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Numerical Analysis of Transient Streaming Potential in Bone

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Bone is the primary structural element which supports external and internal loading in human body. The structure of Bone changes continuously to formation and resorption based on the biological response. This process is called the Bone remodelling. When the bone experience deformation, the origin of this transduction can be sought from electric characteristics (piezoelectricity) of bone solid and existence of electrolytically interstitial bone fluids (streaming potential). Previous study of the transduction which effects on bone has been separately studied in two categories as the piezoelectricity and the streaming potential. However, based on the electrokinetics point of view, it could be assumed that two phenomena are closely related.

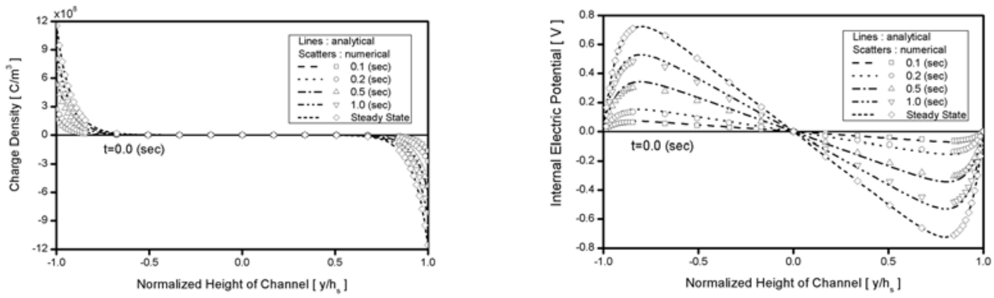
The finite element method (FEM) that is method for solving for the generation mechanism of the transient streaming potential is a numerical method used to reduce a continuum to a discrete numerical model. However this method is not the calculation of the boundary in the vicinity only be inaccurate. As electrokinetics in particular, even though it is pointless and computing environment to take the same fine space increments are not supported, serious errors, such as out of memory occurs calculation in the solid and fluid interface. In this study, a new transient streaming potential equation was proposed and solved to connect the piezoelectricity to the streaming potential in bone. And it is carried out by setting the finite difference method of complex partial differential equation (PDE) that takes a nonhomogeneous space increment with Neumann and Dirichlet boundary condition by setting the finite difference method (FDM).

To development of the new generation mechanism of the transient streaming potential, the free ionic charge density is dominated by Debye-Falkenhagen equation [1]. Debye-Falkenhagen equation represents the variation of charge density with respect to time due to ionic diffusion. The charge density is solved by using numerical method, Finite Difference Method (FDM), in explicit ways.

Verification of theoretical approach was accomplished by comparing with the reference method [2]. When the external electric field acts in pure water, external potential distribution about channel height are depicted, in this case, the surface potential of both walls are applied as $\pm$1V. The results by using proposed method (modified Debye-Falkenhagen equation) is perfectly matched with the results by existing method (Debye-Falkenhagen equation). Nevertheless there are big difference between these two theories. First, Debye-Falkenhagen equation has homogeneous solution only but the modified Debye-Falkenhagen equation has a general solution containing particular solution. Thus, in physical meaning, a steady state solution appears by nonhomogeneous term. Second, since the nonhomogeneous term is represented independently then it has become available to substitute applied externally potential terms. For these reasons, the modified Debye-Falkenhagen equation is more general and applicable as long as the distribution of external potentials as known.

Verification for numerical solution was accomplished by comparing with the theoretical solutions. Verification parameters are identical to the charge density and internal electric potential profiles at five difference time have good agreements with respect to theoretical solutions that have been verified already.

The objective of the study was to propose a modified Debye-Falkenhagen equation and verified a numerical method through theoretical method.



(a) (b)

Fig 1. (a) Distribution of charge density, (b) Distributin of internal electric potential

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