Imaging Spectroscopy at Activation of Carbon Dioxide by Atmospheric Pressure Microwave Discharge

Workshop *"Oberflächentechnologie mit Plasma- und Ionenstrahlprozessen"*
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Inhalt

- IfU Diagnostic Systems GmbH
- Acoustooptic Spectrometer (AOS)
- Motivation of Experiments
- Reactor Concept
- Imaging Spectrometer
- Spectroscopy Results
- Yield and Chemical Conversion
- Conclusion and Future Work

IfU Diagnostic Systems GmbH

Developer, Producer and Distributor of
Fast Optical Emission Spectrometer based on
AOTF (***a***coustoo***p***tic ***t***unable ***f***ilter)

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Emission Spectroscopy

high time resolution - ***spatial resolution***

- pulsed magnetron sputtering processes
- periodic rf/mf applications
- process control

- multi chamber magnetron sputtering
- process control at different regions inside the discharge

Time resolution ⇑ **Light sensitivity** ⇓ **Spatial resolution**

two dimensional Aperture 8x8 mm²

- imaging spectroscopy at large area applications
- monitoring of voluminous plasma processes

AOS 4/5 – Emission Spectrometer

fast, robust, high light sensitivity, high wavelength resolution

Technical parameters AOS 4(5)	
spectral range	245 nm .....800 nm
spectral resolution	0.05nm @ 250nm , 0.5nm @ 800nm
wavelength access	5(1) milliseconds
time resolution in pulse mode	200(10) ns
size	19" rack, height 4

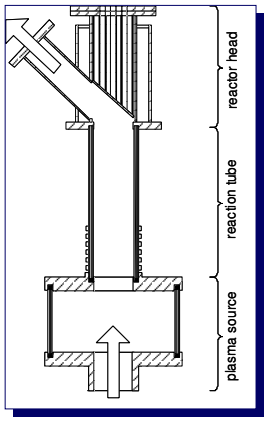
Motivation

- **Green house effect – reduction of Carbon dioxide**
- **Plasma activation of CO_2**
- **CO_2 can be used for chemical synthesis**

CH_4	$\Leftrightarrow$	$C + 2H_2$	+84 kJ/mole
CO_2	$\Leftrightarrow$	$C + O_2$	+406 kJ/mole
$2C + O_2$	$\Leftrightarrow$	$2CO$	-246 kJ/mole
$CH_4 + CO_2$	$\Leftrightarrow$	$2CO + 2H_2$	+244 kJ/mol

- Optical emission spectroscopy for process control
- Optimisation of homogeneous actiovation using imaging spectroscopy

Plasma activation reactor



CYRANNUS® I plasma source from Iplas GmbH, Germany

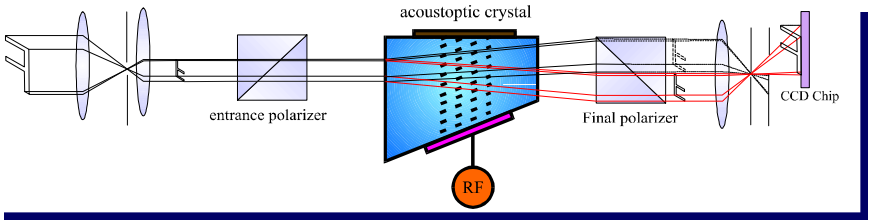
microwave power:
up to 6 kW

flow rates:
about 10 m³/h (200 m³/h possible in inefficient mode)

Gas supply:
Carbon Dioxide, Argon, Methane, Hydrogen

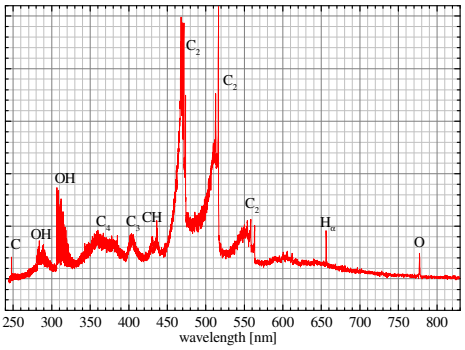
Synthesis reactor equipment at the Dortmund University

Optical arrangement - video spectrometer



spectral range	400 nm ..... 800 nm
spectral resolution	0.15 @ 400nm, 0.5 @ 800nm
picture sampling rate	8Hz (120ms/picture)
spatial resolution	40x40 pixels

Typical spectrum of synthesis gas production at atmospheric pressure



Following specimen were found in emission spectrum:

C – Atomic Carbon,

C_2,C_3, C_4 – Carbon cluster

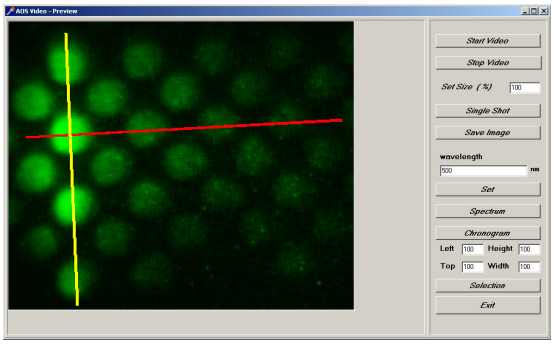
O – Atomic Oxygen (triplet)

H – Atomic Hydrogen

OH, CH – Bands

AOS-Video Software

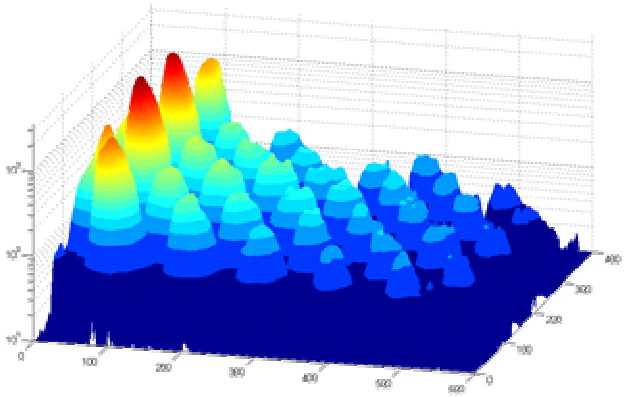
Intensity distribution inside the plasma source



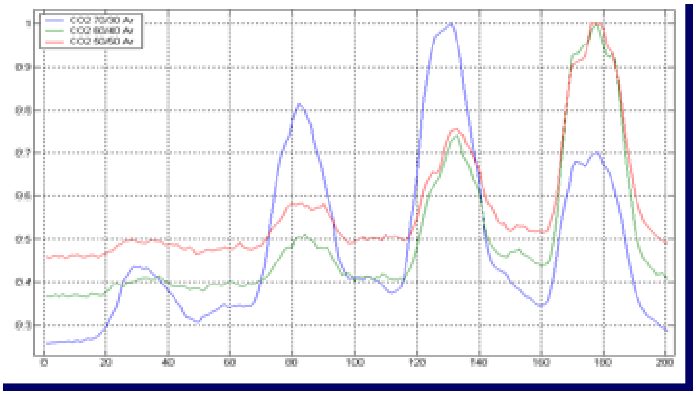
C2-Emission at 516 nm
Central range of plasma source

- Spectrum mode – integration of intensity at selected area for every wavelength
- Chrongram mode – sampling of pictures for selected wavelengths

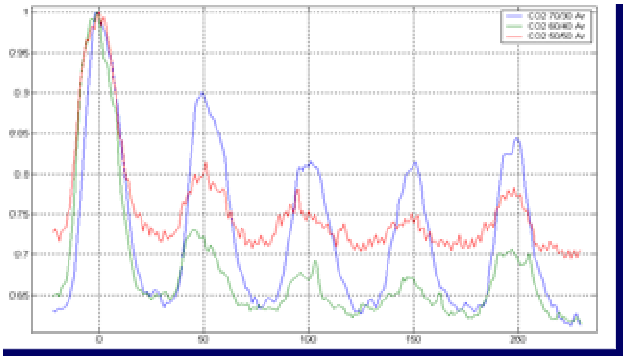
Intensity distribution of the O-Triplets during the Methane experiments



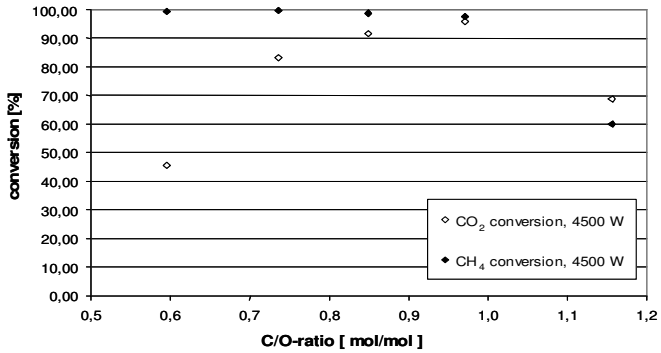
Distribution of C_2-emissions in main stream direction at different streaming conditions



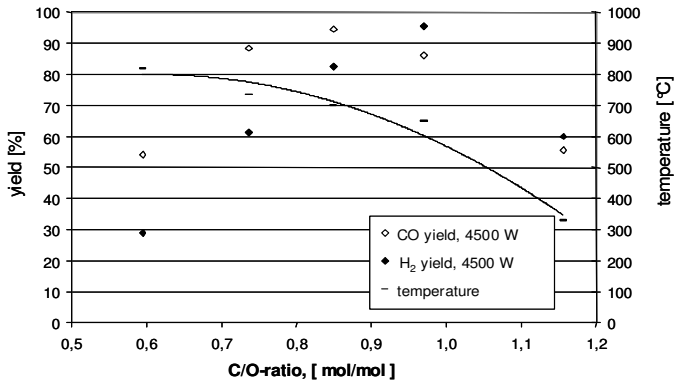
Radial distribution of C_2-emissions at different streaming conditions



Conversion of raw material depending on the ratio of inserted C and O atoms at micro wave power of 4500W



Yield of conversion products depending on the ratio of inserted C and O atoms at micro wave power of 4500W



Conclusions

- Plasma activation of Carbon dioxide adding Methane is able to produce synthesis gas,
- Synthesis reactor handles up to 10 m^3/h gas flow,
- Time resolved emission spectroscopy is able to optimise the plasma activation process
  - for conversion of raw material,
  - yield of conversion,
  - pre selection of conversion products,
- Acoustooptic imaging spectroscopy – useful method to investigate large area or volume plasma phenomena. .

Future Work

- Imaging Spectroscopy
  - spatial resolution 100x100 pixels
  - picture sampling rate 40ms/picture
  - extend the wavelength range to UV
- Time Resolution
  - wavelength access: 1ms
  - pulse mode: 10ns
  - periodical application: less 10ns (phase shift method)
- Process Control
  - evaluation of DAC-module
  - AOS-Profibus-implementation