Diagnosing Etch Chamber State Using RF Signals

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INTRODUCTION

In dry etching reactors used for semiconductor manufacturing, techniques to monitor the chamber state are becoming increasingly important. In this paper, we assess the usefulness of direct VI probe (VIPr) sensor measurements of the RF signals: voltage, current and phase and selected harmonics to diagnose the process chamber state. We also propose using the shift in RF signals after chamber cleaning events as a method for monitoring the small change in the process chamber state that are directly related to the etching performance.

EXPERIMENTS

Two type etching reactor, capacitive coupled plasma (CCP) and inductive coupled plasma (ICP), are used. Fig.1 shows the connection diagram of the CCP etching reactor. A VIPr sensor is inserted between the bottom electrode and matching circuit. Characteristic impedance of the VIPr sensor matches that of the RF path in order to minimize its effect on the RF transmission. Measured RF signals are processed by a fast digital signal processor (DSP) and field-programmable gate array (FPGA); frequency, voltage, current, and phase values are generated for the fundamental and its higher harmonics signal. We will discuss the feasibility of the data utilization.

RESULTS AND DISCUSSION

1. RF Signal Transition during Wafer Processing.

During organic film etching with the ICP etch reactor. RF signal data from VIPr sensor was obtained and analyzed. The frequency to the bottom RF (wafer bias) was ~ 400 kHz. The time evolution of the RF signal is shown in Fig.2. A clear signal transition was observed especially on the 2nd, 3rd, and 4th frequency harmonics for voltage, and the 4th harmonic for current. The transition also corresponded to the endpoint (EP) of the film etch.

We have also investigated the behavior of the VIPr sensor signals during waferless chamber dry cleaning used to remove chamber byproducts after wafer processing. Usually the clean process uses only 13.56MHz of top ICP plasma source where the VIPr sensor is not connected (bottom RF power is not added to prevent electrode damage). Fig.3 shows that a small signal induced by top electrode can still be picked up by the sensor near 13MHz and shows a transition when the chamber surface is cleaned that is also confirmed by the optical emission spectroscopy (OES) signal. The RF signal from the VIPr sensor could be useful information to monitor the inside state of the chamber and to monitor wafer processing.

2. RF Signal Shift Over Time.

As internal components of the chamber erode as a result of normal wafer processing, we can observe a shift in the signals from the VIPr sensor. For example in Fig.4, the impedance value shifts clearly over time during etching of dielectric in an ICP etching reactor. The shift reflects small changes due to impedance changes as parts erode and it is expected that it could be utilized for chamber state monitoring.

For CCP etching reactor, the preventive maintenance (PM) cycle is often determined by the lifetime of parts around the bottom electrode because the ion energy can be relatively high, causing greater erosion. In this report we will show the example of utilizing the RF Signal shift.

We developed preliminary multivariate analysis (MVA) models from RF signals data to track erosion of several chamber parts. The remaining useful life can be predicted which makes predictive preventive maintenance (PPM) possible. If the parameter could be selected appropriately for the model creation, it could be used to predict the lifetime of multiple parts independently. It remains to be demonstrated of this capability is feasible in a production environment as part changes can lead to undesirable shifts in the models. (Fig.5)

CONCLUSION

We have shown the feasibility of diagnosing chamber conditions by utilizing RF signals measured by the VIPr sensor, including an example that enables PPM application by utilizing the shift of RF Signals.
Signal of RF and its harmonics would be useful information to diagnose the state of etch process chamber condition.

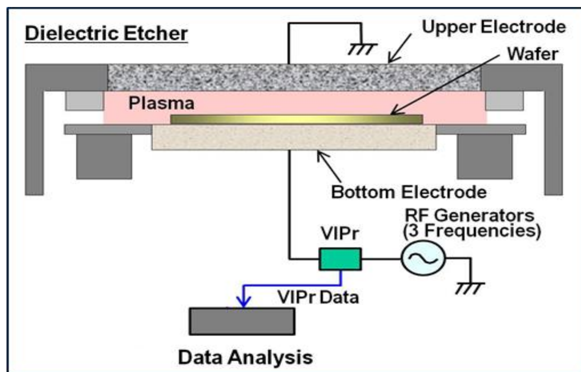

Fig.1: Connection diagram of the etching reactors and VIPr sensor (In the case of CCP Etching Reactor)

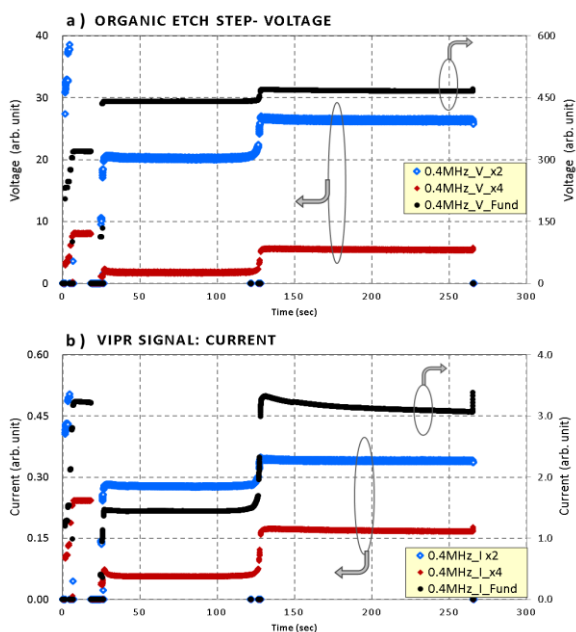

Fig.2: RF signal transition during wafer processing.
a) Voltage signal, b) Current signal, during organic etch process

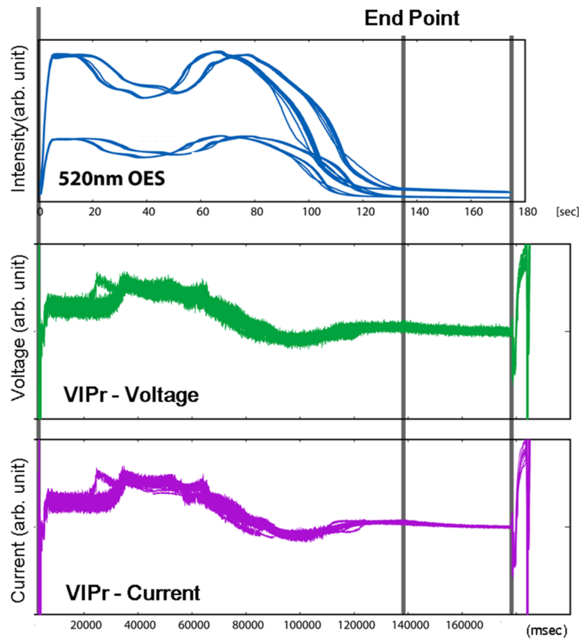

Fig3 Endpoint during chamber dry cleaning

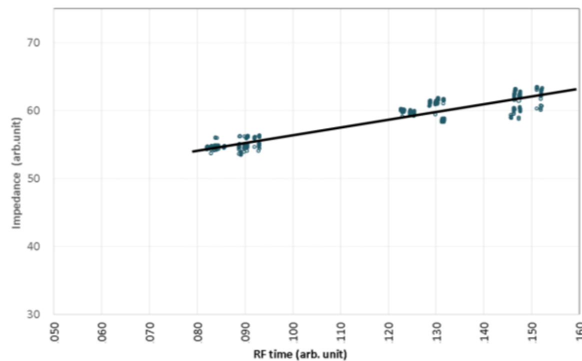

Fig.4: Impedance value shift over time

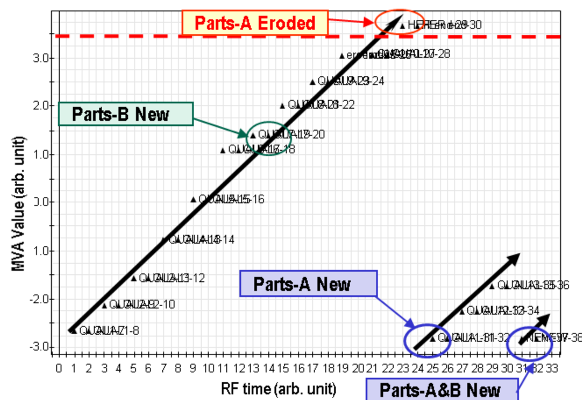

Fig.5: Monitoring multiple consumable parts wear. For the Parts-A, during Parts wear monitoring, Parts-B was also changed to new, but that would not affect the Parts-A monitoring.