Simulation of Interstitial Nanoparticle Flow for Development of Tumor-on-a-Chip Device

J. Park[1], M. P. Vidal-Meza[1], R. Zhou[1], S. Barua[1], C. Wang[1]

[1]Missouri University of Science & Technology, Rolla, MO, USA

Abstract

In drug delivery systems, there is limited information about how nanoparticle size affects the movement through microchannel blood vessels in a tumor tissue. A tumor is a complex phenomenon with vasculatures that have micro-sized gaps in their endothelial cells, also known as the enhanced permeability and retention effect. This allows the enhancement of transport of nutrients and oxygen. A computational fluid dynamics simulation was performed to study the flow of nanoparticles in a microfluidic device, which mimics the cross section of a tumor tissue. For the efficient study of drug delivery to tumor cells, and to also avoid complicated and costly animal studies, a tumor-on-a-chip device, which consists of a tumor tissue microchamber surrounded by porous microarrays (Figures 1 and 2), is under development. CFD simulation was performed to investigate the flow behavior of drug delivery nanoparticles in that device. The Navier-Stokes equation and the convection-diffusion equation were used to model the flow field and particle distribution respectively. Steady flow field was solved using the CFD Module and time-dependent particle concentration was solved using the Chemical Reaction Engineering Module. As shown in Figures 1 and 2, it was simulated that the particle flow surrounded the tumor chamber in about 60s. We also estimated the permeability of nanoparticles from microchannel (mimicking blood stream) to the tumor chamber through the porous arrays. The outcome can be used in mathematical modeling of the system as well as validation of the performance of the tumor-on-a-chip device.

Figures used in the abstract

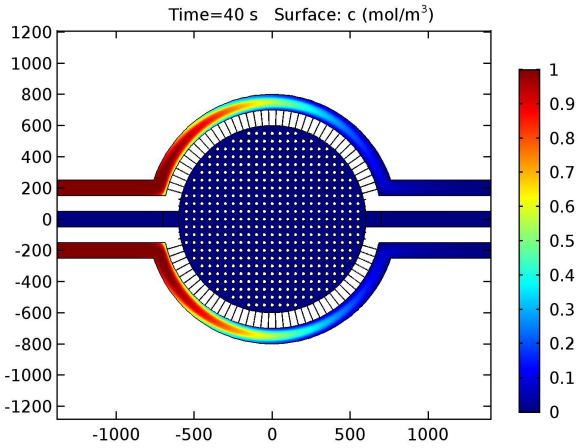

Figure 1: Particle concentration distribution at t=40s (length scales in micrometer)

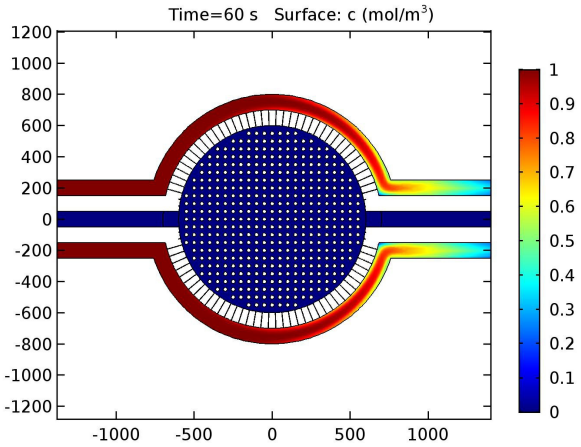

Figure 2: Particle concentration distribution at t=60s (particle diameter=20nm)