

Modeling 3D Calcium Waves From Stochastic Calcium Sparks in a Sarcomere Using COMSOL Multiphysics®

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Abstract

This paper utilizes the COMSOL Multiphysics® general form PDE interface and MATLAB® to model stochastic calcium waves in a sarcomere (basic unit of a heart cell). The model we present here shows the evolution of waves generated from calcium being released stochastically from sites modeled as point sources. The release sites are distributed on z-disc (planes) in a hexagonal pattern, and their opening allows calcium to diffuse and interact with different species of buffers. The release sites are sensitive to calcium levels and after opening and releasing calcium, undergo a refractory period during which they stay closed. The simulations obtained over a sarcomere domain shows individual stochastic releases of calcium self-organizing into propagating waves (Figures 1--4).

Reference

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Vyacheslav M. Shkryl et al., Properties of Ca²⁺ sparks revealed by four-dimensional confocal imaging of cardiac muscle, *JOURNAL OF GENERAL PHYSIOLOGY*, vol. 139, pp. 189–207 (2012).

Figures used in the abstract

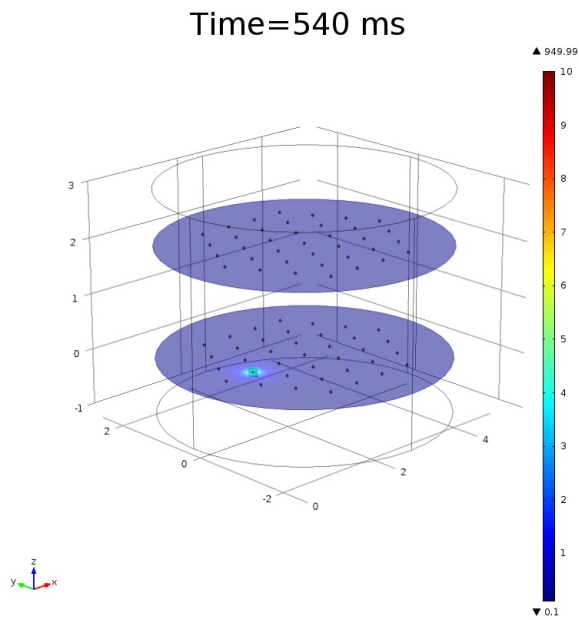


Figure 1: Simulation first stochastic spark occurring on z-disc 1.

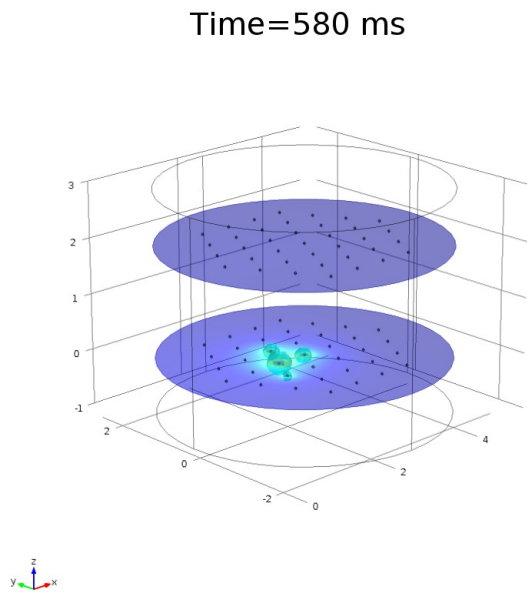


Figure 2: More sparks occurring on z-disc 1. The first Calcium Release Unit (CRU) to open has entered its refractory period.

Time=630 ms

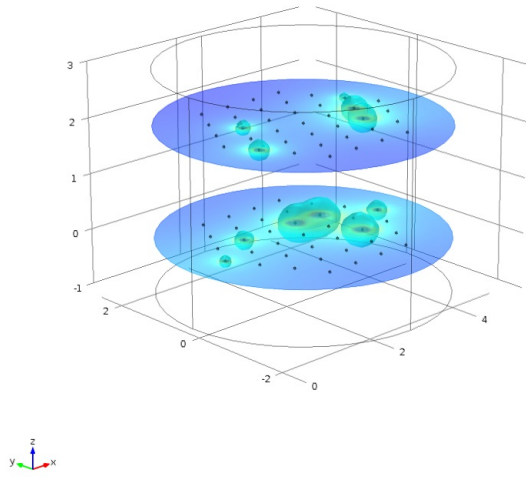


Figure 3: Multiple sparks occurring on z-disc 1 and z-disc 2.

Time=645 ms

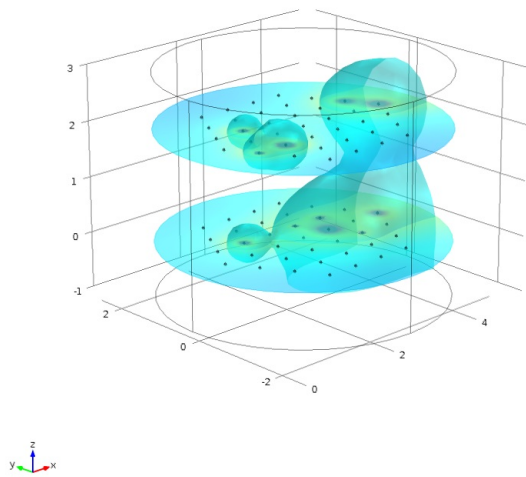


Figure 4: Sparks organize into a propagating calcium wave.