

MIL-STD-750D

5000 Class

High reliability space application tests

MIL-STD-750D
NOTICE 3

METHOD 5001.2

WAFER LOT ACCEPTANCE TESTING

*The content of this test method has been transferred to MIL-PRF-19500, APPENDIX D.

CAPACITANCE-VOLTAGE MEASUREMENTS TO DETERMINE OXIDE QUALITY

1. Purpose. The purpose of this test is to determine the quality of an oxide layer as indicated by capacitance-voltage measurements of a metal-oxide semiconductor capacitor. The overall shape and position of the initial C/V curve can be interpreted in terms of the charge density, and to a certain extent charge type, at the oxide-semiconductor interface. By applying an appropriate bias while heating the sample to a moderate temperature (e.g., +200°C), the mobile ion contamination level of the sample oxide may be determined.

2. Apparatus/materials. Capacitance-voltage plotting system complete with heated/cooled stage and probe (Princeton Applied Research Model 410, MSI Electronics Model 868 or equivalent). A C/V plotter may be constructed from the following components (see figure 50023.3-1 for equipment setup).

2.1 Manual setup.

- a. L-C meter (Boonton 72B or equivalent).
- b. X-Y recorder (hp 7035B or equivalent).
- c. DC voltmeter (Systron Donner 7050 or equivalent).
- D. DC power supply, 0-100 volts.
- e. Heated/cooled stage (Thermochuck TP-36 or equivalent).
- f. Probe in micromanipulator.

2.2 Automatic C/V plotter. (CSM-16 or equivalent).

3. Suggested procedure.

3.1 Sample preparation.

- a. The sample is typically a silicon wafer on which has been grown the oxide to be measured, or wafers with known clean oxide which is exposed to a furnace at temperature to measure the furnace cleanliness. An array of metal dots on the surface of the oxide provides the top electrodes of the metal-oxide-semiconductor capacitors. The metal may either have been deposited through a shadow mask to form the dots, or it may have been deposited uniformly over the oxide surface and then etched into the dot pattern by photolithographic techniques. Cleanliness of the metal deposition is paramount. Contamination introduced during metal deposition is as catastrophic to the oxide quality as is contamination introduced during oxide growth. The metal shall have been annealed, except in cases where the method is being used to investigate the effectiveness of annealing.

NOTE: This test may also be used to determine metal deposition system cleanliness when used with oxide samples known to be contamination free.

- b. The minimum dot size should be such that the capacitance of the MOS capacitor is > 20 pF.
- c. The oxide thickness is typically 1,100 Å. Reduced sensitivity results from oxide thickness greater than 2,000 Å.
- d. The backside of the sample shall have the oxide removed to expose the silicon. The backside may have metal, such as aluminum or gold deposited on it.

3.2 C/V plot (at room temperature).

- a. Place the wafer on the heated/cooled stage. Use vacuum to hold the wafer firmly in place.
- b. Zero the capacitance meter as necessary, place the paper in X-Y plotter and set-up the voltage source for the desired ranged.
- c. Select the capacitor dot to be measured and carefully lower the probe to contact it.
- d. Lower the pen on the X-Y plotter and sweep the voltage over the desired range so a C/V trace for an N-type substrate or P-type substrate, similar to that shown on figure 5002-2 is obtained.

NOTE: If an anomalous trace is obtained, it may be because the capacitor is leaking or shorted. In this case, another dot should be selected.

3.3 Mobile ion drift.

- a. Use the capacitor dot measured in 3.2.d.
- b. With the probe making good contact, apply a positive bias of 10^{10} v/cm to the capacitor dot. (For a 1,000 Å thick oxide, this is a 10-volt bias.) A different voltage is acceptable, if the manufacturer can demonstrate effectiveness.
- c. Heat the sample to $+300^{\circ}\text{C} \pm 5^{\circ}\text{C}$ with the bias applied. Hold at this temperature for three minutes (different times may be acceptable if the manufacturer can demonstrate effectiveness).
- d. With the bias still applied, cool the sample to room temperature (the heating and cooling cycle can be automatically programmed if the Thermochuck system is used).

NOTE: Be certain that the probe does not lose contact with the capacitor dot during the heat/cool cycle. If it should, the test is invalid and should be repeated.

- e. Lower the pen on the X-Y plotter and sweep the voltage over the range necessary to obtain a C/V trace similar to that obtained in 3.2.d. The trace may be displaced on the voltage scale from the original trace, but should be parallel to the original trace. Label this trace as the (+) trace.
- f. Apply a negative bias of the same magnitude selected in 3.3.b to the capacitor dot and repeat steps 3.3.c and 3.3.d.
- g. Lower the pen on the X-Y plotter and sweep the voltage over the range again. This trace may be displaced from the two previous traces and should be labeled as the (-) trace.
- h. An automatic system that performs equivalent functions may be substituted for steps 3.3.b and 3.3.g.

3.4 Interpretation.

- a. Determine the ΔV_{FB} (voltage difference between original trace and bias trace, taken at 90 percent capacitance level (see figure 5002-2)).

- b. Determine the mobile ion contamination concentration, N_o , as follows:

$$N_o = \frac{\epsilon_0 K_{ox} \Delta V_{FB}}{q t_{ox}}$$

Where: ϵ_0 = Permittivity of free space (8.85×10^{-12} coulomb volt⁻¹ m⁻¹).

K_{ox} = Dielectric constant of the oxide (3.8 for silicon dioxide).

q = The charge on an electron (1.6×10^{-19} coulomb).

t_{ox} = Oxide thickness (in meters).

Example:

ΔV_{FB} (measured from C/V curves similar to those shown on figure 5002-2) = 1.4 V.

t_{ox} (measured on wafer prior to metal deposition) = 950 Å.

$$N_o = \frac{(8.85 \times 10^{-12}) (3.8) (1.4)}{(1.6 \times 10^{-19}) (950 \times 10^{-10})} = 3.1 \times 10^{15}/\text{meter}^2 = 3.1 \times 10^{11}/\text{cm}^2$$

So, the mobile ion contamination-level is 3.1×10^{11} mobile ions per square centimeter in this example.

- c. Considerably more information concerning the oxide and the semiconductor substrate can be obtained from interpretation of the C/V trace.

4. Summary.

4.1 Calibration. The voltage scale calibration of the X-Y plotter should be checked against the DVM during set-up. Other instruments should be calibrated at regular intervals.

4.2 Accuracy. The voltage accuracy obtainable is ± 0.1 volt and the ΔV_{FB} accuracy obtainable is ± 0.2 volt. The practical lower limit of detectability of mobile ion contamination is on the order of $2 \times 10^{11}/\text{cm}^2$.

4.3 Documentation. Record results in appropriate control document.

Reference:

Whelon, N.V., "Graphical Relation Between Surface Parameters of Silicon, to be Used in Connections with MOS Capacitance Measurements", Phillips Res. Apt., 620-630 (1965).

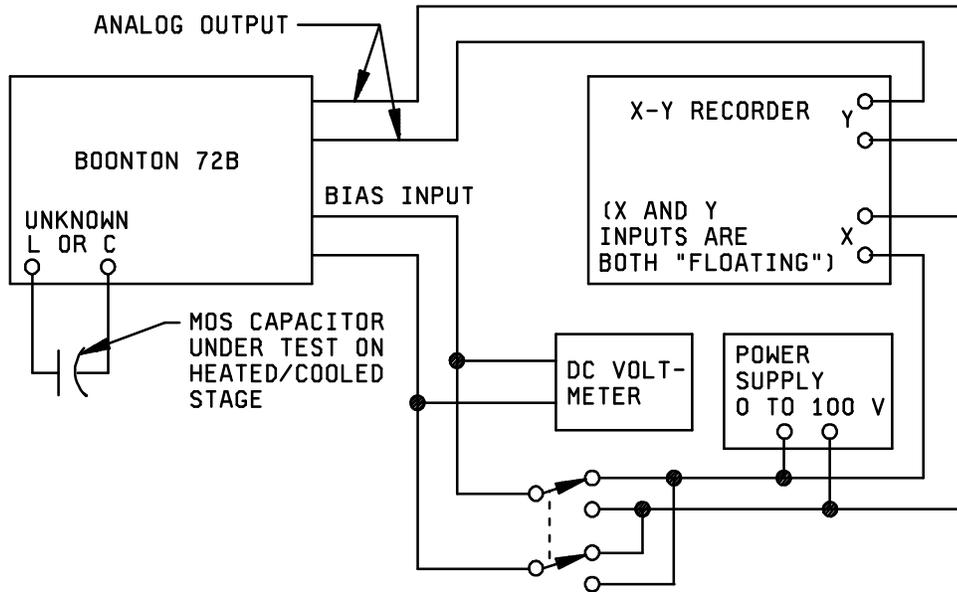


FIGURE 5002-1. Diagram of equipment set-up for measuring relationship of metal-insulator-semiconductor structures.

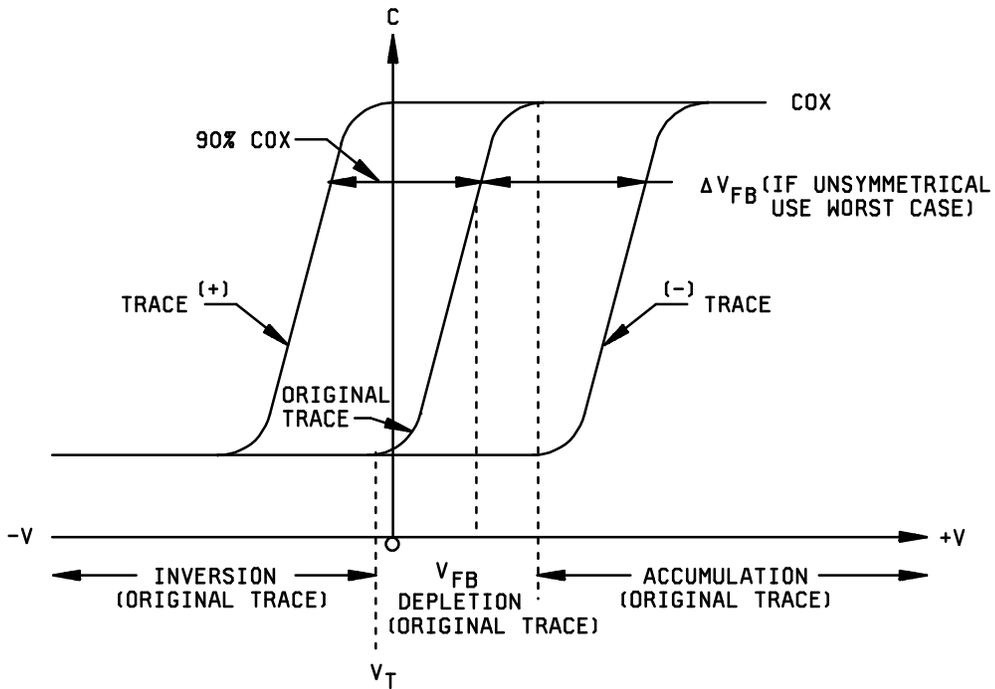


FIGURE 5002-2. C/V traces.

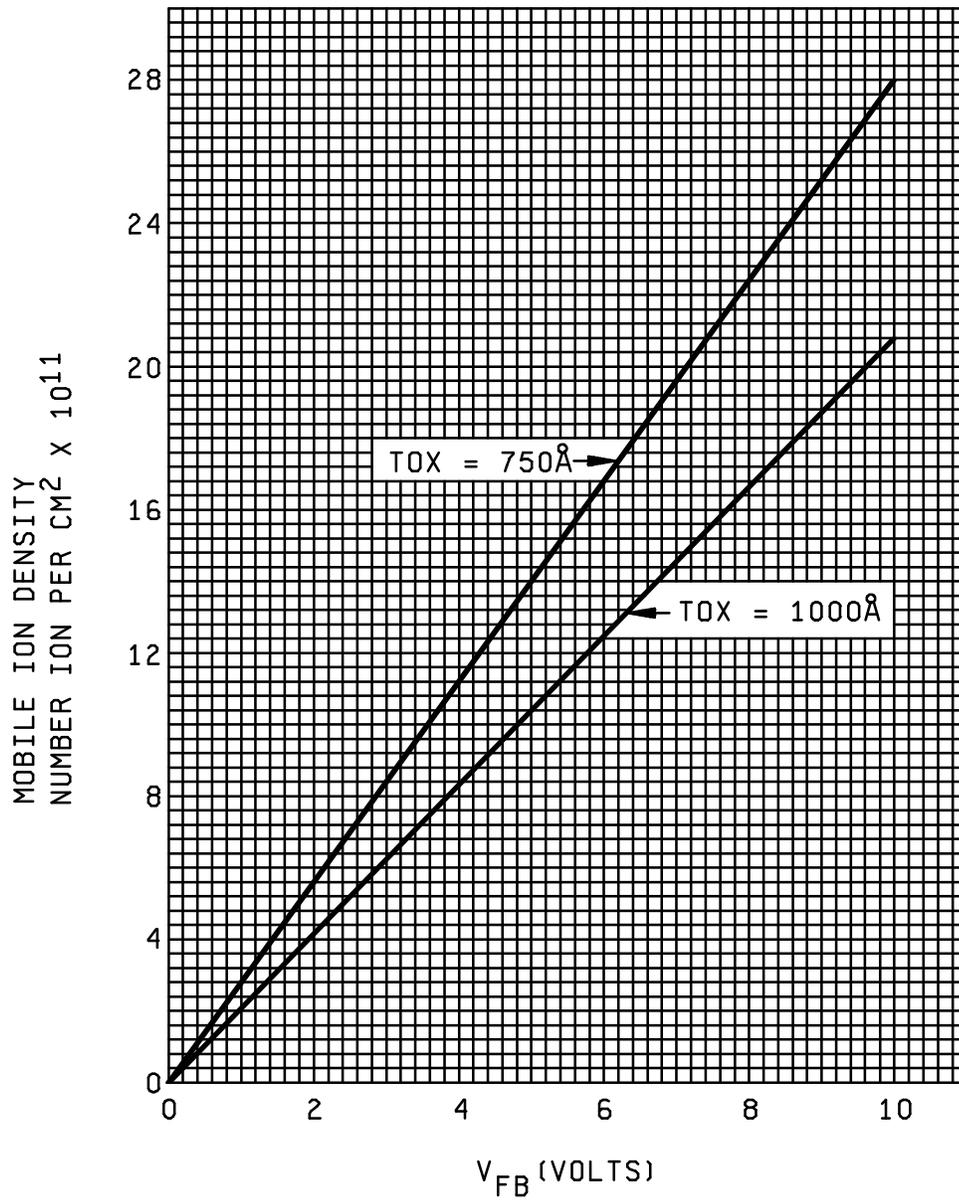


FIGURE 5002-3. Mobile ion density versus voltage shift (V_{FB}).

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METHOD 5010

CLEAN ROOM AND WORKSTATION
AIRBORNE PARTICLE CLASSIFICATION AND MEASUREMENT

1. Purpose. This test method provides a classification system for and means of measuring air cleanliness. It is intended to be used in conjunction with the environmental controls specified in MIL-S-19500.

2. Air cleanliness classes. There are three classes defined by this test method. Classifications are based upon particle count with a maximum allowable number of particles per unit volume 0.5 micron or larger or 5.0 microns and larger. Particle counts are to be taken during normal work activity periods and at a location which will yield the particle count of the air as it approaches the work location.

2.1 Class 100 (3.5). Particle counts must not exceed a total of 100 particles per cubic foot (3.5 particles per liter) of a size of 0.5 micron or larger.

2.2 Class 1000 (35). Particle counts must not exceed a total of 1,000 particles per cubic foot (35 particles per liter) of a size of 0.5 micron or larger or 7 particles per cubic foot (0.25 particles per liter) of a size 5.0 microns and larger.

2.3 Class 10,000 (350). Particle counts must not exceed a total of 10,000 particles per cubic foot (350 particles per liter) of a size of 0.5 micron or larger or 65 particles per cubic foot (2.3 particles per liter) of a size of 5.0 microns and larger.

2.4 Class 100,000 (3,500). Particle counts must not exceed a total of 100,000 particles per cubic foot (3,500 particles per liter) of a size of 0.5 micron or larger or 700 particles per cubic foot (25 particles per liter) of a size of 5.0 microns and larger.

3. Particle counting methods. For proof of meeting the requirements of the class of clean room or clean work station, one or more of the following particle counting methods shall be employed on the site of use.

3.1 Particle sizes 0.5 micron and larger. The equipment to be used must employ the light scattering measurement principle as specified in ASTM F50.

3.2 Particle sizes 5.0 micron and larger. A microscopic counting of particles collected on a membrane filter, through which a sample of the air to be measured has been drawn, may be used in lieu of the light scattering measurement principle as specified in ASTM F25 and SAE-ARP-743.

4. Monitoring techniques. Appropriate equipment shall be selected and monitoring routines established to measure the air cleanliness levels under normal use conditions.

5. Items to be specified. The referenced general specification shall specify the following information:

- a. The class of the workstation or clean room.
- b. The frequency of test. Unless otherwise specified, this frequency shall be, at a minimum, once per month per working shift.
- c. The locations within the clean environment to be monitored.