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Keio University

Thesis Abstract

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Thesis Title

A Study on Fundamental Technologies of Wearable Artificial Kidneys Using Microfluidic Systems

Thesis Summary

Recently, millions of people affected by Chronic Kidney Disease are receiving dialysis treatment which is complained for high costs and restrictions of patients' daily life. A wearable artificial kidney (WAK) which works instead of the dialysis system and allows patients to live daily lives is strongly demanded. In this thesis we propose a WAK using microfluidic system which can exploit the merits of small sizes, fast diffusion, and high specific surface. In particular we focus on the fundamental technologies including separation of wastes from blood and purification of dialysate. We developed a microfiltering device using polyethersulfone (PES) nano porous membranes which is superior in selective separation of molecules of nano orders. The device is geometrically optimized according to theoretical microfluidics so that a 2.5 times urea removal efficiency of a human kidney is realized. We consider a method of using bacteria in dialysate purification for their merits of complex multistage reaction at room temperature. For utilization in microfluidic systems, bacteria are immobilized using alginate gel beads. The gel beads, whose sizes affect the ferment efficiency of bacteria, are formed by an emulsion droplet generating device which is proved theoretically and experimentally to be capable of controlling droplet size. The relation between bead size and bacteria ferment efficiency is evaluated using yeast.

Chapter 1 describes the motivation, original contributions and outline of this work.

Chapter 2 describes the background knowledge and previous research related to this work including function of kidneys, wearable artificial kidney, porous membrane, immobilized organisms and relevant previous researches.

Chapter 3 describes theoretical microfluidics related to separation and theories of diffusion through porous membrane in multilayered microfluidic device. And the structural design, fabrication and optimization of the microfilter according to the theories are also described.

Chapter 4 describes the experimental setup and results including porous membrane separation properties, and diffusion efficiency evaluation of our multilayered microfilter. Also the geometrical optimization of our device is verified to be feasible.

Chapter 5 describes theoretical equations on the equilibrium of drag forces and surface tension in droplets generation, and enzyme kinetics of bacteria immobilized with gel beads, and the design and fabrication of emulsion droplet generating device.

Chapter 6 describes the procedure of gel beads generating and bacteria immobilization, and the experimental evaluation of bead size controlling and bacteria ferment efficiency. By experimental results, our size prediction equation is verified to be reliable with a differential of less than 5%.

Chapter 7 summarizes the results of this work and discusses future research prospects.