A one dimensional model of irreversible aggregation

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Irreversible aggregation of clusters of arbitrary size arises in many physical-chemical processes as aerosol physics, polymer growth, and even in astrophysics. The ability to control aggregation of proteins could be an important tool in the arsenal of the drug development. However, in biochemistry of life this process may play a destructive role as well. For example, many neurodegenerative diseases, including Alzheimers disease, Parkinsons disease, prion diseases, to mention some, are characterized by intracellular aggregation and deposition of pathogenic proteins [1]. Moreover, the abnormal irreversible aggregation of ribosomes leads to irreparable damage of protein synthesis and results in neuronal death after focal brain ischemia [2].

We define and study one-dimensional model of irreversible aggregation of particles obeying a discrete-time kinetics, which is a special limit of the generalized Totally Asymmetric Simple Exclusion Process [3,4] on open chains. The model allows for clusters of particles to translate as a whole entity one site to the right with the same probability as single particles do. A particle and a cluster, as well as two clusters, irreversibly aggregate whenever they become nearest neighbors. Non-equilibrium stationary phases appear under the balance of injection and ejection of particles. By extensive Monte Carlo simulations it is established that the phase diagram in the plane of the injection-ejection probabilities consists of three stationary phases: a multi-particle (MP) one, a completely filled (CF) phase and a 'mixed' (MP+CF) one. The transitions between these phases are: an unusual transition between MP and CF with jump discontinuity in both the bulk density and the current, a conventional first-order transition with a jump in the bulk density between MP and MP+CF, and a continuous clustering-type transition from MP to CF, which takes place throughout the MP+CF phase between them. By the data collapse method a finite-size scaling function for the current and bulk density is obtained near the unusual phase transition line. A diverging correlation length, associated with that transition, is identified and interpreted as the size of the largest cluster. The model allows for a future extension to account for possible cluster fragmentation.

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