The role of reactor and power supply design on chemical and physical processes in liquid and gas-liquid electrical discharges

P. Lukes, M. Clupek, V. Babicky, P. Sunka

Institute of Plasma Physics, Za Slovankou 3, 18200 Prague, Czech Republic

There is considerable interest in the study of pulsed conduction and electrical breakdown in water because of their importance in electrical transmission processes and their practical application to the design and the insulation of high voltage pulsed power systems. More recently, different types of liquid phase electrical discharge reactors have been investigated, and are being developed, since non-thermal plasma generated by electrical discharges initiate various chemical and physical processes in water that can be potentially utilized in different environmental, biological or medical applications. These processes include high electric field, intense ultraviolet radiation, overpressure shock waves and, of particular importance, formation of various reactive chemical species such as radicals (OH, H, O) and molecular species (H_2O_2, H_2, O_2, O_3). It has been demonstrated that these physical and chemical processes are capable to destroy or degrade biological cells and chemical compounds dissolved in water when the magnitudes of the various contributions of these processes strongly depend upon the type and the power of the discharge. Discharges are generated either directly in the water or in the gas phase in close proximity to the liquid surface or in both phases simultaneously. Consequently, AC and DC electric fields are also used to initiate discharge. To generate electric discharges directly in water the pulsed high voltage and electrode systems producing a highly non-uniform electric field (point-plate, wire-cylinder, hole-plate etc.) are often used since very high-localized electric field of the order of 1 MV/cm is needed for electrical breakdown of water compared to only 30 kV/cm for breakdown in gases. In addition, the solution conductivity that is determined by concentration and mobility of ions presented in the water plays also a very important role in the generation of underwater plasma. This is caused mainly by high density of water leading to much higher collision frequency and lower mobility of charges as the mobility of ions is much less than that of electrons. Concerning pulsed electric discharges there are two of the basic types that differ primarily by the amount of energy deposited in the system and they can be classified into "partial" electrical discharges (streamer discharges) where the discharge current flows from one electrode, however, it does not reach the counter electrode, and arc or spark discharge. In the partial discharge with the energy of the order 1J/pulse (called also "streamer corona" or "corona-like") the current is transferred by ions. Higher conductivity (a higher concentration of ions) results in a larger discharge current, and, on the other hand, in shortening of the streamer length (faster compensation of the space charge electric fields on the head of the streamer). This results in a higher power density in the channel (a higher power dissipated in a smaller volume) resulting in an increase in the plasma density, in a higher temperature of the plasma. Spark and arc discharges (energy of ~ 1kJ/pulse) are quite different from the "partial" discharges. The current between electrodes is transferred here by electrons. Due the relatively high breakdown electric field of water, a small inter electrode gap is necessary and the discharge current heats a small volume of plasma that results in generation of almost thermal plasma. Temperatures of the spark and arc discharges plasmas are above 10 000 K and high power UV and also strong shock waves are generated. In this presentation the physical and chemical processes induced by the pulsed electrical discharges in water will be discussed with particular emphasis to the effects of the type of electrical discharge reactor, power supply design and solution conductivity on the production and magnitude of the contributions of these processes in water.