The development of LF power supply for dry scrubber

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ABSTRACT-In this paper, the development of the LF power supply for dry scrubber is discussed. 1500kW, 100kHz LF power supply is designed and tested. The main power stage is used for the FB PWM inverter with an LC filter in the secondary circuit. The operation characteristics of LF power supply are verified by simulation and experimental results.

I. INTRODUCTION

Chemical vapor deposition reactors are widely used in the semiconductor industry for making insulating, semi conductive and conducting films in wafer fabrication.

Dry scrubber system is to treat exhaust gases in semiconductor processing [1].

As shown in Fig. 1, Plasma is generated inside the electrode where the surface area to the plasma volume ration is high and the flow path is long.

When process exhaust gases enter the dry scrubber system, they are forced to pass through the plasma region where energized electrons and ions collide with gas molecules and particles, generating reactive species, which react on expanded electrode surfaces.

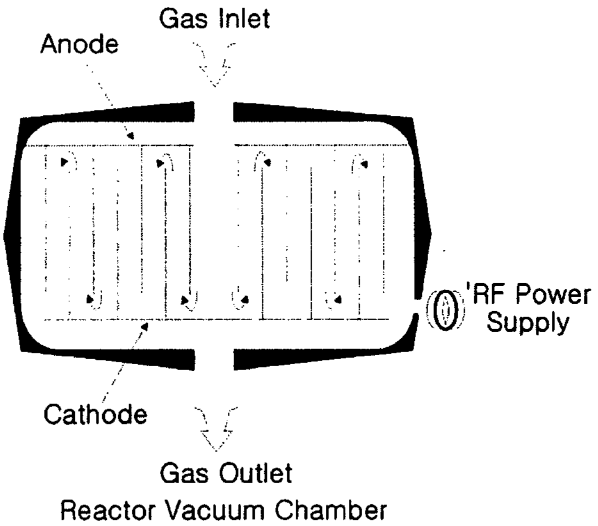

Fig. 1. Dry scrubber system

Solid components and particles are deposited on the electrode surfaces as dens films without reaction on the flow path and neutralized gases are pumped downstream. When the exhaust gas comes into the chamber inside, plasma generation have to be continue for chemical reaction. At that time, the impedance of power supply will change and power supply will be on the worst condition.

Even if the impedance of power supply does not match with that of chamber. We should design the power supply to keep operation.

In this paper, we have studied on the LF power supply for dry scrubber system. The main power stage is used for the FB PWM inverter with an LC filter in the secondary circuit. The operation of the LF power supply is identified. For this, we divided a switching period into six topological modes.

1500kW, 100kHz LF power supply is designed and tested. Manual matching transformer provides a manual impedance match for any given process related variation in impedance [2]. The operation characteristics of LF power supply are verified by simulation and experimental results

II. LF POWER SUPPLY

Fig.2 shows a block diagram of LF power supply for dry scrubber system, which the dry scrubber system is to treat exhaust gases in semiconductor processing.

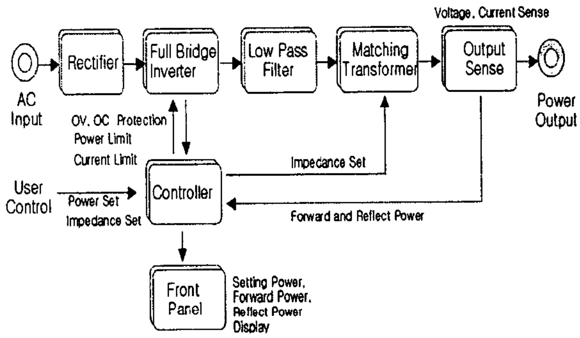

Fig. 2. Block diagram of LF generator for dry scrubber

The full bridge PWM inverter is operated in a mode that provide zero voltage turn on for the active switches. The current and voltage in the transformer primary are shown in Fig. 3 [3,4,5, and 6].

The gating signals are such that, instead of turning on the diagonally opposite switches in the bridge simultaneously, a phase shift is introduced between the switches in the left leg and those in the right leg. This phase shift determines the operating duty cycle of inverter.

The low pass filter construct with five passive L-C elements has good high frequency characteristics with eliminated the high frequency noise from the full bridge inverter output.

The gas pressure in chamber is changes variously. When the variation of gas pressure, the power supply does not match with chamber impedance, and then, the reflect power increases. By using impedance changer, Plasma can be generated inside the chamber when the reflect power is decreased and the forward power is increased.

The value of forward power and reflect power are sensed from output circuit through CT and PT and sent to the control circuit.

The control circuit using PWM control IC 'UC 3879' and one chip micro processor '80C196KC' has a function for out power and impedance assignment, over voltage and over current protection.

The power value, forward power value, and reflect power value are displayed on the LCD.

The current I_L and voltage V_{AB} in the transformer primary side shown in Fig. 3.

The output power of inverter is controlled by duty cycle of power stage.

The duty cycle for each switch is 50% and a phase shift is introduced between the switches in the left leg and the right leg. This phase shift determines the operating duty cycle of the inverter.

The zero voltage switching is achieved by using the energy stored in the leakage inductance of the transformer to discharge the output capacitance of the switches before turning them on.

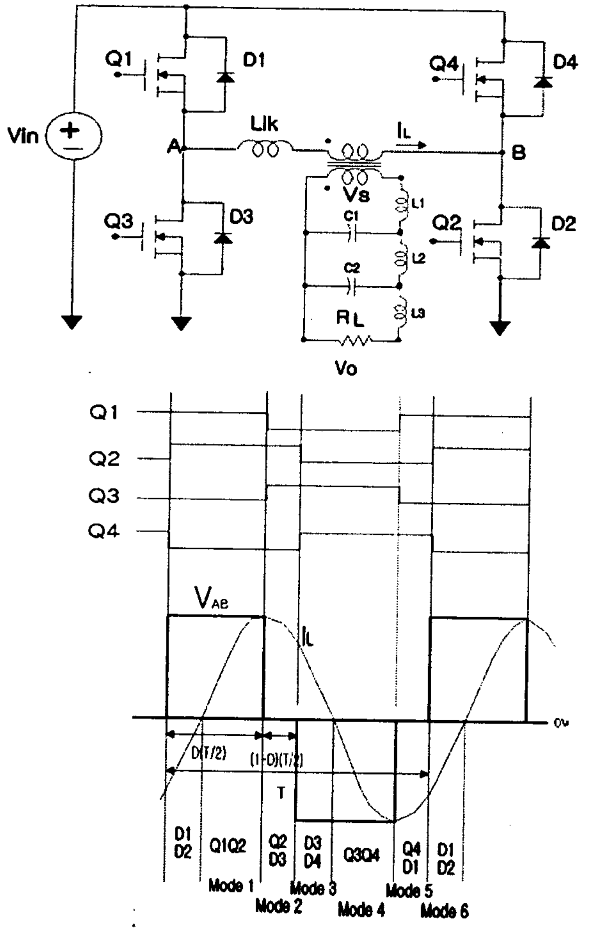

Fig. 3. Voltage and current waveform of transformer in the primary and Power stage Circuit of LF power supply

As shown in Fig. 4, six topological modes exist within one switching cycle in steady state operation. The inverter operation for a half cycle is described as fellow.

◆Mode 1: After switch's body diode D_1 and D_2 are conducting, the current I_L flow through the switch Q_1 and Q_2 and then the current will flow into the transformer secondary. At that time, switch Q_1 and Q_2 are zero voltage turns on

◆ Mode 2 : After switch Q_1 is turn off, switch Q_3's body diode D_3 is turn on. The stored current in the leakage inductance is discharge through the D_3 and Q_2.

◆ Mode 3 : After switch Q_2 is turn off, and switch Q_4's body diode D_4 will start conducting. At this time, if the sufficient energy stored in the leakage inductance, the current will flow through the switch's body diode D_4 and D_3.

◆ Mode 4 : After the current I_L is zero, the current I_L will reverse and the primary current I_L flow through the switch Q_3 and Q_4. At this time, the switch Q_3 and Q_4 are turned on into zero voltage. The cycle will be completed with a similar manner.

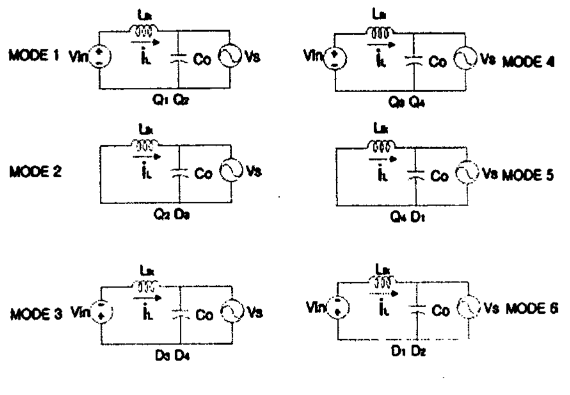

Fig. 4. Operating mode

III. SIMULATIONS AND EXPERIMENT RESULT

We does the simulation and experiment using the Fig. 3 circuit for LF power supply. The simulation circuit was tested using the value in table 1.

We tested the starting characteristics and steady state characteristics at full power (1500W). LF power supply also tested to efficiency with chamber under variable impedance. The simulation was done with 80% duty ratio.

Table 1. System specifications.

Input voltage (Vin)	220VAC
Rated Power (Po)	1500W
Turn Ratio	1: 2.9
Main Switch	APT5020
Switching frequency	100 kHz
Leakage inductance	12uH
PWM IC	uc3879
Filter L1	145uH
Filter L2	83uH
Filter L3	90uH
Filter C1	56PF
Filter C2	41PF
Load	50Ω non inductive load
Impedance value during chamber test	200Ω , 300Ω , 450Ω , 600Ω

Fig. 5 shows a simulation waveform of transformer's primary current and voltage. Fig. 6 shows an experiment waveform of transformer's primary current and voltage at full power (1500W).

Fig. 7 shows a simulation waveform of LF generator's output voltage and Fig. 8 shows a spectrum analysis waveform of fig. 7.

Fig. 9 shows experiment waveform of LF generator's output voltage at dummy load test (50 Ω). Fig. 10 shows a spectrum analysis waveform of fig. 9.

Fig. 11 shows an output waveform of LF generator during starting period. Fig. 12 shows the measured efficiency at varying with impedance (200Ω , 300Ω , 450Ω , 600Ω). The efficiency of LF power supply is very high at 200Ω .

Based on the simulation and experiment result, we are verified that the main switches (Q1, Q2, Q3, Q4) are operated under ZVS.

From the result of Fig. 7, 8, 9, and 10, it is prove that deign of the low pass filter, which has good attenuation of high frequency noise, is good.

Using soft start circuit, the starting current is kept within limit value during starting period.

We could obtain higher than 90% efficiency at 120m of tore, 200Ω of impedance, 141[W] of reflected power.

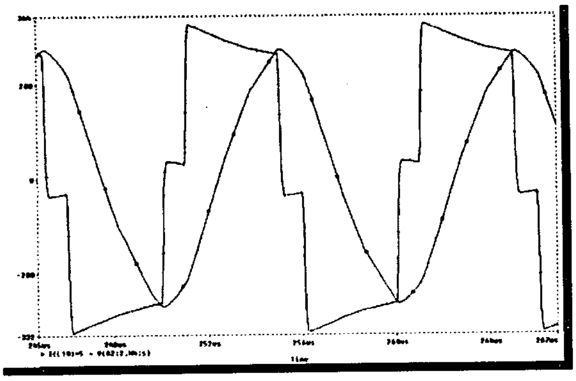

Fig. 5. Voltage and current simulation wave form of transformer

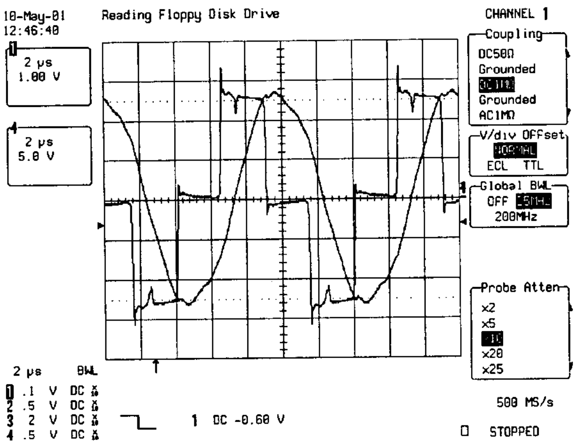

Fig. 6. Voltage and current waveform of transformer

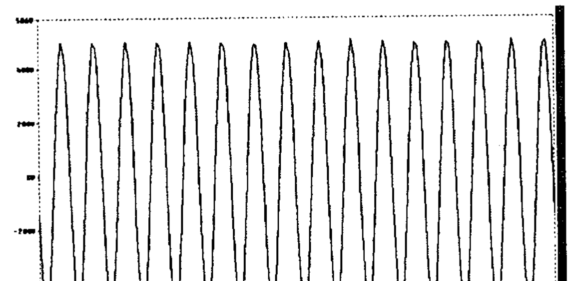

Fig. 7. Simulation output waveform of LF generator

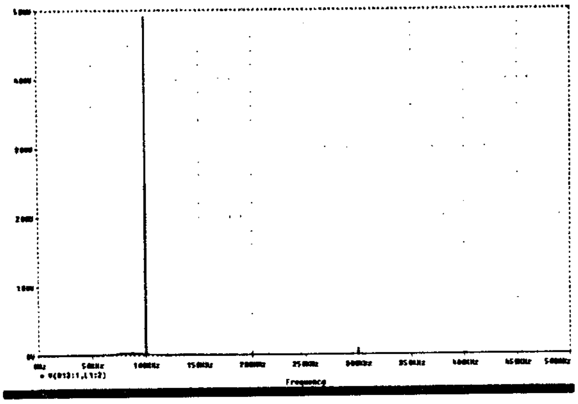

Fig. 8. Simulation waveform of spectrum analysis for LF generator

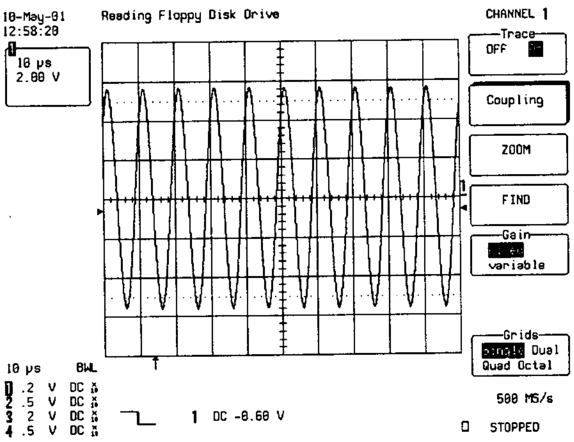

Fig. 9. Experimental output waveform of LF generator

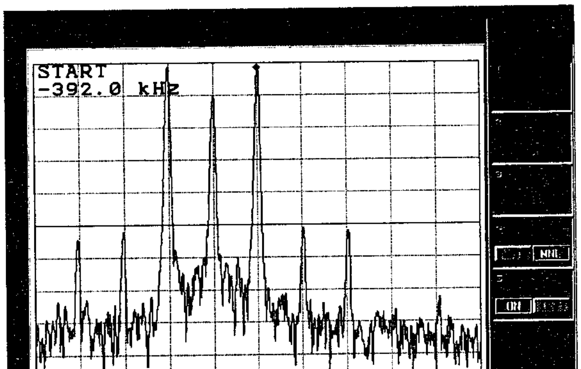

Fig. 10. Experimental waveform of Spectrum analysis for LF generator

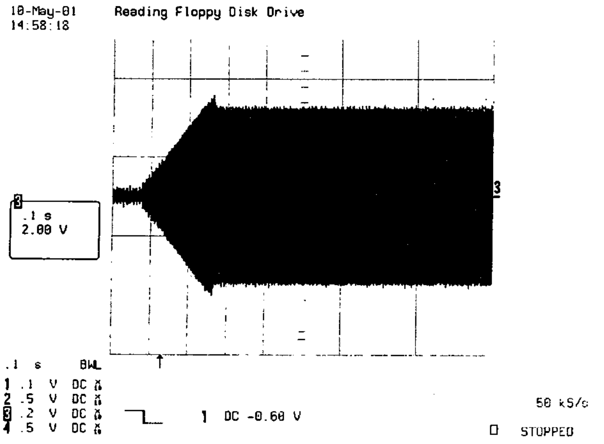

Fig. 11 Start characteristics of the LF power supply

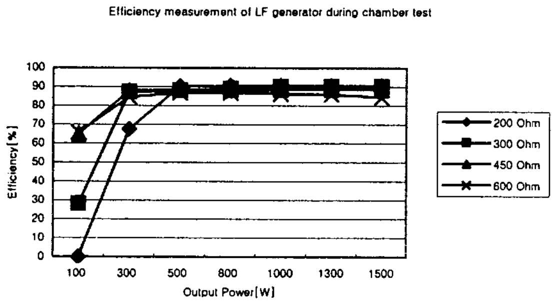

Fig. 12 Efficiency measurement of LF generator during chamber test

IV. CONCULTION

LF power supply for dry scrubber system, which can be treat exhaust gases in semiconductor processing, was studied. The mode analysis of the inverter was described. Using simulation program, an operation characteristics of inverter was performed. Based on the mode analysis and simulation result, a 1500W LF generator has been constructed and tested under the various condition of impedance. From experiment result, as the Lf generator realizes high frequency switching through minimizing the switching losses at the main switches by using Zero voltage Switching (ZVS) technique, it is possible to achieve the high power density and high efficiency of inverter, compared with traditional hard switching PWM technique. Concerning the efficiency, the LF generator could be obtaining 90% at full power. Finally, It is concluded that a LF generator can be effectively operated in the out of phase between the voltage and current because the main switches of LF generator are operated with zero voltage switching.

REFERANCE

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