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Electrical Discharges in Gas Bubbles

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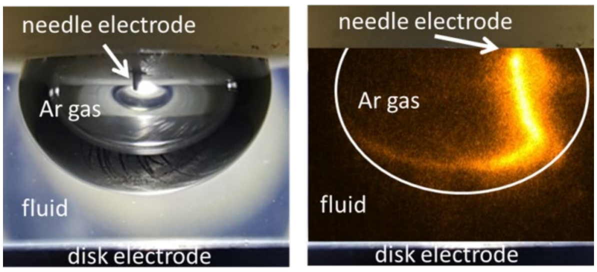

Figure 1 Ar bubble prior to the discharge and during the discharge. The discharge with +5kV between the needle and disk electrodes was imaged with a fast ICCD,15 ns exposure, 360 ns after the start of the discharge.

Pulsed electrical discharges above and along a surface of fluids have found wide range of applications in various fields from environmental to medical [1]. Discharges in dispersed gas bubbles are used in water purification and other applications and single bubbles illuminate the interaction of the discharge with the gas-liquid interface. [2-8]. The discharges in gas bubbles in liquids and gels generate various radicals (O, OH, etc.) and other reactive species (electrons, photons, etc.) that diffuse into the liquid or gel and initiate chemical processes (ex. the production of H_2O_2) useful for the destruction of some contaminants [ex. 6, 7]. Optical Emission Spectroscopy (OES) of the discharge in Ar bubbles attached to a needle electrode (Fig 1) shows electron densities of 10^{20} m^{-3}- 10^{22} m^{-3} and a complex electron energy distribution. [5, 8]

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Here we compare the time evolution of the discharge current and the development of the discharge for bubbles immersed in deionized water, aqueous solutions of NaCl, and hydrogel. These media span the conductivity range of µS/cm to mS/cm, and have the relative dielectric constants of 79 (water) and 3.5 (gel). Nearly rectangular voltage pulses ~1µs long are applied between the needle and disk electrode. Fast images of the discharge are correlated with the development of the discharge current (fig. 2). The development of the discharge is consistent with the changes in the Maxwell relaxation time, τ, given by [9, 10] $\tau=\varepsilon_r\,\varepsilon_o/\sigma$ where ε_r is the relative dielectric constant, ε_o is the vacuum permittivity, and σ is the conductivity of the liquid. We demonstrate experimentally that if the dielectric constant is low (ex. 3.5) and the conductivity is high (mS) then the discharge continues to propagate and the current continues to grow until the applied voltage is removed. The quenching of the discharge typical for a dielectric barrier discharge is not observed. For deionized water, τ>7ms, the current is quenched in ~10s ns by the charge deposition on the surface of the bubble. [] We use a simple circuit model, modified to include the changes in the conductivity of a gas bubbles to gain insight into the development of the shape of the current trace depending on the changes in the time constant.

The shape of the current pulse significantly affects the amount of energy produced by the discharge and hence is an important property for the design and monitoring of plasma sources used for water decontamination and for plasma activation of water and gel for applications in biology, medicine, and agriculture. Discharge and bubble behavior with other gases on ns and ms scales is also discussed.

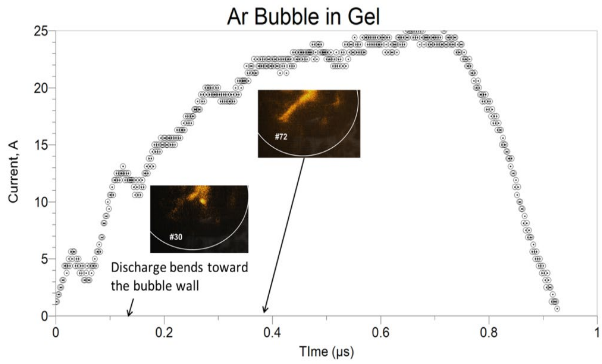

Figure 2 Discharge propagation in Ar bubbles in gel recorded with PI MAX ICCD with gate width (exposure) of 5 ns and a 5 ns step for the first 100 shots and longer thereafter. A typical current trace is shown as a reference.

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