Development of dielectric barrier discharge (DBD) atmospheric plasma reactors for degradation of gaseous, liquid and solid waste

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In general, plasma processes can already be considered as inherently environmental technologies [1]. Plasma processes enable resource saving through high energy utilization efficiency and thus, are environmentally friendly technologies [2].

Atmospheric pressure discharges (APDs) are useful because of their specific advantages over low-pressure discharges. They do not need expensive vacuum equipment, and generate nonthermal plasmas, which are more suitable for assembly line processes. Hence, this category of discharges has significant industrial applications [3]. The use of a dielectric barrier in the discharge gap helps prevent spark formation. DBDs exhibit two major discharge modes: filamentary and glow (homogeneous). The glow discharge mode has obvious advantages over the filamentary one for applications such as treatment of surfaces and deposition of thin films. Glow mode discharges with average power densities comparable to those of filamentary discharges are of enormous interest for applications in which reliable control is required [4].

Plasma treatment is a well-established method for the surface modification and coating of a wide range of materials. It is especially successfully applied for polymers, as it allows the treatment of the surface without affecting the bulk properties [5,6]. Apparently, the energetics of the active species in the plasma are such that the depth of penetration into most polymer materials is only in the order of a few 100 nm. The low surface free energy limits the application due to poor adhesion ability and low wettability. It is estimated that more than 75% of available polymers necessitate further surface improvement prior to commercial use such as painting, coating, printing, gluing, or bonding [7,8].

In comparison, plasma treatment is a fast process [9], as it only takes milliseconds to introduce new chemical groups (such as e.g., carboxylic, hydroxyl, amine, or aldehyde groups) into the surface layers of a polymer material.

We develop laboratory scale plasma reactors for the degradation of gaseous, liquid, and solid waste. All those reactors are designed in way allowing to upscale them easily by a factor of at least 10-20 depending on the design. In this presentation we show examples for the treatment of solid, liquid, and gaseous contaminants in specific reactors and how these reactors are developed using modelling approaches for their optimization.

Reactor for solid waste samples on the example of polymer foils

The dielectric barrier discharge (DBD) reactor (Fig. 1), which was used for the experiments with solid waste (mainly polymers), consists of two parallel stainless-steel electrodes with 30x50 mm^2 dimensions and a 7 mm

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thick alumina ceramic plate as dielectric. The reactor can be easily upscaled and also continuously fed. For the experiments, the DBD plasma settings at ambient air were 16 kV at a frequency of 7 kHz with a spacing of 9 mm between the electrodes and the samples (including the 7 mm thick dielectric). On the influence of the plasma pretreatment on the degradability of the PLA foils, please refer to our publications [10, 11].

Fig. 1: Atmospheric plasma reactor for polymer foils treatment

Reactor designs for liquid waste samples and gaseous contaminants

The design of the reactor and its temperature distribution was modelled using COMSOL® (Fig. 2). The reactor was then manufactured using 3D printing for the exterior, alumina as dielectric, and copper or stainless steel as electrodes.

In Fig. 3 a reactor for catalytic CO_2 conversion to added value chemicals is presented along with flow field simulations.

In Fig. 3 (right) CO_2 conversion in dependence of the applied plasma power and time are presented.

Both reactors can be used also for degradation of liquid waste but with different parameters for plasma and also electrode design.

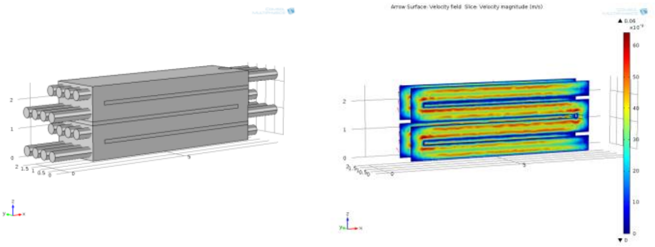

Fig. 2: Modell of the flow field in a plasma reactor with eight electrodes and three gas deflection ceramics [own unpublished results].

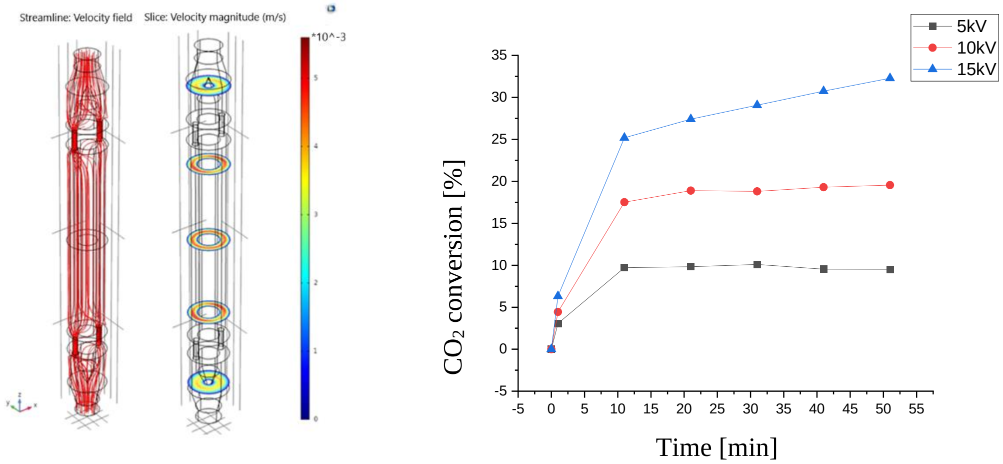

Fig. 3: Modell of the flow field in a plasma reactor (left) with catalyst and CO_2 conversion as a function of time and plasma power (right) [own unpublished results].

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