A CONTROL OF TOXIC PERFLUORINATED COMPOUND BY ELECTRON-BEAM TECHNOLOGY

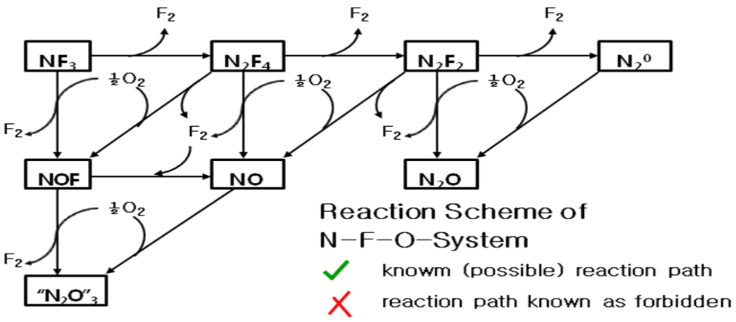
Ryu JY, Choi CY

Division for Industry & Environment, Korea Atomic Energy Research Institute (KAERI), 1266 Sinjeong-dong, Jeongeup-si, Jeollabuk-do, 580-185, Republic of Korea

Introduction

Nitrogen trifluoride (NF_3) is used as a novel etching and cleaning gas in semiconductor industry. And it has a global warming potential (GWP) of 18,000 times relative to CO_2 and atmospheric lifetime of 740 years. In addition, it is very toxic (threshold limit value of 10 ppm) and chemically reactive. [1-2]. Therefore it is strongly required to destruct the NF_3 gas from industrial processes because of more and more emission of NF_3 gas into atmosphere. The purpose of this study is introduction of decomposition of the nitrogen trifluoride (NF_3) by Electron-Beam (EB) irradiation and additive gases (e.g., hydrogen (H_2) and oxygen (O_2)).

The machanism of NF_3 gas dissociation is shown below in Figure 1.



2 NF_3	↔	N_2F_4 + F_2	NO + ½ F_2	↔	NOF
NF_3 + ½ O_2	↔	NOF + F_2	2 NO + ½ O_2	↔	NO•NO_2 ("N_2O_3")
2 NOF + ½ O_2	↔	NO•NO_2 ("N_2O_3") + F_2	N_2F_2	↔	N_2 + F_2
N_2F_4 + O_2	↔	2 NOF + F_2	N_2F_2 + O_2	↔	2 NO + F_2
N_2F_4	↔	N_2F_2 + F_2	N_2F_2 + ½ O_2	↔	N_2O + F_2
N_2F_4 + O_2	↔	2 NO + 2 F_2	N_2 + ½ O_2	↔	N_2O

Figure 1. The mechanism of toxic NF_3 gas [3)]

Materials and methods

The experiments were conducted in a continuous type pilot scale, with a capacity of $3m^3$/hr with NF_3 of 1000 ppm. The electron beam was generated with an ELV-4 type (EB-Tech Co, LTD, Korea) with an 1 MeV, a 40 mA current, and 40 kW power of a commercial scale accelerator. The applied dose (irradiated energy to NF_3 gas, 1 kGy = 1 kJ/kg) was varied from 0 to 400 kGy. The analytical techniques used for this study included GC (Gas Chromatography, 7890N, Agilent Technology) and FTIR (MIDAC i4001). Experimental conditions and setup are shown in Table 1 and Figure 2, respectively.

Table 1. Experimental conditions.

Contents	Experimental conditions
Dose (kGy)	50, 100, 200, 300, 400
Current (mA)	2, 5, 10, 15, 20
NF_3 Conc.	N_2 : 50L/min NF_3 : 1000ppm (50ml/min)
Additive gas(ppm) H_2, O_2, H_2O	500, 1000, 1500, 2000, 2500, 3000
Reactor specifications	Flux : 50L/min capacity: 110*690*202mm (15.3L) Residence time : 18.4sec Reactor temperature : 0~400℃
Irradiation time-Batch (sec)	3, 5, 10, 15, 20

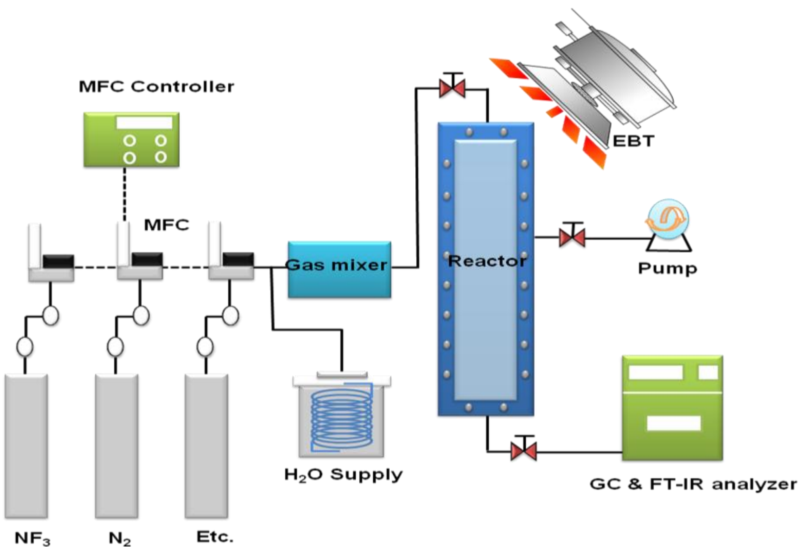


Figure 2. Experimental Setup

Results and discussion:

DRE of NF_3 gas with dose only

The average DRE(%) of NF_3 gas over the dose range of 50-400 kGy at a flow rate of 50L/min with 1,000 ppm NF3 gas is presented in Figure 3. The average DRE(%) values are obtained from replicated experiments. As dose increased DRE(%) of NF_3 gas were also increased and observed to peak at a dose of 400 kGy. At this time, DRE(%) of NF_3 gas was about 90%.

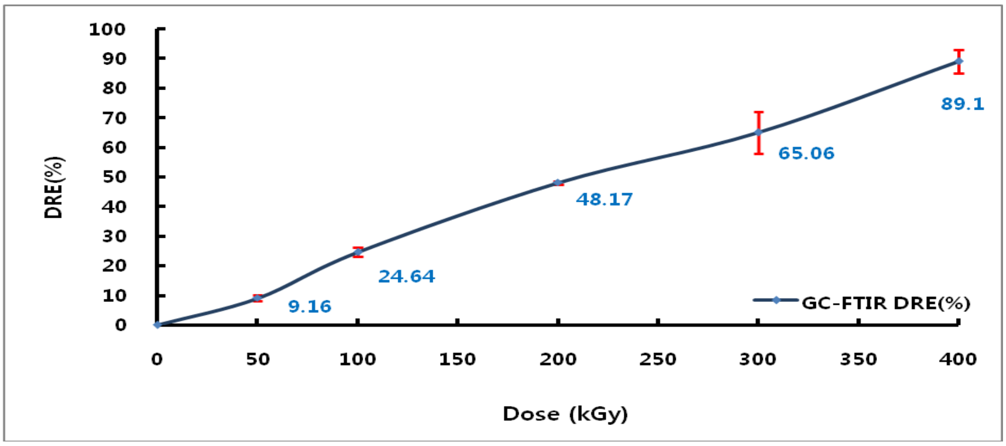


Figure 3. NF_3 DRE(%) with dose only

DRE of NF_3 gas with dose and additive gases

Figure 4 shows the average DRE(%) of NF_3 gas with electron-beam current over H_2 additive gas injection. Injected H_2 gas concentration were 0, 500, 1,000, 1,500, 2,000, 2,500, and 3,000 ppm. Electron-beam current were 5mA, 10mA, and 15mA, respectively. At 5mA with no additive gas, DRE(%) of NF_3 gas was about 54%. At 10mA and 15mA, with no additive gas, DRE(%) of NF_3 gas were about 58% and 65%, respectively. However, DRE(%) of NF_3 gas were about 50%, 60% and 76% at 5, 10, 15mA of electron-beam current , respectively when H_2 additive gas of 500ppm is injected. DRE(%) of NF_3 gas were about 70%, 94% and 98% at 5, 10, 15mA of electron-beam current , respectively when H_2 additive gas of 1, 500ppm is injected. This result shows that H2 additive gas injection increased drastically DRE(%) of NF_3 gas.

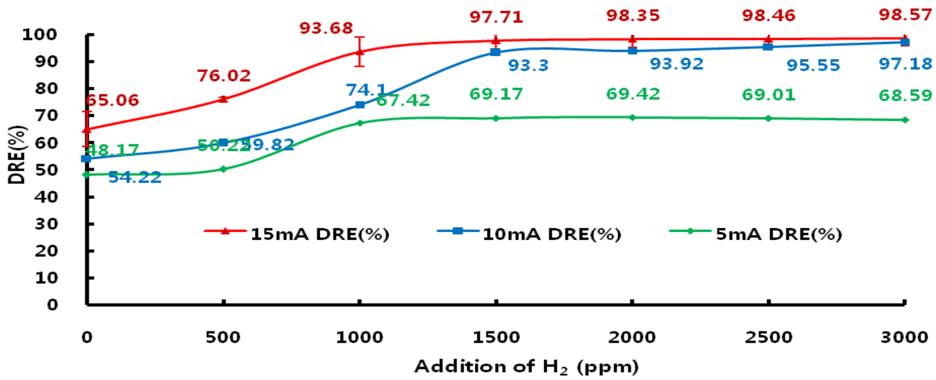


Figure 4. NF_3 DRE(%) with dose and additive gases.

Acknowledgements:

J.-Y. Ryu's work was supported by the Eco-Innovation Project through the Korea Environmental Industry & Technology Istitute funded by the Ministry of Environment and by the Nuclear Research and Development Program of Ministry of Education, Science and Technology .

References:

1. Tsai WT. (2008); *J. Hazard Mater,* 159(2-3): 257
2. Niu X. et al., (2010*); J Natural Gas Chemistry* 19: 463
3. CSK report, Republic of Korea