SmartPIM Application Note No. 2
Chamber Impedance FingerPrinting - ImPrint™

Introduction

With the advent of more intricate structures and more aggressive design rules, both the plasma process and the process tools have become more complex. Unfortunately this increase in design complexity has not been reflected in the levels of sophistication of the process control. The engineer has the same number of tool parameters to judge the state of health. Associated with these more elaborate processes are necessarily narrower process windows in order to achieve repeatable performance. This also makes the reproducible implementation of universal recipes across a tool set more difficult, as small tool-to-tool variations can induce process shifts.

One of the results of all this complexity growth is the increased difficulty of quickly and accurately identifying the cause of process issues. There are now more inputs to a process, which is also more susceptible to shifts/changes in those inputs. Any one characteristic (Bias, Selectivity, RIE lag etc.) may result from a number of different process deviations.

Where a problem cannot be directly identified, the usual approach is to carry out hardware replacement or re-calibration on a "most probable cause" basis. The result is costly in tool downtime, the associated cost of hardware replacement of good parts and the resources assigned to deal with the problem.

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This note describes a method for identifying chamber mis-matches in a systematic way, allowing the user to identify possible sources of mis-match. The SmartPIM™ provides a unique tool fingerprint and measures the fundamental electrical properties that directly influence the plasma performance. This can both highlight tool-to-tool variations and assist in identifying the cause of any future process related issues.

The purpose of chamber impedance profiling is to provide a baseline of a chamber hardware, a fingerprint of the plasma process and to use this information to identify and possibly solve tool-to-tool variation. This profiling procedure can be divided into three steps:

a) Electrical Properties Of The Chamber

The electrical properties of the chamber are measured with no plasma present. In this way stray capacitance or inductance between the electrode (cathode) or coil and the grounded surfaces of the chamber are measured. Note that it must be ensured that the match unit tuning is fixed so that plasma chambers can be compared.

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The wafer-less chamber is pumped to the base pressure. Then a low power set-point (e.g. 5W) is requested at the RF generator. This is insufficient to strike a plasma but drives the electrode with a voltage (typically around 100 V) and the impedance of the tool can now be measured. This process essentially checks if the fundamental electrical characteristics of the hardware are similar.

b) Plasma Properties Of The Chamber

To characterise the response of the plasma chamber, an inert gas discharge is used in a wafer-less process recipe. Using an inert gas eliminates chemical dependencies associated with running the full process recipe. The plasma is only dependent on the chamber hardware and tool supplies like RF power and pumping control. The impedance measured at this point provides a reference point from which tool-to-tool variations can be identified and addressed. Experience has shown that even small hardware differences can have dramatic effects on the characteristics of a Tool.

c) Chemistry Of The Full Process

Using the normal process recipe on blank wafers the full process recipe is monitored. Again tool-to-tool variations can be identified at this point. It may also be useful to further reduce the chemistry profiling, by sequentially adding process gases to the profiling recipe.

By building up this systematic fingerprint of a plasma chamber the cause of variations can be assigned to electrical hardware, process hardware (chamber, pumps etc) or chemistry. Routine monitoring (e.g. pre/post PM) allows the sources of tool related process excursions to be identified and rectified before they impact production. Furthermore, as recipes are transferred in ramp or as more tools are added to the bay, these issues can be tackled using a systematic approach.

This approach will not necessarily lead to a set of perfectly matched process chambers. It will, however, provide the user with an approach to identifying chamber differences and possible causes of those differences. The degree of mis-match and its relevance to the process can only be established using a systematic approach. For example, impedance differences at the fundamental frequency as measured by SmartPIM are generally sufficient to identify differences, with the subtle effects of harmonic matching adding increased sophistication.

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