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Cold flame on Biofilm - Transport of Plasma Chemistry from Gas to Liquid Phase

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One of the most active and fastest growing fields in low-temperature plasma science today is biological effects of gas plasmas and their translation in many challenges of societal importance such as healthcare, environment, agriculture, and nanoscale fabrication and synthesis. Using medicine as an example, there are already three FDA-approved plasma-based surgical procedures for tissue ablation and blood coagulation and at least five phase-II clinical trials on plasma-assisted wound healing therapies. A key driver for realizing the immense application potential of near room-temperature ambient pressure gas plasmas, commonly known as cold atmospheric plasmas or CAP, is to build a sizeable interdisciplinary knowledge base with which to unravel, optimize, and indeed design how reactive plasma species interact with cells and their key components such as protein and DNA. Whilst a logical objective, it is a formidable challenge not least since existing knowledge of gas discharges is largely in the gas-phase and therefore not directly applicable to cell-containing matters that are covered by or embedded in liquid (e.g. biofluid). Here, we study plasma inactivation of biofilms, a jelly-like structure that bacteria use to protect themselves and a major source of antimicrobial resistance. As 60-90% of biofilm is made of water, we develop a holistic model incorporating physics and chemistry in the upstream CAP-generating region, a plasma-exit region as a buffer for as-phase transport, and a downstream liquid region bordering the gas buffer region. A special model is developed to account for rapid chemical reactions accompanied the transport of gas-phase plasma species through the gas-liquid interface and for liquid-phase chemical reactions. Numerical simulation is used to illustrate how key reactive oxygen species (ROS) are transported into the liquid, and this is supported with experimental data of both biofilm inactivation using plasmas and electron spin spectroscopy (ESR) measurement of liquid-phase ROS.