Non-universal behavior of tracer diffusion in two dimensional random obstacle matrices

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Anomalous diffusion may be observed in spatially heterogeneous media, such as biological crowding environments, colloidal glasses, and polymeric materials. The random obstacle matrices are one of models for the heterogeneous media and have been employed to investigate the anomalous tracer diffusion in heterogeneous media. The tracer diffusion coefficient (D) in the random obstacle matrices follows a scaling relation, i.e., $D \sim (\phi - \phi_c)^{\mu}$. Here, ϕ and ϕ_c are the volume fraction of the matrix particles and its value at the pore percolation threshold, respectively. μ denotes the scaling exponent. It has been accepted that the scaling exponent μ for two-dimensional (2D) systems should be universal, i.e., the value of μ should not depend on system details. In this work, however, we perform dynamic Monte Carlo (dMC) simulations, and show that μ is not universal even in 2D systems and should depend on how thoroughly the tracer samples the pore space before moving to different pores. As the maximum displacement (Δ) for the translational motion of the tracer in dMC increases, the tracer samples the pore space less effectively and μ increases. We discretize the pore space of the matrices into triangular cells using Delaunay tessellation, and evaluate the transition rate (W) of the tracer between triangular cells. As Δ increases, the distribution of W becomes singular, which makes the scaling constants to be non-universal.