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Electric Pulse Modification of Mammalian Cell Suspension Conductivity

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Variations in the electrical properties of biological cells elucidate how intense electric pulses (EPs) can alter mammalian cell structure, intracellular organelles, and plasma membrane integrity [1-2]. Time domain dielectric spectroscopy (TDDS) can characterize these changes by measuring the electrical properties of the plasma membrane, cytoplasm, nuclear envelope, and nucleoplasm [1-2]. Because TDDS uses sensitive electronics involved, it is impractical for measuring changes during EP exposure [1]. This study examines the conductivity of the cell suspension during EPs by measuring the voltage and current pulse for pulse durations ranging from 10 ns to 300 ns for buffer solutions of various conductivities while keeping the energy density applied to the cellular suspension constant. We observed increased suspension conductivity following EP exposure to lower conductivity solutions, indicating membrane permeabilization and ion transport out of the cells. Previous models indicate ion motion during an EP is driven by electrophoresis while diffusion through long-lived pores dominates motion on the order of hundreds of microseconds after the EP [3]. Coupling the asymptotic Smoluchowski equation for membrane pore formation with the Nernst-Planck equation for ion motion permits assessment of calcium transport to assess the impact of EP parameters and suspension conductivity on electrophoresis [3]. The implications on short-term and long-term behavior, including dielectric measurements [1-2], will be discussed.

[1] A. L. Garner et al., "Ultrashort electric pulse induced changes in cellular dielectric properties,"Biochem. Biophys. Res. Commun., vol. 362, no. 1, pp. 139–144, 2007.

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[3] A. L. Garner, J. J. Maciejewski, A. Vadlamani, and R. J. Byer, "Electric pulse shape impact on biological effects: A modeling study,"in 2015 Annual Report Conference on Electrical Insulation and Dielectric Phenomena, pp. 632-635.

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