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Atmospheric pressure discharges in tubes and pores

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Atmospheric pressure non-equilibrium plasmas generated by electrical discharges are very attractive due to numerous applications, especially environmental and biomedical. The most common discharge types are coronas and dielectric barrier discharges, which form plasma in the volume or along the surface. However, discharges can be also generated inside cavities and pores of dielectrics placed between the electrodes. A number of hybrid configurations and devices have been developed and utilized in the past decades, e.g. micro-hollow cathode discharge, capillary plasma electrode discharge. Here, the focus is put on discharges in cavities of capillary tubes and porous foams. These discharges are interesting from the point of view of plasma assisted catalytic research that requires stable discharges plasma generation in contact with catalysts, their surface and porous structure. The physical properties of the discharge, conditions of their formation and propagation in tubes and foams are addressed with respect their geometry (e.g. length, diameter, pore size) and the applied voltage. The discharge in capillary tubes (diameter of 0.2-2 mm) was investigated in a single tube, as well as in a bundle of tubes. The single tube tests were essential to understand the mechanism of the discharge, while the tests with a bundle of tubes were performed to assess the stability, spatial homogeneity and chemical activity of the discharge. The spatial-temporal resolved propagation of the discharge front in the tubes was investigated and the discharge front propagation was found to be of order 10^7-10^8 cm/s and increasing with the diminishing tube diameter. Various configurations of tubes separated by one or two porous dielectric layers were tested. The changes of the discharge front propagation velocity as a function of thickness/porosity of the layer and amplitude/frequency of the applied voltage pulses was evaluated and compared. To assess the optimal conditions for the generation of stable plasma inside honeycomb-shaped monolith, tests with several tubes were performed. The properties of discharges generated inside the ceramic foams (pore size of 2 - 200 μm) were investigated and found possible only for a specific combination of the applied voltage and the pore size. The discharge inside the porous foams is repetitive short spark discharge that forms from the foregoing surface barrier discharge and its formation is accompanied with a sudden increase of the discharge current and light emission if compared to the barrier discharge. The mechanism of the discharge results from repetitive accumulation of charges on the resistive foam and their subsequent breakdown through the foam when their number exceeds a critical value. Temporarily resolved imaging reveals these discharges are randomly but homogeneously distributed both in time and volume of the foam. The two discharges were briefly subjected to the investigations of their plasma chemical effects, i.e. generation of O_3, oxidation of NO, and collection of PM and have proven their potential for exhaust treatment in a plasma-catalytic system.

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