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Study of the submonolayer deposition by mean field lattice gas model

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Abstract

We study the early-time morphology and the scaling behavior of the interfaces generated by the deposition, diffusion and aggregation processes. The description of the kinetics is based on the mean field master equation in terms of lattice gas model. The results show that the islands morphology depends on the ratio D/F where D is the diffusion constant and F is the flux of the deposited atoms. In the low temperatures regime, the observed islands present a fractal geometry. However, in the height temperatures regime the atoms have enough time to rearrange on the edge of the island increasing the number of neighbors. This process results in more compact clusters.

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Keywords: Lattice gas model; Mean field; Deposition and diffusion

1. Introduction

Recently, most experimental investigations focus on the study of surfaces with island formation which is a basic process in molecular beam epitaxy (MBE) and thin film growth. Thus unveiling the details of submonolayer deposition is a very

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important task, with numerous particular applications. With the availability of the scanning tunneling microscopy (STM), it is possible to observe directly the details of island formation.

Some versions of the arguments regarding the dependence of the diffusion length l_d and island distribution ρ on constant flux F of the deposited particles, temperature, and diffusion constant D have been long used to determine the activation energy and the diffusion coefficient of monomers [1–5]. However, these studies mostly considered a simple version of the scaling arguments, arriving at the conclusion that the characteristic length l_d scale in the system depends on the flux as $F^{-1/4}$. Compact or fractal island have been observed in various systems. The morphology of these island depends on the temperature, the ratio D/F, and binding energies. Studies include Fe deposition on Fe(0 0 1) [6], Ni on Ni(1 0 0) [7], Cu on Cu(1 0 0) [8–9], Ag on Pt(1 1 1) [10], Sb cluster deposition on amorphous carbon [11]. One of the first studies leading submonolayer island structures has been carried out by observing Au deposition on Ru (0 0 1) surfaces [12–13] where the deposition rate varies between 0.2 and 2 ML/min, and the experiment are done at room temperature. For a small coverage system, the observed islands are compact, but they have a few branches. At increasing coverage the fractal structure of the islands becomes apparent. This transition can be observed by varying the temperatures system: at low temperatures, when out equilibrium effects dominate (in the sense that edge diffusion and atom detachment is limited), the islands present a fractal structure. However, on increasing the temperature, the islands become more compact and assume their equilibrium shapes.

Moreover, various models have been established in order to understand this phenomena. One of this model is termed deposition, diffusion and aggregation (DDA), since it includes the tree elementary processes of deposition, diffusion and aggregation. There are two competing processes that define the typical time scale: deposition characterized by the constant flux F and diffusion characterized by the constant diffusion D, where $1/D$ is proportional to the typical time between two hops. Due to this competition between deposition and diffusion, all physical process depend on the ratio D/F. The monomers density is given by the DDA model as

$$\rho_1 \sim l_d^2 F/D\,, \tag{1}$$

where l_d is the characteristic length scale, given by [14–18]

$$l_d \sim (D/F)^{\psi_d} \tag{2}$$

with $\psi_d = \frac{1}{6}$. The exponent ψ_d can be related to the fractal dimension d_f of island and to the size n^* of the largest cluster that is considered to be mobile, as

$$\psi_d = \frac{1}{4 + d_f}\,, \tag{3}$$

$$\psi_d = \frac{n^*}{2 + 4n^*}\,. \tag{4}$$

by the DDA model, the island are compact with $d_f = 2$ and all clusters except monomers are immobile ($n^* = 1$).