



TVS (Triangular Voltage Sweeping)

The TVS test:

The triangular voltage sweep (TVS) test is designed to measure the number of mobile ions in an oxide layer. This test technique is especially important for the detection of the mobile ion concentration between metal lines in a semiconductor device. This test can be accomplished. This test can be accomplished using a capacitor (Metal 1 to Metal 2, interdigitated metal lines...). A transistor or a MOS capacitor is not required for this measurement. (Figure 1)

The procedure for TVS:

- 1 The TVS test begins with a **voltage forced** between the two capacitor plates. The capacitor is generally forced to an elevated temperature during this test as well. A **temperature of about 250 C** is the most common temperature used for this test. The high temperature will greatly increase the mobility of the ions in the dielectric. The voltage will control the direction of the diffusion of these ions.
- 2 The **initial voltage** is applied so as to generate an electric field of around 1MV/cm across the oxide. This electric field is **maintained** for duration of between 20 seconds and 5 minutes, depending on oxide thickness. While this field is maintained at this elevated temperature, any mobile ions in the dielectric will migrate to the plate charged to the opposite polarity. The intention is that this stress will last long enough for the ions to reach a stable position.
- 3 After this initial stage of the stress, the **voltage** is then **ramped down** from its initial stress value **towards zero** volts. The ramp should be a linear voltage ramp at a rate that is around 1 MV/cm/sec. The voltage is ramped at this steady value through zero **and up to a voltage** that will have a magnitude equal to the **absolute value of the initial stress** condition, but the opposite polarity. Once this value has been obtained, the **voltage is held for the same period of time** as the initial stress condition. After this duration has been achieved, the voltage is **again ramped down through zero to the initial stress condition** again. (Figure 2)

During this triangular voltage sweep, the current through the capacitor is monitored. As long as a bias with the same polarity as the initial stress condition is applied across the capacitor, the mobile ions will tend to stay near the capacitor interface. However, when the voltage crosses zero volts, the ions will be repelled by the switched polarity. Ions near the plate of a capacitor will have the greatest image charge. As they diffuse away from this interface, their image charge is reduced. This generates a displacement current in the capacitor. This current can be seen as a sudden peak in the capacitor current as the voltage crosses zero. Crossing from positive to negative or from negative voltage to positive will produce an opposite polarity current peak. These peaks will not necessarily be equal in magnitude as the ions will be at different interfaces



when they are released by the polarity change (e.g. metal 1 interface vs. metal 2 interface). Differences in the dielectric/metal interface will produce a difference in the coupling between the mobile ions and the different capacitor plates and thus produce a difference in displacement current when they begin to diffuse away.

The magnitude of this current peak will be a function of the mobile ion density, the rate of voltage change and the area of the capacitor. For any given capacitor and ramp rate, the magnitude of the current will only be a function of the mobile ion concentration. This will allow a direct calculation of the mobile ion density based on the magnitude of the current.

$$\text{Mobile Ion Density (ions/cubic cm)} = (I_p/e^-) (1/(t_{ox} A_{ox}))(t_i)$$

Where: I_p is the measured peak current (coulombs/sec. or amps)
 e^- is the charge on an ion (coulombs)
 t_{ox} is the thickness of the oxide (cm)
 A_{ox} is the area of the capacitor
 t_i is the integration time for the current measurement (seconds)

Appendix:

Another popular technique that is to detect the capacitance shift (C-V) generally in the MOS capacitor is called "STVS" while the I-V measurement technique is called "TVS". When a voltage ramp is forced across an MOS capacitor, there will be a large shift in the capacitance when a channel is produced under the gate. This gives the flatband voltage shift. This does not occur when both capacitor plates are good conductors. The shift in the flatband voltage seen in a voltage ramp is sensitive to charge in the capacitor. Ions near the oxide/silicon interface will have a much larger image charge than ions far from the interface. Thus ions that move near the interface can be easily detected by a flatband voltage shift.

When both sides of a capacitor are conductors, then there is no flatband voltage shift. However, the movement of ions will produce a change in the image charge of the ions. This change can be measured by the change in displacement current caused by the movement of the ions. The displacement current in an MOS capacitor will be complicated by the displacement current caused by the formation of the channel in the silicon. Thus the I-V curve from a TVS test is much more difficult to interpret. Thus TVS is best applied when there is a capacitor with good conductors on both sides. STVS is best applied when an MOS capacitor is to be tested.

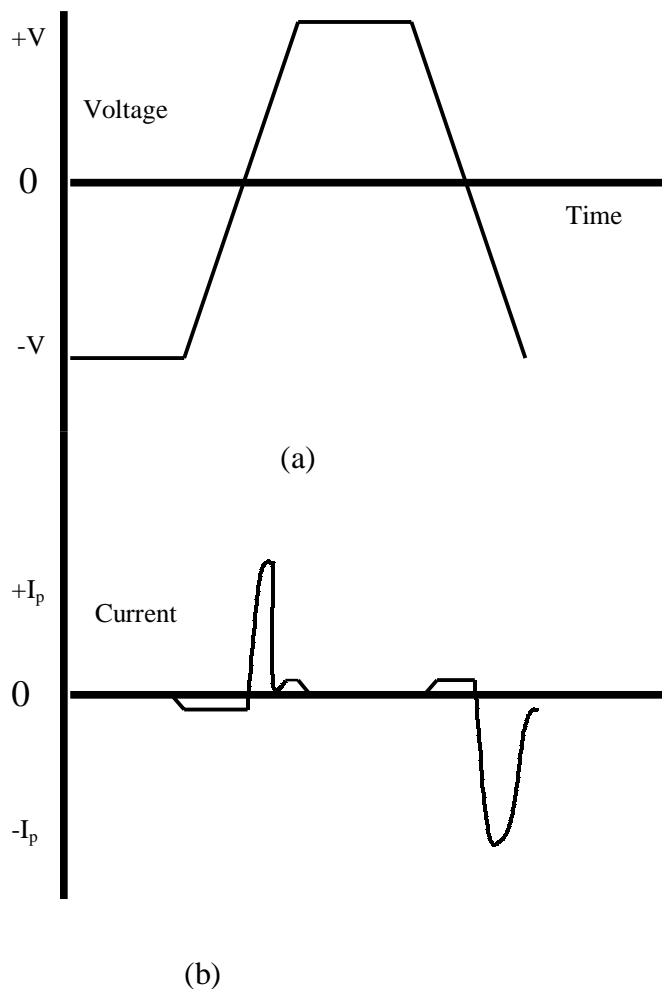


Figure (2)

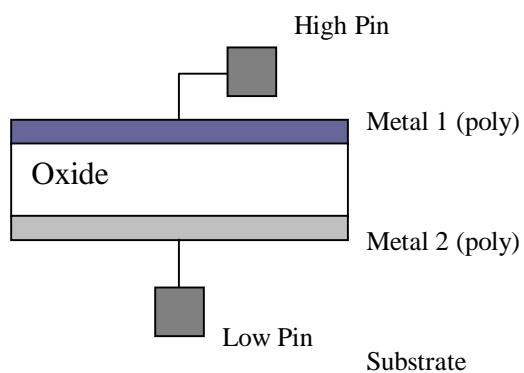




Figure (1)

