

Principles of plasma based VOC reduction

R. Brandenburg¹, D. Cameron², A. Haljaste³, T. Hoder¹, M. Hołub⁴,
T. Ivanova², I. Jõgi³, M.-L. Kääriäinen², and M. Schmidt¹

¹ INP Greifswald (Germany)

² Lappeenranta University of Technology (Finland)

³ University of Tartu (Estonia)

⁴ West Pomeranian University of Technology, Szczecin (Poland)





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European Environment Agency





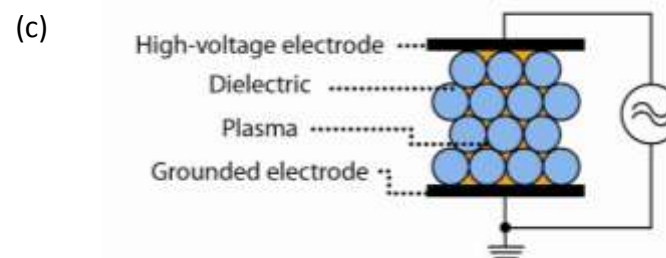
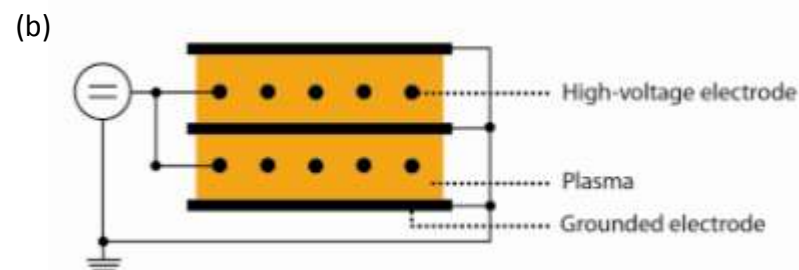
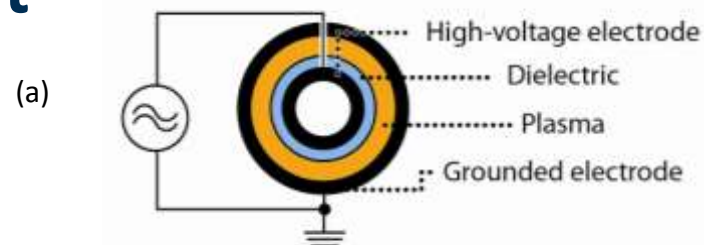
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Introduction

Gas discharges for gas treatment

- Gas flows through an electrode structure utilizing a gas discharge with a non-thermal plasma
- Discharge types (cross sectional views):
 - Barrier discharges (a)
 - Corona discharges (b)
 - Packed bed reactors (c)
- Plasma enables chemical conversion in the treated gas – Plasma Chemistry





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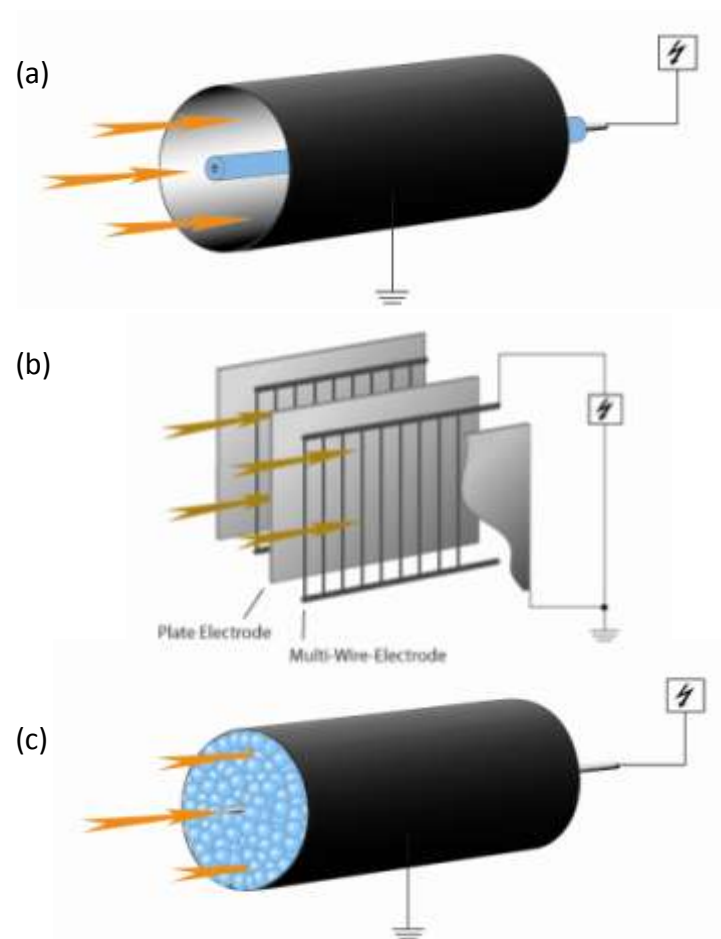
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Introduction

VOC removal in air

- Free electrons generate radicals (collisions) (O, OH, OH₂) and O₃
- Oxidative reactions resulting in CO₂ and H₂O and other by-products
- Efficacy and selectivity depend on gas composition, pollutant and its concentration, temperature, specific energy etc.

Plasma as oxidation stages in combination with other processes like adsorption, catalysis, scrubbing, ...



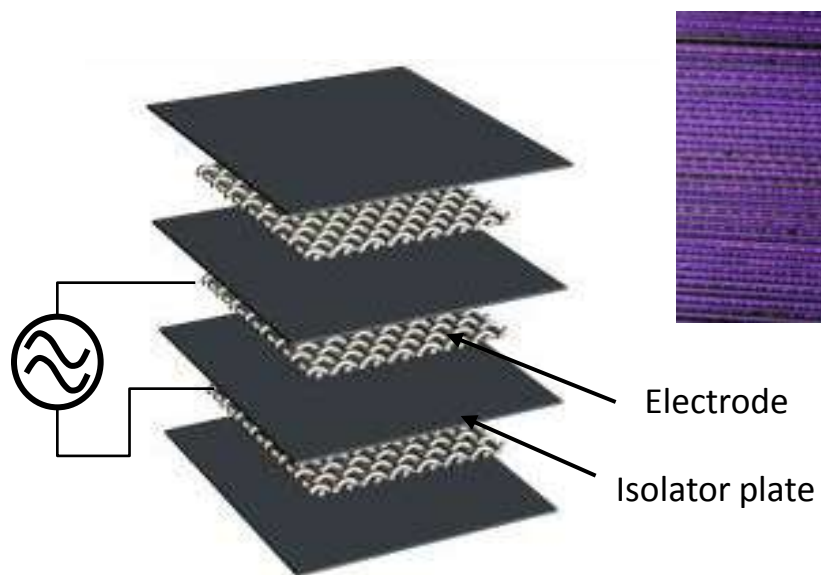


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Introduction

Dielectric Barrier Discharge Stack Reactor (PlasTEP)



S. Müller, R.-J. Zahn; Contributions to Plasma Physics 47 (2007) 520-529



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Chances and prospects of plasma based VOC-removal / Examples

Advantage of plasma based exhaust treatment

- Chemical conversion without increase of gas temperature
- Effects on gas particles and particulate matter (aerosols)
- Effects in gas phase and on surfaces
- Controllable by electrical operation parameters

„Regardless of how strictly we define ‘environmental plasma’, the history and future potential of this technology are quite remarkable.“

Alexander Gutsol

In: „The 2012 Plasma Roadmap“

J. Phys. D: Appl. Phys. 45 (2012) 253001 (37 pp)

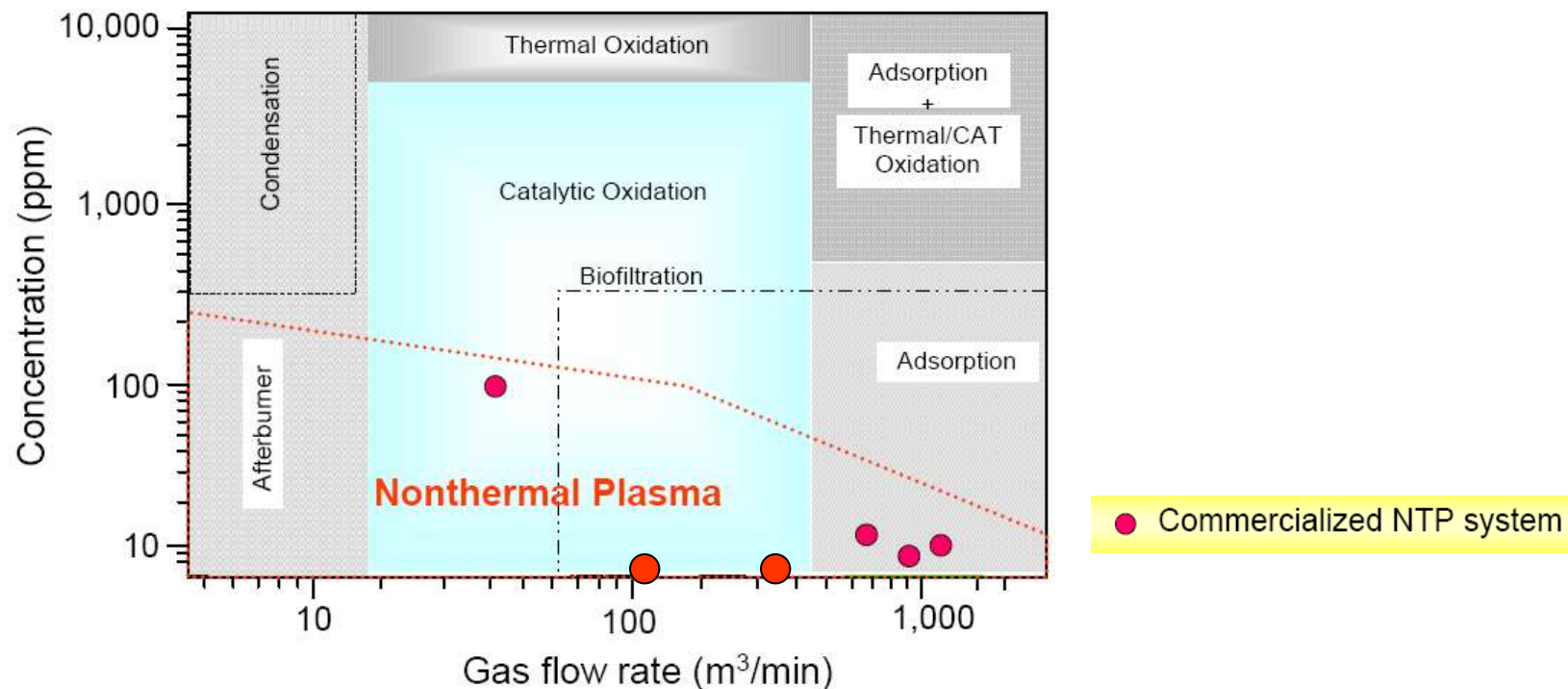


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Chances and prospects of plasma based VOC-removal / Examples

State-of-the-art: plasma deodorization



H.H. Kim et al. International Journal of Plasma Environmental Science & Technology Vol.1, 2007

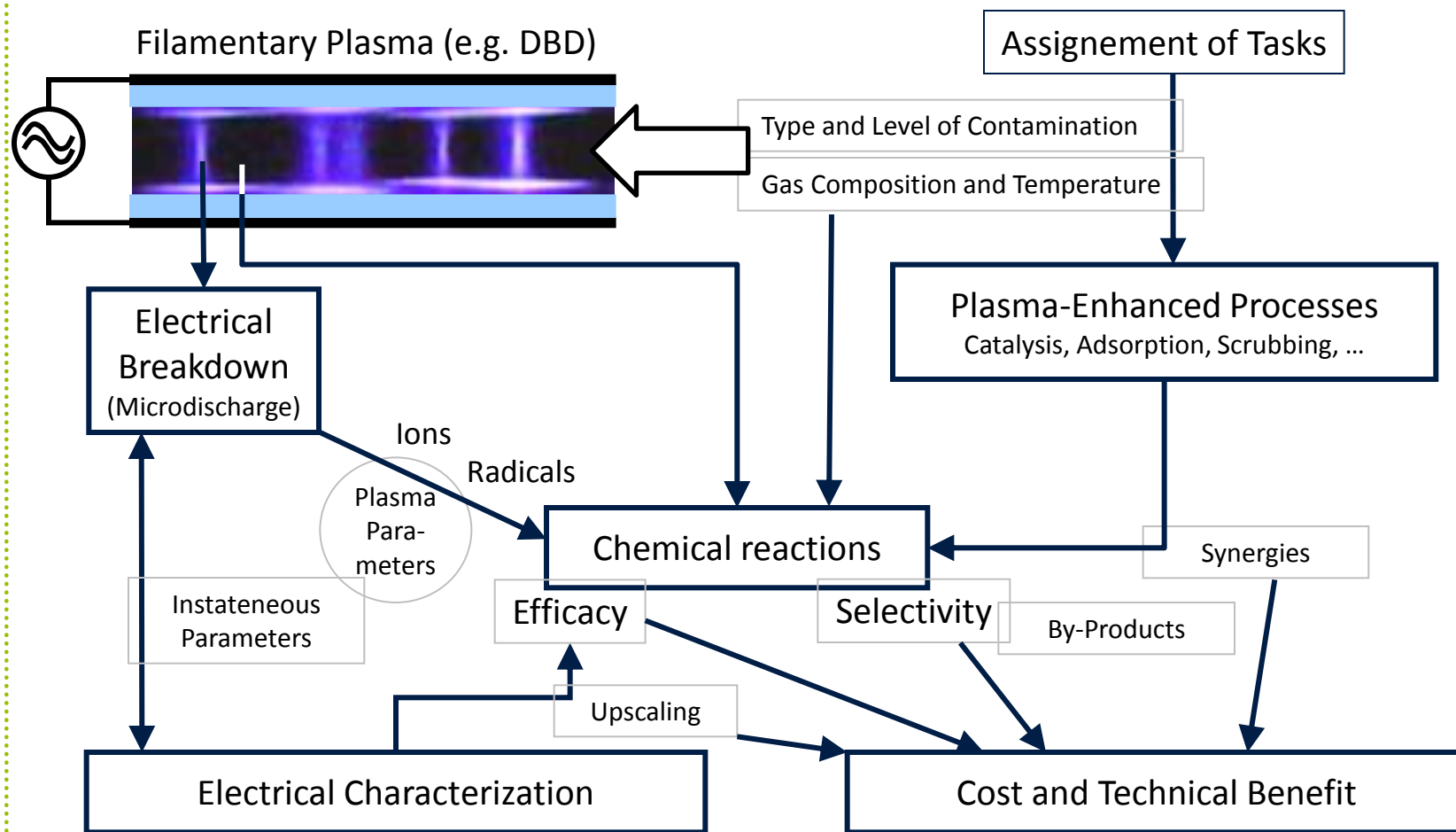


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Plasma Science

Engineering





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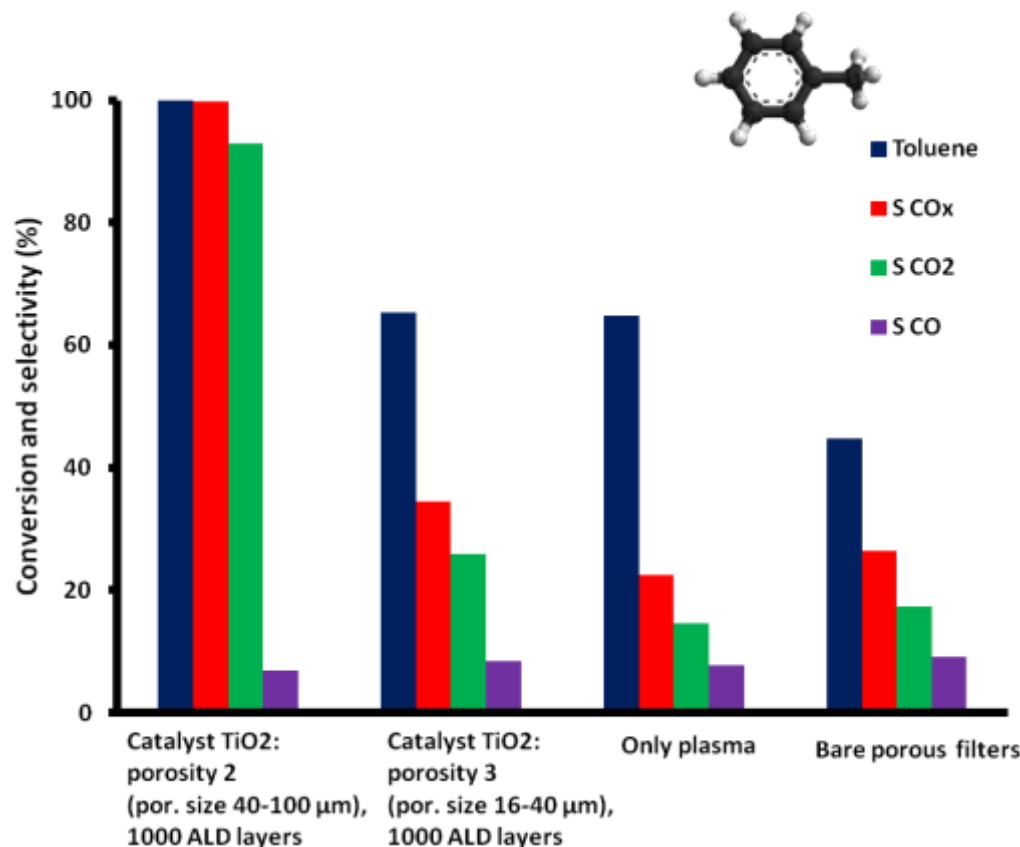
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Chances and prospects of plasma based VOC-removal / Examples

Implementation of catalyst (ASTRaL)

Activity of TiO₂ catalysts, pure porous filters and plasma during (2500 ppm of toluene at 336 J/L)

- 1000 ALD layers of TiO₂ catalyst on glass filters deposited on mesh electrodes (Atomic Layer Deposition)
- Amount of removed toluene depends on applied catalyst and porosity of glass filters
- Improved selectivity of CO_x by catalyst application





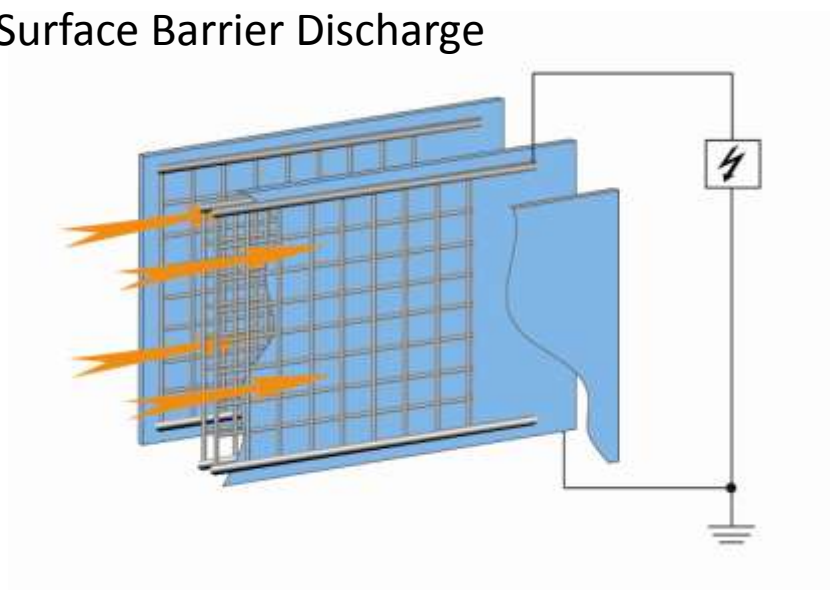
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Synergy between plasma and adsorber (I)

Surface Barrier Discharge



Undersized Active Carbon Sample



Model VOC Ethanol



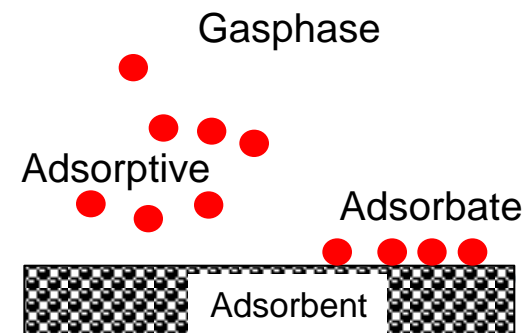
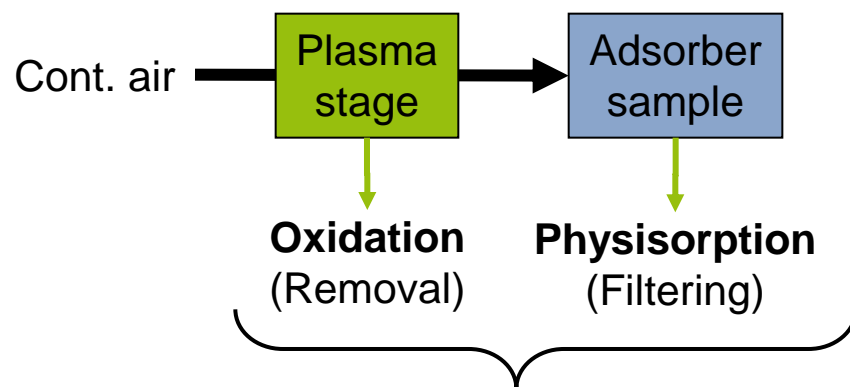


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Plasma supported adsorption



Reduction of resorbed ethanols with plasma treatment before active carbon
= reduction of the absorptive & oxidation of adsorbate

Removal of pollutant & Regeneration of adsorbent



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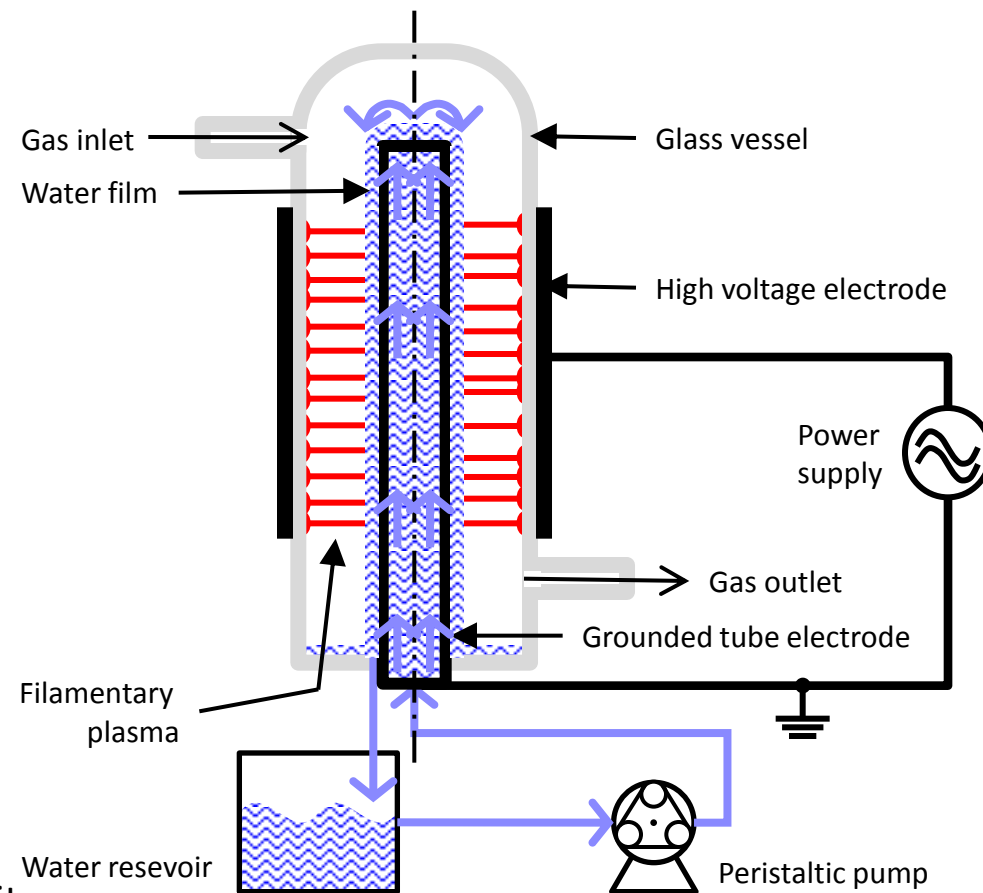
Falling water reactor

Water flows up through vertical hollow cylindrical electrode (inner electrode of a concentric barrier discharge) and flows down making thin water film over inner electrode

→ treatment of water
(dye removal) demonstrated



→ treatment of gas phase?

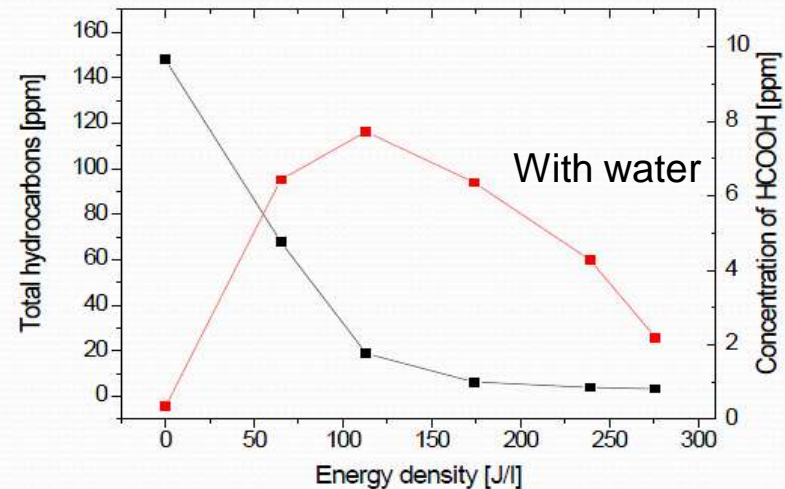
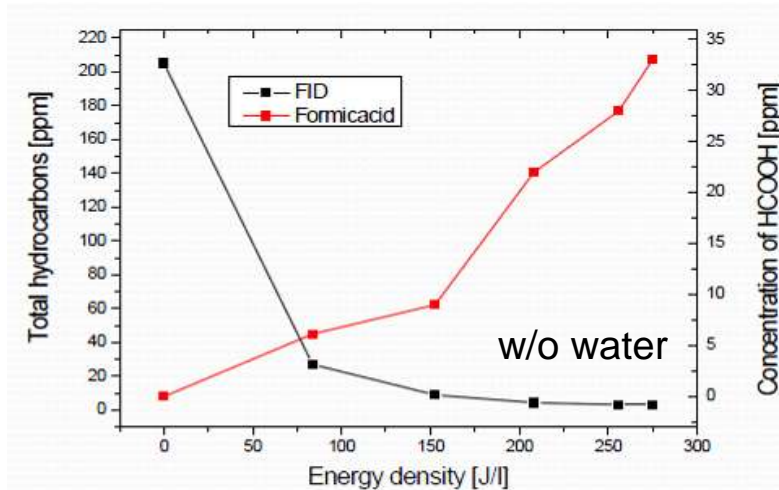
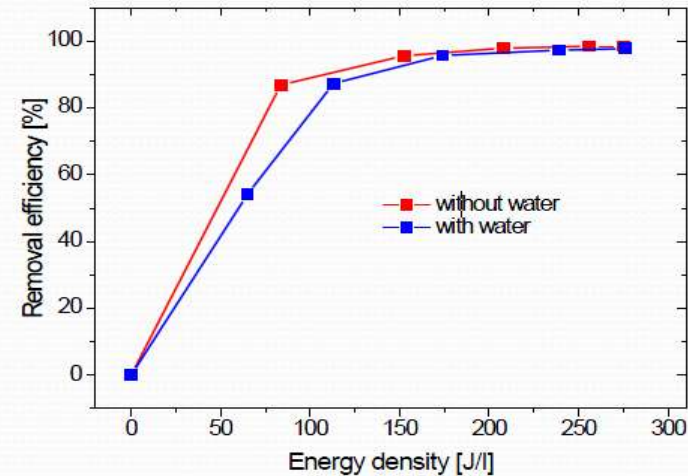


V. Kovacevic, M. Kuraica et al.; Belgrade University

Chances and prospects of plasma based VOC-removal / Examples

Plasma assisted scrubbing

- $C_{11}H_{26}$ reduced by plasma
 → more effective without water film
 → by-product: Formic acid $HCOOH$
- $C_{11}H_{26}$ non-soluble in water
- $HCOOH$ soluble in water





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Outlook

Plasma used mainly for deodorization issues

- Role of oxidation stage → synergy with adsorption, catalysis and scrubbing
- Plasmas offer compact systems with a direct (instantaneous) control via electrical operation parameters

Potential to expanded use of plasmas

- To understand more the physical and chemical processes of combined action, e.g.,
 - quantitative description of plasma-supported adsorption
 - interplay discharge physics, surface processes and plasma chemistry
- To explore other fields of application of plasma chemistry