From Fig. 12, showing peak current as a function of capacitance value, we can see that peak current saturates (also for 10 pF or higher) much faster than manual discharge.

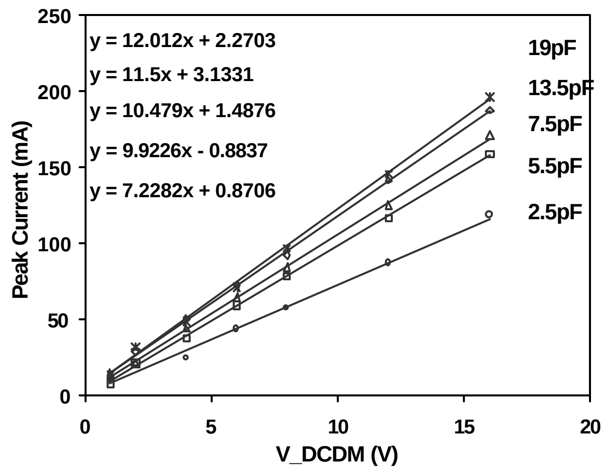

Figure 10: TET ESD/CDM results: Peak current versus charging voltage.

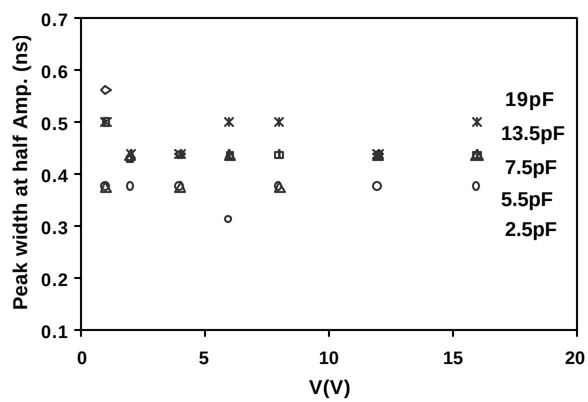

Figure 11: TET ESD/CDM results: Width of first peak versus charging voltage.

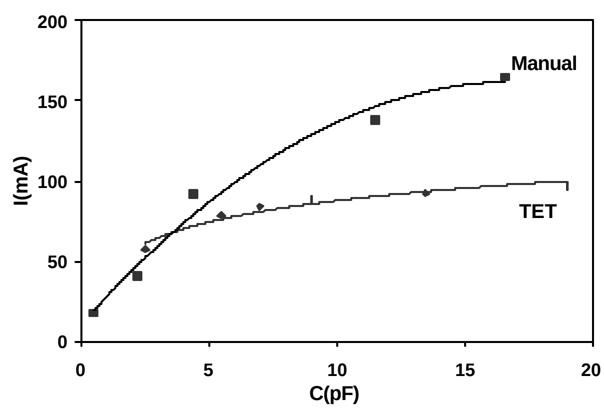

Figure 12: Comparison between manual and TET. Peak current versus Capacitance for 8V.

VI. Conclusion

The Direct-Charge Device Model is intended to replicate the ESD metal-to-metal contact discharge. We showed that D-CDM standards could be set up based on manual discharge data. A calibration procedure was also defined. Commercial D-CDM testers, from I.S.I and T.E.T. were reviewed and are shown to differ somewhat from the standard. Matching the manual data waveform is very difficult because of any parasitic L or C will change the waveform.

References

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[2] The SDM Test Method: Past, Present, and Future. MIchael Chaine, Ion Barth, Tilo Bordeck, Leo G. Henry, Mark A. Kelly, and Tom Meusen Compliance Engineering. Ce-mag.com 09-10/2001

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