Dynamic exponents for thin-film spreading

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In the case of complete wetting, spreading of nonvolatile liquid drops on surfaces exhibits, when examined on the atomic length scale in the direction normal to the substrate, a precursor film about one molecule thick [1]. This precursor film is expected to expand as $R \sim t^{1/2}$, where R is the drop radius, as many experiments have confirmed [2].

In Ref. [3], a quasi two-dimensional (2D) driven Ising lattice gas model was introduced to study this phenomenon. The model considers the evolution of two layers, namely the precursor (bottom) layer and the supernatant (or upper) layer. At each cell of the lattice, an occupation number n_r is defined and allowed to take only the values 1 and 0, depending on whether the cell is occupied (by only one particle) or empty. Initially, all cells are empty except those of the first column for both layers, which acts as a reservoir for particles; if, at any step, any of the cells of this column became empty, it is automatically refilled.

In this model, the energy of the system is given by

$$H = -J \sum_{\langle r,s \rangle} n_r n_s - A \sum_r \frac{n_r}{Z^3}, \qquad (1)$$

where Z takes on the values 1 or 2 (for the precursor and supernatant layers, respectively). The first term describes the interactions between the liquid particles and their nearest neighbors in terms of a coupling constant $J > 0$. The second term, whose intensity is given by the Hamaker constant $A > 0$, describes the interactions between the liquid particles and the substrate [1].

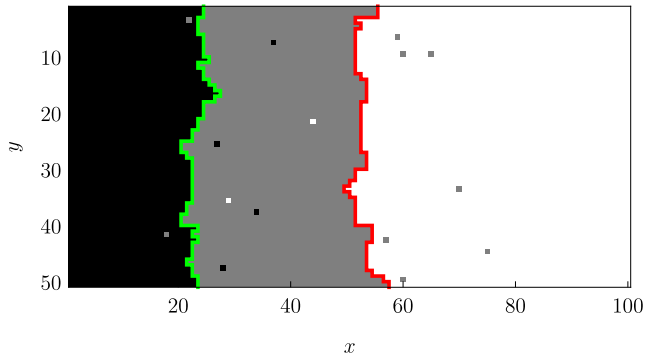

Fig. 1. Top view of a typical snapshot of the two-layers model. Occupied cells with $Z = 1$ (precursor film) and $Z = 2$ (supernatant film) appear in gray and black, respectively; uncolored cells are empty. The red (green) line denotes the edge of the precursor (the supernatant) layer, which we use to define the position of the front, $x = h(y, t)$.

The evolution of the system was simulated by a continuous-time Monte Carlo algorithm with Kawasaki dynamics for pair exchange, for large enough J to achieve a high degree of non-volatility, and for large enough A for the system to be in the complete wetting regime. Under these conditions, the system evolves according to the $R \sim t^{1/2}$ law after a short initial transient.

Very recently, this system has been simulated using Kawasaki dynamics, for a wider range of J and A values [4]. In this case, the precursor film was found to grow as $R \sim t^{\delta}$, with the scaling exponent δ greatly depending on the dynamical parameters for the system. In particular, the $\delta = 1/2$ universal value for the exponent is not recovered for any values of the J and A parameters studied in [4].

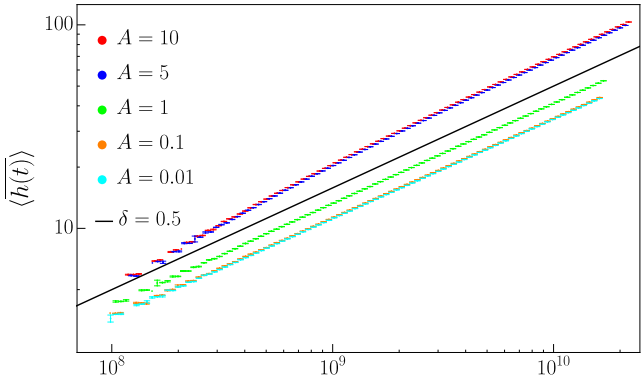

Fig. 2. Log-log plot of the average front position $\langle \bar{h}(t) \rangle$ as a function of time for $T = 1$, $L_x = 1000$, $L_y = 256$, and several values of A. The solid black line corresponds to the reference scaling $\langle \bar{h}(t) \rangle \sim t^{1/2}$. All units are arbitrary.

Thus, controversy exists about the proper description at the atomistic scale of the growth of drops on surfaces under complete wetting conditions. In this contribution, we have tried to shed light on this problem by studying the dependence of the scaling exponent δ on the dynamical parameters of the system. Our results indicate that such a dependence is very weak, with little variation from the universal value $1/2$. We additionally report calculations of correlation functions and front structure factors which, to our best knowledge, are reported for the first time. We discuss our results in the light of continuum descriptions of the process put forward in Ref. [3].

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