Study of cavitation in liquid water under the action of inhomogeneous pulsed electric fields: application to sub-nanosecond electrical breakdown

M. Šlapanská[1], M. Kubečka[1], A. Obrusník[1], J. Hnilica[1] and Z. Bonaventura[1]

[1] *Department of Physical Electronics, Faculty of Science, Masaryk University, Brno, Czech Republic*

Sub-nanosecond electrical breakdown in dielectric liquids is of vital interest, e.g. for applications in high-voltage insulation and high-current switching. Liquid dielectrics in strong nonuniform electric fields are under influence of electrostrictive force that tents to move the fluid into the regions with higher electric field. If the voltage rise is fast enough, the liquid does not have enough time to set into motion thanks to inertia. Then the poderomotive force induces significant stress in the bulk of the liquid leading to generation of a negative pressure. At certain threshold, the negative pressure causes cavitation ruptures of the fluid. Free electrons then can be produced by emission from the surface inside the cavity and accelerated to energies exceeding the energy for ionization of water and contribute thus to formation of microstreamers. In this work we use hydrodynamic model for motion of dielectric fluid to study the dynamic of water in a pulsed strongly inhomogeneous electric fields in the approximation of compressible flow described by equation of continuity for mass and momentum [1, 2]

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{u}) = 0$$

$$\rho \left[\frac{\partial \vec{u}}{\partial t} + (\vec{u} \cdot \nabla)\vec{u} \right] = -\nabla p + \vec{F} + \eta \left[\nabla^2 \vec{u} + \frac{1}{3} \nabla (\nabla \cdot \vec{u}) \right]$$

where ρ is the fluid density, p is the pressure, $\vec{u}$ is the velocity, η is the dynamic viscosity, and

$$\vec{F} \approx \varepsilon_0 \varepsilon \nabla E^2$$

is the force acting on the body of the fluid thanks to inhomogeneous electric field E. The set of continuum equations is closed by the Tait equation of state for water [3, 4, 5].

The model allows to find pressure field in the liquid for considered electrode geometry and high voltage pulse and calculate probability for cavitation voids generation.

This contribution is funded by the Czech Science Foundation grant no. 18-04676S.

References

[1] M. N. Shneider and M. Pekker, Phys. Rev. E **87**, 043004 (2013)

[2] M. N. Shneider and M. Pekker, J. Appl. Phys. **114**, 214906 (2013)

[3] R. I. Nigmatulin and R. Kh. Bolotnova, High Temperature **49** 2, 303 (2011).

[4] R. I. Nigmatulin and R. Kh. Bolotnova, High Temperature **46** 3, 325 (2011).

[5] Y.-H. Li, J. Geophys. Res. **70** 10, 2665 (1967)