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Non-Thermal Plasma in Liquids: from Chemical and Biological Water Cleaning to Synthesis of New Materials in Liquid Nitrogen

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As estimated by the Environmental Protection Agency (EPA), nearly thirty-five percent of all deaths in developing countries are related directly to contaminated water. Regarding human consumption, chemical treatments such as chlorination can render potable water toxic, which attracts a special attention to the plasma approaches. Plasma plays without any doubts a significant role in water chemical and biological purification both indirectly (mostly by plasma generated ozone and ultraviolet – UV radiation) and directly using different types of the water-submerged discharges. Novel results in both biological and chemical water purification using submerged non-equilibrium gliding arc plasma are going to be in focus of this presentation.

If plasma is organized not remotely but directly in water, effectiveness of the treatment due to plasma-generated UV-radiation, active chemicals (including ozone), and electric field can be much higher. Organization of plasma inside of water also leads to additional significant contribution of short-living active species (electronically excited molecules, active radicals like OH, O etc.), charged particles and plasma-related strong electric fields into cleaning and sterilization. All separate plasma-related species and factors provide significant synergistic effect when applied all together in direct plasma sterilization.

Energy cost of water treatment is one the most critical parameters of the plasma technologies focused on water disinfection and sterilization. While the conventional technology of water chlorination is not ecologically friendly, it is very cheap, which creates significant challenge for all relevant plasma-based technologies. Especially important is operational cost of the plasma-based technologies, because of significant consumption of electric energy in the related processes. To be competitive in cleaning of large volumes of water, electric energy consumption is expected not to exceed 3-10 kJ/L for treatment of strongly contaminated non-transparent water, and 30-100 J/L for disinfection of slightly biologically contaminated, chemically clean, transparent water (where plasma-generated UV is effective). In general, energy cost of the plasma-induced water disinfection and sterilization strongly depends on quality of water to be cleaned. The plasma-generated UV-radiation can provide the energy-effective disinfection and sterilization if water is sufficiently UV-transparent, which permits to meet the above-mentioned electric energy cost requirement. If water is strongly contaminated and not UV-transparent, the decontamination requires significant contribution of the plasma-generated active species (ROS, RNS) resulting in about 100-times higher energy consumption, which can be still acceptable. In this perspective, when water is UV transparent, the low energy cost of disinfection and sterilization can be achieved when plasma can effectively generate the UV emission in the range of wavelengths optimal for killing relevant microorganisms. Such effective UV-radiation is usually provided by thermal and quasi-thermal plasmas, especially discharges in air bubbles with nitrogen oxides emitting the UV. Keeping in mind the restrictions related to electric energy cost and electrodes erosion, the energetic thermal plasma sources (like high current thermal arc discharges) have significant challenges. In contrast to that the “warm” discharges, like sparks and gliding arcs, are preferential for water disinfection and sterilization. Novel results in both biological and chemical water purification using such submerged discharges are going to be discussed in this presentation.

To demonstrate more intriguing new research of the cold discharges submerged in liquids, novel data on the cryogenic plasma generated in liquid nitrogen are going to be presented. In addition to fundamentals of the cryogenic plasmas, application-focused results on the synthesis of polymeric nitrogen are going to be discussed in the conclusion of the presentation.