NumericalAnalysis of a Thermal Plasma Scrubber for $CF_4$ Decomposition

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Perfluorocompound (PFC) gases emitted in semiconductor and displaymanufacturing processes have a very long life time in theatmosphere and a high global warming potential (GWP) which is thousands oftimes higher than those of carbon dioxide and hydrocarbons. PFCs decompositionrequire a high temperature environment due to their high chemical stability.Therefore, DC non-transferred thermal plasma scrubbers were commercialized tothe semiconductor process as post-treatment.

Among PFCs, $CF_4$is the most non-degradable greenhouse gas which is decomposed in a hightemperature above 2,300 K. In order to propose more efficient decompositionenvironment, in this work, the numerical analysis for $CF_4$ exhaustgas decomposition in the thermal plasma reactor was carried out in variousdesign variables. The decomposition reaction was applied include water, sincethe chemical reaction with water molecules drops the decomposition temperatureto about 1,500 K through the reaction with $H_2$. The calculatedresults were verified by comparing measured arc voltage and input power asexperimental data.

As severaldesign variables, the injected angles of $CF_4$ gas to the reactor werecontrolled to 30°,45°, 60°, 75°, and 90°. The injected location of$CF_4$ gas was applied to 50, 80, 110, and 200 mm from the torch exit. Inthe numerical analysis result, vertical injection of $CF_4$ gas at 90° creates the improved mixingof $CF_4$ gas with the thermal plasma flame. In addition, thebottleneck shaped reactor extended the high temperature region due to a vortexgeneration by strong turbulence. It is expected that the decomposition rate isimproved as increasing the residence time of $CF_4$ at the hightemperature region over 1,500 K. Furthermore, the chemical reactions for the $CF_4$decomposition was contained to the numerical analysis as an enhanced thermalplasma simulation. It offers not only thermal environment expectation alsodecomposed chemicals information. As a result, the optimal design condition isproposed to expect the higher decomposition rate.