Available online at www.sciencedirect.com

ScienceDirect

Physica A 373 (2007) 1–10

PHYSICA A

www.elsevier.com/locate/physa

Density profiles in the totally asymmetric exclusion processes with both local inhomogeneity and Langmuir kinetics

Kang Qiu[a], Xianqing Yang[a,*], Wei Zhang[a], Dapeng Sun[a], Yuemin Zhao[b]

[a]*College of Science, China University of Mining and Technology, Xuzhou 221008, China*
[b]*School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou 221008, China*

Received 25 January 2006; received in revised form 24 March 2006
Available online 7 July 2006

Abstract

In this article, the density profiles in the totally asymmetric simple exclusion processes (TASEPs) with both Langmuir kinetics and the local inhomogeneity, have been investigated by Monte Carlo simulations and a mean-field theory. The model is relevant for the understanding of the biological and chemical phenomena. Unlike the density profiles of TASEPs with the local defect, computer simulations indicate that the low-density phase, the shock-wave phase and the high-density phase have been found in the two sublattices. Eight possible steady density profiles such as hp/hp, sp/sp, lp/lp, hp/sp, sp/hp, sp/lp, lp/sp and hp/lp are discovered in the phase diagram. Both the hopping rate p and the kinetics rate Ω_D influence on the density profiles not only upward, but also downward the defect. An approximate mean-field theory is presented and used to calculate phase diagrams and particle profiles. The approximate results can only agree with Monte Carlo simulations in the special cases. The reason is that the flow limited by the defect, is neglected in considering the mean-field theory.
© 2006 Elsevier B.V. All rights reserved.

Keywords: TASEP; Langmuir kinetics; Local defect; Density profile; Phase transitions

---

1. Introduction

In recent years, totally asymmetric simple exclusion processes (TASEPs) have become a subject of increasing scientific interest in physics, chemistry and biology [1,2]. The TASEPs are one-dimensional lattice gas models where particles move in one direction and interact only though hard-core exclusion. Although the rules of the TASEPs are very simple, they show a very rich dynamical behavior which are typically not observed in one-dimensional systems in thermal equilibrium. Particularly illuminating examples are boundary induced phase transitions [3], spontaneous symmetry breaking [4,5], and phase segregations [6,7]. Therefore, they have been used in order to develop more general concepts for systems far from equilibrium, e.g., a free-energy formalism [8]. Moreover, the TASEPs are important in studies of one-dimensional multiparticle dynamical phenomena such as traffic problems [9], diffusion through biological membrane channels [10], and the motion of molecular motor [11–15].

---

[*] Corresponding author.
E-mail address: xianqyang@sina.com.cn (X. Yang).

0378-4371/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.physa.2006.06.015

Most investigations of the TASEPs concentrate on translationally invariant systems where particles can always be found on the lattice [1]. Analytical solutions for the stationary state have been provided in the systems with the periodic [16] and open boundary conditions [17,18], in different update schemes [19–21]. Work has also been done on TASEPs models on a ring where the quenched hopping rates between neighboring sites are introduced at random [22–24]. The effects induced by random hopping rates on TASEPs with open boundary conditions were considered in Refs. [25,26]. A characteristic feature of the TASEPs and its variants is their sensitivity to spatial inhomogeneities or quenched disorder of any kind. For example, in the stationary states of the TASEPs models the particle density changes from a homogeneous phase into a segregated density phase as the strength of the quenched disorder is increasing. For sitewise disorder the analytical results are scare and most of our knowledge is based on Monte Carlo simulations [25] and mean-field calculations [26].

Recently, the case of systems without particle conservation in the bulk attracted much attention. In Ref. [27], the effects of a single detachment or attachment site in the bulk of an asymmetric simple exclusion process were studied. And in Refs. [28–31], the interplay of the totally asymmetric exclusion process with local absorption/desorption kinetics of single particles acting at all sites, termed "Langmuir kinetics" (LK) was considered. These models were inspired by the dynamics of motor proteins, which move along cytoskeletal filaments in a certain preferred direction while detachment and attachment can also occur between the cytoplasm and the filament. The combined process of TASEPs and LK showed the new feature of a local shock in the density profile of the stationary state. However, in the systems of TASEPs without particle conservation, effects of quenched hopping rates between neighboring sites have not been investigated. For molecular motors moving along a disordered substrate this seems to be relevant scenario [32,33]. Another, different from the TASEPs only with quenched disorder, the system has nonconservation of particle number and particle flow in the bulk which may result in many unexpected phenomena, therefore studying the density profiles in the TASEPs with both LK and local inhomogeneity is needed. The main goal of this paper is to investigate the effects of the local inhomogeneity on the density profiles in the system of TASEPs with LK theoretically and numerically, respectively.

The paper is organized as follows. In Section 2 the model considering TASEPs with both LK and the defect is presented. Monte Carlo simulations are discussed in Section 3. In Section 4, we propose a simple approximate method to explain the computer simulations. And summary and conclusion are in Section 5.

2. Model

A one-dimensional open boundary chain of N sites is considered, where N is a large even number. Each site can either be empty ($n_i = 0$) or occupied by one particle ($n_i = 1$). All sites are coupled to particle reservoirs, i.e., particles are attached with rate w_A if the site is empty and detached with rate w_D. At site 1, particles can also enter the system from the left with rate α if the site 1 is empty, while particles at the last site N can exit with rate β. Moreover, in the bulk particles can hop from site i to site $i+1$ with unit rate if site $i+1$ is empty ($i = 1, \ldots, N$), except at local inhomogeneity where particles can jump with a rate p ($0 \leqslant p \leqslant 1$). Local inhomogeneity, i.e., sitewise disorder here is put at site $i = N/2$, far away from the two boundaries. Obviously, for $w_A = w_D = 0$, one arrives back at the TASEPs respecting the local inhomogeneity [25,26]; and for $p = 1$, one obtains the TASEPs with LK presented by Parmeggiani et al. [28].

Here we are interested in large system size ($N \gg 1$) and, eventually, in the "thermodynamics limit" $N \to \infty$. The "reduced" rates Ω_A and Ω_D are defined as $\Omega_A = w_A N$ and $\Omega_D = w_D N$, respectively. The parameters such as Ω_A, Ω_D, α, β and the binding constant $K = \Omega_A/\Omega_D$ remain unchanged as $N \to \infty$.

The present model exhibits a particle–hole symmetry as many other TASEPs. A jump of a particle to the right corresponds to a vacancy move by one step to the left. At the defect, a particle hopping with the rate p to the right can be interpreted as a vacancy jumping to the left with the same rate. Similarly, at the left boundary, a particle entering the system can be considered as a vacancy leaving the lattice, and vice versa at the right boundary. Attachment and detachment of particles can be described as detachment and attachment of vacancies, respectively.

Download English Version:

https://daneshyari.com/en/article/978325

Download Persian Version:

https://daneshyari.com/article/978325

Daneshyari.com