Electrical Discharges in Liquid Water: a Global Model for the Breakdown and the Post-breakdown

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A 0D thermochemical global model of a pulsed electrical discharge formed directly in water has been developed. The experiment to be modelled is presented in detail in [1]. Typical current and voltage waveforms are shown in figure 1. The discharge is split in 3 time-based stages: (1) the pre-breakdown which includes the initiation and the propagation of the streamers (not modelled). (2) the breakdown which corresponds to the energy injection stage (3) the post-breakdown when the energy injection has stopped. The present study is only dedicated to the second and third stages resulting from a thermal initiation process.

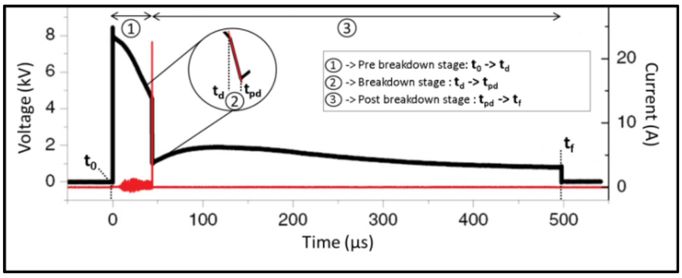

Figure. 1: *Voltage and current signals monitored for an applied voltage of 9kV and a water conductivity of 100 µS/cm*

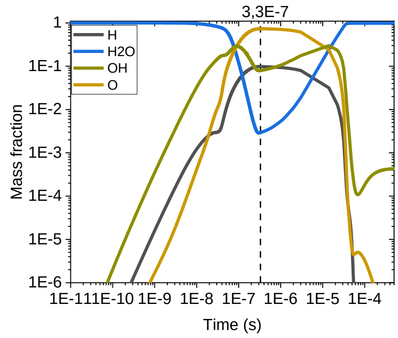

Figure. 2: *Evolution of O, H, OH and H_2O density for a pure H_2O discharge*

The breakdown phase, which occurs in a pre-existing gas volume formed during the initiation phase, lasts a few thousands of nanoseconds, allowing the assumption of a constant gas volume. This hypothesis is also strengthened by experimental observations [1]. The post breakdown phase begins when the deposited energy becomes negligible. During this stage the gaseous volume shows a bubble dynamic dependence: the gas volume expands and contracts just as cavitation bubbles.
This type of discharge is known to be in a strong thermal and chemical non-equilibrium. The model then includes two temperatures: electron temperature and heavy species translation temperature. Equilibrium is assumed for vibrational and rotational temperatures ($T_g = T_v = T_{rot}$). The energy deposited during one pulse is estimated using voltage and current measurements. We assume that the energy is uniformly deposited in the discharge filament volume only during the breakdown phase. The EEDF is assumed to be Maxwellian because of the high prevailing pressure. To calculate the electron and gas temperature, two energy balances are solved. Each chemical species is characterized by the time evolution of its density (Fig.2). The chemical non-equilibrium is described using a 31 species scheme involving 628 reactions. Transport properties are obtained according the Chapman-Enskog theory [2]. Diffusion towards the liquid is estimated according to Henry's law. The time evolution of the species concentrations, gas and electron temperatures will be obtained according several sets of initial conditions.

Références

[1] C. Rond *et al.*, « Time-resolved diagnostics of a pin-to-pin pulsed discharge in water: pre-breakdown and breakdown analysis », *Journal of Physics D: Applied Physics*, vol. 51, n° 33, p. 335201, août 2018, doi: 10.1088/1361-6463/aad175.

[2] J. O. Hirschfelder, C. F. Curtiss, et R. B. Bird, *Molecular theory of gases and liquids*, New York,NY: Wiley, 1964.

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