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Contact Electromigration

Summary:

Contact migration is the interdiffusion of the contact metal and silicon, either under current stress conditions or at temperature. The migration may take place with metal contacts on silicon, and the migrating species could be either metal in silicon or silicon into the metal depending on the stress conditions.
The contact electromigration test structure is designed to detect defects in the contacts that will cause a short lifetime due to electromigration. Mechanisms such as *the collection of silicon precipitants* in positive contacts, *junction spiking* due to the depletion of silicon from negatively biased contacts or metal voiding due to step coverage problems can be identified from this test.

Test description:

Two test options are provided for different type of contacts: traditional and stud contacts. For traditional contacts, the test forces a high current density in a contact chain for a specific period of time. The current forced is the maximum current that can be forced without causing the temperature of the silicon in the current path from reaching the eutectic temperature of the aluminum and silicon. For stud contacts or contacts less than 0.5 µm in diameter, a test structure is provided with a self-heating resistor. The metal connecting the contacts passes over the heater resitor. The heater resitor also includes a minimum width metal serpentine line that is used for a thermometer. The heater resitor will bring the metal lines connected to the contacts to a high temperature. This allows the testing of this structure at a high temperature but a lower current density. This structure avoids the problems associated with the very high temperatures generated in the contacts when current densities high enough to cause joule heating in the metal lines are used.

Analysis:

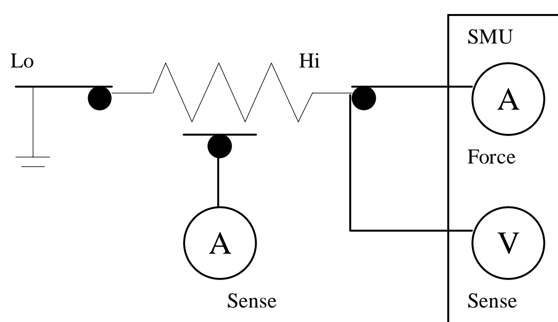
Measure the change in contact resistance (R_{cont}), and I_{leak},(Isub), as a function of stress or Time.

R_{cont} Increase	silicon accumulation in the contact; Void formation in the metal.
R_{cont} decrease	potential dirty contacts; Insufficient alloying of contacts to start with.
I_{leak} increase	junction spiking. Stress current too high and contact melted.

Test Method:

The test is conducted by forcing an increasing current through the self-heated resistor. Each time the current is increased through the resistor, the change in resistance of the narrow metal serpentine resistor on top of the heater is measured. The change in resistance combined with the TCR (temperature coefficient of resistance) of the metal line is used to calculate the temperature

of the metal line. When the narrow serpentine metal line indicates that the line has reached the desired stress temperature, the current forced through the resistor is held constant. This value is re-evaluated periodically through the remainder of the stress to insure that the structure is at the correct stress temperature. Once the stress temperature is achieved, the specified stress current is forced through the test line for a specific period of time. During this stress, the resistance of the line and the leakage current to the substrate or well (active contacts only) should be monitored. The test should terminate if the resistance or leakage exceeds preset limits.
Following this stress, the resistance of the test line should be measured with the current forced in the opposite direction than it was stressed. For metal lines without refractory metal this is to detect what is called rectifying contacts. Rectifying contacts are formed when silicon from the aluminum metal lines deposit epitaxially in the contacts. These contacts can become N-doped due to the presence of the aluminum and thus form an N-to-P contact to P-doped silicon. This generates a diode that conducts only in one direction. Fortunately, this is often a very leaky diode. Thus, a large difference in the resistance of the test line depending on the polarity is an indication of the rectifying contact effect.



The result output:

Contact resistance increase/decrease Vs. Time
Leakage current Vs.Time

Start

Measure R_{ini} @T_{ini}

Measure TCR @ T_{ini}

Firstly Force I, measure the resistance R.

Current ramp
Measure R, calculate T,

Calculate the differential thermal resistance

? T reach 80%T_{tar}

Y

Measure R calculate T,
Using last thermal resistance Q to Estimate the ΔI

Force new current, measure R, Calculate T, and Q

? T within Error band

Y

Check if the leakage current > the defined criteria
Otherwise EOT

EOT

Stress Istress

Measure R

? ΔR>criteria or Stress time reach limit

Y