The Use of C_4F_6 for Dielectric Etch with Reduced Global Warming Emissions

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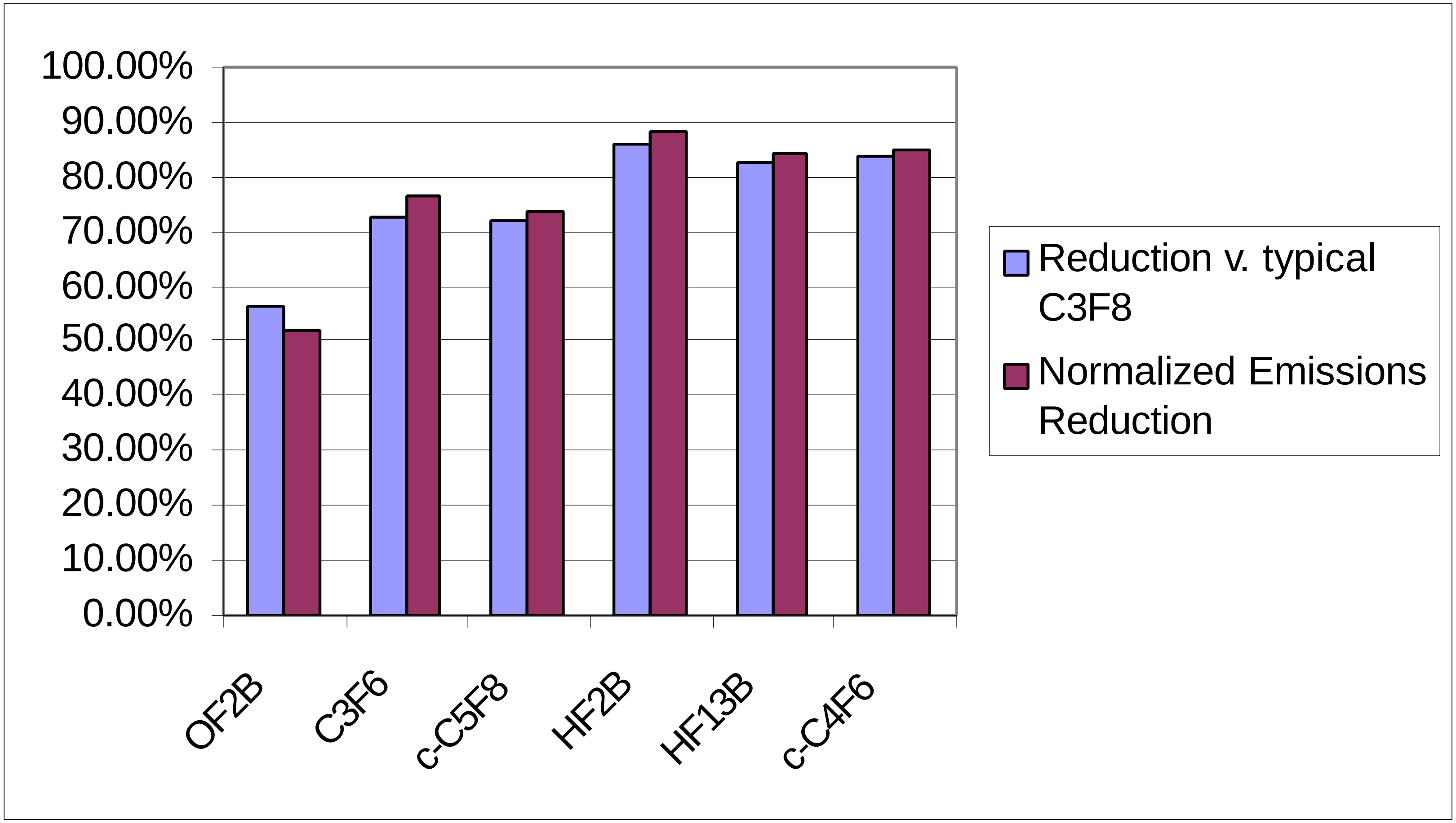
Agenda

- Unsaturated Fluorocarbons and C_4F_6.
- Experimental.
- Process and emissions performance.
- Conclusions.
- Future work.

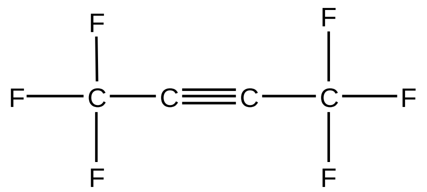
Unsaturated Fluorocarbons Tested

- octafluoro-2-butene (C_4F_8, CF_3-CF=CF-CF_3) (OF2B)
- hexafluoropropene (C_3F_6, CF_2=CF-CF_3)
- octafluorocyclopentene (c-C_5F_8)
- hexafluorobenzene (C_6F_6)
- hexafluorocyclobutene (c-C_4F_6)
- hexafluoro-1,3-butadiene (C_4F_6, CF_2=CF-CF=CF_2) (HF13B)
- hexafluoro-2-butyne (C_4F_6, CF_3-C≡C-CF_3) (HF2B)

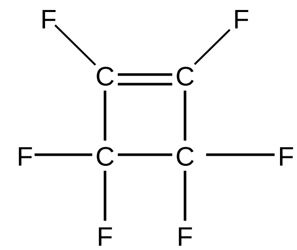
Best Emissions Reduction for Each UFC



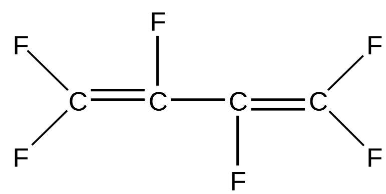
C_4F_6 Isomers



Hexafluoro-2-butyne
Boiling Point: -25 C
TSCA listed



Hexafluorocyclobutene
Boiling Pt: 1 C
Not TSCA listed



Hexafluoro-1,3-butadiene
This is the AMAT Sifren46 isomer
Boiling Point: 7 C
TSCA listed

Experimental

- All processes run on inductively coupled high density plasma etch chamber on patterned wafers with via test structures.
- Via etch process performance assessed by cross sectional scanning electron microscopy (SEM).
- Emissions measured using Fourier transform infrared (FTIR) spectrometer with 10 cm cell.
  - Effluents monitored: CF_4, CHF_3, C_2F_6, C_3F_8, C_2F_4, SiF_4, HF, CO, CO_2, COF_2, and the etch gas used.

Experimental (cont.)

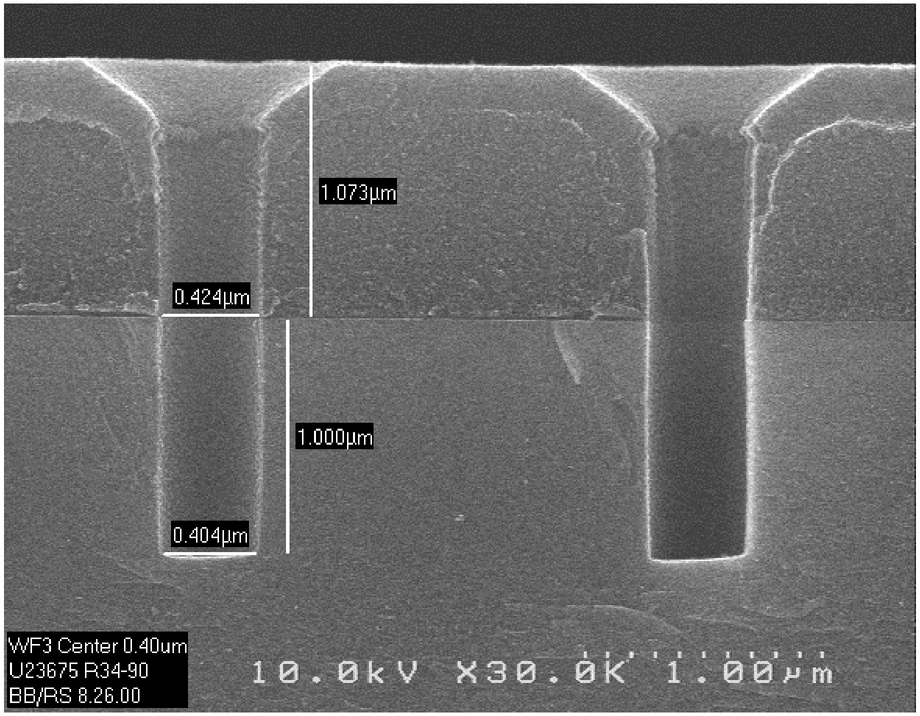
- Metric for reporting Global Warming Emissions:

$$kgCE = \sum_i Q_i \times \frac{12}{44} \times GWP_{100i}$$

where i indexes each gas, Q_i is the quantity in kg of each gas, and GWP_{100i} is the global warming potential of each gas.

- Process of comparison is a typical C_3F_8 based process: Emissions = 0.316 kgCE ;   Via Depth = 0.8411 μm

Process Results: HF13B

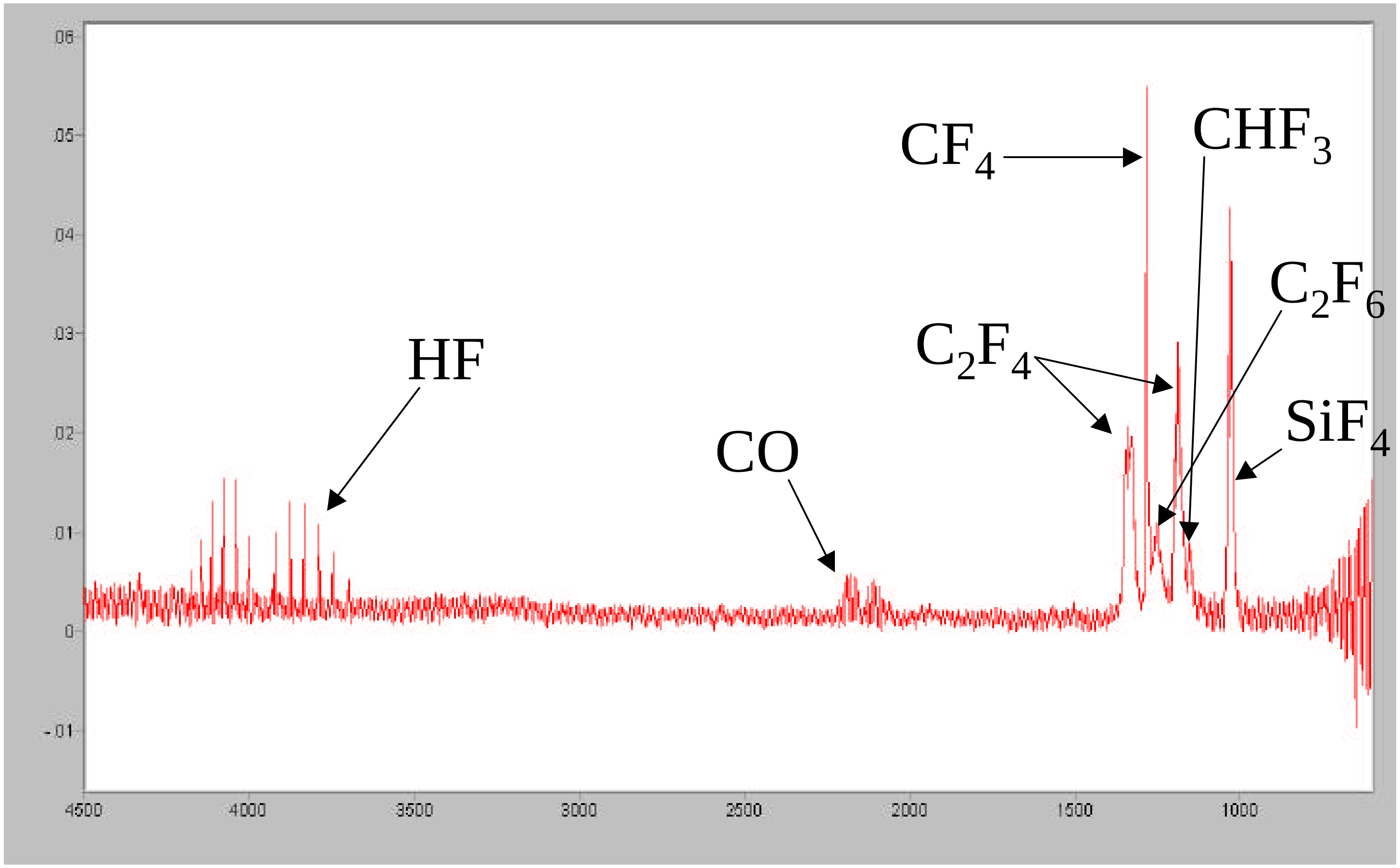


Low roof and wall temperatures lead to greater process kit longevity.

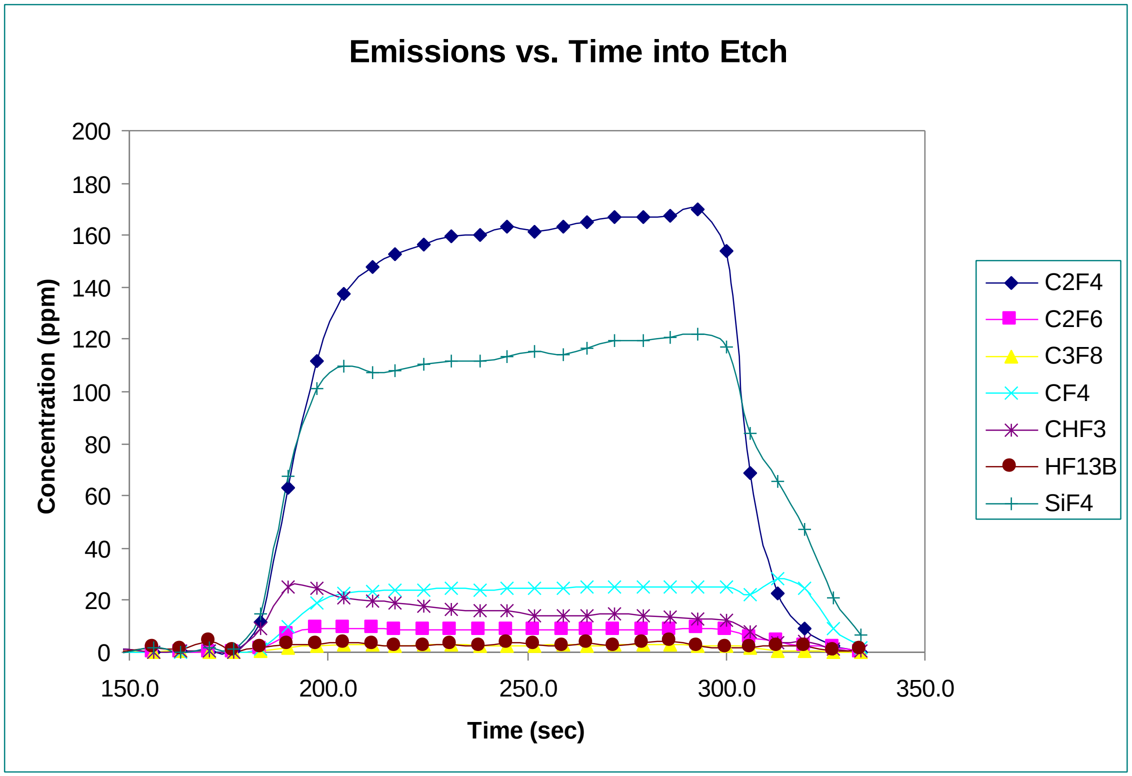
Process Conditions:
1000 W Bias Power
2160 W Source Power
27 sccm HF13B Flow
75 sccm Ar Flow
6 mTorr Pressure
160 C Roof Temperature
120 s Etch Time

Recent accomplishment:
No need for O_2 in process. This leads to a greater process control as the etch rate and resist selectivity strongly depends on O_2 flow.

FTIR Spectra for HF13B Process



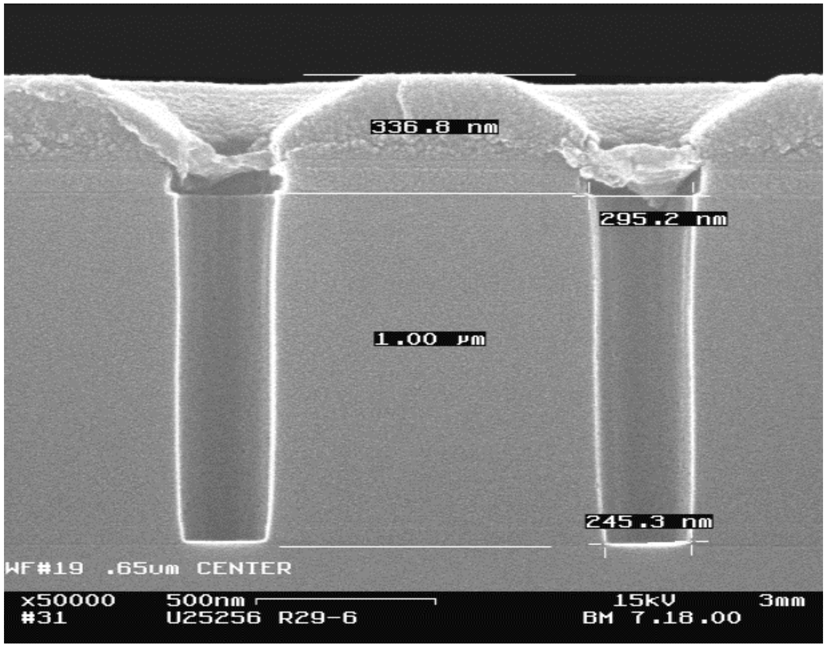
Emissions Results: HF13B



Significantly more C_2F_4 being produced than C_2F_6, CF_4, C_3F_8, or CHF_3.

Total Emissions:
0.0628 kgCE
Reduction:
82.1%
HF13B Destruction Efficiency:
99.5%

Process Results: HF13B

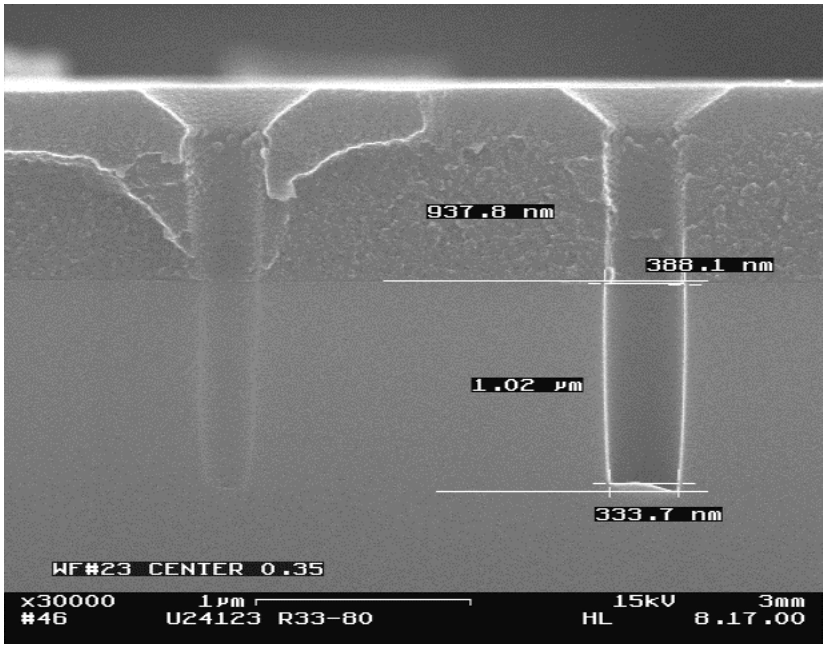


The breakthrough step is a less selective etch needed to breakthrough the silicon oxynitride ARC layer.

Breakthrough step:
1000 W Bias Power
1936 W Source Power
10 sccm HF13B Flow
75 sccm Ar
25 sec

Etch step:
1000 W Bias Power
1936 W Source Power
22 sccm HF13B Flow
75 sccm Ar
6 mTorr Pressure
160 C Roof Temperature
90 sec

Process and Emissions Results: HF2B



Total Emissions:
0.0539 kgCE
Reduction:
82.9%
HF2B Destruction Efficiency:
99.3%

Process Conditions:

1000 W Bias Power	1680 W Source Power
24 sccm HF2B Flow	75 sccm Ar Flow
6 mTorr Pressure	160 C Roof Temperature
120 s Etch Time	

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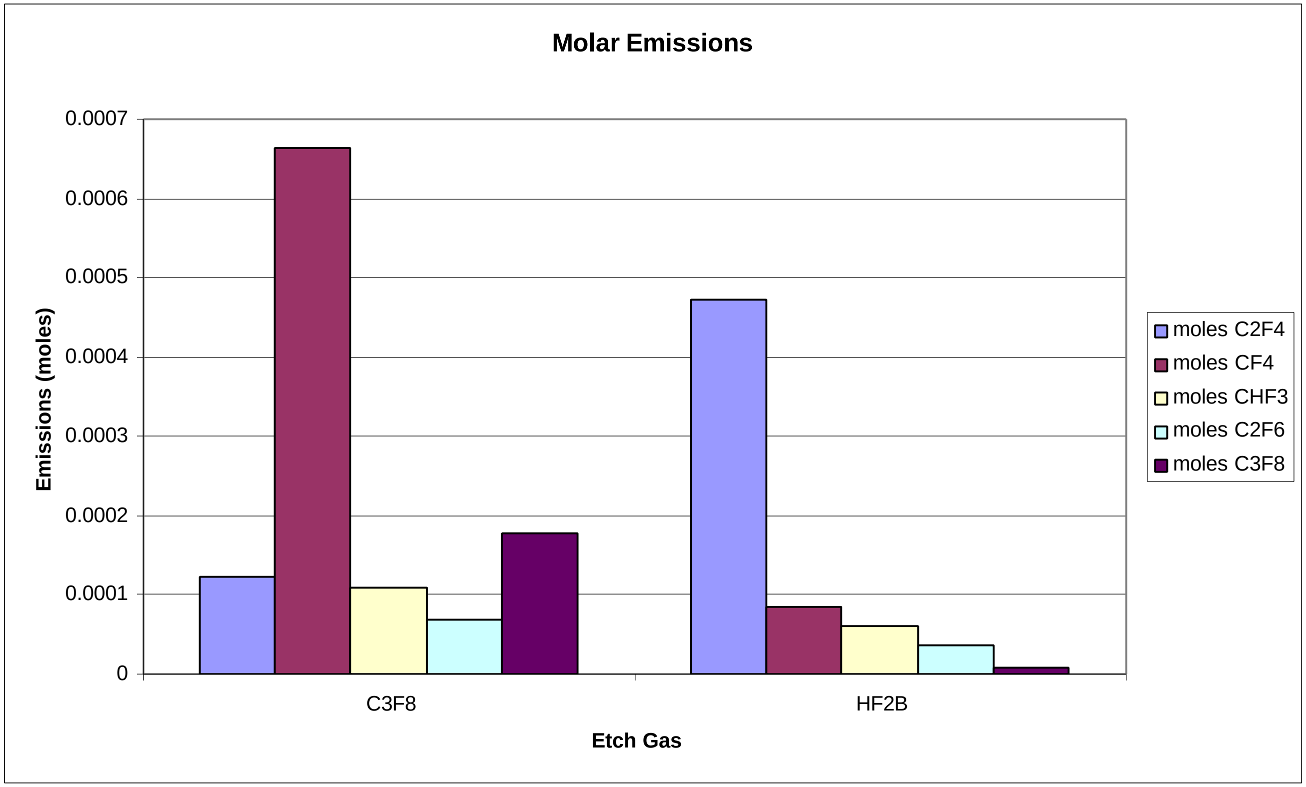
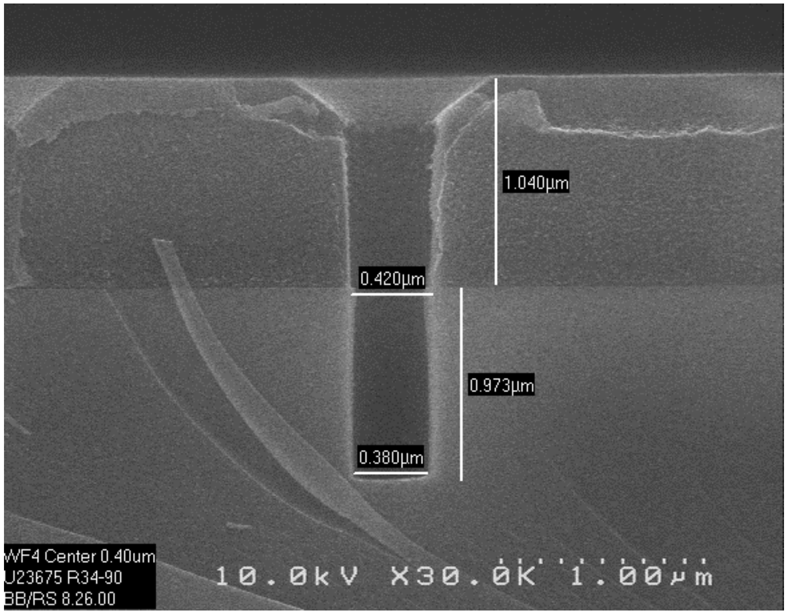
Components of the Emissions: HF2B



Process and Emissions Results: c-C4F6



Total Emissions:
0.0774 kgCE
Reduction:
75.5%
c-C_4F_6 Destruction Efficiency:
98.5%

Process Conditions:

800 W Bias Power	1920 W Source Power
24 sccm c-C_4F_6 Flow	75 sccm Ar Flow
6 mTorr Pressure	160 C Roof Temperature
120 s Etch Time	

Conclusions

- Developed etch processes based on three isomers of C_4F_6 and compared to a typical C_3F_8 based process.
  - Low/no resist erosion
  - Comparable etch rates and feature profiles
  - >80% global warming emissions reduction
- Processes are simple with only C_4F_6 and carrier gas as inputs.
- Emissions reduction is a result of high production of C_2F_4 rather than CF_4 as well as no impact of unreacted etch gas.

Future Work

- Examine selectivity of these chemistries to common stop layers.
- Evaluate the performance in a medium density plasma environment.
- Examine the process and emissions performance on common low-k dielectric etch applications.

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