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Selective nucleation and controlled growth: quantum dots on metal, insulator and semiconductor surfaces

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Nucleation and growth models are well developed for nucleation on homogeneous substrates, and they can typically be described in terms of three energy parameters. Nucleation on substrates containing point-defect traps has been investigated, at the cost of introducing more energy parameters. This paper outlines the quantitative description of such growth models, using rate and rate-diffusion equations, in terms of energies for individual surface processes, with examples taken from metal–metal, metal–insulator and semiconductor growth. The challenge to modelling is to describe the large range of length and time-scales in thin-film fabrication and degradation, without relying on too many (unknown) material parameters, which often occur in combination. Separating them into elementary processes often proves to be a challenge. One typically requires selective nucleation using patterned substrates, in combination with controlled, self-organized, growth for reliable nanotechnology. Reconstructed semiconductor surfaces offer both a further challenge to modelling and an opportunity for future technology; these paradoxes are discussed briefly.

Keywords: nucleation and growth; rate equations; rate-diffusion equations; metal growth; patterned substrates; semiconductor growth

1. Introduction

Nucleation and growth on surfaces has been studied intensively over the last 30 years. In the specific case of deposition from the vapour, it is well known that individual atomic events can strongly influence and even dominate the final micro- or nanostructure of epitaxial thin films (Venables 1994, 2000). Scanning-tunnelling-microscopy (STM) (Brune 1998; Bennett & von Känel 1999) and field-ion-microscopy (FIM)

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