SEMI E143-0306 (Reapproved 0512)
TEST METHOD FOR MEASURING POWER VARIATION INTO A 50 Ω LOAD AND POWER VARIATION AND SPECTRUM INTO A LOAD WITH A VSWR OF 2.0 AT ANY PHASE ANGLE

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NOTICE: This Document was reapproved with editorial changes.

1 Purpose

1.1 The purpose of this Test Method is to provide an accurate method for measuring the output power and spectral content of radio frequency (RF) generators being driven into both matched and mismatched loads to simulate their actual performance in RF power delivery systems for semiconductor processing equipment to support SEMI E113.

2 Scope

2.1 This Test Method specifies the testing procedures and test equipment required for precisely determining the output power and spectral variations of RF generators. This Test Method uses a spectrum analyzer, power meter, and signal sampling device, all of which have been previously calibrated by a suitable method recommended by the manufacturer. This Test Method is used to validate three main performance characteristics of RF generators in order to support the following SEMI E113 specifications:

2.1.1 This Test Method is used to validate that RF generators shall provide consistent power delivery with a variation of less than ±1% of the requested power level (over time and during steady-state wafer processing conditions) when operated into a matched (50 Ω) load.

2.1.2 This Test Method is used to validate that RF generators shall provide consistent power delivery with a variation of less than ±1.5% of the requested power level (over time and during steady-state wafer processing conditions) when operated into a load impedance with a reflection coefficient of ≥0.33 at any phase angle (voltage standing wave ratio [VSWR] of ≥2.0) from 10% to 100% of the maximum rated output power.

2.1.3 This Test Method is used to validate that RF generators providing a single- or fixed-frequency output shall provide an output-power harmonic or spurious spectral content of −40 dB or less when operated into a load impedance with a reflection coefficient of ≥0.33 at any phase angle (VSWR of ≥2.0) from 10% to 100% of the maximum rated output power.

2.1.4 This Test Method can also be used to validate output-power harmonic or spurious spectral content for variable- or multiple-frequency output RF generators provided that the following two conditions are met and understood:

2.1.4.1 The variable frequency RF generator must be placed in a single fixed-frequency mode for purposes of this test in order to obtain valid results.

2.1.4.2 The output power harmonic or spurious spectral content of the variable-frequency RF generator will typically be higher than the −40 dB requirement for a fixed-frequency RF generator.

2.2 The primary focus for this Test Method is semiconductor processing equipment including, but not limited to, the following equipment types:

- Dry etch equipment
- Film deposition equipment (chemical vapor deposition [CVD] and physical vapor deposition [PVD])

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

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3 Limitations

3.1 This Test Method is meant to provide a general means of measuring the true output power and spectral variations of RF generators operating over a wide range of frequency and power. Limitations in the frequency and power coverage of this method are determined by the individual system components chosen.

3.2 This Test Method assumes that the transmission system characteristic impedance is 50 Ω.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI E113 — Specification for Semiconductor Processing Equipment RF Power Delivery Systems

SEMI E114 — Test Method for RF Cable Assemblies Used in Semiconductor Processing Equipment RF Power Delivery Systems

4.2 *United States Military Standards (MIL) Specifications*[1]

MIL-PRF-39012 — General Specification for Connectors, Coaxial, Radio Frequency

MIL-STD-348 — Military Interface Standard, Radio Frequency Connector Interfaces

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CVD* — chemical vapor deposition

5.1.2 *DC* — direct current

5.1.3 *FCC* — Federal Communications Commission

5.1.4 *MIL* — United States Military Standards

5.1.5 *NEC* — National Electric Code

5.1.6 *PVD* — physical vapor deposition

5.1.7 *RF* — radio frequency

5.1.8 *UL* — Underwriter's Laboratory, Inc.

5.1.9 *VNA* — vector network analyzer

5.1.10 *VSWR* — voltage standing wave ratio

5.2 *Definitions*

5.2.1 *cable assembly* — the section of cable (transmission line), including the connectors, used to connect various parts of the RF power delivery system.

5.2.2 *electrical length* — the length of the cable assembly at the operating frequency expressed in terms of degrees, where one wavelength at the nominal operating frequency is equal to 360°.

5.2.3 *harmonic frequency* — the harmonic frequencies are defined as integer multiples of the fundamental frequency. For example, the second harmonic of 13.56 MHz is 27.12 MHz.

5.2.4 *load impedance* — the load impedance is the impedance to which an RF generator is driven into.

5.2.5 *matched load* — a matched load impedance is defined as typically having a magnitude of 50 ±3.3 Ω at a phase angle of up to ±3.8°. In other words, the load is considered matched if the reflection coefficient is <0.032 at any phase angle.

[1] United States Military Standards, available through http://www.everyspec.com

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5.2.6 *mismatched load* — a load impedance that is purposely made to be different (either larger or smaller) in magnitude, phase, or both than 50 Ω in order to produce a determined VSWR value. As an example, a 3:1 mismatched load could be produced by using either a 150 + j0 or 16.7 + j0 Ω load and varying the electrical length up to a half wavelength to outline a contour of 3:1 VSWR magnitude through all phase angles.

5.2.7 *RF generator* — a component in the RF power delivery system used to develop RF energy.

5.2.8 *RF load* — another term used to describe an RF termination.

5.2.9 *RF system* — the RF system is defined as the combination of the RF generator, matching network, chamber interface, and the associated connecting cable assemblies that are specific to a particular tool/chamber.

5.2.10 *RF termination* — a device for terminating RF transmission systems, and converting RF electrical energy into heat. RF terminations normally have values that are the same as the characteristic impedance of the transmission system.

5.3 *Symbols*

5.3.1 *dB* — decibel

5.3.2 *dBc* — decibels relative to carrier power

5.3.3 *dBm* — decibels relative to 1 milliwatt

5.3.4 *ft.* — foot

5.3.5 *in.* — inch

5.3.6 *kW* — kilowatt

5.3.7 *m* — meter

5.3.8 *MHz* — megahertz

5.3.9 Ω — ohm

5.3.10 *W* — watt

6 Test Apparatus

6.1 *Spectrum Analyzer* — This instrument is designed to be used in conjunction with a high-power RF signal sampler, or coupling device, that will reduce the coupled signal to an acceptable level (typically <1 W or +30 dBm) that will not damage the sensitive input circuitry of the spectrum analyzer. Choose instruments capable of providing a spectral display across the intended frequency range (including the highest order harmonic desired).

6.2 *RF Termination* — This device provides a low VSWR (i.e., high return loss) termination for the testing of the RF generator. Use an RF termination sized appropriately for the RF generator under test. The return loss of the RF termination shall be no less than 30 dB. This return loss ensures maximum power transfer between the RF generator and the termination.

NOTE 1: It is very important that the return loss remain stable at all times under RF power as this could affect the contour of the VSWR magnitude path through all phase angles.

6.3 *Signal Sampler* — These nondirectional devices are capable of sampling a portion (usually very small) of the output RF power available on the transmission line and sending it to an external device for display or further processing purposes.

6.4 *RF Generator Supply* — This power supply is used as a source of clean RF energy for the purposes of producing RF power for the system. Use an RF generator sized for the test to be performed and that provides a very stable output at all levels.

6.5 *Cables and Connectors* — Various interconnecting cables are required to perform the tests outlined in this test method. These include low-loss cables to connect the direct current (DC) power source to the measuring instrument and to the RF load, in addition to low-loss RF cables and connectors to connect the RF generator output to the load. All cable assemblies shall adhere to industry standards for cables and connectors (e.g., MIL-PRF-39012, MIL-STD-348).

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