Forward and Reverse TLP Curves of PN Junction ESD Diodes

AND90200/D

ESD is ns−us time interval charge transition phenomena, which may cause short time EOS for electronic device or electronic systems. ESD protection device aims to provide a low impedance path for ESD transient high power charge transition. ESD diode is such a device that can provide low impedance current path. Figure 1 is a circuit symbol of ESD diode.

To characterize ESD diode, TLP (Transmission Line Pulse) is commonly used to measure ESD diode high current and high voltage IV characteristics in forward and reverse condition. Figure 2 shows the circuit diagram of Zener diode under TLP test. Here, parameter values of TLP pulse are: {Vlow = 0 V, Vhigh = ±(0−1500) V (Rint = 50 Ω), dly = 1 ns, tr = 1 ns, tf = 1 ns, pw = 1e − 7 μs}.

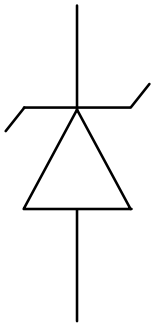

Figure 1. Circuit Symbol of ESD Diode

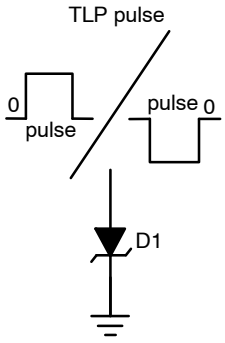

Figure 2. PN Junction Diode Under Positive or Negative Pulse

Positive TLP Pulse

In forward bias case, the time domain current and voltage characteristics of ESD diode are shown in Figure 3 and Figure 4. Here, the TLP pulse voltage Vhigh = 500 V.

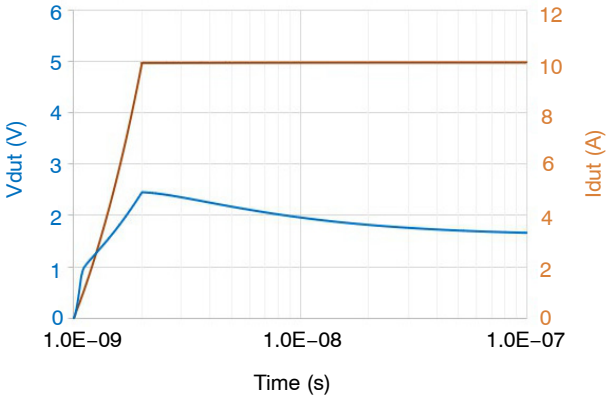

Figure 3. Time Domain Voltage and Current on Diode

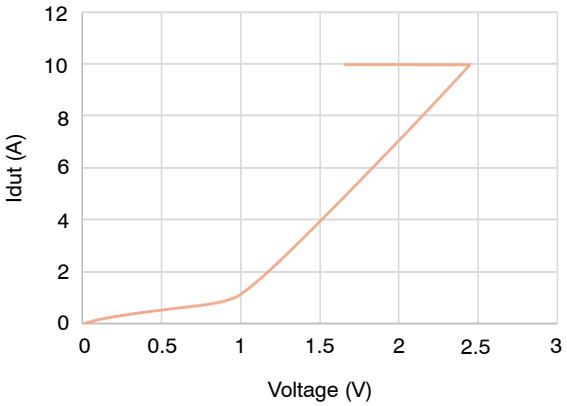

Figure 4. IV Curve of Diode During Forward Turn On

As can be seen from time domain voltage and current, the voltage increase to peak value (Vdut = ~2.5 V) at 1 ns and then drop to about steady state value (Vdut = ~1.7 V) at 20 ns. Figure 4 is the plot of IV curve in Figure 3. It is clearly shown that IV curve snapback from ~2.45 V to 1.65 V when current reach ~10 A.

The physics of this turn−on snap back is due to carrier modulation effect inside diode, which is different from regular snapback effect [1]. As diode is forward conducting, high minority carrier injection happened inside device. As a result, the low doping region inside device will be filled with high injection carriers, which make the resistance of current path smaller.

This snapback effect during turn−on transient is stronger for high voltage diode than low voltage diode. Also, this dynamic snapback effect will be much stronger if a series of pn junctions devices is serially connected, like diode connected with BJT or SCR.

Negative TLP Pulse

When the negative pulse is applied to pn junction diode, diode will reversely breakdown and then conduct reverse current. In diode reverse conduction mode, diode is majority carrier device, which shows strong resistive characteristics of semiconductor material.

Consider the current in depletion region, based on equation $I = quN \times A \times V$, taking the avalanche multiplication factor M(x), total device current is $I = q \times u \times N \times M(x) \times A \times V$. For a given device current, the voltage snapback amplitude is related with avalanche multiplication factor M(x). The higher M(x) results in stronger snapback. Voltage snapback effect is also dependent on current level when avalanche happens. Higher current tends to result in higher voltage snapback effect.

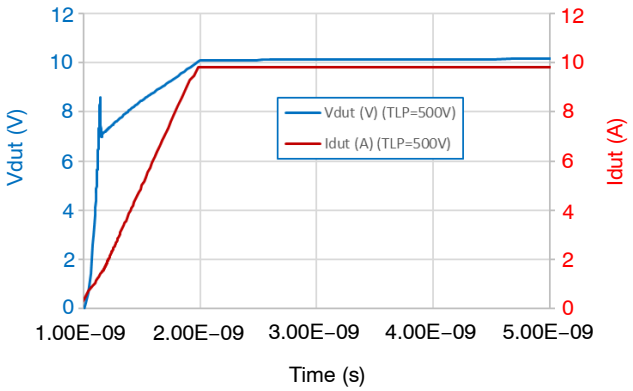

Figure 5. Time Domain Voltage and Current on Diode During Reverse Conducting Transient

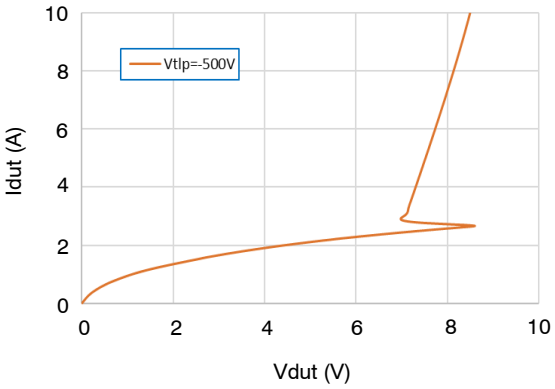

Figure 6. IV Curve of Diode During Reverse Conducting Transient

References

[1] https://en.wikipedia.org/wiki/Snapback_(electrical)

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