Periodic ESD Tests & Measurements for Wafer Fabs

by Mr Inderjit Singh
(Cesstech (S) Pte Ltd)

Abstract

This article serves to provide a brief introduction to the ESD tests and measurements which could be periodically conducted within the Photolithography (Reticle) process of Front End Semiconductor / Wafer Fabrication facilities as part of an overall ESD control and management program.

Introduction

Over the years and with on-going "learning thro' mistakes" philosophy, a great number of people have come to grips with the need for maintaining proper ESD (Electrostatic Discharge) control in key processes. Take for example, in the front end semiconductor or wafer fabrication facilities, static charge can cause issues with particle contamination (ESA – Electrostatic Attraction), ESD events resulting in meltdown of metal layers and even equipment or microprocessor lockups, especially in the Photolithography process which involves handling and processing of reticles or photomasks. With decreasing geometry sizes in the semiconductor operations good ESD control is vital to a higher yield and greater productivity. With proper ESD controls in place, defects, especially to reticles, can be tremendously reduced, equipment downtime reduced and time between inspections increased. However, implementing a good ESD program is only the beginning – maintaining the program through regular checks and measurements is vital to the success of the program.

A Compliance Verification Plan for ESD control

A good program should look at all aspects of proper ESD controls and cover everything from the administrative elements like objectives, training and compliance verification plan to the technical requirements and specifications of materials and processes. The ESD ANSI S20.20 Standard is a good reference guide for the design, implementation and management of such a ESD control program. As per the ESD ANSI S20.20 Standard and as part of the "Compliance verification plan" it is vital that periodic checks and measurements be carried out to address & assess the manufacturing environment with regards to ESD control. In a wafer fabrication facility, periodic measurement of the following critical "control points" or parameters is important :

a. Personnel – eg : garments, handling procedures
b. Materials – eg : Reticle pods / carriers, Reticle pick
c. Production Tools – eg : Reticle Inspection stations, Stockers
d. Storage & Transfer Mechanisms - eg : Reticle Racks, transfer trolleys, WIP racks
e. Cleanroom Environment – eg : Flooring, Workstation, Ionizers (if present), seating, walls

For each of these critical control points, the basic tests involved and the measurement instruments / equipment required include :

a. Resistance measurements using a wide range resistance meter with 5lbs electrodes
b. Surface charge or Tribocharging propensity measurements in volts / in using a electrostatic fieldmeter or voltmeter
c. Offset / Float voltage and discharge time measurements for Ionizers using a charged plate monitor (CPM)
d. Measurements of ESD events / EMI using a ESD monitoring and management tool, monitor or a EM Field meter

The measurement tools / instruments used should be the "inspection / selection or acceptance/qualification level" type meters and not just indicating type (Pass/Fail) audit-grade type measurement tools. Besides the instruments, one will also require accessories like clips, cables and stainless steel plates etc for performing some of the tests especially for personnel, garments and tools.

ESD Measurement Tests & Frequency

The basic ESD measurements and tests as part of a periodic compliance verification plan and audit in a wafer fab will entail the measurement of various critical control points as classified in the *five* categories viz, *personnel*, *materials*, *production tools*, *storage & transfer mechanisms* and the *cleanroom environment*. This paper only attempts to recommend tests that should be conducted in the photolithography / reticle handling processes of a wafer fab. However, the same methodology could be extended to other parts of the facility which are deemed to be Electrostatic Protected Areas (EPAs) . Table 1 summarises all the critical control points and the applicable standards.

Tests and Measurements

Personnel tests

The personnel tests will involve doing a static test of the resistive characteristics of the cleanroom garments (jumpsuit) – ie, performing a point to point and sleeve to sleeve measurement of the resistance of the garments. This test can be done by the laundry vendor and/or within the facility itself . Besides this, a dynamic test should also be conducted with the operator wearing the cleanroom garments (complete with footwear) in the cleanroom facility – this test will involve measurement of the resistance as well as the voltage generated by the footwear & flooring in combination with the operator / personnel . The frequency for both tests should be on a *quarterly* basis irrespective of whether the laundry vendor does the in-place garment testing after each washing.

Materials

The material testing will involve testing primarily the reticle pods, the reticle pick and any other manual transfer tools / mechanisms. The testing will again involve point to point and point to ground resistance measurements as well as measurement of the surface charge or tribocharging propensity of the surface in volts/in. The tribocharging propensity should be measured after rubbing the surface with a gloved finger or using a cotton twill cloth - this will help confirm whether the material falls in the static dissipative or conductive range. These tests should be performed at least on a *semi-annual* basis.

Production Tools

In the photolithography / reticle operations of a wafer fab, tools like reticle inspection station, surface measurement / inspection tools, reticle stockers and steppers / scanners need to be periodically tested. The testing will involve measurement of the resistive characteristics which involve grounding checks (point to point and point to ground) and/or tribocharging propensity of materials that come in direct contact with the reticle like the transfer arms and even the enclosure walls itself which are mostly made of plastic or polycarbonate materials in many instances. In a typical reticle stocker for instance, the shelving material where the reticle sits, needs to be tested to ensure proper grounding is in place and that proper static dissipative or conductive material has been used. If ionizers are present (especially in most reticle stockers and inspection stations), the balance and discharge time tests need to be run to ensure that the ionizers are still working efficiently. Due to unavailability of downtime, most of these tools go unmeasured over a long period of time and their deterioration cannot be seen until a catastrophic ESD event occurs. If the ionizers are not tested at least on a *semi-annual* basis the emitter points of these corona-type ionizers will get dirty and their balance will begin to drift . Downtime should be made available at least on a semi-annual basis, if for nothing, but to test at least the ionizers and the tool's grounding. Depending on the complexity of the tool like a stepper, for example, the internal transfer mechanisms might not be available for measurement but attempts should be made (where practically possible) to look at the resistance characteristics of at least the loading / unloading areas with respect to grounding and static charge. If load / unload areas are concealed then the access doors to these areas, should also be tested to ensure that these are ESD safe with respect to grounding and static charge.

Besides these normal resistance and tribo-charging propensity measurements, optionally, especially for tools that cannot be accessed for testing, a EMI/ESD handheld meter or a ESD monitor with a remote antenna could also be placed either within the most accessible part of the tool (eg : load/unload area) or placed very close to the tool (externally) to measure either or both the electromagnetic field strength in volts/m and the number of ESD events that take place, over say 1 minute. Although there are currently no guidelines or acceptance criteria, at least this will help establish some kind of baseline readings such that periodic testing and measurement values could be compared against these baseline levels – if higher values are seen then perhaps a more detailed testing could be done. Again testing on a *semi-annual basis* is encouraged.

Critical Control Point	Standard	Frequency
Personnel • Garments • Flooring / Footwear System	ESD STM2.1-1997 ESD STM97.1-1999	Quarterly
Materials • Reticle Pods • Reticle Pick • Manual Transfer Tools	ESD S4.1-1997 & SEMI E43	Quarterly
Production Tools Eg: Reticle Stockers, Steppers, Inspection stations	ESD S4.1-1997 SEMI E43 ESD STM3.1-2000	Semi Annual
Storage & Transfer Mechanisms Reticle Storage racks, WIP racks, Reticle transfer trolleys	ESD ADV 53.1-1995	Quarterly
Cleanroom Environment • Flooring • Workstations (incl. S/S tables) • Seating • Ionizers	ESD STM7.1-2001 ESD S4.1-1997 ESD STM12.1-1997 ESD STM3.1-2000	Quarterly or Semi Annual

Table 1 : A Summary of the Recommended Parameters that need to be Periodically Tested with the Applicable Standards & Measurement Frequency.

Storage and Transfer Mechanisms

The reticle storage racks, WIP racks and transfer trolleys should be periodically tested on a *quarterly* basis. The testing will involve point to point and point to ground resistance measurements. For a multi-tier storage rack, the point to point resistance measurement between the highest to lowest shelf should be measured and likewise for the point to ground, the resistance should be measured between the highest and then the lowest shelf with respect to the groundable point (in most cases the rack is grounded to the floor).

Cleanroom Environment

Flooring, workstations, seating and ceiling installed ionizers (if present) should be periodically tested as part of the cleanroom environment.

a. For the *ionizers*, the testing will involve measurement of the balance or swing voltage and the decay time from 1000V to 100V. This should be done on a *quarterly* or at least on a *semi-annual* basis.
b. For the *workstations*, the point to ground measurements should be taken and if ionizers are present over the workstations, these should also be measured as per (a) above. The materials like reticle pods, reticle picks etc, within the workstations, should also be measured, if required. These tests should be done on a *quarterly* basis.
c. For *seating*, the point to point and point to ground resistance measurements should be done on a *quarterly* basis
d. The point to ground resistance of the *flooring* should be measured on a *quarterly* basis after identification of the groundable point for the flooring.

Sampling Plan and Acceptance Criteria

The sampling plan for each of the parameters should be based on risk assessment criteria and statistically correct sample sizes, where possible. For example it will be almost impossible to measure each raised floor tile or each reticle pod but, on the other hand, every reticle rack or workstation within an EPA should be tested. As a recommendation, the sample size should be based on:

- criticality of the station or process
- criticality of the technical element or parameter being measured
- impact to the product quality & reliability if the measurements show a failed reading
- recommendation of applicable standards or in-house reference ESD documents or guidelines

The acceptance criteria is also dependent on in-house specifications as most of the standards do not give actual acceptance values. As a general guideline, the following measurement values are most commonly visible in the industry :

a. Resistance ranges (for garments, materials, racks, transfer mechanisms etc) are generally established between 1MΩ to 1GΩ
b. Surface or static charge or tribocharging propensity measurements range between 100V/in to 500V/in – as a guideline the electrostatic limits put forward in the International Technology Roadmap for Semiconductors (ITRS) could be used in establishing the levels based on product geometry (eg : at 0.13μm line width, the recommended electrostatic limit is 375 volts/in)
c. For ionizers, the swing voltages should be within ±150V and the discharge time (from 1000V to 100V) could range between 30s to 180secs depending on the type of ionizers used

The ANSI ESD S20.20 standard does recommend acceptance ranges and could be used as a general guide. Refer to table 2 below for a quick guide for some of the technical elements.

No	Item	Standard	Recommended range
1	Common Point / Equipment ground	ANSI EOS / ESD S6.1	< 1.0 ohm
2	Flooring / Footwear System	ESD STM97.1 or ESD STM97.2	< 35 x 10^6 ohm Or 100V
3	Work Surface	ESD S4.1 ESD STM4.2	< 1 x 10^9 ohms < 200V
4	Flooring	ANSI ESD S7.1	< 1 x 10^9 ohms
5	Footwear	ESD S9.1	< 1 x 10^9 ohms
6	Seating	ESD STM 12.1	< 1 x 10^9 ohms

Table 2 : An Extract of Recommended Acceptance Criteria for Some Technical Elements / Parameters - from the ANSI/ESD S20.20 Standard

Conclusion

Periodic ESD testing to ensure compliance is both important and necessary as part of a good ESD control & management program. After establishing baseline levels, periodic testing will confirm that the critical technical elements are conforming to acceptance levels. Besides establishing periodic testing parameters and levels, certain other continuous monitoring options could also be utilized to reduce the frequency of testing. For example if continuous ground monitors are implemented in tools, then perhaps the periodic testing for the grounding could be eliminated altogether. There are ESD monitoring and management tools now available that can capture ESD events and alert the user immediately – these can be interfaced with existing facility monitoring systems or to the microprocessor of the tool itself. A combination of continuous monitoring and periodic testing for compliance verification is perhaps the best option to ensure continuous conformity and yield guarantee.

Editor's Note :

Inderjit Singh is presently a Director with Cesstech (S) Pte Ltd which is a provider of microcontamination and ESD solutions for ultra clean environments and processes including third party cleanroom performance testing & certification and ESDC testing & audits.

This article is reprinted from Technology Digest – Mar 2004 issue by permission