Thermal plasma for VOC reduction, point of use systems (POU-Units)

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A New Generation POU Gas Treatment System for Wafer & TFT-LCD Manufacturing Process Exhaust
Solution of Kyoto Protocol & Mechanism
Overview

- The PlasmaAir Company
- The development history
- Why water Plasma
- Chemical reactions
- Plasma Sources
- The PlasmaAir Thermal Treatment Process
- What’s different from others
- Non Thermal Plasma Development
- Summery
Services

Engineering
- Development and qualification of exhaust gas treatment processes
- Qualification of processes with technical scale plants
- Development of plasma generators
- Qualification of plasma systems

Analysis:
- VOC Measurements (FID measurements)
- Dust on aerosol measurements in gas streams
- Trace analysis in gas streams
- Odour measurements (analysis)
- Sound measurement
The Products

**Plasma Systems**
- Thermal Plasma sources
- Plasma System for the treatment of high concentrated CFC gas
- Non Thermal Plasma units for exhaust gas treatment

**Chemical scrubber systems**
- Scrubber for Amines in foundries
- packed column scrubbers for HF, HCl, Nox in plastics
- new development especially for treatment of alcohols
- scrubber in stainless steel for dust separation

**Biological exhaust gas treatment**
PFC/CFC Reduction in chemical industry,

- Problem in the chemical industry:
  - A flow of R23 and R24 mixed with 5% Air (about 10 kg/h) has to be treated in a chemical company in Germany.
  - Several different thermal and mechanical processes were investigated in cooperation with universities and different companies.
  
- The only successful method with long lifetime and a high destruction efficiency was the water plasma system of PlasmaAir AG.

For example:
- \[ \text{C2F6} + 4 \text{H}_2\text{O}_{\text{Plasma}} = 6 \text{HF} + 2 \text{CO}_2 + \text{H}_2 \]
Since 2002 a system consisting of 2 reactors is in operation

<table>
<thead>
<tr>
<th>Capacity</th>
<th>2x 20 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>El. Power</td>
<td>2x 20 kW</td>
</tr>
<tr>
<td>Operation power</td>
<td>ca 16 kW</td>
</tr>
</tbody>
</table>

Destruction efficiency

Depending on the ration el Power /CFC. Up 99,999 % were achieved.
Dioxin: below the limit of detection
DC Thermal Plasma

N2 Plasma Torch of PlasmaAir Company

PlasmaAir AG

Multi Gas Plasma Torch (Water Plasma)

PlasmaAir Power supply
Arc Heated Thermal Plasma Source for Steam

Parameter:
- el input power: 5-40 kW
- thermal efficiency: 70-95%
- plasma gas: 250-700 mg/s
  - Argon: ca. 30 mg/s
- plume temperature: max. 9000°C in the center ca. 4000 in average
- possible plasma gas: Water steam, Air, O2, CO, CO2.....
- Operation time: > 800 h continues operation

Temperature profile at the exit of the water plasma torch
Exhaust gas problem in Semiconductor Industry

- PFC/CFC gas in Nitrogen
- POU Systems required
- not water solvable gas
- heat resistance gases (fire extinguishing gas)
- low operation costs
- high decomposition rate (>99 \%) required
Problematic Exhaust gases and
Principle & Reaction

Stage One: Plasma Pyrolysis & Thermal Section
- \( \text{SiH}_4 + 2 \text{H}_2\text{O}_{\text{Plasma}} = \text{SiO}_2 + 4 \text{H}_2 \)
- \( 2 \text{NF}_3 + 3 \text{H}_2\text{O}_{\text{Plasma}} = 6 \text{HF} + \text{N}_2 + 3/2 \text{O}_2 \)
- \( \text{CF}_4 + 2 \text{H}_2\text{O}_{\text{Plasma}} = 4 \text{HF} + \text{CO}_2 \)
- \( \text{C}_2\text{F}_6 + 4 \text{H}_2\text{O}_{\text{Plasma}} = 6 \text{HF} + 2 \text{CO}_2 + \text{H}_2 \)
- \( \text{SF}_6 + 3 \text{H}_2\text{O}_{\text{Plasma}} = 6 \text{HF} + \text{SO}_2 + 1/2 \text{O}_2 \)
- \( \text{H}_2 + 1/2 \text{O}_2 = \text{H}_2\text{O} \)

Stage Two: Quench & Water Scrubbing Section
- \( \text{HF} + \text{H}_2\text{O} = \text{F} (\text{H}_2\text{O})^- + \text{H} (\text{H}_2\text{O})^+ \)
- \( \text{SO}_2 + \text{H}_2\text{O} = \text{H}_2\text{SO}_3 = \text{H}^+ + \text{HSO}_3^- \)
What different from others?

- Normal Plasma Sources are operated with Nitrogen or Argon (non oxidizing):
  - N2 is a non-reactive plasma gas for non-chemical reaction between the plasma gas (N2) and process gas (PFC/SiH4).
  - It is simply a heat source. Not really a plasma chemical treatment.

- Water Plasma Source:
  - H/O free radicals provider, it reacts directly with the process gas and forms desirable small and stable molecules.
  - It is both a heat source and a provider of radicals.
  - It is true plasma method for the destruction of PFC.
  - Specially Designed for Halogen Compounds treatment.
POU Water-Plasma Scrubber for Semiconductor industry

- New Generation POU Scrubber
- Lower CFC concentration than in chemical industry
- Exhaust gas mixed with Nitrogen
- Special Design & Unique Technology
- No neutral gas or Hydrogen/Oxygen gases
- Input power can be adapted to the requirement (energy efficient)
- Burn and Wet scrubbers can be the basis of the new design
- Compact design
- Fully automatic working system
- Flexible in using plasma gas (Air, Steam, Nitrogen…)
- Evaluation & Performance Test
- Water cooled reactors
Schematic flow of a Water Plasma System for CFC Decomposition

Utilities:
- Power: 20KVA (operation 10~20KVA)
- City Water: 3~5SLM
- Soft Water for Steam: 0.2 L/min
- Cooling Water: 20~40 L/min
- Argon: 0.5 ~1.0 SLM
- O2/CDA: Depends
- N2: Purge Only

Features of Design:
- **Venturi-Quench**: Quench Stream Temp from 2000C to 45C to prevent the byproduct generation.

Material Usage:
- Reactor: Special Alloy; Corrosion Resistance at high temp (3000C)
- **Metal Parts**: Stainless steel or teflon coating prevent corrosion of hardware.
Scrubber for Semiconductor industry
Field Tests and Case Study (01), conducted in Semiconductor Industry

- **Project -01**
  - **Process**: Etch (Equip: Lam Research)
  - **Site Operation**:
    - 7 Chambers Etch treated
  - **Operation Condition**
    - Total Gas Flow into Scrubber: 288.5 SLM
    - Plasma Power Level: 16 KW
    - Steam flow: 1m3/hr (over heated)
    - Argon flow: 0.7 L/min
  - **Efficiency**: (Test via FT-IR)

<table>
<thead>
<tr>
<th>Gas</th>
<th>Conc. (PPMv)</th>
<th>DRE%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recipe</td>
<td>Inlet</td>
</tr>
<tr>
<td>SF6</td>
<td>2488</td>
<td>1674</td>
</tr>
<tr>
<td>C2F6</td>
<td>2494</td>
<td>1294</td>
</tr>
<tr>
<td>CF4</td>
<td>2494</td>
<td>1294</td>
</tr>
<tr>
<td>HF</td>
<td>2494</td>
<td>1294</td>
</tr>
<tr>
<td>HCl</td>
<td>2494</td>
<td>1294</td>
</tr>
</tbody>
</table>

* CF4 is C2F6 byproduct  ** No HCN & COF2 detected
Case Study (02)

- **Project -02**
  - **Process**: PECVD (Equip: Novellus-C1)
  - **Site Operation**:
    - 4 CVD Chambers
  - **Operation Condition**
    - Total Gas Flow: 185 SLM
    - Plasma Power Level: 12 KW
    - Steam: 0.8 m3/hr
    - Argon: 0.6 L/min
    - CDA: 30SLM
  - **Efficiency**: (Test via FT-IR)

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recipe</td>
<td>Inlet</td>
</tr>
<tr>
<td>SiH4</td>
<td>1725</td>
<td>766</td>
</tr>
<tr>
<td>C3F8</td>
<td>6132</td>
<td>820</td>
</tr>
<tr>
<td>CF4</td>
<td>824</td>
<td>1.5</td>
</tr>
<tr>
<td>NH3</td>
<td>27717</td>
<td></td>
</tr>
<tr>
<td>HF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COF2</td>
<td>1548</td>
<td>1.86</td>
</tr>
</tbody>
</table>

* CF4 was byproduct of C3F8

Since the site condition, High of System adjust to 1800mm.
Non Thermal Plasma Development for exhaust gas treatment air

Application

VOC Treatment
- Big Volume flows
- low concentrations of VOC’s
- org C emission limits

Odor Reduction
- Big Volume flows
- low concentrations of VOC’s
Process for VOC treatment

Process for odor reduction
PlasmaAir DPD Discharge Module optimized for exhaust gas treatment
Set up of the cabinet
Picture of the cabinet
Summery

- PlasmaAir has had a water steam plasma in operation in chemical industry since 7 years for high concentrated CFC decomposition.
- Based on this experience a system optimized for the application of the semiconductor industry was developed.
- All components are coming from Korea (SBM Plasma Scrubber).
- The components were successful tested and the system is now integrated and ready for use.
- The decomposition efficiency depends on the specific power per exhaust gas and is more than 98%.
- The input power into the system is between 8-20 kW free selectable by the operator depending on the exhaust gas composition and volume.