Development of PFCs Scrubber using a High Density Enlarged Plasma Source

D. H. Shin[1*] , S. M. Chun[1], G. Yang[1], Y. C. Hong[1], S. Lee[2], S. Yun[2], K. S. Kim[2], and N. J. Choi[2]

[1] *Institute of Plasma Technology, Korea Institute of Fusion Energy(KFE), Korea*
[2] *Young Jin IND, Korea*

Abstract: A POU scrubber system is essential for the abatement of waste gases containing PFCs emitted during the semiconductor and display manufacturing processes. In recent years, the development of low-power and large-capacity scrubbers is required due to greenhouse gas emission regulations. In order to overcome the limitation of a single plasma source, a hybrid plasma source combining arc and microwave sources was applied to develop a 300 LPM processing POU scrubber with double capacity of the conventional one. A high density enlarged plasma source has a volumetric expandability of over 45% for a single arc plasma. Theoretically, the arc plasma source consumes about 24 kW of power with 300 LPM nitrogen and 5000 ppm CF_4 processing, howenver the high density enlarged hybrid source showed 90% decomposition rate at 18 kW.

Keywords: PFCs, scrubber, high-density enlarged, hybrid plasma, POU

SF_6 and CF_4 gases, saturated molecular fluorine are used as cleaning gases in the semiconductor industry [1-3]. Currently, the introduction of Extreme Ultraviolet (EUV) equipment is making the semiconductor industry super advanced. A large amount of waste gas is generated due to the introduction of a highly integrated and advanced process, and the processing capacity of the scrubber currently in use is experiencing difficulties in handling the process gas. Due to this increase in fair gas, low-carbon policies and movements are being developed worldwide.

In order to solve this problem, research was conducted to develop a large-capacity scrubber. The large-capacity scrubber uses a hybrid plasma that combines Arc and microwave.

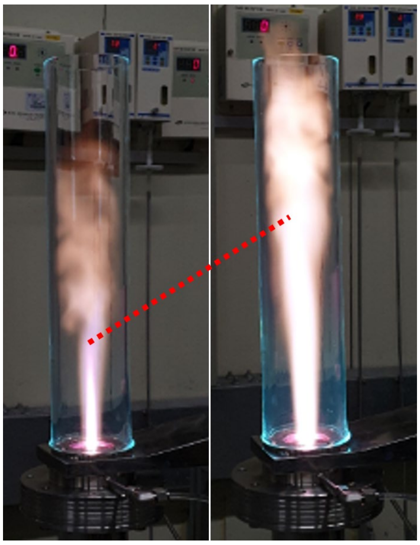


Fig. 1. Comparison with Arc and hybrid plamsa flame

Fig. 1 is a photograph comparing arc plasma and hybrid plasma (arc+microwave) flame, when arc plasma power is 6 kW, hybrid plasma is microwave 1 kW power is applied to arc plasma at 5 kW. The high-density region of hybrid plasma is enlarged by aporoximately 194% compared to arc plasma, which can be expected to lengthen the reaction time.

Arc plasma velocity (v_{arc}) is assumed to be an anode diameter of about 20 mm, a flow rate of 20 lpm, and a plasma temperature of 10000 K,

$$v_{arc} = \frac{Flow}{Area} \times \Delta T \cong 9.2 \times 10^6 \; [m/s]. \quad (1)$$

The fuction of time (t_{arc}) for the arc plasma to pass through a 20 mm high waveguide is

$$t_{arc} = \frac{v_{arc}}{S_{waveguide}} \cong 2.1 \times 10^{-8} \; [s]. \quad (2)$$

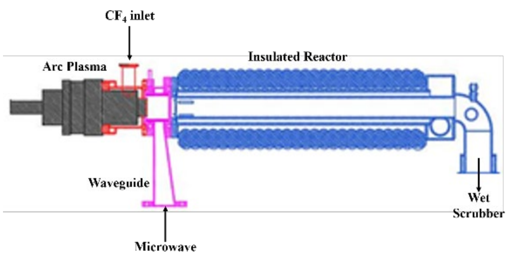
Converting microwave frequency (f) 2.45GHz to a function of time ($t_{M.W}$) gives

$$t_{M.W} = \frac{1}{f} \cong 4.1 \times 10^{-10} \; [s]. \quad (3)$$

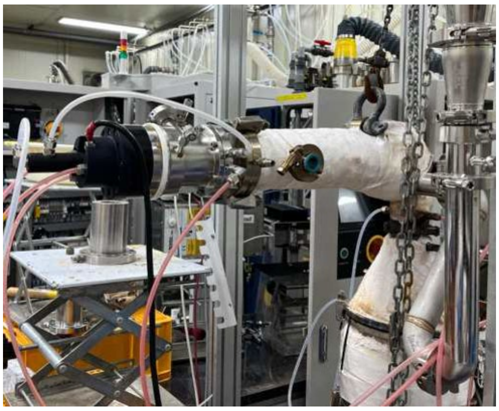
According to the calculations of fuctions (2) and (3), the heating time $t_{M.W}$ due to microwave oscillation is faster than the time t_{arc} for the arc plasma to pass through the waveguide, so that it can be seen that while the arc plasma is passing through the waveguide, heating is possible with oscillation by microwave. Also, studies on the expansion of dense regions should be further investigated via optical emission spectrum (OES) analysis.

CF_4 decomposition test was carried out by applying hybrid plasma source. In the case of the conventional scrubber, the electric energy required to decomposition for 90% of CF_4 at 5000 ppm in N_2 150 lpm was 12kW. However, considering the reaction time of the high density enlarged plasma, 5000 ppm of CF_4 applied to 300 lpm of N_2 was tested.

Fig. 2 (a) and (b) show the schematic design of hybrid plasma and reactor combination and photo of experimental set up. The arc and microwave power was changed to find the most optimal power distribution area, and measured the CF_4 decomposition rate. When treated with arc plasma, it showed a decomposition rate of 91.6% at a power of 21 kW. The arc plasma power was changed from 14 kW to 16 kW, and the microwave power was applied from 1 kW to 3 kW in that interval.



(a)



(b)

Fig. 2. (a) schematic design of hybrid plasma reactor for scrubber and (b) photo of experimental set up

Table 1 shows the test results by power change, and the lowest power among the powers showing the best decomposition rate was 18 kW, and about 15% energy saving was possible compared to arc plasma treatment.

Table 1. Results of decompositon test

Arc (kW)	Microwave (kW)	Inlet (ppm)	Outlet (ppm)	DRE (%)
21	0	5125.5	385.0	91.6
14	4.5	5118.2	425.0	91.0
15	3	5214.0	455.0	90.4
16	0	5047.6	1414.5	69.4
16	2	5041.4	837.7	81.8

In particular, CF_4 has proven to be difficult to destroy and remove because of its chemical thermal stability due to the strong covalent nature of its bonding [3]. Dissociation energy in CF_4 is represented by $e+CF_4 \rightarrow CF_3+F+e$ (12.5 eV) [4]. For the experimental conditions with DREs > 90%, the total flow rates are two times that of conventional scrubber showing the effectiveness of the hybrid plasma abatement system.

In conclusion, we presented the new abatement tool to effectively abate highly stable CF_4 using a hybrid plasma source by enlarged high density plasma region. The hybird plasma operated at 18 kW with arc 15 kW and microwave 3 kW. The scrubber is applied hybrid plasma source is much more cost effective, compact, and economic in comparison with two scrubber system. Also, FTIR analysis exhibited high DREs of more than 90% up to 300 lpm N_2 for CF_4. Finally, the aforementioned characteristics make the hybrid plasma attractive for the destruction and removal of chemically stable gases emitted by the semiconductor industry.

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References

[1] L.G. Meira Filho, et al. The science of climate change, Cambridge University Press, New York (1996)
[2] T. Gierczak, et al. Geophys. Res, **96**, 5001 (1991)
[3] D. H. Shin, et al. Phys. Plasmas **13**, 114504 (2006)
[4] M. Miletic, et al. Rapid Commun. Mass Spectrom **12**, 753 (1998)