TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Mechanical Science & Engineering Institute of Process Engineering & Environmental Technology

Modular two-phase plasma catalyst reactor for the functionalization of liquids

Dipl.-Ing. **Alexander Alfred Zyla**, Graduate

Motivation

- ✓ **Proof of Concept** of Process Principle and production of **plasma activated water** (**PAW**)
- ✓ **saving energy and expensive catalysts** by using low-temperature atmospheric pressure plasma for multiphase reactions
- ✓ **increasing the yield** of functionalized liquids
- ✓ establishing of a **system with increased resilience and low cost**
- ✓ using **3D-printing** to built a plasma reactor
- ✓ basis for **technology transfer** and **interdisciplinary development** of plasma technology
- ✓ **wide range** of **application fields**

Agriculture:
Exp.: plant treatment;
functionalization of agents

Medicine:
Exp.: sterilization of surfaces

Water-treatment:
Exp.: reduction of biofilms;
water sterilization

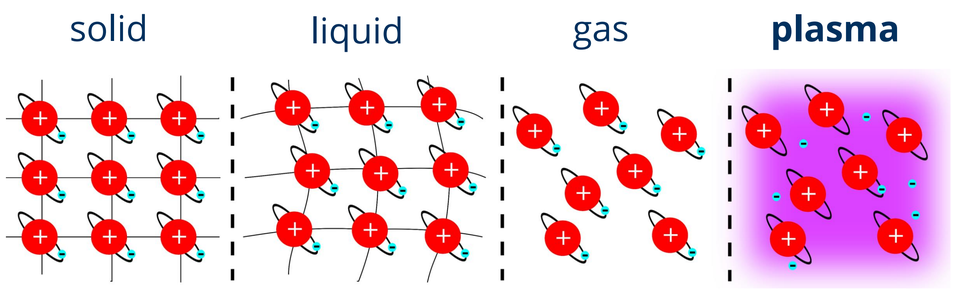
Food and consumer goods industry:
Exp.: curing meat

Process industry:
Exp.: alternative catalysis method

Research and development:
Exp.: plasma examinations;
electrode development

Plasma

Aggregate states:

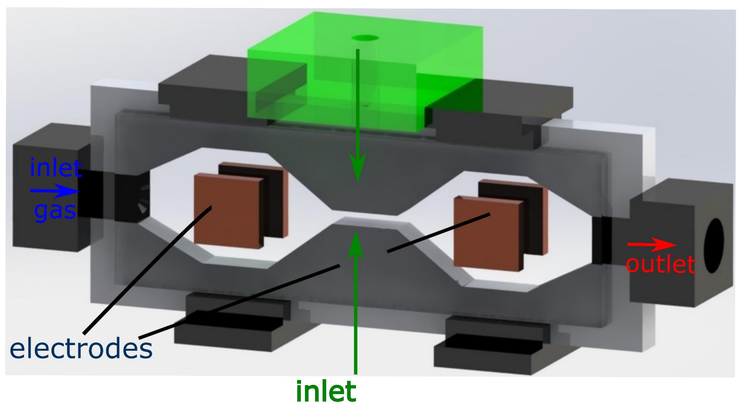


The material world usually surrounds us in three classical states of aggregation: **solid**, **liquid** and **gas**. In addition to these three states of aggregation, there are others.
A state in which free electrons and ionized atoms occur is called plasma. [LANGMUIR, 1928]

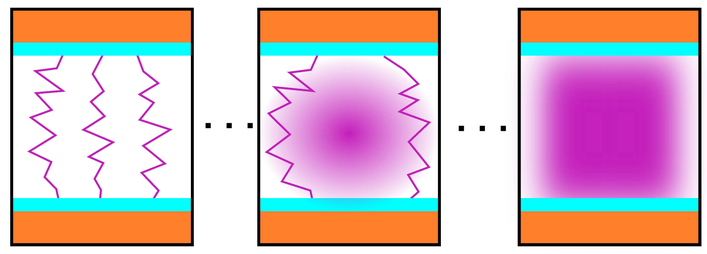
In a plasma, atoms, or molecules, ions and electrons move around freely and interact simultaneously.
The intensity of a plasma depends on the degree of ionization ($10^{-8} \leq x_{ion} \leq 1$).
Low temperature atmospheric pressure plasma can be ignited under normal ambient conditions.

Two-phase plasma catalyst reactor (ZPPK reactor)

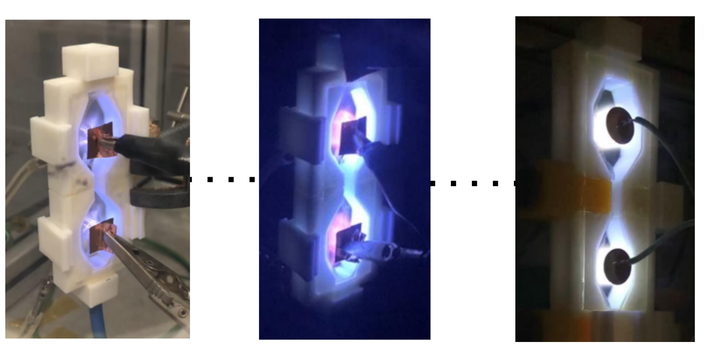
ZPPK-Reactor and process principle:



Classification of usable plasma states:



filamentary plasma on the left and homogeneous/diffuse plasma on the right

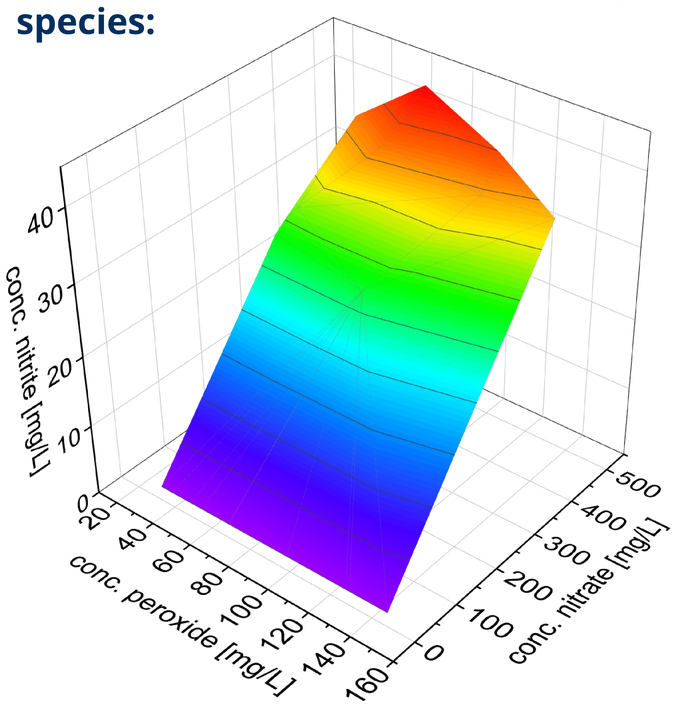


X: For more complex reaction chains multi-stage systems can be established.

Experimental results

Plasma activated water was produced. It is characterized by increased concentrations of reactive oxygen and nitrogen species (RONS) and a reduced ph-value.

Detected reactive oxide and nitrogen species:



Catalyzed reactions:

Peroxide:

$$2\boldsymbol{H_2O} + e^- \rightarrow 2H_{aq} + 2 \cdot OH_{aq} + e^-$$
$$2 \cdot OH_{aq} \rightarrow \boldsymbol{H_2O_2}$$

Ions:

$$N_2 + e^- \rightarrow 2N + e^-$$
$$O_2 + e^- \rightarrow 2O + e^-$$

Nitrite:

$$N + 2O \rightarrow NO + O \rightarrow \boldsymbol{NO_2}^-$$

Nitrate:

$$2NO_2^- \leftrightarrow NO + \boldsymbol{NO_3}^-$$

Nitric acid:

$$NO_3^- + H \rightarrow ONOOH$$

By using optimized process parameters, the ph value of the PAW was reduced to 2,66.

Discussion

- **Peroxide** is formed independently of nitrate and nitrite. Peroxide is only formed in the liquid phase.
- The nitrate and nitrite concentrations show a clear dependence. **Nitrite** is an intermediate product in the formation of **nitrate**. Both species are mainly formed in the gas phase and are absorbed by the liquid phase.

To increase the yield, the gas composition used, the energy input and the atomization rate were optimized:
The PAW with a reduced ph value of 2,66 can be used for sterilization processes.
The low pH value is achieved by a disproportionately increased yield of the peroxides, nitrates, nitrites and nitric acid dissolved in the water.

Future Challenges:

➢To simplify access to the technology it needs compact and pre-validated: **High-voltage sources; Examination tools for plasma diagnosis; Gas-flow controller** and **Pump-systems**

➢using the system (ZPPK-Reactor) for more **interdisciplinary** scientific work

➢Collected Data can be combined for **BigData analysis**

Abstract with references
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Research Group of Mechanical Process Engineering
Technische Universität Dresden
01062 Dresden
http://www.tu-dresden.de/mw/mvt

Contact:
Alexander Alfred Zyla
E-Mail 1: alexander_alfred.zyla@mailbox.tu-dresden.de
E-Mail 2: a.a.z@posteo.de
Tel.: 0049 162 4191409

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