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A level set based topology optimization method for micropump design utilizing induced-charge electro-osmosis

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Abstract

This paper proposes a level set-based topology optimization method for the design of micropumps driven by induced-charge electro-osmosis. Electro-osmosis is a phenomenon that occurs when ions move in response to an electric field and gather at a liquid-solid interface. Electro-osmosis can be the basis of micropump designs that have no mechanical moving parts but such pumps are typically driven by DC electric fields, so electrolysis may cause problems, such as pollution of sample liquids and deterioration of the electrodes. Therefore, a phenomenon called induced-charge electro-osmosis, which occurs under AC electric fields, has recently attracted attention, since it avoids the problems caused by electrolysis. The performance of a micropump design is greatly influenced by its interior shape. Ordinarily, micropump structures are designed by trial and error, but this approach may fail to adequately achieve the desired characteristics. On the other hand, topology optimization methods can systematically obtain optimal solutions. Therefore, we apply a topology optimization method in an optimal design problem for a micropump, and use a level set-based topology optimization method so that clear boundaries between the solid and fluid domains are expressed in the optimal configurations. First, the optimization problem is formulated to maximize the volume of flow at an outlet boundary. Next, based on this formulation, a new topology optimization algorithm is constructed that employs the FEM when solving the governing and adjoint equations, and when updating the level set function. Finally, several numerical examples are provided to confirm the usefulness of the proposed optimum design method.