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Surface Diffusion and Size Evolution of Nanostructures in Laser-Directed Atomic Deposition*

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Lasers have been recently shown to be a very promising tool for fabrication of surface nanostructures[1-3]. Using standing waves of laser light, ordered arrays of quantum dots and quantum wires can be produced by directed-deposition. In this laser-directed atom lithography, atoms from a collimated beam are deposited onto a substrate through a near-resonant laser standing wave. The interaction between the light and the deposited atoms focuses the atoms to the standing waves nodes. As a consequence, ordered arrays of wires or dots are formed on the substrate with a periodicity corresponding to the half-wavelength of the laser light.

Calculations of the atomic trajectory in the standing wave indicate that the feature width of deposited lines or dots can be as small as several nanometers if atoms remain at the place where they land. However, such narrow structures have never been experimentally observed, implying that thermal diffusion of atoms on the surface plays a significant role in determining the size of the nanostructures. Indeed, experiments have shown that a rough substrate with reduced surface diffusion of deposited atoms greatly narrows the feature width of sodium lines[2]. Kinetic Monte Carlo simulations also demonstrated that the feature width of lines in laser-focused deposition increases drastically at higher growth temperature with enhanced surface diffusion processes[3].

However, a powerful criterion that can be used to predict and control the size evolution in laser-focused deposition has been lacking. We examine the diffusion effect on the size broadening by considering two major diffusion processes for deposited atoms, namely terrace diffusion and step-edge descending. A criterion is derived to predict the size evolution of nanostructures, which is a function of terrace diffusion barrier, Ehrlich-Schwoebel step-edge barrier, substrate temperature, deposition flux, and laser properties. Our predicted values of the feature width of quantum wires and dots are in good agreement with available experimental findings.

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[1] A.S. Bell, et al, *Surf. Sci*. 433, **40** (1999) and references therein.
[2] R.E. Behringer, V. Natarajan, and G. Timp, Surf. Sci. 104, 291 (1996).
[3] E. Jurkik *et al*., *Phys. Rev.* B **60**, 1543 (1999).

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